Total Maximum Daily Loads of Nitrogen and Phosphorus for Assawoman Bay, Isle of Wight Bay, Sinepuxent Bay, Newport Bay and Chincoteague Bay in the Coastal Bays Watersheds in Worcester County, Maryland

REVISED FINAL

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ERRATA: Typographical error were identified related to Sinepuxent Bay Average Annual Nitrogen $WLA_{ProcessWater}$ allocation as well as the listed totals for $WLA_{ProcessWater}$ allocations. These typos have been corrected.

Coastal Bays Nutrient TMDL
Document version: Sept. 23, 2014

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LIST OF ABBREVIATIONS

ASIS	Assateague Island National Seashore
BMPs	Best Management Practices
BRF	Bay Restoration Fund
CAFO	Concentrated Animal Feeding Operation
CBEM	Coastal Bays Eutrophication Model
CBP	Chesapeake Bay Program
CBP-P5	Chesapeake Bay Program Phase 5 Community Watershed Model
CE-QUAL-ICM	Corps of Engineers Water Quality Compartment Model
Chl *a*	Chlorophyll a
CNMP	Comprehensive Nutrient Management Plan
CWA	Clean Water Act
DO	Dissolved Oxygen
DEM	Digital Elevation Model
DNR	Department of Natural Resources
DNREC	Delaware Department of Natural Resources and Environmental Control
ft	Feet
GIS	Geographic Information Systems
HSPF	Hydrological Simulation Program - FORTRAN
Km	Kilometers
LA	Load Allocation
lb	Pound
lbs/day	Pounds per day
lbs/yr	Pounds per year
m	Meter
MACS	Maryland Agriculture Cost-Share Program
MAFO	Maryland Animal Feeding Operation
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
mg/L	Milligrams per Liter
MOS	Margin of Safety
MPAR	Maximum Practicable Anthropogenic Reduction
MD 8-Digit	Maryland 8-Digit
MDL	Maximum Daily Load
mgd	Millions of Gallons per Day
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
SAV	Submerged Aquatic Vegetation
SELFE	Semi-implicit Eulerian-Lagrangian Finite Element
SIC	Standard Industrial Classification
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solid
USGS	US Geological Survey
VADEQ	Virginia Department of Environmental Quality
WLA	Wasteload Allocation
WMA	Water Management Administration
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segments
WWTP	Wastewater Treatment Plant
µg/L	Micrograms per Liter
USEPA	U.S. Environmental Protection Agency

EXECUTIVE SUMMARY

Section 303(d) of the federal Clean Water Act (CWA) and the US Environmental Protection Agency's (USEPA) 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 2013a). Upon approval by the USEPA, this document establishes Total Maximum Daily Loads (TMDLs) for nitrogen and phosphorus for the Maryland 8-Digit (MD 8-Digit) Assawoman Bay, Isle of Wight Bay, Sinepuxent Bay, Newport Bay and Chincoteague Bay (Maryland Coastal Bays).

The designated use for the tidal MD 8-Digit Assawoman Bay, Isle of Wight Bay, Newport Bay, Sinepuxent Bay, and Chincoteague Bay (Maryland Coastal Bays) is Use II: *Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting* (COMAR 2009a and 2011). The Maryland Coastal Bays are not attaining its *Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting* designated use because of impacts from the nutrients nitrogen and phosphorus. The Maryland Department of the Environment (MDE) has identified the waters of the Maryland Coastal Bays on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report) as impaired by nutrients (MDE 2010).

Table ES-1 below identifies the specific nutrient impairments for these waterbodies. Nitrogen and phosphorus TMDLs for areas within Maryland's Northern Coastal Bays were approved by the USEPA in 2002. Nitrogen and Biological Oxygen Demand (BOD) TMDLs for the MD 8-Digit Newport Bay were approved by the USEPA in 2003. The TMDLs described within this document were developed to address the water quality impairments associated with excess nutrient loadings, and supersede the previous TMDLs.

Table ES-1: Nutrient Impairments for the Maryland Coastal Bays (MDE 2010).

Year listed	MD 8-Digit Tidal Basin	Basin Code	2010 IR Assessment Unit ID	Specific Area	Identified Pollutant	Listing Category
1996	Assawoman Bay	02130102	MD-02130102-T-Assawoman_Bay	Open water	Nitrogen	5
					Phosphorus	5
			MD-02130102-T-Greys_Creek	Grey's Creek	Nitrogen	5
					Phosphorus	5
1996	Isle Of Wight Bay	02130103	MD-02130103-T-Turville_Creek	Turville Creek	Nitrogen	4a
					Phosphorus	4a
			MD-02130103-T-Manklin_Creek	Manklin Creek	Nitrogen	5
					Phosphorus	5
			MD-02130103-T-Herring_Creek	Herring Creek	Nitrogen	4a
					Phosphorus	4a
			MD-02130103-T-Bishopville_Prong	Bishopville Prong	Nitrogen	4a
					Phosphorus	4a
			MD-02130103-T-StMartin_River	St. Martin River	Nitrogen	4a
					Phosphorus	4a
			MD-02130103-T-Shingle_Landing_Prong	Shingle Landing Prong	Nitrogen	4a
					Phosphorus	4a
			MD-02130103-T-Isle_Of_Wight_Bay	Open Water	Nitrogen	5
					Phosphorus	5
1996	Newport Bay	02130105	MD-02130105-T-Newport_Creek	Newport Creek	Nitrogen	4a
			MD-02130105-T-Marshall_Creek	Marshall Creek	Nitrogen	5
					Phosphorus	5
			MD-02130105-T-Kitts_Branch	Kitts Branch	Biochemical Oxygen Demand	4a
			MD-02130105-T-Ayer_Creek	Ayer Creek	Nitrogen	4a
			MD-02130105-T-Newport_Bay	Newport Bay	Nitrogen	4a
1996	Sinepuxent Bay	02130104	MD-02130104-T	Sinepuxent Bay	Nitrogen	5
					Phosphorus	5
1996	Chincoteague Bay	02130106	MD-02130106-T	Chincoteague Bay	Nitrogen	5
					Phosphorus	5

Listing category definitions: 4a – TMDL developed; 5 – TMDL required.

The TMDLs for nitrogen and phosphorus were determined using a time-variable, three-dimensional water quality eutrophication model package, which includes a watershed model (Hydrological Simulation Program – FORTRAN (HSPF)); a hydrodynamic model (Semi-implicit Eulerian-Lagrangian Finite Element model (SELFE)); a water quality model (Corps of Engineers-Water Quality-Integrated Compartment Model (CE-QUAL_ICM)), and a sediment flux model. Loading caps for total nitrogen and total phosphorus entering the Maryland Coastal Bays are established for both growing season and average annual flow conditions. The Maximum Daily Loads (MDLs) associated with the long-term annual average TMDLs of nitrogen and phosphorus, which were calculated for the Maryland Coastal Bays as part of this analysis, are provided in Appendix F.

To assure that critical conditions are addressed, the growing season TMDLs for nitrogen and phosphorus are presented in Tables ES-2 and ES-3 below. These TMDLs apply from May 1 through October 31. The allowable loads have been allocated between point and nonpoint sources. Load Allocations (LAs) have been assigned to the nonpoint sources, and Wasteload Allocations (WLAs) have been assigned to National Pollutant Discharge Elimination System (NPDES) – regulated point sources, , as well as Concentrated Animal Feeding Operations (CAFOs). 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 2013a). An implicit MOS, consisting of a number of conservative assumptions incorporated into the modeling process, was used.

Table ES-2: Total nitrogen growing season TMDLs for the Maryland Coastal Bays in pounds per growing season (lbs/growing season).

Basin Name	TMDL (lbs/growing season)	Upstream Loads[1] (WLA+LA)	$WLA_{Process\ Water}$	WLA_{CAFO}	LA	MOS
Greys Creek	46,422	29,042	0	339	17,041	Implicit
Assawoman Bay[2,4]	**143,441**	**96,044**	**0**	**339**	**47,058**	**Implicit**
Bishopville Prong	25,592	11,777	333	1,411	12,071	Implicit
Shingle Landing Prong	27,750	0	7,520	678	19,552	Implicit
St. Martin River[2]	68,348	11,777	7,853	2,224	46,494	Implicit
Herring Creek	7,250	0	0	0	7,250	Implicit
Turville Creek	12,998	0	0	373	12,625	Implicit
Manklin Creek	7,541	0	0	0	7,541	Implicit
Isle of Wight Bay[2,4]	**133,238**	**11,777**	**21,664[3]**	**2,597**	**97,200**	**Implicit**
Ayer Creek/Kitts Branch	37,036	0	5,463	268	31,305	Implicit
Newport Creek	9,361	0	0	440	8,921	Implicit
Marshall Creek	16,796	0	1,934	562	14,300	Implicit
Newport Bay[2,4]	**88,819**	**0**	**7,397**	**1,526**	**79,896**	**Implicit**
Sinepuxent Bay[4]	**45,442**	**0**	**1,859**	**0**	**43,583**	**Implicit**
Chincoteague Bay[4]	**569,121**	**308,377**	**0**	**2,118**	**258,626**	**Implicit**

[1] Upstream Loads denotes loadings from outside Maryland's portion of the watershed. This allocation includes point and nonpoint sources.
[2] This allocation includes the allocations for the applicable sub-basins.
[3] This allocation does not include the Ocean City WWTP loads.
[4] TMDL represents assimilative capacity of the tidal MD 8-Digit waterbody.

Table ES-3: Total phosphorus growing season TMDLs for the Maryland Coastal Bays (lbs/growing season)

Basin Name	TMDL (lbs/growing season)	Upstream Loads[1] (WLA+LA)	$WLA_{Process\ Water}$	WLA_{CAFO}	LA	MOS
Greys Creek	3,446	2,194	0	28	1,223	Implicit
Assawoman Bay[2,4]	**10,196**	**6,887**	**0**	**28**	**3,281**	**Implicit**
Bishopville Prong	2,797	1,450	0	116	1,231	Implicit
Shingle Landing Prong	2,639	0	614	56	1,969	Implicit
St. Martin River[2]	6,486	1,450	614	183	4,239	Implicit
Herring Creek	586	0	0	0	586	Implicit
Turville Creek	924	0	0	31	893	Implicit
Manklin Creek	645	0	0	0	645	Implicit
Isle of Wight Bay[2,4]	**12,451**	**1,450**	**2,916[3]**	**214**	**7,871**	**Implicit**
Ayer Creek/Kitts Branch	2,990	0	632	22	2,335	Implicit
Newport Creek	648	0	0	36	612	Implicit
Marshall Creek	1,208	0	322	46	840	Implicit
Newport Bay[2,4]	**6,673**	**0**	**955**	**125**	**5,594**	**Implicit**
Sinepuxent Bay[4]	**3,269**	**0**	**6**	**0**	**3,264**	**Implicit**
Chincoteague Bay[4]	**41,488**	**24,122**	**0**	**174**	**17,191**	**Implicit**

[1] Upstream Loads denotes loadings from outside Maryland's portion of the watershed. This allocation includes point and nonpoint sources.
[2] This allocation includes the allocations for the applicable sub-basins.
[3] This allocation does not include the Ocean City WWTP loads.
[4] TMDL represents assimilative capacity of the tidal MD 8-Digit waterbody.

The average annual TMDLs for nitrogen and phosphorus are presented in Tables ES-4 and ES-5. The allowable loads have been allocated between point sources and nonpoint sources. LAs have been assigned to the nonpoint sources, and WLAs have been assigned to the Process water point sources, as well as CAFO facilities.

Table ES-4: Total nitrogen average annual TMDLs for the Maryland Coastal Bays in pounds per year (lbs/yr).

Basin Name	TMDL (lbs/yr)	Upstream Loads[1] (WLA+LA)	$WLA_{Process\ Water}$	WLA_{CAFO}	LA	MOS
Greys Creek	101,333	64,962	0	678	35,693	Implicit
Assawoman Bay[2,4]	**300,669**	**204,889**	**183**	**678**	**94,919**	**Implicit**
Bishopville Prong	54,619	25,434	665	2,823	25,697	Implicit
Shingle Landing Prong	58,520	0	15,278	1,357	41,885	Implicit
St. Martin River[2]	143,671	25,435	15,943	4,451	97,843	Implicit
Herring Creek	14,413	0	0	0	14,413	Implicit
Turville Creek	26,311	0	0	747	25,564	Implicit
Manklin Creek	14,692	0	0	0	14,692	Implicit
Isle of Wight Bay[2,4]	**276,986**	**25,435**	**47,869[3]**	**5,198**	**198,484**	**Implicit**
Ayer Creek/Kitts Branch	80,669	0	14,215	535	65,919	Implicit
Newport Creek	20,465	0	0	879	19,586	Implicit
Marshall Creek	30,827	0	3,836	1,124	25,867	Implicit
Newport Bay[2,4]	**185,471**	**0**	**18,051**	**3,050**	**164,370**	**Implicit**
Sinepuxent Bay[4]	**90,347**	**0**	**3,741**	**0**	**86,606**	**Implicit**
Chincoteague Bay[4]	**1,166,469**	**633,578**	**0**	**4,236**	**528,655**	**Implicit**

[1] Upstream Loads denotes loadings from outside Maryland's portion of the watershed. This allocation includes point and nonpoint sources.
[2] This allocation includes the allocations for the applicable sub-basins.
[3] This allocation does not include the Ocean City WWTP loads.
[4] TMDL represents assimilative capacity of the tidal MD 8-Digit waterbody.

Table ES-5: Total phosphorus average annual TMDLs for the Maryland Coastal Bays (lbs/year).

Basin Name	TMDL (lbs/yr)	Upstream Loads[1] (WLA+LA)	$WLA_{Process\ Water}$	WLA_{CAFO}	LA	MOS
Greys Creek	6,847	4,375	0	56	2,416	Implicit
Assawoman Bay[2,4]	**19,985**	**13,501**	**0**	**56**	**6,428**	**Implicit**
Bishopville Prong	5,603	2,890	0	232	2,481	Implicit
Shingle Landing Prong	5,316	0	1,218	112	3,987	Implicit
St. Martin River[2]	12,988	2,890	1,218	366	8,514	Implicit
Herring Creek	1,146	0	0	0	1,146	Implicit
Turville Creek	1,813	0	0	61	1,752	Implicit
Manklin Creek	1,240	0	0	0	1,240	Implicit
Isle of Wight Bay[2,4]	**24,715**	**2,890**	**5,784[3]**	**427**	**15,613**	**Implicit**
Ayer Creek/Kitts Branch	6,233	0	1,629	44	4,560	Implicit
Newport Creek	1,295	0	0	72	1,223	Implicit
Marshall Creek	2,425	0	639	92	1,694	Implicit
Newport Bay[2,4]	**13,589**	**0**	**2,268**	**251**	**11,070**	**Implicit**
Sinepuxent Bay[4]	**6,381**	**0**	**11**	**0**	**6,370**	**Implicit**
Chincoteague Bay[4]	**82,304**	**47,797**	**0**	**348**	**34,159**	**Implicit**

[1] Upstream Loads denotes loadings from outside Maryland's portion of the watershed. This allocation includes point and nonpoint sources.
[2] This allocation includes the allocations for the applicable sub-basins.
[3] This allocation does not include the Ocean City WWTP loads.
[4] TMDL represents assimilative capacity of the tidal MD 8-Digit waterbody.

The water quality goal of these TMDLs is to 1) reduce excessive algal blooms that result in high chlorophyll *a* concentrations, and 2) maintain the dissolved oxygen concentrations at levels above the water quality criteria for the specific designated uses of the Maryland Coastal Bays. Several legislative and policy-derived programs will be utilized to implement these TMDLs. NPDES permits will reflect TMDL loadings as they are renewed. The Chesapeake Bay Restoration Fund will be used to upgrade septic systems. Additionally, Maryland has several well-established programs to assist in implementing the TMDLs, such as the Maryland Coastal Bays Program. Maryland's Water Quality Improvement Act (WQIA) of 1998 requires that nutrient management plans be implemented for all agricultural lands throughout Maryland. These and other programs are described in further detail in the Assurance of Implementation Section of this TMDL, to assure implementation of the TMDLs.

1.0 INTRODUCTION

Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to develop a Total Maximum Daily Load (TMDL) for each impaired water quality limited segment (WQLS) on the *Integrated Report of Surface Water Quality* (Integrated Report), taking into account seasonal variations and a protective margin of safety (MOS) to account for uncertainty. A TMDL reflects the total pollutant loading of the impairing substance a waterbody can receive and still meet water quality standards.

TMDLs are established to determine the pollutant load reductions needed to achieve and maintain water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria differ among waters with different designated uses.

The designated use for the tidal Maryland 8-Digit (MD 8-Digit) Assawoman Bay, Isle of Wight Bay, Newport Bay, Sinepuxent Bay, and Chincoteague Bay (Maryland Coastal Bays) is Use II: *Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting* (COMAR 2009a and 2011). The Maryland Department of the Environment (MDE) has identified the waters of the Maryland Coastal Bays on the Integrated Report as impaired by nutrients (see Table 1)(MDE 2010).

These areas were identified as impaired by nutrients due to signs of eutrophication, expressed as high levels of chlorophyll *a* (Chl *a*) and low concentrations of dissolved oxygen (DO). Eutrophication is the over-enrichment of aquatic systems from excessive nutrient inputs (nitrogen and/or phosphorus). The nutrients act as a fertilizer leading to excessive algae growth. The algae die and are consumed, eventually, by bacteria. During the consumption process the bacteria utilize the available DO, which results in decreased DO concentrations in the water column. Therefore, MDE measures and analyzes DO and Chl *a* concentrations to understand the impact of nitrogen and phosphorus loads on the ecosystem. .

Upon approval by the USEPA, this document establishes TMDLs for nitrogen and phosphorus for the MD 8-Digit Assawoman Bay, Isle of Wight Bay, Sinepuxent Bay, Newport Bay and Chincoteague Bay (Maryland Coastal Bays). These areas will be referred to as the Maryland Coastal Bays from this point forward. It also supersedes any previously developed nutrient TMDLs for these watersheds.

Table 1: Nutrient Impairments for the Maryland Coastal Bays (MDE 2010).

Year listed	MD 8-Digit Basin	Basin Code	2010 IR Assessment Unit ID	Specific Area	Identified Pollutant	Listing Category
1996	Assawoman Bay	02130102	MD-02130102-T-Assawoman_Bay	Open water	Nitrogen	5
					Phosphorus	5
			MD-02130102-T-Greys_Creek	Grey's Creek	Nitrogen	5
					Phosphorus	5
1996	Isle Of Wight Bay	02130103	MD-02130103-T-Turville_Creek	Turville Creek	Nitrogen	4a
					Phosphorus	4a
			MD-02130103-T-Manklin_Creek	Manklin Creek	Nitrogen	5
					Phosphorus	5
			MD-02130103-T-Herring_Creek	Herring Creek	Nitrogen	4a
					Phosphorus	4a
			MD-02130103-T-Bishopville_Prong	Bishopville Prong	Nitrogen	4a
					Phosphorus	4a
			MD-02130103-T-StMartin_River	St. Martin River	Nitrogen	4a
					Phosphorus	4a
			MD-02130103-T-Shingle_Landing_Prong	Shingle Landing Prong	Nitrogen	4a
					Phosphorus	4a
			MD-02130103-T-Isle_Of_Wight_Bay	Open Water	Nitrogen	5
					Phosphorus	5
1996	Newport Bay	02130105	MD-02130105-T-Newport_Creek	Newport Creek	Nitrogen	4a
			MD-02130105-T-Marshall_Creek	Marshall Creek	Nitrogen	5
					Phosphorus	5
			MD-02130105-T-Kitts_Branch	Kitts Branch	Biochemical Oxygen Demand	4a
			MD-02130105-T-Ayer_Creek	Ayer Creek	Nitrogen	4a
			MD-02130105-T-Newport_Bay	Newport Bay	Nitrogen	4a
1996	Sinepuxent Bay	02130104	MD-02130104-T	Sinepuxent Bay	Nitrogen	5
					Phosphorus	5
1996	Chincoteague Bay	02130106	MD-02130106-T	Chincoteague Bay	Nitrogen	5
					Phosphorus	5

Listing category definitions: 4a – TMDL developed; 5 – TMDL required.

2.0 SETTING AND WATER QUALITY DESCRIPTION

This section provides the setting and water quality description of the Coastal Bays, including information on the watershed's geology, land use, nutrient sources, point sources, non-point sources and water quality assessment. For more specific information on each individual tidal waterbody in the Coastal Bays, the reader is referred to Appendices A-E.

2.1 General Setting and Source Assessment

2.1.1 Watershed Description

The Coastal Bays are a shallow coastal lagoon system that spans three states; however, the majority of the system is located in Maryland. The Maryland Coastal Bays are comprised of several individual MD 8-Digit waterbodies: Assawoman Bay, Isle of Wight Bay (including the St. Martin's River), Sinepuxent Bay, Newport Bay and Chincoteague Bay. The Coastal Bays are located on the eastern side of the Delmarva (Delaware-Maryland-Virginia) Peninsula and include portions of Worcester County (Maryland), Sussex County (Delaware), and Accomack County (Virginia) (see Figure 1). Areas of interest in the watershed are Ocean City (Maryland), Assateague Island National Seashore, Ocean Pines (Maryland), Berlin (Maryland), Chincoteague National Wildlife Refuge (Virginia), Wallops Island National Wildlife Refuge (Virginia), Selbyville (Delaware), Fenwick Island (Delaware), South Bethany (Delaware), Bethany Beach (Delaware), and Ocean View (Delaware). The system connects to the Atlantic Ocean through two inlets: Ocean City Inlet and Chincoteague Inlet. Table 2 provides the watershed acres within each of the three States draining into the Coastal Bays.

Tier II watersheds are areas identified by the State of Maryland that drain to high quality waters, which need to be preserved with respect to current anti-degradation policies and regulations. In the MD 8-Digit Chincoteague Bay watershed, Maryland has identified the Little Mill Creek 1, which has a drainage area of 3,096 acres, as being a Tier II stream segment. There are no other Tier II waters within the Maryland Coastal Bays watershed (COMAR 2012).

Natural water depths in the Coastal Bays are generally less than 8 feet (ft), except for the main navigation channels around the inlets. The tidal range varies by location. Tidal range near the Ocean City Inlet is more than 3.4 ft, dropping to 0.4 ft in the middle of the Chincoteague Bay and 1.5 ft in Assawoman Bay. Strong mixing usually occurs when wind blows across these shallow waters. The residence times for the entire system range from 71.7 to 96.2 days, depending on flow regime and waterbody (see Table 3 for residence times of the individual waterbodies) (Wang 2009). The total watershed area (land area only) draining to the Coastal Bays is 210,360 acres (851 square kilometers).

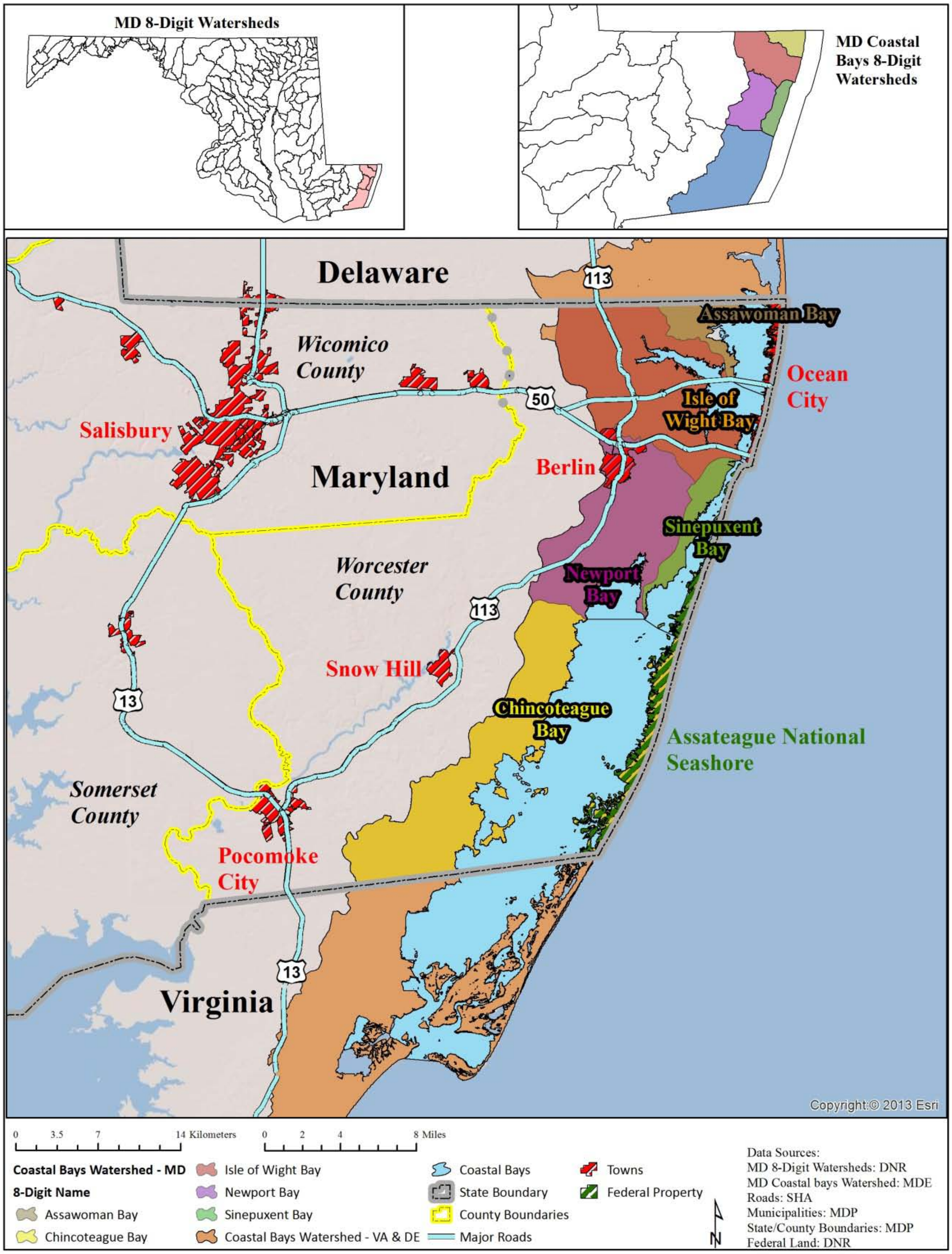

Figure 1: Location map of the Coastal Bays System

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Table 2: Coastal Bays watershed Areas per StateJurisdictions.

Jurisdictions	Area (acres)
Delaware	31,442
Maryland	120,353
Virginia	58,565
Total[1]	**210,360**

[1] Acres calculated from watershed model segmentation and are therefore slightly different than summation of land-use acres.

Table 3: Coastal Bays individual watershed areas and residence times.

Watershed	Area (acres)	Residence Time (Days)			
		High Flow	Mean Flow	Median Flow	Low Flow
Assawoman Bay	31,693	37.4	43.4	47.7	52.4
Isle of Wight	41,016	5.1	5.4	5.6	5.9
Sinepuxent Bay	7,647	9.2	9.6	9.9	10.4
Newport Bay	28,386	47.2	60.0	71.8	92.1
Chincoteague Bay	101,618	83.0	89.7	93.7	96.6
Total[1]	**210,360**	**71.7**	**80.4**	**87.0**	**96.2**

[1] Acres calculated from watershed model segmentation and are therefore slightly different than summation of land-use acres.

2.1.2 Land Use

Land use in the Coastal Bays watershed varies widely. Upstream areas in Virginia and Delaware comprise 89,920 acres or 43% of the total watershed area. The Maryland land uses are comprised of forest and other herbaceous growth - 45,367 acres (22% of the total watershed area); mixed agriculture - 32,140 acres (15%); water features - 21,478 acres (10%); urban land - 17,525 acres (8%), and barren or beaches – 3,660 acres (2%). Land use information was derived from the 2002 Delaware Land Use and Land Cover (Delaware Spatial Data Implementation Team 2003), Worcester County (Maryland) Land Use Database (Worcester County Department of Planning 2007), and, for Virginia, from the National Land Cover Database [U.S. Geological Survey (USGS) 1999]. The Worcester County land use information is highly detailed and for the purposes of this study was reclassified and aggregated to match the Chesapeake Bay Program Phase 5 Community Watershed Model (CBP-P5) land use classifications. For more details about the reclassification process, see the report entitled, “Maryland Coastal Bays Watershed Modeling Report” (VIMS 2013). Figure 2 presents the spatial land use distribution in the Coastal Bays watershed. Figure 3 shows the relative amounts of the different land uses in the Coastal Bays watershed.

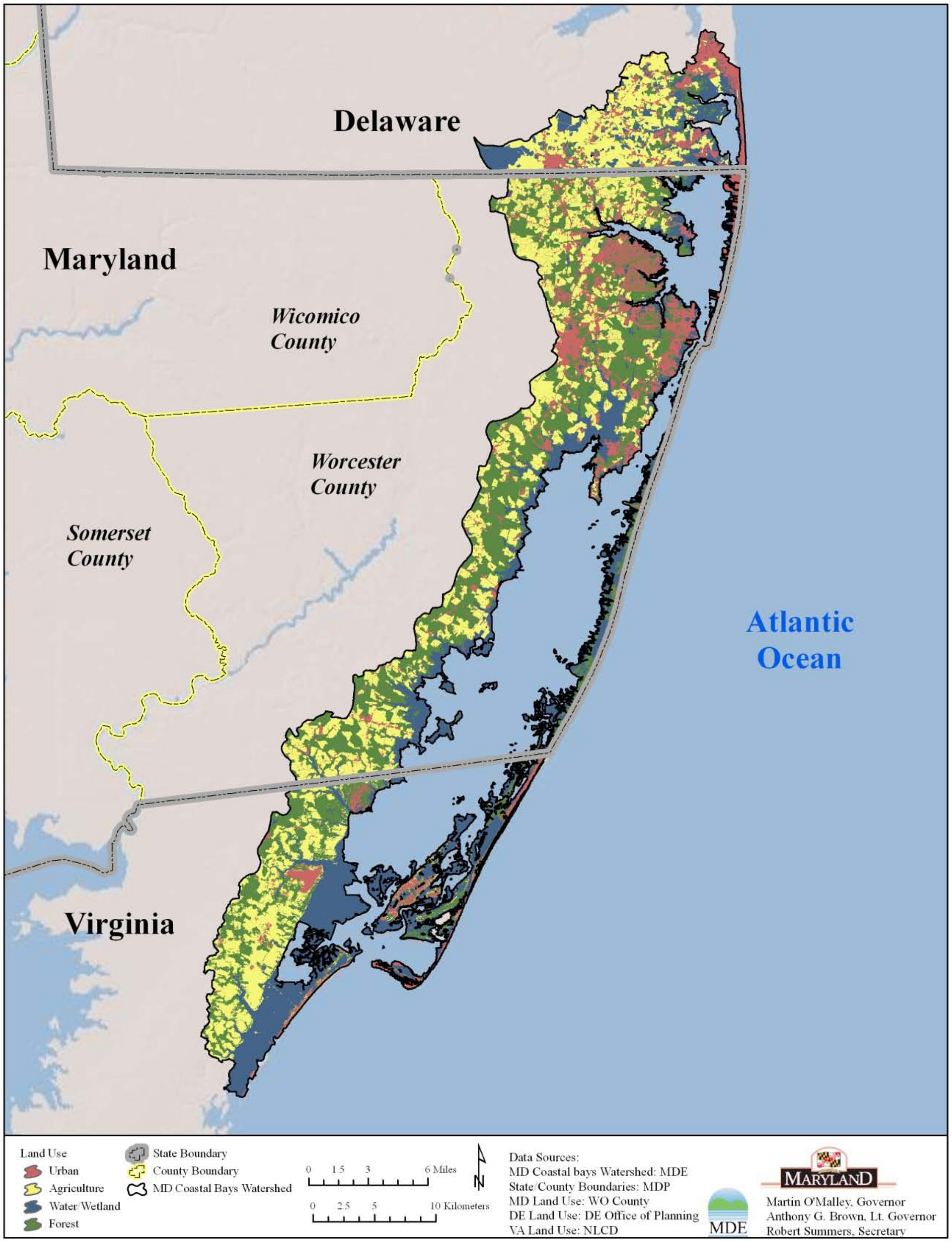

Figure 2: Land use distribution in the Coastal Bays watershed

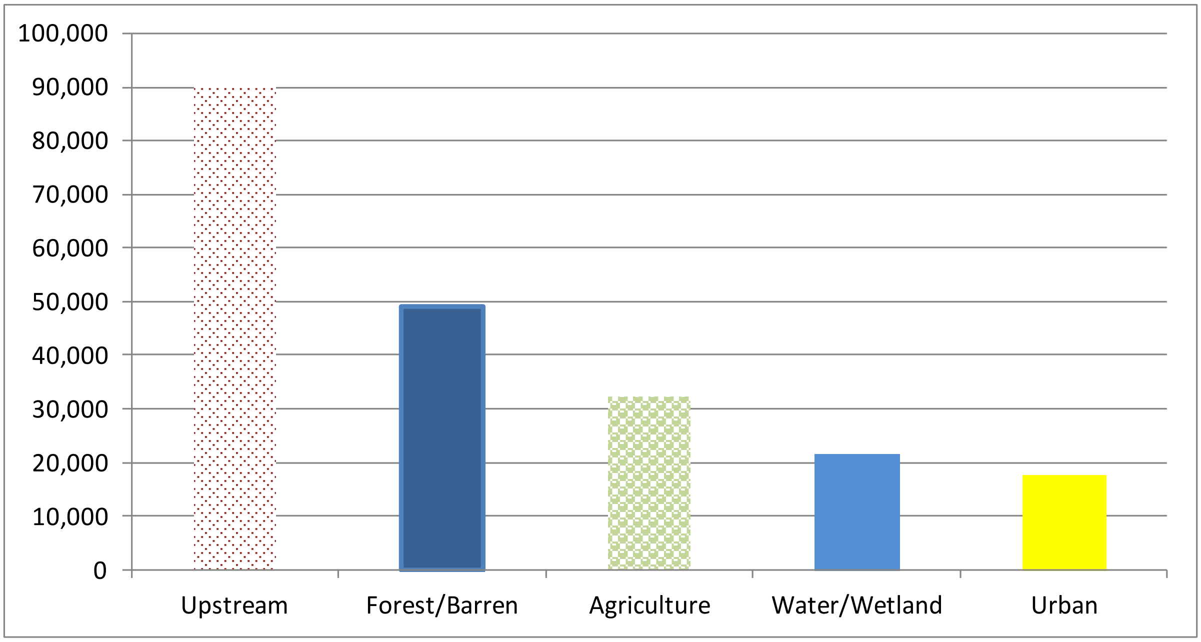

Figure 3: Proportions of land use in the basins draining the Coastal Bays watershed

2.1.3 Geology

The Maryland Coastal Bays watershed lies within the Atlantic Coastal Plain physiographic province of Maryland and is about 110 miles east of the fall line that separates the Plain from the Piedmont Plateau. The Atlantic Coastal Plain's surficial geology is characterized by thick, unconsolidated marine sediments deposited over the crystalline rock formations of the Piedmont Province. The soils are underlain by sediment consisting chiefly of gravel, silt, clay, sand, and shell fragments. The depth of these soils is generally more than 1 mile thick, but in the case of Ocean City, the soil depth is more than 1.5 miles thick. Drainage is impeded in almost 75% of the acreage of soils in Worcester County. About 20% of the soils in Worcester County can be farmed without artificial drainage (USDA, SCS 1973).

The Maryland Coastal Bays watershed is an eroded plain with three main physiographic divisions: mainland, coastal beaches and tidal marshes. All of the farmland is located on the mainland; where the soils are generally level to undulating. Many areas of the mainland are a few feet above the normal level of the streams and in many places adjacent to marshland. The beaches are located mostly on the barrier islands of Fenwick Island, Assateague Island, and Chincoteague Island. The tidal marshes are located on the eastern shores of the mainland and the western shores of the barrier islands (USDA, SCS 1973).

Groundwater is water that collects or flows beneath the Earth's surface, filling the porous spaces in soil, sediment, and rocks. Groundwater originates from rain and melting snow/ice and is the water source for aquifers, springs, and wells. The upper limit of groundwater is called the water table. Since the Coastal Bays are located in the Coastal Plain, some areas of the Coastal Bays receive direct discharge from groundwater to surface waters since the water table is close to the land surface. In the Coastal Bays watershed, the lag time from actions taken on the land surface and reaction within the waterbodies may be substantial. Phillips, Focazio and Bachman (1999) report that groundwater travel times can vary from 6 to 12 years in the Coastal Plain portion of the Chesapeake Bay Watershed. Sanford *et al.* (2012) developed a model to use in predicting trends in nitrate transport in groundwater on the Delmarva

Peninsula. Sanford *et al.* estimate a return time (from recharge area to discharge to a receiving waterbody) of less than 10 years (near streams) to over 100 years (near stream divides).

2.1.4 Nutrients Source Assessment

2.1.4.1 Point Sources: National Pollutant Discharge Elimination System (NPDES) Loads

Point sources are discharges that can be traced back to the end of a pipe. As defined by the USEPA's National Pollutant Discharge Elimination System (NPDES) Permit Guidelines, these sources include municipal wastewater treatment plants (WWTPs), industrial facilities, municipal separate storm sewer systems (MS4s) and stormwater from regulated industrial facilities, injection wells, and spray irrigation facilities. There are twenty-six Process water point source facilities within the Coastal Bays watershed from all jurisdictions. In the upstream watershed areas, there are ten facilities with permits regulating the discharge of nutrients.

In Maryland, there are five municipal WWTPs with surface discharge NPDES permits located within the Coastal Bays modeling domain: Newark WWTP, Ocean Pines WWTP, Berlin WWTP, Assateague Island National Seashore WWTP and Ocean City WWTP. The Ocean City WWTP discharges into the Atlantic Ocean, outside of the Maryland Coastal Bays watershed. The Berlin WWTP incorporates spray irrigation as part of its discharge process, and these fields are located within the Upper Pocomoke River watershed.

In Maryland, there are five spray irrigation facilities located within the modeling domain: Riddle Farm WWTP, Lighthouse Sound WWTP, Assateague Pointe WWTP, River Run WWTP, and Perdue Farms. There are two injection well facilities located within the modeling domain: The Mystic Harbor and The Landings. There are three industrial point sources located within the modeling domain: Perdue Farms, Inc. – Showell Complex, Kelly Foods Corporation, and Berlin Properties North, LLC.

The combined estimated, average annual loads from point sources by type are displayed in Table 4. Table 5 presents the delivered total nitrogen (TN) and total phosphorus (TP) loads for each identified facility. This information was gathered from several sources including MDE's point source database, Delaware Department of Natural Resources and Environmental Conservation (DNREC), and Virginia Department of Environmental Quality (VADEQ). The Virginia municipal loadings were estimated using the facilities' Standard Industrial Classification (SIC) codes, identified flow, and methods used in the CBP-P5 model.

Under the Clean Water Act, concentrated animal feeding operations (CAFOs) require NPDES permits for their surface water discharges, or potential discharges (CFR 2013b). In January, 2009, Maryland implemented new regulations governing CAFOs (COMAR 2013a,b,c), which were approved by the USEPA in January, 2010. Under these regulations, CAFOs are required to fulfill the conditions of a general permit. These conditions include instituting a Comprehensive Nutrient Management Plan (CNMP) that meets the Nine Minimum Standards to Protect Water Quality, which include: 1) ensure adequate storage capacity, 2) ensure proper management of mortalities to prevent the discharge of pollutants into waters of the State, 3) divert clean water, as appropriate, from the production area to keep it separate from process wastewater, 4) prevent direct contact of confined animals with waters of the State, 5) chemical handling, 6) conservation practices to control nutrient loss, 7) protocols for manure and soil testing, 8) protocols for the land application of manure and wastewater, and 9) record keeping. These are described in further detail in the general CAFO permit (MDE 2009a). The general permit also prohibits the discharge of pollutants, including nutrients, from CAFO production areas, except as a result of events greater than the 25-year, 24-hour storm. There are twenty-two operators in the Maryland Coastal Bays watershed that have filed notices of intent to apply for permits under Maryland's CAFO or Maryland Animal Feeding Operation (MAFO) regulations.

Table 4: Average daily flows and estimated annual TN and TP loads for process water point sources discharging into the Maryland Coastal Bays modeling domain, 2001 – 2004.

Facility	**Type**	**Average Flow [Million gallons per day(MGD)]**	**Estimated Delivered TN Load [pounds per year (lbs/yr)]**	**Estimated Delivered TP Load (lbs/yr)**
Maryland				
Berlin WWTP	Municipal	0.070	751	14
Newark WWTP	Municipal	0.039	1,034	300
Ocean Pines WWTP	Municipal	0.9	10,093	867
Berlin North WWTP	Industrial	0.044	5,378	484
Assateague Island National Seashore	Municipal	0.004	662	191
Perdue Farms, Inc.: Showell Facility	Industrial	0.63	5,279	193
Kelly Foods Corporation	Industrial	0.006	112	2
Riddle Farm WWTP – outfall 001	Spray Irrigation	0.0576	0	0
Riddle Farm WWTP – outfall 002	Spray Irrigation	0.198	0	0
Lighthouse Sound WWTP	Spray Irrigation	0.038	183	0
Assateague Pointe WWTP	Spray Irrigation	0.042	367	0
River Run WWTP	Spray Irrigation	0.11	2,614	0
Perdue Farms – Bishopville Hatchery	Spray Irrigation	0.004	549	0
The Mystic Harbour	Injection Well	0.103	853	0
The Landings	Injection Well	0.10	0.00	0
Upstream - Delaware			**2,359**	**484**
Upstream - Virginia			**26,507**	**7,596**
Total			**354,981**	**51,885**

*The Ocean City WWTP is located within the watershed but discharges to the Atlantic Ocean, outside of the boundary of the Coastal Bays system. The water quality modeling domain extends into the Atlantic Ocean along Fenwick Island. The facility was incorporated into the analysis for completeness with an average flow of 5MGD, estimated delivered TN load of 298,240 lbs/year and estimated delivered TP load of 41,754 lbs/year. Average flow shown for Berlin North WWTP is surface discharge only.

2.1.4.2 Nonpoint Source Loads

Urban Stormwater and Agricultural Loads

Nonpoint source loads and urban stormwater loads entering the Maryland Coastal Bays were estimated using the Hydrologic Simulation Program-FORTRAN (HSPF) watershed model. Urban stormwater regulated by an NPDES stormwater permit, such as a Municipal Separate Storm Sewer System (MS4) permit, industrial stormwater permit, etc., is considered a point source by USEPA; however, there are no NPDES stormwater permits within the Maryland Coastal Bays watershed. Urban stormwater loads are thus presented as nonpoint sources in this document. The HSPF model is used to estimate flows, suspended solids, and nutrient loads from the watersheds' sub-basins. The HSPF model consists of 199 watershed segments. Two of the segments, Birch Branch and Bassett Creek, have measured flow data collected by the USGS, and therefore include simulated stream reaches. The model generates simulated runoff and loads for many different parameters (see VIMS 2013 for details). The model timeframe spanned the period of 2000-2005. The TMDL analysis was conducted using the 2001-2004 period as a baseline, which includes dry, wet and average years. The year 2000 served as the model's initialization period, and the available water quality data was only available up to August of 2005; therefore, the delivered loads in the figures represent an average for the 2001-2004 period.

Nonpoint source loads generated by the HSPF watershed model are linked to a three-dimensional, time-variable hydrodynamic model and a water quality model, coupled with a sediment process model designed specifically for the Coastal Bays system. The water quality model is used to determine the maximum nutrient load that can enter the Maryland Coastal Bays while maintaining the water quality criteria associated with its designated uses. The water quality modeling framework is described in Section 4.2.

The Coastal Bays HSPF watershed model incorporated several sets of data from various sources, which are considered to be the best and most readily available data. The spatial distribution of precipitation was estimated from the meteorological data available in the area, which included: (1) hourly time-series of precipitation measured at Ocean City Municipal Airport (Maryland), Wallops Island (Virginia), and Assateague Island (MD); (2) daily precipitation data measured at the Selbyville (Delaware) WWTP; and (3) an hourly time series of precipitation developed for the CBP-P5 model in the nearby area. The CBP-P5 precipitation data were used to cover gaps in the hourly sources and to disaggregate daily values into hourly values. Agricultural information, including nutrient application rates and crop distribution, was obtained from the Chesapeake Bay Program (CBP) at the county level (USEPA 2008). Application rates were adjusted based on the following references: Delaware Department of Planning land use data; the 2002 U.S. Agricultural Census Data; data provided by VADEQ on the number of animals per model segment; and manure transport information provided in Parker and Li (2006). Seamless 30-meter (m) Digital Elevation Models (DEMs) from the National Elevation Data Base (USGS 1999) were used to identify the longest surface flow path for ungaged model segments. The intersection of the lowest end of the flow path with the hydrodynamic model was used to segment the ungaged watersheds. The HSPF model developed by the USGS for the Delaware Inland Bays watershed (Gutiérrez-Magness and Raffensperger 2003) was extended to cover the this model's timeframe (2000-2005) and is used "as is" for the portion of the Coastal Bays watershed located in Delaware to predict the hydrology and nutrient loads to the system.

The HSPF model simulates nonpoint source loads from all natural and human-induced sources, including direct atmospheric deposition. Details of the HSPF watershed model developed to estimate these nonpoint source loads are found in VIMS (2013). Table 5 presents the delivered loads from the different land uses within the watershed.

Table 5: Average annual nonpoint source delivered TN and TP loads, 2001-2004.

MD 8-Digit Waterbody	Upstream	MD 8-Digit Contribution			
		Forest/ Barren	Mixed Agricultural	Urban	Total Land Use Load for Watershed
TN Load(lbs/yr)					
Assawoman Bay	215,432	1,657	17,645	21,568	256,302
Isle of Wight Bay	64,813	6,951	131,088	95,578	298,431
Newport Bay	0	6,203	92,167	46,188	144,558
Sinepuxent Bay	0	1,671	6,054	21,662	29,387
Chincoteague Bay	239,951	10,916	158,537	18,289	427,693
Total	**520,196**	**23,476**	**388,674**	**200,979**	**1,156,371**
TP-lbs/yr					
Assawoman Bay	16,527	80	1,103	2,038	19,748
Isle of Wight Bay	5,171	585	8,435	8,704	22,895
Newport Bay	0	529	5,927	4,407	10,863
Sinepuxent Bay	0	143	388	2,060	2,591
Chincoteague Bay	16,600	882	10,108	1,910	29,500
Total	**39,359**	**2,270**	**25,310**	**18,659**	**85,597**

lbs/yr = pounds per year

On-Site Wastewater Disposal (Septic Systems)

The average septic system delivers about 30 lbs of nitrogen per year to the groundwater. Of the estimated 420,000 septic systems in Maryland, 52,000 septic systems are in the Critical Area (within 1000 ft of tidal waters of the State); approximately 80 percent of the nitrogen from a septic system in the Critical Area will reach surface waters (MDE 2009b). In the Maryland Coastal Bays watershed, there are 4,188 septics, of which 3,021 (72%) are in the Critical Area. Therefore, septic system nutrient loads need to be taken into account as a source of nutrients within the Coastal Bays watershed.

Septic nutrient loading values were calculated using 2000 U.S. Census data (US Census Bureau 2000), CBP's sewer service area Geographic Information System (GIS) coverage (USEPA 2010), the CBP-P5 land river segment GIS coverage (USEPA 2010), DNREC's 1997 septic system coverage (DNREC 1997), Maryland Department of Planning's (MDP) septic system coverage (MDP 2007), and the HSPF watershed model segmentation (VIMS 2013). The estimated delivered load from septic systems is 184,067 lbs/yr TN. Table 6 lists septic system loadings to the individual MD 8-Digit waterbodies in the Maryland Coastal Bays. These loads were calculated based on a methodology used by the EPA-CBP. Further details on the septic system load estimation methodology can be found in VIMS (2013).

Table 6: Average annual on-site wastewater disposal (septic systems) delivered TN loads, 2001-2004.

MD 8-Digit Waterbody	TN Load (lbs/yr)	
	Upstream	MD 8-Digit Contribution
Assawoman Bay	19,225	10,658
Isle of Wight Bay	1,145	38,527
Sinepuxent Bay	0	6,971
Newport Bay	0	21,183
Chincoteague Bay	73,259	13,099
Total	**93,629**	**90,438**

Atmospheric Deposition

Atmospheric deposition occurs when pollutants are transferred from the air to the earth's surface. In the watershed model, this load is simulated as part of the nonpoint source loads. The estimated TN deposition per area is applied to all the simulated land uses, as well as to the simulated streams in the two segments in which there are USGS gaging stations (Birch Branch and Bassett Creek). For the other segments within the watershed model, the loading rates for the different land uses inherently capture the loadings from atmospheric deposition because they were added to the land-use loads during model calibration in the Birch and Bassett Creek segments. For more details, see the documentation for the USEPA's CBP-P5 Model (USEPA 2010).

The time series used for estimating direct atmospheric deposition to the surface waters of the Coastal Bays for the model simulation period was obtained from the National Atmospheric Deposition Program, which collected data at Assateague Island National Seashore for the period of 2001 – 2004. Only wet-deposited nitrogen is collected at the station. Scientific consensus is that dry-deposited nitrogen is roughly equal to wet (MDE 2013). Accordingly, the deposition amount was doubled to account for both wet and dry conditions. In keeping with the Chesapeake Bay TMDL/Community Multi-scale Air Quality Model methodology, a 20:1 nitrogen to phosphorus ratio was assumed, so as to incorporate phosphorus deposition (USEPA 2010). For more detailed information, see Wang *et al.* (2013). The total direct atmospheric deposition loads to the surface waters of the individual waterbodies in the Coastal Bays system are presented in Table 7.

Table 7. Average annual TN and TP atmospheric deposition loads, 2001-2004.

MD 8-Digit Waterbody	TN Load (lbs/yr)		TP Load (lbs/yr)	
	Upstream	MD 8-Digit Contribution	Upstream	MD 8-Digit Contribution
Assawoman Bay	18,337	45,025	918	2,249
Isle of Wight Bay	0	51,901	0	2,594
Newport Bay	0	30,214	0	1,510
Sinepuxent Bay	0	43,396	0	2,169
Chincoteague Bay	213,444	334,129	10,668	16,700
Total	**231,781**	**504,665**	**11,586**	**25,222**

Shoreline Erosion

The entire length of the natural shoreline within Maryland's tidal zone consists of unconsolidated sands, silts, and clays. This geology contrasts, for example, with the hard rock shores characteristic of much of New England. Consequently, it is relatively easy for water to erode the unconsolidated sediments in Maryland's coastal plain. Apart from this generalization, however, it is important to realize that the challenges posed by shoreline erosion in Maryland reflect the unique combination of both natural and man-made conditions affecting a particular shoreline region. Natural conditions include weather, soil composition, topography, bathymetry (water depth), fetch (the distance across water affected by wind and, hence, wave energy), surface water conditions, and groundwater conditions. Shores consisting of very fine or unconsolidated silts and clays, or lighter organic materials (such as marshes) are particularly at risk, especially when exacerbated by unfavorable weather, wave energy, and soil drainage conditions (DNR 2000).

In addition to direct economic, environmental, and cultural impacts, shore erosion has important off-site impacts; the most obvious and pervasive being the deposition of sediment into the State's tidal waters. This sediment degrades water quality and aquatic resources by increasing turbidity, which blocks sunlight needed for submerged plant growth and impairs visibility for sight-feeding fish. Sediment that remains suspended in the water column clogs the gills of aquatic organisms, which is particularly dangerous to the survival of very young and juvenile fish. Additional impacts follow as eroded sediment and debris drop out of the water column and are deposited on the bottom surface of the tidal system. These impacts include smothering oyster bars and submerged aquatic vegetation beds, increasing dredging costs, and impairing commercial and recreational navigation. Sediment also releases nutrients into the water, thereby robbing water of dissolved oxygen essential to other aquatic life by accelerating the growth and decay of algae (DNR 2000).

Given the extent of coastline in the Coastal Bays system, nutrient inputs from shoreline erosion had to be taken into account in the model. Table 8 presents the estimated TN and TP loads associated with shoreline erosion for the Coastal Bays system. These estimates were calculated based on information presented in Wells, Hennessee, and Hill (2002 and 2003), and Wells *et al.* (2008).

Table 8. Average annual TN and TP loads associated with shoreline erosion, 2001-2004.

MD 8-Digit Waterbody	**TN Load (lbs/yr)**		**TP Load (lbs/yr)**	
	Upstream	MD 8-Digit Contribution	Upstream	MD 8-Digit Contribution
Assawoman Bay	0	10,923	0	1,008
Isle of Wight Bay	0	18,729	0	2,196
Newport Bay	0	6,221	0	833
Sinepuxent Bay	0	9,064	0	1,469
Chincoteague Bay	91,807	53,918	12,649	7,429
Total	**91,807**	**98,855**	**12,649**	**12,935**

Figure 4 presents the average annual loads of nitrogen and phosphorus from all sources to the Maryland Coastal Bays during the 2001-2004 period.

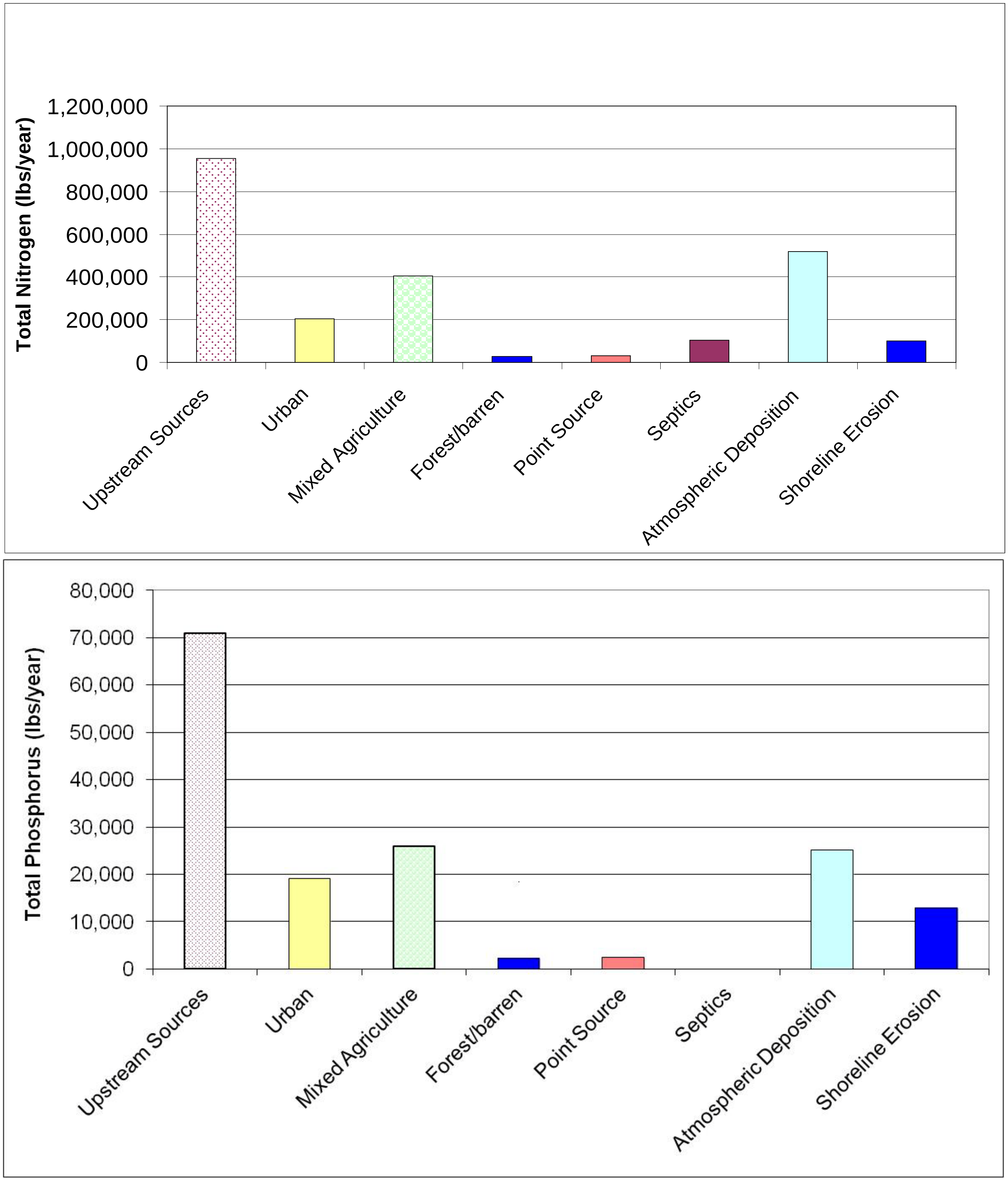

Figure 4: Average annual TN and TP loads (lbs/yr) from all sources delivered to the Maryland Coastal Bays, 2001-2004

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In the Maryland portion of the Coastal Bays watershed, the estimated 2001-2004 average annual, delivered nonpoint source TN load is 1,330,117 lbs/yr, and the TP load is 84,396 lbs/yr. From Maryland, the estimated 2001-2004 average annual point source TN load is 27,710 lbs/yr, and the estimated 2001-2004 average annual point source TP load is 2,434 lbs/yr.

2.2 Water Quality Characterization

Eutrophication is the over-enrichment of aquatic systems from excessive nutrient inputs (nitrogen and/or phosphorus). The nutrients act as a fertilizer leading to excessive growth of algae. The algae grow rapidly, die and are subsequently consumed by bacteria. The bacterial consumption of algae uses the available oxygen in the water column, which produces hypoxic (low oxygen) or anoxic (no oxygen) conditions. Typically, problems associated with eutrophication are most likely to occur during the growing season (May 1 – October 31). The two key water quality parameters associated with eutrophication are Chl *a* and DO.

A number of different organizations conduct water quality monitoring in the Coastal Bays watershed. The Maryland Coastal Bays Program collects data throughout the watershed, and VADEQ collected water quality data for portions of the lower Chincoteague Bay. These datasets, however, did not meet the requirements of the modeling domain (one dataset was not within the water quality modeling framework and the other was collected after the model calibration period). These datasets can still be used to verify trends within the watershed. The eutrophication model was developed using data collected from 2000-2005. There are a total of forty-five stations with available data. These stations are operated by the Maryland Department of Natural Resources (DNR) (twenty-seven stations) and the U.S. National Park Service- Assateague Island National Seashore (ASIS) (eighteen stations). These datasets were combined to give the best possible range and coverage for the analysis.

Figure 5 presents the locations of all the water quality monitoring stations, submerged aquatic vegetation (SAV) grow zones. Figures 6 through 10 present the DO and Chl *a* data for representative stations - generally, one located in the upstream or headwaters portion, and one in the downstream or open water portion. A key trend noted in the data is that the majority of low DO and high Chl *a* values are observed in the headwater tributaries rather than in the open waters of the Maryland Coastal Bays.

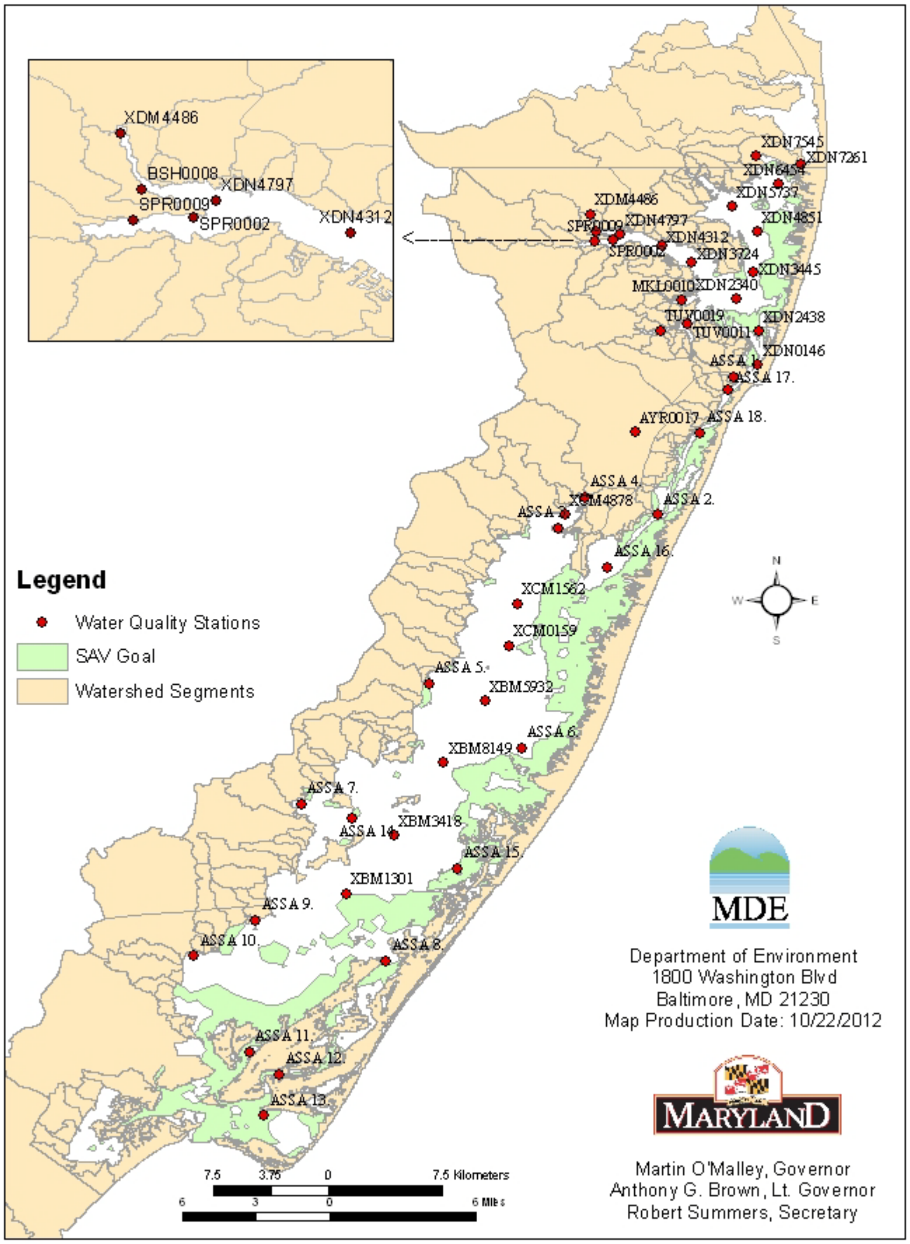

Figure 5: Location of water quality monitoring stations and SAV grow zones.

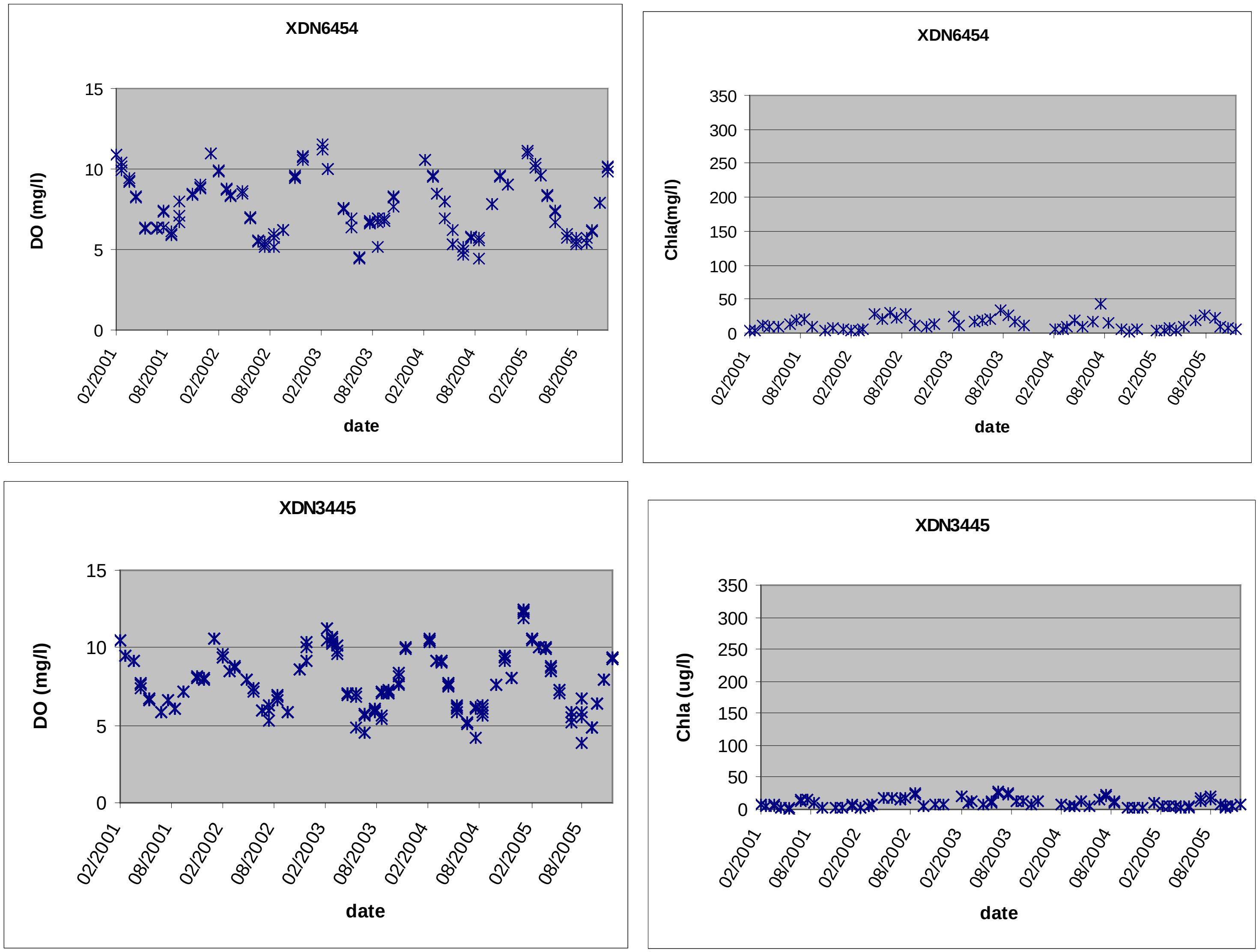

Figure 6: DO and Chl *a* data for stations XDN6454 (Upstream) and XDN3445 (downstream/open water) - MD 8-Digit Assawoman Bay.

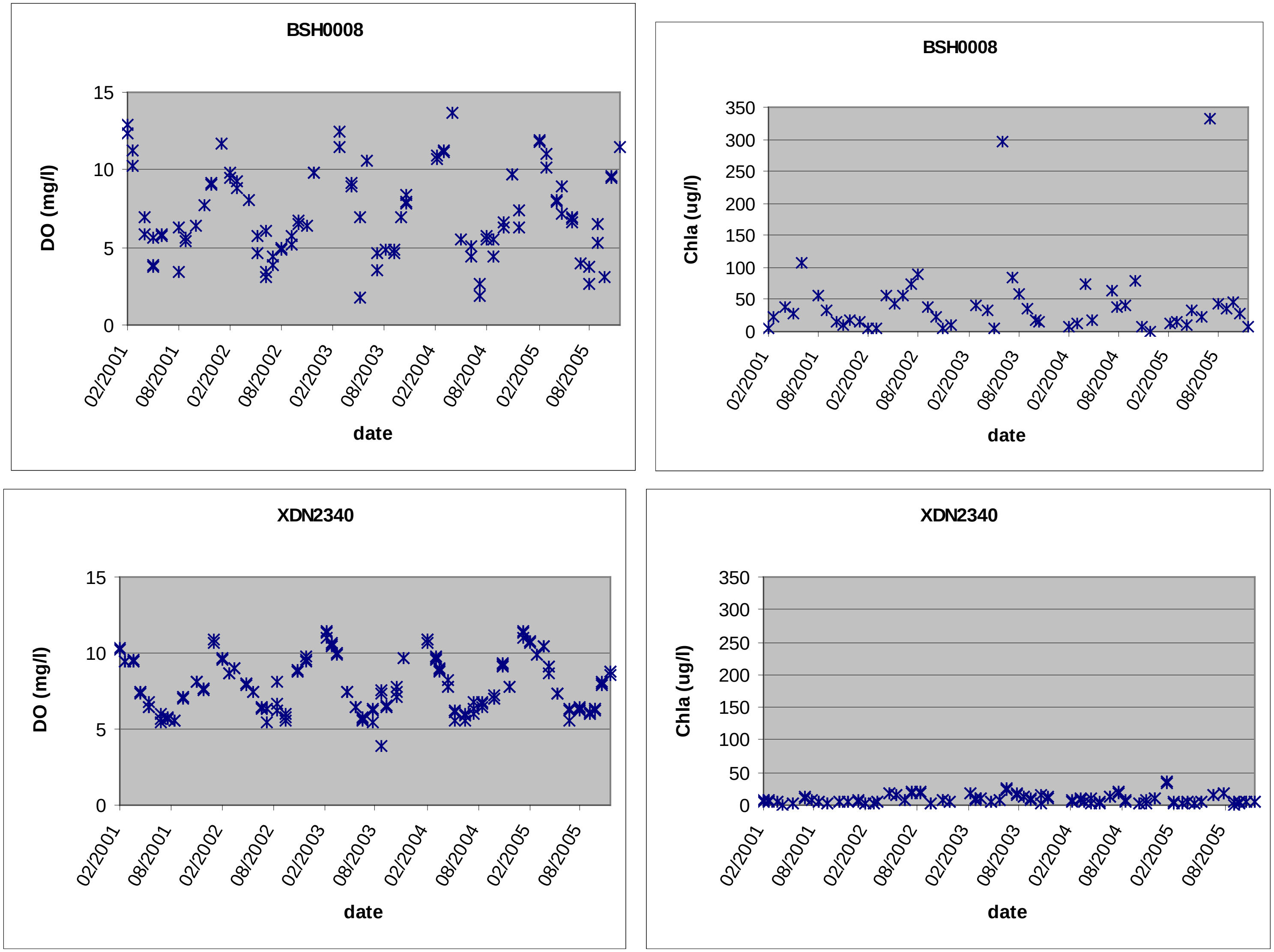

Figure 7: DO and Chl *a* data for stations BSH0008 (Upstream) and XDN2340 (downstream/open water) - MD 8-Digit Isle of Wight Bay.

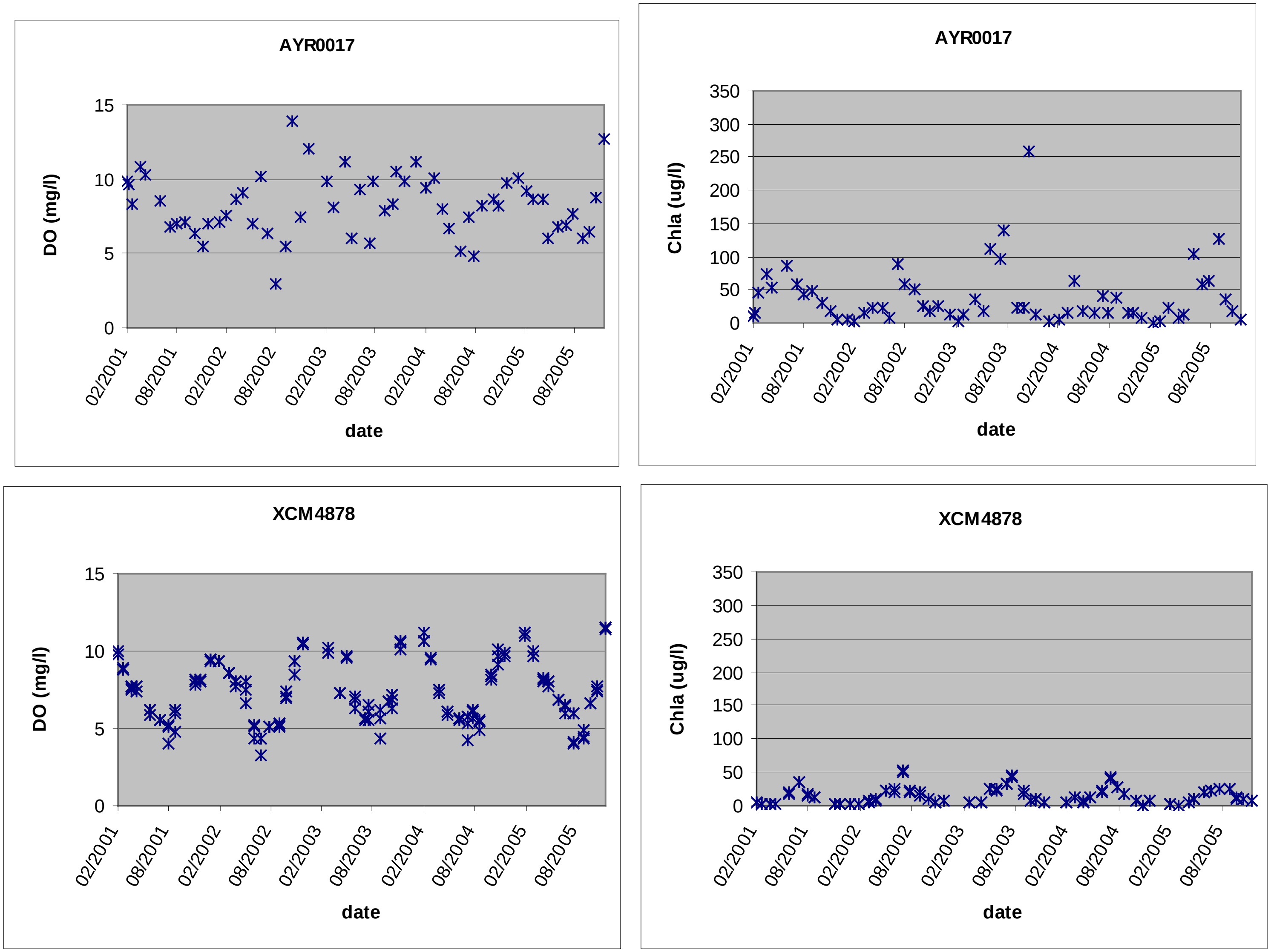

Figure 8: DO and Chl a data for stations AYR0017 (Upstream) and XCM4878 (downstream/open water) - MD 8-Digit Newport Bay.

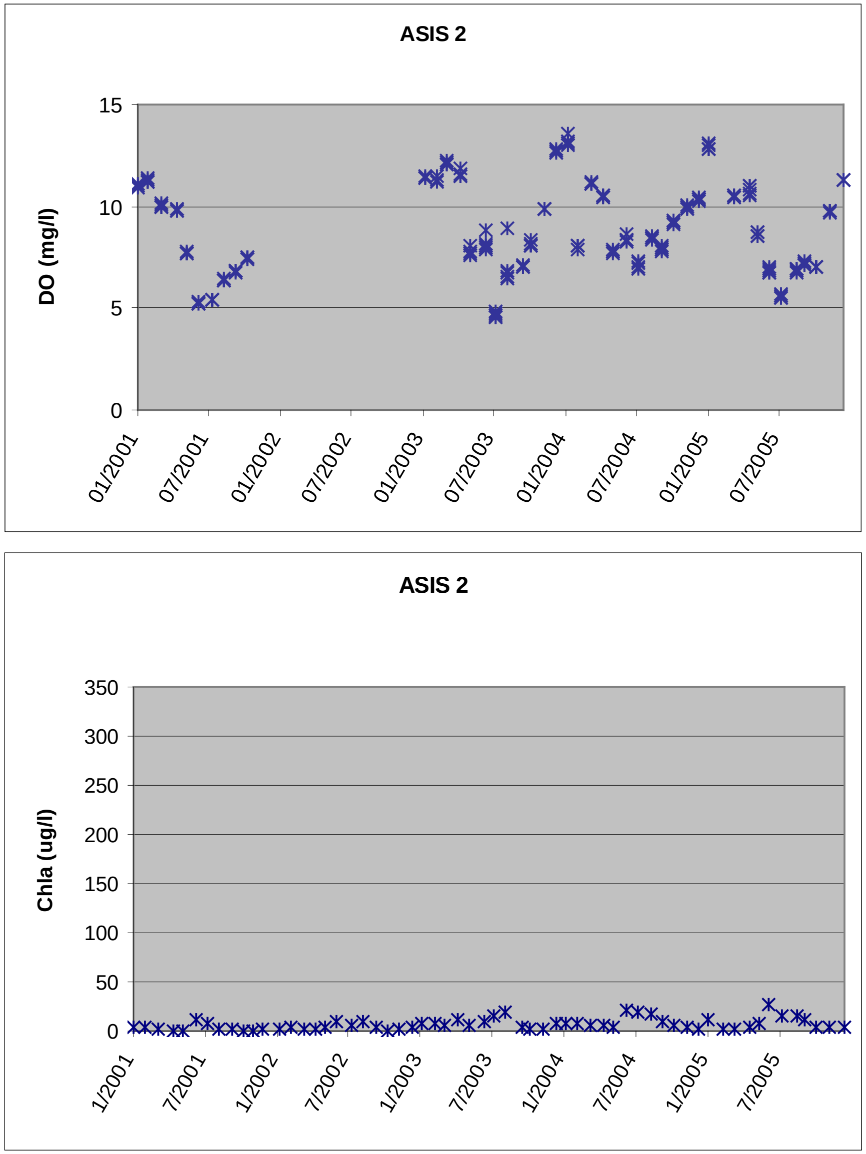

Figure 9: DO and Chl *a* data for station ASIS 2 - MD 8-Digit Sinepuxent Bay.

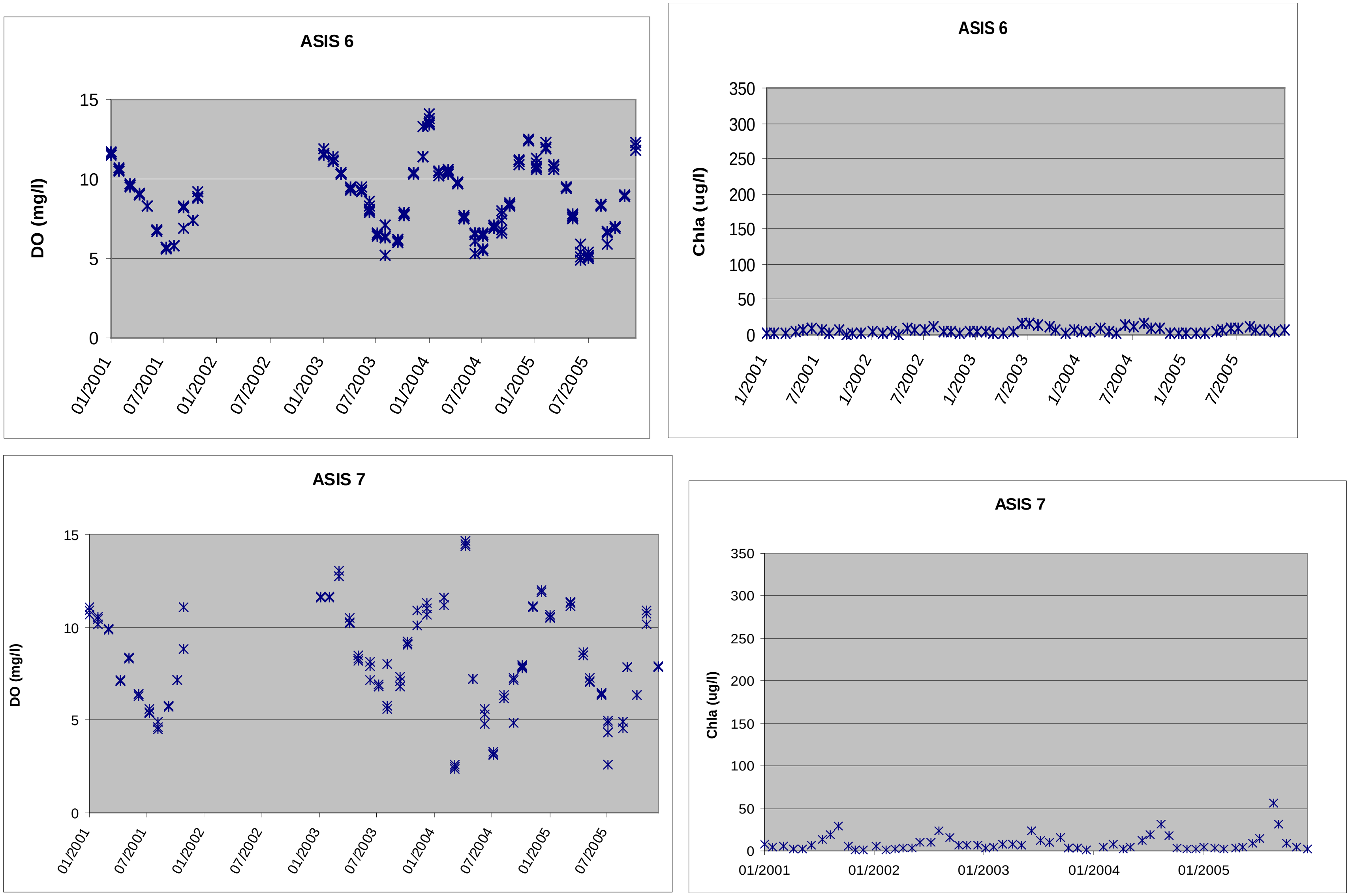

Figure 10: DO and Chl a data for stations ASIS 6 and ASIS 7 - MD 8-Digit Chincoteague Bay.

2.3 Water Quality Impairment

The Maryland Coastal Bays are designated as Use II—*Support of estuarine and marine aquatic life and shellfish harvesting* (COMAR 2009a and 2011). Two categories of water quality criteria apply to this designated use - a set of numeric criteria for DO and narrative criteria for Chl *a*.

2.3.1 Dissolved Oxygen Criteria

Maryland requires a minimum DO concentration of 5.0 milligrams per Liter (mg/L) at any time (COMAR 2009b). Table 9 presents the frequency of DO levels falling below 5.0 mg/L at each station.

Table 9: 2001-2004 water quality monitoring data indicating the percent of time DO levels are below 5 mg/L.

MD-8digit-basin	Sub-basin Name	Station	Growing Season (% < 5.0 mg/L)	Average Annual (% < 5.0 mg/L)
Asswoman Bay	Assawoman Bay	XDN3445	0.00	0.00
		XDN4851	0.00	2.33
		XDN5737	0.00	0.00
		XDN6454	4.17	2.33
Isle of Wight Bay	Bishopville Prong	BSH0008	47.83	26.19
		XDM4486	37.50	20.93
	Shingle Landing Prong	SPR0002	16.67	8.89
		SPR0009	17.39	9.30
	St. Martin River	XDN3724	12.50	6.82
		XDN4312	29.17	15.56
		XDN4797	16.67	8.89
	Turville Creek	TUV0011	16.67	8.89
		TUV0019	0.00	10.64
	Manklin Creek	MKL0010	62.50	35.56
	Isle of Wight Bay	XDN0146	0.00	0.00
		XDN2340	0.00	0.00
		XDN2438	0.00	0.00
Newport Bay	Ayer Creek	AYR0017	8.33	4.17
	Newport Bay	XCM4878	13.04	6.98
		ASSA 3.	0.0	0.00
		ASSA 4.	0.0	0.00
Sinepuxent Bay	Sinepuxent Bay	ASSA 1.	5.6	2.94
		ASSA 2.	5.6	2.94
		ASSA 16.	0.0	0.00
		ASSA 17.	0.0	0.00
		ASSA 18.	0.0	0.00
Chincoteague Bay	Chincoteague Bay	XBM1301	0.00	0.00
		XBM3418	0.00	0.00
		XBM5932	0.00	0.00
		XBM8149	0.00	2.27
		XCM0159	8.70	4.55
		XCM1562	0.00	0.00
		ASSA 5.	0.0	0.00
		ASSA 6.	0.0	0.00
		ASSA 7.	11.1	8.82
		ASSA 14.	5.6	5.88
		ASSA 15.	5.6	5.88

2.3.2 Chlorophyll *a* Criteria

Maryland does not have numeric criteria for Chl *a*. Maryland's narrative criterion for Chl *a* states that "Concentrations of chlorophyll *a* in free-floating microscopic aquatic plants (algae), may not exceed levels that result in ecologically undesirable consequences that would render tidal waters unsuitable for designated uses" (COMAR 2009b).

In other estuarine areas, Maryland has previously used a TMDL endpoint for Chl *a* of 50 µg/L, or in some cases, a goal of 50 µg/L with a maximum allowable absolute value of 100 µg/L as in guidelines set forth by Thomann and Mueller (1987) and by the "EPA Technical Guidance Manual for Developing Total Maximum Daily Loads, Book 2, Part 1" (1997). These guidelines acknowledge that it is acceptable to maintain Chl *a* concentrations below a maximum of 100 µg/L, with a target threshold of less than 50 µg/L.

However, for the Maryland Coastal Bays TMDL, Maryland is interpreting "protection of aquatic life" to include the protection of submerged aquatic vegetation (SAV). SAV are an important component of the Coastal Bays ecosystem. SAV are vascular plants that live and grow completely underwater or just up to the water's surface. SAV are found in shallow areas where sufficient light for photosynthesis can penetrate the water column. SAV performs a number of important ecological functions. It has long been recognized as a major source of food for waterfowl. SAV plays an important role in providing habitat and nursery areas for many species of fish and invertebrates. Aquatic plant beds and their associated leaves and stems provide cover for many fish such as minnows and killifish. SAV is also important in the process of removing suspended sediment from the water column. The leaves and stems reduce water currents and wave energy, while the roots tend bind to the bottom substrate. This allows suspended sediments in the water column to settle out and helps to prevent bottom sediments from being resuspended. SAV also helps to retard shoreline erosion by absorbing wave energy (FWS 1992).

In the Coastal Bays system, many factors (*e.g.* substrate composition, depth, and current speed) affect the suitability of a given area to serve as habitat for SAV. However, a consensus has emerged among scientists most familiar with this particular system that, in SAV growth areas, a chlorophyll *a* concentration whereby the 90^{th} percentile does not exceed 15 µg/L is supportive of SAV survival and growth (Dennison *et al.* 1993).

The Maryland Coastal Bays Program has identified several SAV grow zones within the Maryland Coastal Bays. In order to be protective of these areas, a 2,500-foot buffer was applied to the identified SAV grow zones, and the water quality monitoring stations within the buffered grow zones have been identified. The majority of the stations within the Maryland Coastal Bays (54%) are being treated as SAV growth areas. The stations that are not located in the grow zones are generally located in the headwaters of the system. Table 10 presents the stations that are not located within SAV grow zones. Therefore, depending on station location and proximity to SAV grow zones, two Chl a endpoints have been chosen. Table 11 presents the occurrence frequency of Chl *a* levels exceeding the applicable criteria at each monitoring station.

Table 10: Stations identified as not within SAV grow zones or the 2,500 ft buffer.

Station Name	MD 8-Digit Basin (Sub-Basin)
XDN5737	Assawoman Bay
XDM4486	Isle of Wight Bay (Bishopville Prong)
BSH0008	Isle of Wight Bay (Bishopville Prong)
SPR0009	Isle of Wight Bay (Shingle Landing Prong)
SPR0002	Isle of Wight Bay (Shingle Landing Prong)
XDN4797	Isle of Wight Bay (St. Martins River)
XDN4312	Isle of Wight Bay (St. Martins River)
XDN3724	Isle of Wight Bay (St. Martins River)
MKL0010	Isle of Wight Bay (Manklin Creek)
TUV0019	Isle of Wight Bay (Turville Creek)
TUV0011	Isle of Wight Bay (Turville Creek)
AYR0017	Newport Bay (Ayer Creek/Kitts Branch)
XCM4878	Newport Bay
ASSA4	Newport Bay
XBM3418	Chincoteague Bay
XBM5932	Chincoteague Bay
XCM1562	Chincoteague Bay

Table 11: 2001-2004 water quality monitoring data indicating the percent of time chlorophyll *a* levels are not meeting the TMDL endpoint.

MD-8digit-basin	Sub-basin Name	Station	Applicable Endpoint (µg/L)	Growing Season (% > Endpoint Concentration)	Average Annual (% > Endpoint Concentration)
Asswoman Bay	Assawoman Bay	XDN3445	<15	29.17	17.78
		XDN4851	<15	45.83	27.91
		XDN6454	<15	70.83	41.86
		XDN5737	<50	0.00	0.00
Isle of Wight Bay	Bishopville Prong	BSH0008	<50	39.13	26.19
		XDM4486	<50	50.00	41.86
	Shingle Landing Prong	SPR0002	<50	25.00	15.56
		SPR0009	<50	43.48	27.91
	St. Martin River	XDN3724	<50	0.00	4.55
		XDN4312	<50	4.17	6.67
		XDN4797	<50	8.33	11.11
	Turville Creek	TUV0011	<50	4.17	2.22
		TUV0019	<50	8.33	4.26
	Manklin Creek	MKL0010	<50	4.17	2.22
	Isle of Wight Bay	XDN0146	<15	8.33	6.67
		XDN2340	<15	20.83	13.33
		XDN2438	<15	12.50	8.89
Newport Bay	Ayer Creek	AYR0017	<50	37.50	25.00
	Newport Bay	XCM4878	<50	4.00	2.33
		ASSA 3.	<15	50.00	27.66
		ASSA 4.	<50	4.17	2.17
Sinepuxent Bay	Sinepuxent Bay	ASSA 1.	<15	8.33	4.26
		ASSA 2.	<15	12.50	6.38
		ASSA 16.	<15	20.83	10.64
		ASSA 17.	<15	12.50	6.38
		ASSA 18.	<15	12.50	6.38
Chincoteague Bay	Chincoteague Bay	XBM1301	<50	4.35	2.27
		XBM3418	<50	0.00	0.00
		XBM5932	<50	0.00	0.00
		XBM8149	<15	56.52	29.55
		XCM0159	<15	39.13	20.45
		XCM1562	<50	0.00	0.00
		ASSA 5.	<15	33.33	16.67
		ASSA 6.	<15	12.50	6.25
		ASSA 7.	<15	37.50	19.15
		ASSA 14.	<15	4.35	2.17
		ASSA 15.	<15	0.00	0.00

3.0 TARGETED WATER QUALITY GOAL

The objective of the nutrient TMDLs established in this document is to ensure that DO and Chl *a* concentrations in the Marylnd Coastal Bays meet the applicable water quality criteria associated with the specific designated use of the system. Specifically, the TMDLs of nitrogen and phosphorus are intended to control excessive algal growth and increase DO concentrations in areas not currently meeting water quality criteria.

4.0 TOTAL MAXIMUM DAILY LOADS DEVELOPMENT AND ALLOCATION

4.1 Overview

The following sections describe the modeling frameworks used for simulating nutrient loads, hydrology, and the associated water quality responses. Section 4.2 summarizes the TMDL analysis framework and model calibration. Section 4.3 describes the scenarios and results that were generated using the modeling framework. Sections 4.4–4.5 describe how the nutrient TMDLs and load allocations for point sources and nonpoint sources were developed for the Maryland Coastal Bays. Section 4.6 explains the rationale for the margin of safety applied within the analysis, and the last section summarizes the TMDLs for the Maryland Coastal Bays. For more detailed information for each individual MD 8-Digit watershed in the system, the reader is referred to Appendices A-E.

4.2 Analysis Framework

4.2.1 Computer Modeling Framework

To develop a TMDL, a linkage must be defined between the selected water quality targets or goals and the identified pollutant sources. This linkage establishes the cause-and-effect relationship between the sources of the applicable pollutant and the water quality response of the impaired water quality segment to that pollutant. For nonpoint sources, the relationship can vary seasonally due to factors such as precipitation. Once defined, the linkage yields an estimate of total loading capacity, e.g., the TMDL, for the modeled system (USEPA 1999).

A set of time-variable models, which constitute the Coastal Bays Eutrophication Model (CBEM), was developed as the computational framework to link the sources of nutrient loadings to the DO criteria and chlorophyll *a* goals. The overall CBEM package is linked to a watershed model, which applies HSPF program language. The CBEM incorporates a hydrodynamic model, the Semi-implicit Eulerian-LaGrangian Finite Element model (SELFE), and a water quality model with a sediment flux sub-model, the Corps of Engineers Water Quality Compartment Model (CE-QUAL-ICM). This water quality simulation package provides a generalized framework for modeling nutrient fate and transport in tidal surface waters (Cerco and Cole 1995).

The stormwater load and nonpoint source loading estimation was conducted using the HSPF watershed model, which simulates the fate and transport of pollutants over the entire model hydrologic cycle. This is described in Section 2.1.4.2. For more detailed information, see “Maryland Coastal Bays Watershed Modeling Report” (VIMS 2013). The CE-QUAL-ICM is a multi-dimensional water quality model for tidal surface waters, and in the CBEM application it represents twenty-two water quality parameters from the water column and sediment bed. It is externally coupled with the SELFE model. SELFE is an unstructured-grid model designed for the effective simulation of 3D baroclinic circulation across river-to-ocean scales. It uses a semi-implicit finite-element Eulerian-Lagrangian algorithm to solve the shallow water equations, written to realistically address a wide range of physical processes as well as atmospheric, ocean, and river forcings (Zhang and Baptista 2008). The CE-QUAL-ICM was also coupled with a sediment flux model developed by DiToro and Fitzpatrick (1993), which was modified for this project. The state variables, resulting fluxes, and complete model documentation are described in Wang *et al.* (2013) and DiToro and Fitzpatrick (1993).

The spatial domain of the CBEM extends longitudinally from where the Assawoman Canal connects to White Creek in Delaware south to the Chincoteague Inlet, including the area draining to Bogues Bay in Virginia. The spatial domain also extends out seven to nine kilometers (km) into the Atlantic Ocean. The Maryland Coastal Bays are located within Worcester County, Maryland and have upstream areas within Delaware and Virginia. This modeling domain is represented by CBEM model segments. A diagram of the model segmentation is presented in Wang *et al.* (2013). The CBEM package was calibrated to reproduce observed water quality conditions from 2000-2005. The calibration of the model for these six years establishes an analytical tool that may be used to assess a range of scenarios with differing flow and nutrient loading conditions. For a detailed explanation of the CBEM, please refer to the modeling report "The Hydrodynamic/Water Quality Modeling and TMDL Development for Maryland's Coastal Bay System" (Wang *et al.* 2013).

4.2.2 Eutrophication Model Calibration

The calibration of the eutrophication model entails modifying the model input parameters until the model output optimally matches the set of observed water column data. Observed water quality, hydrology, and nutrient loading data collected from 2000-2005 were used to calibrate the CBEM. Time series and longitudinal data profiles from the stations for various nutrient parameters may be found in Wang *et al.* (2013).

4.2.3 TMDL Analysis Framework

The nutrient TMDL analysis consists of two components: an assessment of growing season loading conditions and an assessment of average annual loading conditions. Both the growing season and the average annual TMDL analyses investigate the critical conditions under which symptoms of eutrophication are typically most acute. During excessively dry or wet years, the flux in loadings has a significant impact on water quality. Additionally, water quality is most impacted by nutrient inputs during late summer when flows are low, the system is poorly flushed, and sunlight and temperatures are most conducive to excessive algal production. The TMDL analysis allows a comparison of current nutrient loading conditions to future conditions that project the water quality response to various simulated nutrient load reductions.

4.2.3.1 Dissolved Oxygen Analytical Framework

The eutrophication model was calibrated to forty-five water quality monitoring stations located throughout the Coastal Bays. The station locations represent the geographic areas where available water quality data can be compared to water quality modeling results for the purpose of model calibration and evaluation. With the extensive geographic coverage and the known confidence in the model simulation at the monitoring stations, it was decided that the model scenario results would be analyzed at these segment locations for the purposes of determining both use attainment and the assimilative capacity of the system. The assessment methodology for the simulation results is as follows:

At the twenty-five DNR stations and the twelve ASIS stations within Maryland, each of which corresponds to a water quality segment in the CBEM, simulated dissolved oxygen concentrations were assessed using a daily average for the growing season [May 1 – October 31 (184 days)], since water quality data indicate that the growing season is the critical period for exceedances of the dissolved oxygen criteria. Model results for DO are generated in four-hour increments and at five depths throughout the water column. These modeled DO results were adjusted to account for the diel swing based on temperature/season using the statistical work of Perry (2012). The daily means from these DO outputs were calculated. These daily DO means were then compared to the DO criterion of 5 mg/L. For each station, the number of days that the daily mean was below the criterion in the time period was calculated as a percentage of time. An example of the calculation for the percent of time the criterion was exceeded is as follows: If, on 25 days within the growing season (184 days are in the growing season), the daily means were lower than 5 mg/L, then the percent DO exceedance at that station would be 13.6%. The goal is to maintain the DO exceedance of the daily means at less than 10% at all stations at all times. This is in fitting with USEPA's guidance, which has recommended making non-attainment decisions with respect to conventional pollutants, including nitrogen and phosphorus, when more than 10% of measurements exceed (or in this case, fall below) the water quality criterion (Regas 2005).

4.2.3.2 Chlorophyll *a* Analytical Framework

At the thirty-seven water quality sampling stations segments within Maryland (twenty five DNR stations and twelve ASIS stations), model results were compared to the numeric interpretation of the narrative Chl *a* criteria, as described in Section 2.3.2. Simulated Chl *a* concentrations were assessed using a daily mean for the growing season [May 1 – October 31 (184 days)], since the water quality data indicate that the growing season is the critical period for exceedances in the Chl *a* target. Model results for Chl *a* are generated in four-hour increments; only the surface layer output was used, since this is where Chl *a* is sampled. The daily means from these outputs were calculated at each station. The daily means were then compared to the criterion of either 50 µg/L for non-SAV grow zones, or 15 µg/L for SAV grow zones. The number of days that the daily mean was above the criterion in the time period was calculated as a percentage of time. An example of the calculation for percent of time the applicable criterion was exceeded is as follows: If, on 25 days within the growing season (184 days are in the growing season), the daily mean exceeds the applicable criterion, then the percent exceedance would be 13.6%. The end goal is to maintain the exceedance of the daily means at less than 10% at all sampling station segments at all times. This is in fitting with USEPA's guidance, which has recommended making non-attainment decisions with respect to conventional pollutants, including nitrogen and phosphorus, when more than 10% of measurements exceed the water quality criterion (Regas 2005).

4.3 Scenario Descriptions and Results

The scenario results are grouped according to *baseline conditions* and *future conditions*. The baseline condition is intended to provide a point of reference with which to compare future scenarios that simulate conditions of a TMDL. The future conditions scenario is associated with the TMDLs. Additional scenarios were tested including the following: a natural conditions scenario (in which land is assumed to be all forested and atmospheric deposition is reduced by 90%) to simulate the removal of all anthropogenic sources possible water quality conditions; a maximum practicable anthropogenic reduction scenario (MPAR) to determine the maximum reduction achievable with current technologies; incremental reduction scenarios (20%, 40%, and 60% reductions); and multiple geographic isolation scenarios to tailor the final TMDL scenario. These scenarios were used as guides to develop the future conditions scenario. These scenarios are described more fully in

Wang *et al.* (2013). Of note, for the MPAR scenario percent reductions are calculated from CBP-P5 scenario results for the Eastern Shore for total nitrogen and total phosphorus. CBP-P5 scenario results are available for the following scenarios: no-action (no reductions applied to the baseline); E-3 (Everyone, Everything, Everywhere – maximum reductions from all sources); 2009 Progress (incorporates reductions from implementation through 2009); and 2010 progress (incorporates reductions from implementation through 2010). For each land use sector, the mean percent reduction from the baseline and the three available reduction scenarios was used to calculate the reduction rate for the Coastal Bays watershed model: no-action to E3; 2009 progress to E3; and 2010 progress to E3. Table 13 below presents the percentages applied to each source sector.

Table 13: Maximum Practicable Anthropogenic Reduction (MPAR) percentages for each source sector based on CBP-P5.3.2 scenario results.

Source Sector	TN Reduction (%)	TP Reduction (%)	TSS[1] Reduction (%)
Animal Feeding Operations (AFO)	67	69	29
Concentrated Animal Feeding Operations (CAFO)	48	52	31
Crop	64	34	50
Pasture	45	46	54
Urban	51	68	73
Septic	57	0	0
Forest	0	0	0

[1] TSS: Total Suspended Solids

The baseline and future conditions scenarios were used to estimate the average annual TMDLs. The following analyses allow for a comparison between current water quality conditions and future conditions that project various simulated nitrogen and phosphorus load reductions.

4.3.1 Scenario Descriptions

4.3.1.1 Baseline Conditions Scenario

The baseline conditions scenario represents the nutrient loadings associated with the observed water quality conditions in the Maryland Coastal Bays and its tributaries from 2001-2004. This four year model simulation accounts for various loading and hydrologic conditions in the system, which captures the possible critical conditions and seasonal variations of the system. The modeling approach also specifically examines conditions during the growing season months when the river system is poorly flushed, and sunlight and warm water temperatures are more conducive to causing water quality problems associated with excessive nutrient enrichment.

The nonpoint source nutrient loads, including urban stormwater loads, were estimated using the Coastal Bays HSPF watershed model. The HSPF watershed model utilized land use information and hydrology associated with the 2001-2004 period to generate loading estimates for this scenario. The HSPF watershed model simulates urban stormwater and nonpoint source loadings for all natural and human-induced sources, including direct atmospheric deposition and loads from septic systems. For point source loads, this scenario uses the point source discharge monitoring data from 2001-2004.

Additionally, time series and longitudinal data profiles from the DNR and ASIS stations for various nutrient parameters are available in Wang *et al.* (2013).

4.3.1.3 Future Conditions (TMDL) Scenario

Using the exploratory scenarios that were previously mentioned, the future conditions or TMDL scenario was compiled. Based on the results of the exploratory scenarios, it was determined that the Bishopville Prong/Shingle Landing Prong tributaries required the highest nutrient reductions in order to meet water quality standards, i.e., MPAR reductions. The reductions applied to atmospheric deposition were based off the allocation scenario (2025) for Worcester County in the Chesapeake Bay TMDL. See USEPA (2010) for further details regarding atmospheric deposition reductions. The reductions from controllable sources required to meet water quality standards in the future conditions scenario are presented in Table 14. See Wang *et al.* 2013 for more detailed information about the TMDL scenario.

Table 14: Future condition (TMDL) scenario TN and TP reductions by watershed.

Waterbody	Reduction percent needed to meet Water Quality Standards
Assawoman Bay (including Greys Creek)	20%
Bishopville Prong/Shingle Landing Prong (Isle of Wight Bay)	Maximum Practical Anthropogenic Reduction (MPAR)
Isle of Wight Bay (all areas except those identified above)	40%
Newport Bay	20%
Sinepuxent Bay	0%
Chincoteague Bay	20% to Maryland's portion of the watershed

4.3.2 Scenario Results

The baseline and TMDL scenario results for DO for the growing season and average annual conditions are presented in Tables 15 and 16 below, respectively. The station segment name and corresponding percent of time the criterion is not being met is presented. As shown, the future conditions (TMDL) scenario meets the DO assessment criteria representing the water quality target.

Table 15: Growing season DO attainment assessment of model results for the baseline and TMDL scenarios by station.

MD 8-Digit Basin	TMDL Basin	Station Segment	Baseline (% < 5.0 mg/L)	TMDL Scenario (% < 5.0 mg/L)
Asswoman Bay	Assawoman Bay	XDN3445	0.00	0.00
		XDN4851	0.00	0.00
		XDN5737	0.00	0.00
		XDN6454	0.00	0.00
Isle of Wight Bay	Bishopville Prong	BSH0008	15.49	0.00
		XDM4486	37.09	8.56
	Shingle Landing Prong	SPR0002	1.36	0.00
		SPR0009	15.76	6.66
	St. Martin River	XDN3724	0.00	0.00
		XDN4312	0.00	0.00
		XDN4797	1.63	0.00
	Turville Creek	TUV0011	0.0	0.00
		TUV0019	0.00	0.00
	Manklin Creek	MKL0010	78.26	0.27
	Isle of Wight Bay	XDN0146	0.00	0.00
		XDN2340	0.00	0.00
		XDN2438	0.00	0.00
Newport Bay	Ayer Creek	AYR0017	5.98	0.00
	Newport Bay	XCM4878	1.77	0.00
		ASSA 3	0.00	0.00
		ASSA 4	2.58	0.00
Sinepuxent Bay	Sinepuxent Bay	ASSA 1	0.00	0.00
		ASSA 2	0.00	0.00
		ASSA 16	0.00	0.00
		ASSA 17	0.00	0.00
		ASSA 18	0.00	0.00
Chincoteague Bay	Chincoteague Bay	XBM1301	0.00	0.00
		XBM3418	0.00	0.00
		XBM5932	0.00	0.00
		XBM8149	0.00	0.00
		XCM0159	0.00	0.00
		XCM1562	0.00	0.00
		ASSA 5	0.00	0.00
		ASSA 6	0.00	0.00
		ASSA 7	0.00	0.00
		ASSA 14	0.00	0.00
		ASSA 15	0.00	0.00

Table 16: Average annual DO attainment assessment of model results for the baseline and TMDL scenarios by station segment.

MD 8-Digit Basin	TMDL Basin	Station segment	Baseline (% < 5.0 mg/L)	TMDL Scenario (% < 5.0 mg/L)
Asswoman Bay	Assawoman Bay	XDN3445	0.00	0.00
		XDN4851	0.00	0.00
		XDN5737	0.00	0.00
		XDN6454	0.00	0.00
Isle of Wight Bay	Bishopville Prong	BSH0008	7.81	0.00
		XDM4486	18.70	4.32
	Shingle Landing Prong	SPR0002	0.68	0.00
		SPR0009	7.95	3.36
	St. Martin River	XDN3724	0.00	0.00
		XDN4312	0.00	0.00
		XDN4797	0.82	0.00
	Turville Creek	TUV0011	0.00	0.00
		TUV0019	0.00	0.00
	Manklin Creek	MKL0010	39.45	0.14
	Isle of Wight Bay	XDN0146	0.00	0.00
		XDN2340	0.00	0.00
		XDN2438	0.00	0.00
Newport Bay	Ayer Creek	AYR0017	3.01	0.00
	Newport Bay	XCM4878	0.89	0.00
		ASSA 3	0.00	0.00
		ASSA 4	1.30	0.00
Sinepuxent Bay	Sinepuxent Bay	ASSA 1	0.00	0.00
		ASSA 2	0.00	0.00
		ASSA 16	0.00	0.00
		ASSA 17	0.00	0.00
		ASSA 18	0.00	0.00
Chincoteague Bay	Chincoteague Bay	XBM1301	0.00	0.00
		XBM3418	0.00	0.00
		XBM5932	0.00	0.00
		XBM8149	0.00	0.00
		XCM0159	0.00	0.00
		XCM1562	0.00	0.00
		ASSA 5	0.00	0.00
		ASSA 6	0.00	0.00
		ASSA 7	0.00	0.00
		ASSA 14	0.00	0.00
		ASSA 15	0.00	0.00

The baseline and TMDL scenario results for Chl *a* for the growing season and average annual conditions are presented in Tables 17 and 18 below, respectively. The station segment name, applicable criterion, and percent of time the criterion is not being met are presented. As shown, the future conditions or TMDL scenario meets the Chl *a* assessment criteria representing the water quality target.

Table 17: Growing season Chl *a* assessment of model results for the baseline and TMDL scenarios by station segment.

MD 8-Digit Basin	TMDL Basin	Station segment	Applicable Endpoint (µg/L)	Baseline (% > Endpoint Concentration)	TMDL Scenario (% > Endpoint Concentration)
Asswoman Bay	Assawoman Bay	XDN3445	<15	3.94	0.00
		XDN4851	<15	4.48	1.36
		XDN6454	<15	2.99	1.22
		XDN5737	<50	0.00	0.00
Isle of Wight Bay	Bishopville Prong	BSH0008	<50	19.43	3.40
		XDM4486	<50	38.59	5.57
	Shingle Landing Prong	SPR0002	<50	5.57	0.82
		SPR0009	<50	6.66	3.40
	St. Martin River	XDN3724	<50	1.36	0.00
		XDN4312	<50	2.72	0.00
		XDN4797	<50	5.98	0.95
	Turville Creek	TUV0011	<50	0.54	0.00
		TUV0019	<50	1.36	0.00
	Manklin Creek	MKL0010	<50	2.45	0.00
	Isle of Wight Bay	XDN0146	<15	0.00	0.00
		XDN2340	<15	4.21	1.22
		XDN2438	<15	0.00	0.00
Newport Bay	Ayer Creek	AYR0017	<50	0.14	0.14
	Newport Bay	ASSA 3	<15	8.83	4.62
		XCM4878	<50	0.00	0.00
		ASSA 4	<50	0.00	0.00
Sinepuxent Bay	Sinepuxent Bay	ASSA 1	<15	0.00	0.00
		ASSA 2	<15	0.00	0.00
		ASSA 16	<15	0.00	0.00
		ASSA 17	<15	0.00	0.00
		ASSA 18	<15	0.00	0.00
Chincoteague Bay	Chincoteague Bay	XBM1301	<15	0.00	0.00
		XBM8149	<15	2.31	0.00
		XCM0159	<15	2.85	0.00
		ASSA 5	<15	4.48	0.00
		ASSA 6	<15	0.00	0.00
		ASSA 7	<15	8.15	0.14
		ASSA 14	<15	3.53	0.00
		ASSA 15	<15	0.00	0.00
		XBM3418	<50	0.00	0.00
		XBM5932	<50	0.00	0.00
		XCM1562	<50	0.00	0.00

Table 18: Average annual Chl *a* assessment of model results for the baseline and TMDL scenarios by station segment.

MD 8-Digit Basin	TMDL-basin	Station segment	Applicable Endpoint (µg/L)	Baseline (% > Endpoint Concentration)	TMDL Scenario (% > Endpoint Concentration)
Asswoman Bay	Assawoman Bay	XDN3445	<15	1.99	0.00
		XDN4851	<15	2.26	0.68
		XDN6454	<15	1.51	0.62
		XDN5737	<50	0.00	0.00
Isle of Wight Bay	Bishopville Prong	BSH0008	<50	10.00	1.71
		XDM4486	<50	19.66	2.81
	Shingle Landing Prong	SPR0002	<50	2.81	0.41
		SPR0009	<50	3.36	1.71
	St. Martin River	XDN3724	<50	0.68	0.00
		XDN4312	<50	1.37	0.00
		XDN4797	<50	3.01	0.48
	Turville Creek	TUV0011	<50	0.27	0.00
		TUV0019	<50	0.68	0.00
	Manklin Creek	MKL0010	<50	1.23	0.00
	Isle of Wight Bay	XDN0146	<15	0.00	0.00
		XDN2340	<15	2.12	0.62
		XDN2438	<15	0.00	0.00
Newport Bay	Ayer Creek	AYR0017	<50	0.07	0.07
	Newport Bay	ASSA 3	<15	4.73	2.74
		XCM4878	<50	0.00	0.00
		ASSA 4	<50	0.00	0.00
Sinepuxent Bay	Sinepuxent Bay	ASSA 1	<15	0.00	0.00
		ASSA 2	<15	0.00	0.00
		ASSA 16	<15	0.00	0.00
		ASSA 17	<15	0.00	0.00
		ASSA 18	<15	0.00	0.00
Chincoteague Bay	Chincoteague Bay	XBM1301	<15	0.00	0.00
		XBM8149	<15	1.16	0.00
		XCM0159	<15	1.44	0.00
		ASSA 5	<15	2.26	0.00
		ASSA 6	<15	0.00	0.00
		ASSA 7	<15	4.79	0.07
		ASSA 14	<15	1.78	0.00
		ASSA 15	<15	0.00	0.00
		XBM3418	<50	0.00	0.00
		XBM5932	<50	0.00	0.00
		XCM1562	<50	0.00	0.00

4.4 TMDL Loading Caps

TMDL loading caps were developed using the results of the scenarios described in the preceding sections. The TMDLs for nitrogen and phosphorus are presented below in Tables 19 and 20.

For the period of May 1 through October 31, the following TMDLs apply:

Table 19: Growing season TMDLs.

	Nitrogen TMDL (lbs/growing season)	Phosphorus TMDL (lbs/growing season)
Greys Creek	46,422	3,446
Assawoman Bay[1,2]	**143,441**	**10,196**
Bishopville Prong	25,592	2,797
Shingle Landing Prong	27,750	2,639
St. Martin River[1]	68,348	6,486
Herring Creek	7,250	586
Turville Creek	12,998	924
Manklin Creek	7,541	645
Isle of Wight Bay[1,2]	**133,238[3]**	**12,451[2]**
Ayer Creek/Kitts Branch	37,036	2,990
Newport Creek	9,361	648
Marshall Creek	16,796	1,208
Newport Bay[1,2]	**88,819**	**6,673**
Sinepuxent Bay[2]	**45,442**	**3,269**
Chincoteague Bay[2]	**569,121**	**41,488**

[1] This allocation includes the allocations for the applicable sub-basins.
[2] TMDL is for tidal MD 8-Digit waterbody. A portion of the load is from upstream sources.
[3] This allocation does not include the Ocean City WWTP loads.

The average annual TMDLs for nitrogen and phosphorus are:

Table 20: Average annual TMDLs.

	Nitrogen TMDL (lbs/yr)	Phosphorus TMDL (lbs/yr)
Greys Creek	101,333	6,847
Assawoman Bay[1,2]	**300,669**	**19,985**
Bishopville Prong	54,619	5,603
Shingle Landing Prong	58,520	5,317
St. Martin River[1]	143,671	12,988
Herring Creek	14,413	1,146
Turville Creek	26,311	1,813
Manklin Creek	14,692	1,240
Isle of Wight Bay[1,2]	**276,986[3]**	**24,715[2]**
Ayer Creek/Kitts Branch	80,669	6,233
Newport Creek	20,465	1,295
Marshall Creek	30,827	2,425
Newport Bay[1,2]	**185,471**	**13,589**
Sinepuxent Bay[2]	**90,347**	**6,381**
Chincoteague Bay[2]	**1,166,469**	**82,304**

[1] This allocation includes the allocations for the applicable sub-basins.
[2] TMDL is for the tidal MD 8-Digit waterbody. A portion of the load is from upstream sources.
[3] This allocation does not include the Ocean City WWTP loads.

4.5 Load Allocations between Point Sources and Nonpoint Sources

This section describes one viable allocation of loads between point sources and nonpoint sources. A more detailed overview of the potential allocations to various sources is provided in the accompanying point and nonpoint source Technical Memoranda. The allocations presented are quantified for the growing season (May 1st through October 31st) and average annual conditions. The State reserves the right to revise these allocations provided the allocations are consistent with the achievement of water quality standards.

Load Allocation

Nonpoint Source Loads

A Load Allocation (LA) was assigned to the nonpoint source loads in the watershed. These include loads from the various land uses within the watershed, septic systems, shoreline erosion, and atmospheric deposition. Reductions required from these sources varied among the different TMDL watersheds. Bishopville Prong and Shingle Landing Prong required the greatest reductions from nonpoint sources. No reductions were applied to shoreline erosion in any of the TMDL watersheds.

Waste Load Allocation

Urban Stormwater Loads

In November 2002, USEPA advised States that MS4 all NPDES regulated stormwater discharges, such as MS4s, industrial stormwater permits, etc., must be addressed by the wasteload allocation (WLA) portion of a TMDL (USEPA 2002). However, there are no NPDES regulated stormwater discharges in the Maryland Coastal Bays watershed. Therefore, all urban stormwater loadings are included in the LA portion of the TMDL.

Point Source Process Water Loads

WLAs were assigned to all of the process water point source discharges in the watershed. During the 2001-2004 baseline conditions time period, there were sixteen active process water point sources in Maryland, one active process water point source in Delaware, and nine active process water point sources in Virginia with permits regulating the discharge of nutrients. All of these point sources were accounted for in the TMDL scenario; however, WLAs were only assigned to the Maryland process water point sources. The loads associated with the Virginia and Delaware process water point sources are included as part of the aggregate upstream loads. The current maximum permitted flows for the facilities were used in the allocation/TMDL scenario. Six of the sixteen process water point source facilities in Maryland discharge via spray irrigation for the treatment of effluent rather than directly discharging to surface waters. There are three industrial process water point sources. The flows and concentrations from these facilities vary from plant to plant, and their permits, the flows and concentrations are set at levels based on the implementation of best available technologies to achieve water quality criteria. There are also two injection well facilities in the watershed. All significant point sources are addressed by this allocation and are described in more detail in the technical memorandum entitled "*Significant Nutrient Point Sources in the Maryland Coastal Bays Watershed.*"

CAFO Loads

Under the Clean Water Act, CAFOs require NPDES permits for their surface water discharges, or potential discharges (CFR 2013b). In January, 2009, Maryland implemented new regulations governing CAFOs (COMAR 2013a,b,c), which were approved by the USEPA in January, 2010. Under these regulations, CAFOs are required to fulfill the conditions of a general permit. These conditions include instituting a Comprehensive Nutrient Management Plan to meet the Nine Minimum Standards to Protect Water Quality, which include: 1) ensure adequate storage capacity, 2) ensure proper management of mortalities to prevent the discharge of pollutants into waters of the State, 3) divert clean water, as appropriate, from the production area to keep it separate from process wastewater, 4) prevent direct contact of confined animals with waters of the State, 5) chemical handling, 6) conservation practices to control nutrient loss, 7) protocols for manure and soil testing, 8) protocols for the land application of manure and wastewater, and 9) record keeping. These are described in further detail in the general CAFO permit (MDE 2009a). The general permit also prohibits the discharge of pollutants, including nutrients, from CAFO production areas, except as a result of events greater than the 25-year, 24-hour storm. Estimated TN and TP loads under TMDL conditions for these facilities were derived from CAFO loading rates for Worcester and Somerset

Counties, which were in turn derived from the Chesapeake Bay Program Phase 5.3.2 Watershed Model (USEPA 2010).

4.5.1 Growing Season TMDL Allocations

The nitrogen and phosphorus allocations for the growing season (May1 – October 31) conditions are presented in Tables 21 - 22.

Table 21: Growing season TMDL allocations for nitrogen (lbs/growing season).

Basin Name	TMDL	Upstream Loads[1] (WLA+LA)	$WLA_{Process\ Water}$	WLA_{CAFO}	LA
Greys Creek	46,422	29,042	0	339	17,041
Assawoman Bay[2,4]	**143,441**	**96,044**	**0**	**339**	**47,058**
Bishopville Prong	25,592	11,777	333	1,411	12,071
Shingle Landing Prong	27,750	0	7,520	678	19,552
St. Martin River[2]	68,348	11,777	7,853	2,224	46,494
Herring Creek	7,250	0	0	0	7,250
Turville Creek	12,998	0	0	373	12,625
Manklin Creek	7,541	0	0	0	7,541
Isle of Wight Bay[2,4]	**133,238**	**11,777**	**21,664[3]**	**2,597**	**97,200**
Ayer Creek/Kitts Branch	37,036	0	5,463	268	31,305
Newport Creek	9,361	0	0	440	8,921
Marshall Creek	16,796	0	1,934	562	14,300
Newport Bay[2,4]	**88,819**	**0**	**7,397**	**1,526**	**79,896**
Sinepuxent Bay[4]	**45,442**	**0**	**1,859**	**0**	**43,583**
Chincoteague Bay[4]	**569,121**	**308,377**	**0**	**2,118**	**258,626**

[1] Upstream Loads denotes loadings from outside Maryland's portion of the watershed. This allocation includes point and nonpoint sources.
[2] This allocation includes the allocations for the applicable sub-basins.
[3] This allocation does not include the Ocean City WWTP loads.
[4] TMDL represents assimilative capacity of the tidal MD 8-Digit waterbody.

Table 22: Growing season TMDL allocations for phosphorus (lbs/growing season).

Basin Name	TMDL	Upstream Loads[1] (WLA+LA)	$WLA_{Process\ Water}$	WLA_{CAFO}	LA
Greys Creek	3,446	2,194	0	28	1,223
Assawoman Bay[2,4]	**10,196**	**6,887**	**0**	**28**	**3,281**
Bishopville Prong	2,797	1,450	0	116	1,231
Shingle Landing Prong	2,639	0	614	56	1,969
St. Martin River[2]	6,486	1,450	614	183	4,239
Herring Creek	586	0	0	0	586
Turville Creek	924	0	0	31	893
Manklin Creek	645	0	0	0	645
Isle of Wight Bay[2,4]	**12,451**	**1,450**	**2,916[3]**	**214**	**7,871**
Ayer Creek/Kitts Branch	2,990	0	632	22	2,335
Newport Creek	648	0	0	36	612
Marshall Creek	1,208	0	322	46	840
Newport Bay[2,4]	**6,673**	**0**	**955**	**125**	**5,594**
Sinepuxent Bay[4]	**3,269**	**0**	**6**	**0**	**3,264**
Chincoteague Bay[4]	**41,488**	**24,122**	**0**	**174**	**17,191**

[1] Upstream Loads denotes loadings from outside Maryland's portion of the watershed. This allocation includes point and nonpoint sources.
[2] This allocation includes the allocations for the applicable sub-basins.
[3] This allocation does not include the Ocean City WWTP loads.
[4] TMDL represents assimilative capacity of the tidal MD 8-Digit waterbody.

4.5.2 Average Annual TMDL and Maximum Daily Load Allocations

The nitrogen and phosphorus allocations for the average annual conditions are presented in Tables 23 and 25. The Maximum Daily Load (MDL) allocations are presented in Tables 24 and 26. A detailed description of MDLs and the methodology used to derive the MDLs is presented in Appendix F.

Table 23: Average annual TMDL nitrogen allocations (lbs/yr).

Basin Name	TMDL	Upstream Loads[1] (WLA+LA)	$WLA_{Process\ Water}$	WLA_{CAFO}	LA
Greys Creek	101,333	64,962	0	678	35,693
Assawoman Bay[2,4]	**300,669**	**204,889**	**183**	**678**	**94,919**
Bishopville Prong	54,619	25,434	665	2,823	25,697
Shingle Landing Prong	58,520	0	15,278	1,357	41,885
St. Martin River[2]	143,671	25,435	15,943	4,451	97,843
Herring Creek	14,413	0	0	0	14,413
Turville Creek	26,311	0	0	747	25,564
Manklin Creek	14,692	0	0	0	14,692
Isle of Wight Bay[2,4]	**276,986**	**25,435**	**47,869[3]**	**5,198**	**198,484**
Ayer Creek/Kitts Branch	80,669	0	14,215	535	65,919
Newport Creek	20,465	0	0	879	19,586
Marshall Creek	30,827	0	3,836	1,124	25,867
Newport Bay[2,4]	**185,471**	**0**	**18,051**	**3,050**	**164,370**
Sinepuxent Bay[4]	**90,347**	**0**	**3,741**	**0**	**86,606**
Chincoteague Bay[4]	**1,166,469**	**633,578**	**0**	**4,236**	**528,655**

[1] Upstream Loads denotes loadings from outside Maryland's portion of the watershed. This allocation includes point and nonpoint sources.
[2] This allocation includes the allocations for the applicable sub-basins.
[3] This allocation does not include the Ocean City WWTP loads.
[4] TMDL represents assimilative capacity of the tidal MD 8-Digit waterbody.

Table 24: Maximum Daily Load nitrogen allocations in pounds per day (lbs/day).

Basin Name	MDL	Upstream Loads[1] (WLA+LA)	$WLA_{Process\ Water}$	WLA_{CAFO}	LA
Greys Creek	782	517	0	2	264
Assawoman Bay[2,4]	**2,080**	**1,542**	**1**	**2**	**536**
Bishopville Prong	410	184	2	8	216
Shingle Landing Prong	433	0	42	4	387
St. Martin River[2]	1,026	184	44	12	786
Herring Creek	104	0	0	0	104
Turville Creek	182	0	0	2	180
Manklin Creek	109	0	0	0	109
Isle of Wight Bay[2,4]	**1,710**	**184**	**131[3]**	**14**	**1,380**
Ayer Creek/Kitts Branch	622	0	39	1	581
Newport Creek	177	0	0	2	175
Marshall Creek	232	0	11	3	218
Newport Bay[2,4]	**1,365**	**0**	**50**	**8**	**1,307**
Sinepuxent Bay[4]	**465**	**0**	**10.2**	**0**	**455**
Chincoteague Bay[4]	**6,194**	**3,592**	**0**	**12**	**2,590**

[1] Upstream Loads denotes loadings from outside Maryland's portion of the watershed. This allocation includes point and nonpoint sources.
[2] This allocation includes the allocations for the applicable sub-basins.
[3] This allocation does not include the Ocean City WWTP loads.
[4] TMDL represents assimilative capacity of the tidal MD 8-Digit waterbody.

Table 25: Average annual TMDL phosphorus allocations (lbs/yr).

Basin Name	TMDL	Upstream Loads[1] (WLA+LA)	$WLA_{Process\ Water}$	WLA_{CAFO}	LA
Greys Creek	6,847	4,375	0	56	2,416
Assawoman Bay[2,4]	**19,985**	**13,501**	**0**	**56**	**6,428**
Bishopville Prong	5,603	2,890	0	232	2,481
Shingle Landing Prong	5,316	0	1,218	112	3,987
St. Martin River[2]	12,988	2,890	1,218	366	8,514
Herring Creek	1,146	0	0	0	1,146
Turville Creek	1,813	0	0	61	1,752
Manklin Creek	1,240	0	0	0	1,240
Isle of Wight Bay[2,4]	**24,715**	**2,890**	**5,784[3]**	**427**	**15,613**
Ayer Creek/Kitts Branch	6,233	0	1,629	44	4,560
Newport Creek	1,295	0	0	72	1,223
Marshall Creek	2,425	0	639	92	1,694
Newport Bay[2,4]	**13,589**	**0**	**2,268**	**251**	**11,070**
Sinepuxent Bay[4]	**6,381**	**0**	**11**	**0**	**6,370**
Chincoteague Bay[4]	**82,304**	**47,797**	**0**	**348**	**34,159**

[1] Upstream Loads denotes loadings from outside Maryland's portion of the watershed. This allocation includes point and nonpoint sources.
[2] This allocation includes the allocations for the applicable sub-basins.
[3] This allocation does not include the Ocean City WWTP loads.
[4] TMDL represents assimilative capacity of the tidal MD 8-Digit waterbody.

Table 26: Average annual MDL phosphorus allocations (lbs/day).

Basin Name	MDL	Upstream Loads[1] (WLA+LA)	$WLA_{Process\ Water}$	WLA_{CAFO}	LA
Greys Creek	53	34	0.00	0.2	19
Assawoman Bay[2,4]	**147**	**106**	**0.00**	**0.2**	**41**
Bishopville Prong	46	22	0.00	0.6	24
Shingle Landing Prong	42	0	3.3	0.3	39
St. Martin River[2]	102	22	3.3	1.0	76
Herring Creek	9	0	0.0	0.0	9
Turville Creek	14	0	0.0	0.2	14
Manklin Creek	10	0	0.0	0.0	10
Isle of Wight Bay[2,4]	**162**	**22**	**15.8[3]**	**1.2**	**123**
Ayer Creek/Kitts Branch	49	0	4.5	0.1	44
Newport Creek	12	0	0.0	0.2	12
Marshall Creek	17	0	1.8	0.3	15
Newport Bay[2,4]	**102**	**0**	**6.2**	**0.7**	**95**
Sinepuxent Bay[4]	**38**	**0**	**0.03**	**0.0**	**37**
Chincoteague Bay[4]	**426**	**256**	**0.0**	**1.0**	**169**

[1] Upstream Loads denotes loadings from outside Maryland's portion of the watershed. This allocation includes point and nonpoint sources.
[2] This allocation includes the allocations for the applicable sub-basins.
[3] This allocation does not include the Ocean City WWTP loads.
[4] TMDL represents assimilative capacity of the tidal MD 8-Digit waterbody.

4.6 Margin of Safety (MOS)

A Margin of Safety is required as part of a TMDL in recognition of many uncertainties in the understanding and simulation of water quality in natural systems. For example, knowledge is incomplete regarding 1) the magnitude of pollutant loads from various sources due to normal variations in precipitation and process changes, and 2) the specific impacts of those pollutants on the chemical and biological quality of complex, natural waterbodies. The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental protection.

Based on USEPA guidance, the MOS can be achieved through two approaches (USEPA 1991). One approach is to explicitly reserve a portion of the loading capacity as a separate term in the TMDL (*i.e.*, TMDL = LA + WLA + MOS). The second approach is to incorporate the MOS as conservative assumptions used in the TMDL analysis (implicit MOS).

The State has adopted an implicit MOS for the Maryland Coastal Bays nutrient TMDLs using conservative assumptions explained as follows: the model was calibrated to forty-five water quality monitoring stations located throughout the Coastal Bays. The station locations represent the geographic areas where available water quality data can be compared to water quality modeling results for the purpose of model calibration and evaluation. With the extensive geographic coverage and the known confidence in the model simulation at the monitoring stations, as well as the fine scale of the model segmentation and the time-variable qualities of the model framework, the analysis provides the most robust analysis possible given the available data. The simulation period selected for establishing the allowable loads includes a typical flow year (2001), a very dry year (2002), and two very wet years

(2003 and 2004). Generally, during dry years, the system can experience higher water temperatures combined with low flows. During wet years, higher flows and consequently increased pollutant loadings are expected. The two very wet years in this analysis produced the highest nutrient loadings in the model results. Since 50% of the model simulation period is comprised of high nutrient loadings, a conservative assumption is inherently included in the analysis. Additional conservative assumptions include the following:

1) A 2,500-foot buffer was extended around the identified SAV grow zones, effectively increasing the SAV area - and the area to which the more stringent Chl *a* criterion is applied - more than two-fold;
2) Animal manure application to agricultural lands was taken into consideration at the local level, and the maximum application rates reported by Parker and Li (2006) were also applied;
3) The post-processing of modeling results incorporates an accounting of the diel swing of dissolved oxygen;
4) The analysis used a daily average, which is the smallest timescale supported by the modeling framework;
5) For SAV grow zones and surrounding buffer areas, the model assessment used a threshold of <15 µg/L Chl *a*, rather than a 90^{th} percentile of 15 µg/L;
6) The watershed model assumes all land acres discharge directly to streams;
7) Nutrient sequestration and/or transformation in wetlands is not considered; and
8) Point source discharges in the model scenarios are set at permitted discharge and concentration limits.

Incorporation of these conservative assumptions, the robust nature of the modeling framework, and the critical periods in the modeling used to develop the TMDL supports the assertion of an implicit MOS. Therefore, a MOS accounting for uncertainties in the analysis of water quality conditions in the Maryland Coastal Bays is considered as being implicitly included in the model simulation, and consequently, in the TMDL.

4.7 Summary of Total Maximum Daily Loads

The growing season TMDLs in pounds per growing season for nitrogen and phosphorus, applicable from May 1 – October 31, for the Maryland Coastal Bays are presented below, where:

TMDL = Total Maximum Daily Load
LA = Load Allocation (Nonpoint Source)
WLA = Waste Load Allocation (Point Source)
MOS = Margin of Safety

For Nitrogen:

Basin Name	TMDL (lbs/growing season)	Upstream Loads[1] (WLA+LA)	$WLA_{Process\ Water}$	WLA_{CAFO}	LA	MOS
Greys Creek	46,422	29,042	0	339	17,041	Implicit
Assawoman Bay[2,4]	**143,441**	**96,044**	**0**	**339**	**47,058**	**Implicit**
Bishopville Prong	25,592	11,777	333	1,411	12,071	Implicit
Shingle Landing Prong	27,750	0	7,520	678	19,552	Implicit
St. Martin River[2]	68,348	11,777	7,853	2,224	46,494	Implicit
Herring Creek	7,250	0	0	0	7,250	Implicit
Turville Creek	12,998	0	0	373	12,625	Implicit
Manklin Creek	7,541	0	0	0	7,541	Implicit
Isle of Wight Bay[2,4]	**133,238**	**11,777**	**21,664[3]**	**2,597**	**97,200**	**Implicit**
Ayer Creek/Kitts Branch	37,036	0	5,463	268	31,305	Implicit
Newport Creek	9,361	0	0	440	8,921	Implicit
Marshall Creek	16,796	0	1,934	562	14,300	Implicit
Newport Bay[2,4]	**88,819**	**0**	**7,397**	**1,526**	**79,896**	**Implicit**
Sinepuxent Bay[4]	**45,442**	**0**	**1,859**	**0**	**43,583**	**Implicit**
Chincoteague Bay[4]	**569,121**	**308,377**	**0**	**2,118**	**258,626**	**Implicit**

[1] Upstream Loads denotes loadings from outside Maryland's portion of the watershed. This allocation includes point and nonpoint sources.
[2] This allocation includes the allocations for the applicable sub-basins.
[3] This allocation does not include the Ocean City WWTP loads.
[4] TMDL represents assimilative capacity of the tidal MD 8-Digit waterbody.

For Phosphorus:

Basin Name	TMDL (lbs/growing season)	Upstream Loads[1] (WLA+LA)	$WLA_{Process\ Water}$	WLA_{CAFO}	LA	MOS
Greys Creek	3,446	2,194	0	28	1,223	Implicit
Assawoman Bay[2,4]	**10,196**	**6,887**	**0**	**28**	**3,281**	**Implicit**
Bishopville Prong	2,797	1,450	0	116	1,231	Implicit
Shingle Landing Prong	2,639	0	614	56	1,969	Implicit
St. Martin River[2]	6,486	1,450	614	183	4,239	Implicit
Herring Creek	586	0	0	0	586	Implicit
Turville Creek	924	0	0	31	893	Implicit
Manklin Creek	645	0	0	0	645	Implicit
Isle of Wight Bay[2,4]	**12,451**	**1,450**	**2,916[3]**	**214**	**7,871**	**Implicit**
Ayer Creek/Kitts Branch	2,990	0	632	22	2,335	Implicit
Newport Creek	648	0	0	36	612	Implicit
Marshall Creek	1,208	0	322	46	840	Implicit
Newport Bay[2,4]	**6,673**	**0**	**955**	**125**	**5,594**	**Implicit**
Sinepuxent Bay[4]	**3,269**	**0**	**6**	**0**	**3,264**	**Implicit**
Chincoteague Bay[4]	**41,488**	**24,122**	**0**	**174**	**17,191**	**Implicit**

[1] Upstream Loads denotes loadings from outside Maryland's portion of the watershed. This allocation includes point and nonpoint sources.
[2] This allocation includes the allocations for the applicable sub-basins.
[3] This allocation does not include the Ocean City WWTP loads.
[4] TMDL represents assimilative capacity of the tidal MD 8-Digit waterbody.

The average annual TMDLs in pounds per year for the Maryland Coastal Bays are presented below, where:

TMDL = Total Maximum Daily Load
LA = Load Allocation (Nonpoint Source)
WLA = Waste Load Allocation (Point Source)
MOS = Margin of Safety

For Nitrogen:

Basin Name	TMDL (lbs/yr)	Upstream Loads[1] (WLA+LA)	$WLA_{Process\ Water}$	WLA_{CAFO}	LA	MOS
Greys Creek	101,333	64,962	0	678	35,693	Implicit
Assawoman Bay[2,4]	**300,669**	**204,889**	**183**	**678**	**94,919**	**Implicit**
Bishopville Prong	54,619	25,434	665	2,823	25,697	Implicit
Shingle Landing Prong	58,520	0	15,278	1,357	41,885	Implicit
St. Martin River[2]	143,671	25,435	15,943	4,451	97,843	Implicit
Herring Creek	14,413	0	0	0	14,413	Implicit
Turville Creek	26,311	0	0	747	25,564	Implicit
Manklin Creek	14,692	0	0	0	14,692	Implicit
Isle of Wight Bay[2,4]	**276,986**	**25,435**	**47,869[3]**	**5,198**	**198,484**	**Implicit**
Ayer Creek/Kitts Branch	80,669	0	14,215	535	65,919	Implicit
Newport Creek	20,465	0	0	879	19,586	Implicit
Marshall Creek	30,827	0	3,836	1,124	25,867	Implicit
Newport Bay[2,4]	**185,471**	**0**	**18,051**	**3,050**	**164,370**	**Implicit**
Sinepuxent Bay[4]	**90,347**	**0**	**3,741**	**0**	**86,606**	**Implicit**
Chincoteague Bay[4]	**1,166,469**	**633,578**	**0**	**4,236**	**528,655**	**Implicit**

[1] Upstream Loads denotes loadings from outside Maryland's portion of the watershed. This allocation includes point and nonpoint sources.
[2] This allocation includes the allocations for the applicable sub-basins.
[3] This allocation does not include the Ocean City WWTP loads.
[4] TMDL represents assimilative capacity of the tidal MD 8-Digit waterbody.

For Phosphorus:

Basin Name	TMDL lbs/yr	Upstream Loads[1] (WLA+LA)	$WLA_{Process\ Water}$	WLA_{CAFO}	LA	MOS
Greys Creek	6,847	4,375	0	56	2,416	Implicit
Assawoman Bay[2,4]	**19,985**	**13,501**	**0**	**56**	**6,428**	**Implicit**
Bishopville Prong	5,603	2,890	0	232	2,481	Implicit
Shingle Landing Prong	5,317	0	1,218	112	3,987	Implicit
St. Martin River[2]	12,988	2,890	1,218	366	8,514	Implicit
Herring Creek	1,146	0	0	0	1,146	Implicit
Turville Creek	1,813	0	0	61	1,752	Implicit
Manklin Creek	1,240	0	0	0	1,240	Implicit
Isle of Wight Bay[2,4]	**24,715**	**2,890**	**5,784[3]**	**427**	**15,613**	**Implicit**
Ayer Creek/Kitts Branch	6,233	0	1,629	44	4,560	Implicit
Newport Creek	1,295	0	0	72	1,223	Implicit
Marshall Creek	2,425	0	639	92	1,694	Implicit
Newport Bay[2,4]	**13,589**	**0**	**2,268**	**251**	**11,070**	**Implicit**
Sinepuxent Bay[4]	**6,381**	**0**	**11**	**0**	**6,370**	**Implicit**
Chincoteague Bay[4]	**82,304**	**47,797**	**0**	**348**	**34,159**	**Implicit**

[1] Upstream Loads denotes loadings from outside Maryland's portion of the watershed. This allocation includes point and nonpoint sources.
[2] This allocation includes the allocations for the applicable sub-basins.
[3] This allocation does not include the Ocean City WWTP loads.
[4] TMDL represents assimilative capacity of the tidal MD 8-Digit waterbody.

5.0 ASSURANCE OF IMPLEMENTATION

Section 303(d) of the Clean Water Act and current USEPA regulations require reasonable assurance that the TMDL load and wasteload allocations can and will be implemented in order to achieve water quality standards. In the Coastal Bays watershed, the maximum anthropogenic reduction demonstrates that water quality standards can be met. However, only two of the subwatersheds needs these extreme reductions to meet water quality standards.

The implementation of point source nutrient controls, which will be an integral component to meet water quality standards in the Maryland Coastal Bays, will be executed through NPDES permits. Worcester County has in place a no new discharge policy, whereby no new surface discharges will be permitted within the watershed (Worcester County Comprehensive Management Plan 2006). New facilities will have to employ spray irrigation, and new development will need to connect to an existing disposal system and still maintain the facility’s nutrient loading cap.

The implementation of nonpoint source nutrient controls, which will be an integral component to achieve water quality standards in the Maryland Coastal Bays, will be executed through changes in land use and cooperative reductions from the agricultural sector. Worcester County’s current stormwater management requirements, adopted in 2000, incorporate changes mandated by the State. Specifically, they include a menu of non-structural best management practices (BMPs) that allow for a more environmentally sensitive approach to site development (Worcester County Water Resources Element 2011). Worcester County has also developed a Watershed Restoration Action Strategy for the Assawoman Bay. The county will utilize this strategy to identify and prioritize watershed restoration efforts, which will include the reduction of nutrient loads from the watershed. Additional planned implementation measures in the Maryland Coastal Bays watershed involve the upgrade of septic systems, whether by connecting these systems to currently operating facilities or the addition of denitrification. Funding for upgrading to the denitrifying systems can be provided through the Bay Restoration Fund (BRF).

Maryland’s Water Quality Improvement Act requires that comprehensive and enforceable nutrient management plans be developed, approved, and implemented for all agricultural lands throughout Maryland. This act specifically required that nutrient management plans for nitrogen are developed and implemented by 2002, and plans for phosphorus be completed by 2005. It is reasonable to expect that nonpoint loads can be reduced during the growing season conditions. The nutrient loading sources during the growing season include groundwater discharges of the dissolved forms of the impairing substances, the effects of agricultural ditching and the presence of animals in watershed stream, and the deposition of nutrients and organic matter to the streambed from higher flow events. When these sources are controlled in conjunction with one another, it is reasonable to assume that nonpoint source reductions from the agricultural sector of the magnitude required by this TMDL can be achieved.

In the Coastal Bays watershed, the lag time from actions taken on the land surface and reaction within the waterbodies may be substantial. Phillips, Focazio and Bachman (1999) report that groundwater travel times can vary from 6 to 12 years on the Coastal Plain portion of the Chesapeake Bay Watershed. Sanford et al. (2012) developed a model for predicting the trends in nitrate transport in groundwater. Sanford et al. estimate a return time (from recharge area to discharge to a receiving waterbody) of less than 10 years (near streams) to over 100 years (near stream divides). This needs to be taken into consideration when analyzing the results of post TMDL water quality monitoring data for the purposes of assessing implementation practices.

Additional potential funding sources for implementation include Maryland's Agricultural Cost Share Program (MACS), which provides grants to farmers to help protect natural resources, and the Environmental Quality and Incentives Program, which focuses on implementing conservation practices and BMPs on land involved with livestock and production. Finally, many of the statewide practices designed to meet the nutrient TMDLs within the Chesapeake Bay watershed will also assist in meeting nutrient reduction goals within the Maryland Coastal Bays.

It should be noted that a portion of the drainage basin of the Maryland Coastal Bays (also referred to as "Upstream Loads") lies in Delaware and/or Virginia, beyond the jurisdictional and regulatory authority of Maryland. The upstream loads assigned to Delaware and/or Virginia sources are consistent with and equitable to allocations given to sources in Maryland, and are reasonable and achievable with existing technology and practices.

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