Total Maximum Daily Loads of Nitrogen and Phosphorus for Five Tidal Tributaries in the Northern Coastal Bays System Worcester County, Maryland

FINAL

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List of Abbreviations

BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
CCMP	Comprehensive Conservation Management Plan for Maryland's Coastal Bays
CEAM	Center for Exposure Assessment Modeling
CHL*a*	Active Chlorophyll
COMAR	Code of Maryland Regulations
CWAP	Clean Water Action Plan
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphorus
DNR	Maryland Department of Natural Resources
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
EUTRO5.1	Eutrophication Module of WASP5.1
km^2	Square Kilometers
LA	Load Allocation
lb/acre	Pounds Per Acre
lb/yr	Pounds Per Year
MCBP	Maryland Coastal Bays Program
MDE	Maryland Department of the Environment
MOS	Margin of Safety
mg/l	Milligrams Per Liter
μg/l	Microgram Per Liter
NCBEM	Northern Coastal Bays Eutrophication Model
NEP	National Estuaries Program
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
ON	Organic Nitrogen
OP	Organic Phosphorus
PO_4	Ortho-Phosphate
SOD	Sediment Oxygen Demand
TMDL	Total Maximum Daily Load
UMCES	University of Maryland Center for Environmental Science
USGS	United States Geological Survey
WASP5.1	Water Quality Analysis Simulation Program 5.1
WLA	Waste Load Allocation
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WRAS	Watershed Restoration Action Strategy
WWTP	Waste Water Treatment Plant

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EXECUTIVE SUMMARY

The Northern Coastal Bays (Assawoman Bay and Isle of Wight Bay) were identified on the State's 1996 list of water quality limited segments (WQLSs) as impaired by nutrients (nitrogen and phosphorus). The St. Martin River, a tributary of Isle of Wight Bay, was first identified on the 1994 303(d) list, also impaired by nutrients. To begin addressing these impairments, this document proposes to establish Total Maximum Daily Loads (TMDLs) for the nutrients nitrogen and phosphorus in the tributaries of the Northern Coastal Bays. The Northern Coastal Bays are located in the northeast section of Worcester County, Maryland and include Assawoman Bay and Isle of Wight Bay. The portion of these bays within Maryland can be delineated into nine separate water bodies. The following outline identifies these nine water bodies. Tributaries of a given water body are indicated by sublevels of the outline.

<u>Nine Waterbodies in the Northern Coastal Bays System</u>

- Assawoman Bay
  - Greys Creek
- Isle of Wight Bay
  - St. Martin River*
    - Shingle Landing Prong*
    - Bishopville Prong*
  - Herring Creek*
  - Turville Creek*
  - Manklin Creek

* The asterisks denote waters for which TMDL analyses are conducted in this report.

The Northern Coastal Bays are impaired by the nutrients nitrogen and phosphorus, which cause excessive algal blooms and violations of the dissolved oxygen criterion. The water quality goals of the TMDLs proposed in this report are to reduce high chlorophyll *a* concentrations (a surrogate for algal blooms), and to maintain the dissolved oxygen criterion at a level whereby the designated uses will be met.

To begin addressing these conditions, Maryland is first establishing nutrient TMDLs for the following five major tributaries in the Northern Coastal Bays system: St. Martin River, Bishopville Prong, Shingle Landing Prong, Herring Creek and Turville Creek. TMDLs for the remaining portions of the Northern Coastal Bays system will be established at a later time, when additional data and analytical tools allow.

The TMDLs were determined using the Water Quality Analysis Simulation Program (WASP) Version 5.1. The TMDLs for the St. Martin River, Bishopville Prong, and Shingle Landing Prong, are established for both low stream flow, which represents the critical conditions, and average annual flow conditions, which ensure that seasonal variations are addressed.

In Herring Creek and Turville Creek, the WASP model is limited due to the large size of the model segment representing these creeks. For these areas, the nutrient limits are being established as phased TMDLs. Under a phased TMDL, control activities and future monitoring are scheduled as part of an adaptive management approach to resolving the water quality impairments. The analyses for these two creeks are performed solely to determine average annual loading limits.

For Herring Creek, which drains to the Isle of Wight Bay, the average annual TMDL for nitrogen is 9,547 lb/yr, and the average annual TMDL for phosphorus is 1,235 lb/yr. The nonpoint sources, including direct atmospheric deposition, are allocated as 8,592 lb/yr of total nitrogen, and 1,111 lb/yr of total phosphorus, with the remainder being allocated to a margin of safety. There are no point sources to which loads can be allocated.

For Turville Creek, which drains to the Isle of Wight Bay, the average annual TMDL for nitrogen is 26,272 lb/yr, and the average annual TMDL for phosphorus is 3,928 lb/yr. The nonpoint sources, including direct atmospheric deposition, are allocated as 23,645 lb/yr of total nitrogen, and 3,535 lb/yr of total phosphorus, with the remainder being allocated to a margin of safety. There are no point sources to which loads can be allocated.

For the St. Martin River, the low flow TMDL for nitrogen is 4,378 lb/month, and the low flow TMDL for phosphorus is 1,908 lb/month. The nonpoint sources are allocated as 1,985 lb/month of total nitrogen, and 364 lb/month of total phosphorus. The point sources are allocated as 2,288 lb/month of nitrogen and 1,525 lb/month of phosphorus. The low flow TMDLs apply during the period May 1 through October 31. The average annual TMDL for nitrogen is 222,110 lb/yr and the average annual TMDL for phosphorus is 41,133 lb/yr. The nonpoint sources are allocated as 141,453 lb/yr of total nitrogen and 21,688 lb/yr of total phosphorus. The point sources are allocated as 73,212 lb/yr of nitrogen and 18,303 lb/yr of phosphorus.

For Shingle Landing Prong, the low flow TMDL for nitrogen is 2,060 lb/month, and the low flow TMDL for phosphorus is 219 lb/month. The nonpoint sources are allocated as 508 lb/month of total nitrogen, and 63 lb/month of total phosphorus. The point sources are allocated as 1,525 lb/month of nitrogen and 153 lb/month of phosphorus. The low flow TMDLs apply during the period May 1 through October 31. The average annual TMDL for nitrogen is 104,700 lb/yr and the average annual TMDL for phosphorus is 12,926 lb/yr. The nonpoint sources are allocated as 71,644 lb/yr of total nitrogen and 10,541 lb/yr of total phosphorus. The point sources are allocated as 29,285 lb/yr of nitrogen and 1,830 lb/yr of phosphorus.

For Bishopville Prong, the low flow TMDL for nitrogen is 665 lb/month, and the low flow TMDL for phosphorus is 109 lb/month. The nonpoint sources are allocated as 632 lb/month of total nitrogen and 103 lb/month of total phosphorus. Several very small point sources are included indirectly as upstream/background loads, but have not been assigned explicit allocations. The low flow TMDLs apply during the period May 1 through October 31. The average annual TMDL for nitrogen is 64,946 lb/yr, and the average annual TMDL for phosphorus is 9,471 lb/yr. The nonpoint sources are allocated as 61,699 lb/yr of total nitrogen and 8,997 lb/yr of total phosphorus. As in the low flow case, no explicit allocations are assigned to upstream point sources.

Four factors provide assurance that these TMDLs will be implemented. First, NPDES permits will assure implementation of the waste load allocations. Second, Maryland's Water Quality Improvement Act of 1998 requires that nutrient management plans be implemented for all agricultural lands throughout Maryland. Third, the Maryland Coastal Bays Program has invested years of technical investigation and community involvement to protect the future of the bays. This has been formalized in the creation of a comprehensive plan to restore and protect Maryland's Coastal Bays. Finally, Maryland has adopted a watershed cycling strategy, which will assure that routine future monitoring and TMDL evaluations are conducted. The schedule for future monitoring is formalized as part of this TMDL documentation in regard to the adaptive management approach that underlies the phased TMDLs.

1.0 INTRODUCTION

Section 303(d)(1)(C) of the federal Clean Water Act and the applicable federal regulations direct each State to develop a Total Maximum Daily Load (TMDL) for each impaired water quality limited segment (WQLS) on the Section 303(d) list, taking into account seasonal variations and a protective margin of safety (MOS) to account for uncertainty. A TMDL reflects the total pollutant loading of an impairing substance a waterbody can receive and still meet water quality standards.

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

The St. Martin River was first identified on Maryland's 1994 303(d) list for nutrients. Assawoman Bay, and Isle of Wight Bay were first identified on Maryland's 1996 303(d) list for nutrients. The Maryland Department of the Environment (MDE) submitted each of these lists to the U.S. Environmental Protection Agency (EPA) for review and approval. These waters, and the tributaries discussed below, are hereafter referred to collectively as the "Northern Coastal Bays."

The 1996 list acknowledges that "impairments may be very localized," indicating that spatial refinement of impairments could come about "as the State develops additional information" during the TMDL analysis. As a result of such additional information, Maryland's portion of the Northern Coastal Bays have been partitioned into nine separate water bodies. The following outline identifies these nine water bodies. Tributaries of a given water body are indicated by sublevels of the outline.

<u>Nine Waterbodies in the Northern Coastal Bays System</u>

- Assawoman Bay
  - Greys Creek
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  - Turville Creek*
  - Manklin Creek

* The asterisks denote waters for which TMDL analyses are conducted in this report.

Due to limitations of data and the water quality analysis models, TMDLs are being established at this time for five of the nine water bodies. TMDLs for the two open bays (i.e. Assawoman Bay and Isle of Wight Bay), and several tidal embayments are not being established at this time. Nevertheless, the nutrient load reductions presently being proposed for the tidal tributaries listed below are predicted to have a beneficial effect on the open bays in the interim period while TMDLs for the open bays are under development.

Five Waterbodies for which TMDLs are Being Established

Three (3) separate TMDLs are proposed for the St. Martin River and its two primary tributaries, Shingle Landing Prong and Bishopville Prong. In addition, two (2) TMDLs are proposed for Herring Creek, and Turville Creek, which drain to Isle of Wight Bay, for a total of five (5) TMDLs.

These waters are impaired by nutrients due to signs of eutrophication, which are expressed as high chlorophyll *a* and low dissolved oxygen. Eutrophication is the over-enrichment of aquatic systems by excessive inputs of nutrients (nitrogen and/or phosphorus). The nutrients act as a fertilizer leading to excessive growth of aquatic plants, which eventually die and decompose, leading to bacterial consumption of dissolved oxygen. For these reasons, this document proposes to establish TMDLs for nutrients in the Northern Coastal Bays.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

The Northern Coastal Bays are shallow coastal lagoons located behind Fenwick Island on the Atlantic Coast of Worcester County, Maryland (Figure 1). The Northern Coastal Bays system consists of two major bays: Assawoman Bay and Isle of Wight Bay. The majority of the freshwater input to the system comes from the St. Martin River. The Northern Coastal Bays watershed occupies an area of approximately 49,880 acres (200 km^2). The open surface water area accounts for an additional 13,270 acres (54 km^2). Most of the Northern Coastal Bays watershed is on the mainland of the Delmarva Peninsula, with the remaining area associated with Fenwick Island. The watershed is characterized by low topographic relief, high groundwater tables, poor surface drainage, and sandy soils.

The following sections provide information on land use and annual point and nonpoint source loads for the two open bays and for seven tidal tributaries. Figure 2 shows the geographic distribution of the different land uses throughout the Northern Coastal Bays watershed. Figures 3a – 3g, in the following section, show the relative distribution of various land uses within the drainage areas of the two bays (Assawoman & Isle of Wight), the St. Martin River basin, and the remaining tidal tributaries addressed by this TMDL analysis. The land use information is based on 1997 Maryland Office of Planning land cover data, 1997 Delaware Office of Planning land cover data, and 1997 Farm Service Agency data.

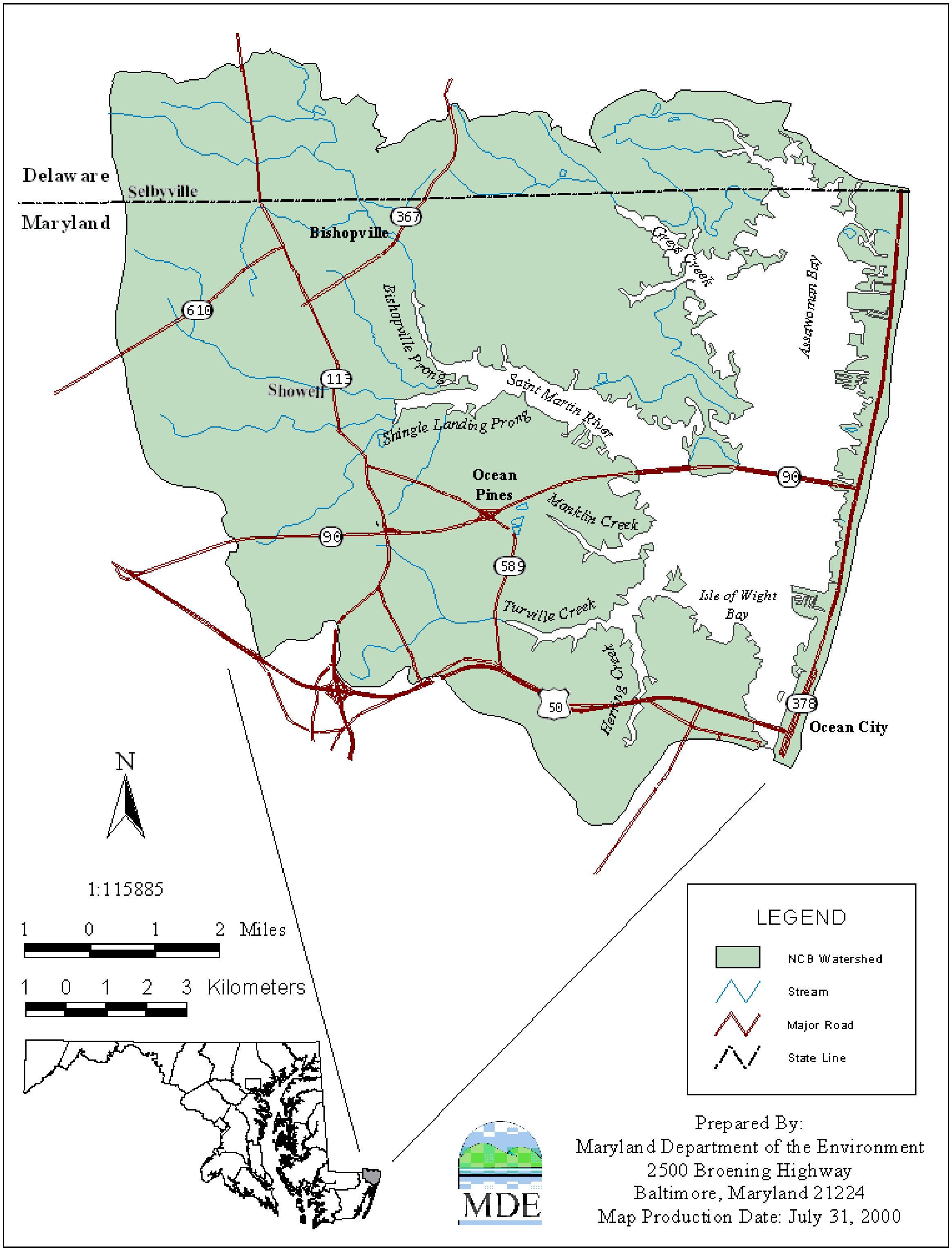

Figure 1: Location Map of the Northern Coastal Bays Drainage Basin within Maryland and Delaware

The average annual nonpoint source loads presented below are the baseline loads relative to which the average annual TMDL limits can be compared. The baseline average annual nonpoint source load was calculated by summing all of the individual land use areas and multiplying by the corresponding land use loading coefficients, as described further in Appendix A. The baseline loading coefficients were based on a study conducted in the Maryland Coastal Bays (University of Maryland, 1993). Figures 4a - 4g, in the following section, show the relative distribution of average annual nonpoint source nitrogen and phosphorus loads attributable to various land uses, for each of the major watersheds addressed by this analysis.

Two significant point sources are addressed explicitly by TMDL allocations in this analysis. They are discussed in Section 2.1.2 below.

2.1.1 Assawoman Bay and Greys Creek

Although TMDLs are not presently being proposed for this region of the Northern Coastal Bays, the following information is provided for completeness.

Assawoman Bay: The Assawoman Bay has a drainage area of 10,691 acres (43.3 km^2). The average depth is 3.3 ft (1 m) and can reach up to 8 ft (2.5 m) in the middle of the bay. The land uses in the watershed consist of forest and other herbaceous (4,118 acres, 39 %), mixed agriculture (3,611 acres, 34 %), and urban (2,962 acres, 28%). Figure 3a shows the relative amounts of the different land uses in the Assawoman Bay watershed.

In the Assawoman Bay watershed, the baseline average annual total nitrogen load is 137,836 lb/yr. Direct atmospheric deposition to the water's surface accounts for approximately 37% of the load, and direct groundwater discharge accounts for approximately 7% of the load (USGS 2000). The estimated average annual total phosphorus load is 12,594 lb/yr. Direct atmospheric deposition to the water's surface accounts for approximately 25% of the load. There are no significant point source dischargers of nutrients in the Assawoman Bay watershed, and thus the total load constitutes the nonpoint source load. Figure 4a shows the relative contributions of nitrogen and phosphorus from the various sources.

Greys Creek: Greys Creek, a significant embayment in the Maryland portion of Assawoman Bay, drains a watershed area of approximately 5,965 acres (24.1 km^2). The Greys Creek watershed land use consists of mixed agriculture (2,959 acres, 49.6 %), forest and other herbaceous cover (2,386 acres, 40 %), urban (620 acres, 10.4 %). The water surface area of Greys Creek is 504 acres (2 km^2).

2.1.2 Isle of Wight Bay and Tributaries

Although TMDLs are not presently being proposed for all of the regions described below, the following information is provided for completeness.

Isle of Wight Bay: The Isle of Wight Bay has a drainage area of 39,186 acres (159 km^2), which includes the St. Martin River watershed. Although the average depth is 4 ft (1.22 m), the inlet at

Ocean City has a depth of up to 30.5 ft (9.3 m). The land use in the Isle of Wight watershed consists of forest and other herbaceous (14,970 acres, 31 %), mixed agriculture (14,550 acres, 31 %), urban (9,770 acres, 21%). The water surface area of the Isle of Wight Bay is approximately (7,760 acres, 17 %). Figure 3b shows the relative amounts of the different land uses in the Isle of Wight Bay watershed.

In the Isle of Wight Bay watershed, the baseline average annual total nonpoint source nitrogen load is 413,801 lb/yr. Direct atmospheric deposition to the water's surface accounts for approximately 17% of the load, and direct groundwater discharge accounts for approximately 3% of the load. The baseline average annual nonpoint source total phosphorus load is 43,202 lb/yr. Direct atmospheric deposition to the water's surface accounts for approximately 10% of the load. Figure 4b shows the relative contributions of nitrogen and phosphorus from the various sources.

<u>Herring Creek</u>: Herring Creek, a significant embayment in the Maryland portion of the Isle of Wight Bay, drains a watershed area of approximately 3,016 acres (12.2 km^2). The Herring Creek watershed land use consists of mixed agriculture (275 acres, 9 %), forest and other herbaceous cover (1,793 acres, 59%), urban (708 acres, 23 %). The water surface area of Herring Creek is 239 acres (1 km^2, 8%). Figure 4c shows the relative contributions of nitrogen and phosphorus from the various sources.

<u>Turville Creek</u>: Turville Creek, a significant embayment in the Maryland portion of the Isle of Wight Bay, drains a watershed area of approximately 6,046 acres (24.5 km^2). The Turville Creek watershed land use consists of mixed agriculture (1,544 acres, 26 %), forest and other herbaceous cover (2,927 acres, 48 %), urban (1,392 acres, 24 %). The water surface area of Turville Creek is 182 acres (0.7 km^2, 3%). Figure 4d shows the relative contributions of nitrogen and phosphorus from the various sources.

<u>Manklin Creek</u>: Manklin Creek, a significant embayment in the Maryland portion of the Isle of Wight Bay, drains a watershed area of approximately 1,862 acres (7.5 km^2). The Manklin Creek watershed land use consists of mixed agriculture (187 acres, 9%), forest and other herbaceous cover (473 acres, 23 %), urban (1,203 acres, 57 %). The water surface area of Manklin Creek is 225 acres (0.9 km^2, 11%).

<u>St. Martin River, Shingle Landing Prong, and Bishopville Prong</u>: The St. Martin River, the most significant tributary to the Isle of Wight Bay is approximately 3.7 miles (5.9 km) in length, and drains a watershed area of 26,110 acres (106 km^2). The St. Martin River watershed land use consists of forest and other herbaceous cover (9,190 acres, 33 %), mixed agriculture (12,310 acres, 44 %), urban (4,620 acres, 17%). The water surface area of the St. Martin River is 1,680 acres (7 km^2). Figure 3c shows the land uses for the St. Martin River watershed.

In the St. Martin River watershed, the baseline average annual total nitrogen load is 276,777 lb/yr. Direct atmospheric deposition to the water's surface accounts for approximately 6% of the load, and direct groundwater discharge accounts for approximately 1% of the load. The estimated average annual total phosphorus load is 31,619lb/yr. Direct atmospheric deposition to the water's surface accounts for approximately 3% of the load. Figure 4e shows the relative contributions of nitrogen and phosphorus from the various sources.

Shingle Landing Prong: Shingle Landing Prong, a significant tidal tributary to the St. Martin River, drains a watershed area of approximately 11,832 acres (47.9 km^2). The Shingle Landing Prong watershed land use consists of mixed agriculture (6,121 acres, 52 %), forest and other herbaceous cover (4,124 acres, 35 %), urban (1,578 acres, 13 %). The water surface area of Shingle Landing Prong is 33 acres (0.1 km^2). Figure 4f shows the relative contributions of nitrogen and phosphorus from the various sources.

Bishopville Prong: Bishopville Prong, a significant tidal tributary to the St. Martin River, drains a watershed area of approximately 10,817 acres (43.8 km^2). The Bishopville Prong watershed land use consists of mixed agriculture (5,144 acres, 48%), forest and other herbaceous cover (3,774 acres, 35 %), urban (1,899 acres, 18 %). The water surface area in Bishopville Prong is negligible. Figure 4g shows the relative contributions of nitrogen and phosphorus from the various sources.

There are two significant point source discharges of nutrients in the larger St. Martin River watershed, which were included as explicit loads in the modeling analyses. These sources are the Ocean Pines Service Area Wastewater Treatment Plant (WWTP), and Perdue Farms Inc. in Showell, Maryland. The Ocean Pines Service Area WWTP discharges directly into the St. Martin River. The Perdue Farms processing plant in Showell discharges into an unnamed tributary of Church Branch, which drains to Shingle Landing Prong, a tributary of the St. Martin River. In 1998, these point sources were contributing about 36,566 lb/yr of nitrogen and 2,313 lb/yr of phosphorus to the St. Martin River and eventually to the Isle of Wight Bay.

Several other point source discharges were considered, but are not directly included in the modeling analyses. The MountAire Processing Plant, in Delaware on Bishopville Prong of the St. Martin River, only discharges non-contact cooling water. The Ocean City WWTP discharges into the Atlantic Ocean. If it contributes loads, those would be accounted for by observed concentrations at the boundary of the Isle of Wight Bay with the Atlantic Ocean, which are included in the modeling framework. The Perdue Hatchery located in Bishopville, Maryland is estimated to contribute less than one-half of one percent of the load at the upstream water quality model boundary on Bishopville Prong (model segment 22) during low flow conditions. This is a conservative (high) estimate, because it does not account for transport losses between the point of discharge and the upstream boundary of the water quality model. Consequently, the load is not explicitly simulated as a discrete point source; however, it is considered indirectly as part of the nutrient load at the upstream boundary. See Appendix A for further discussion.

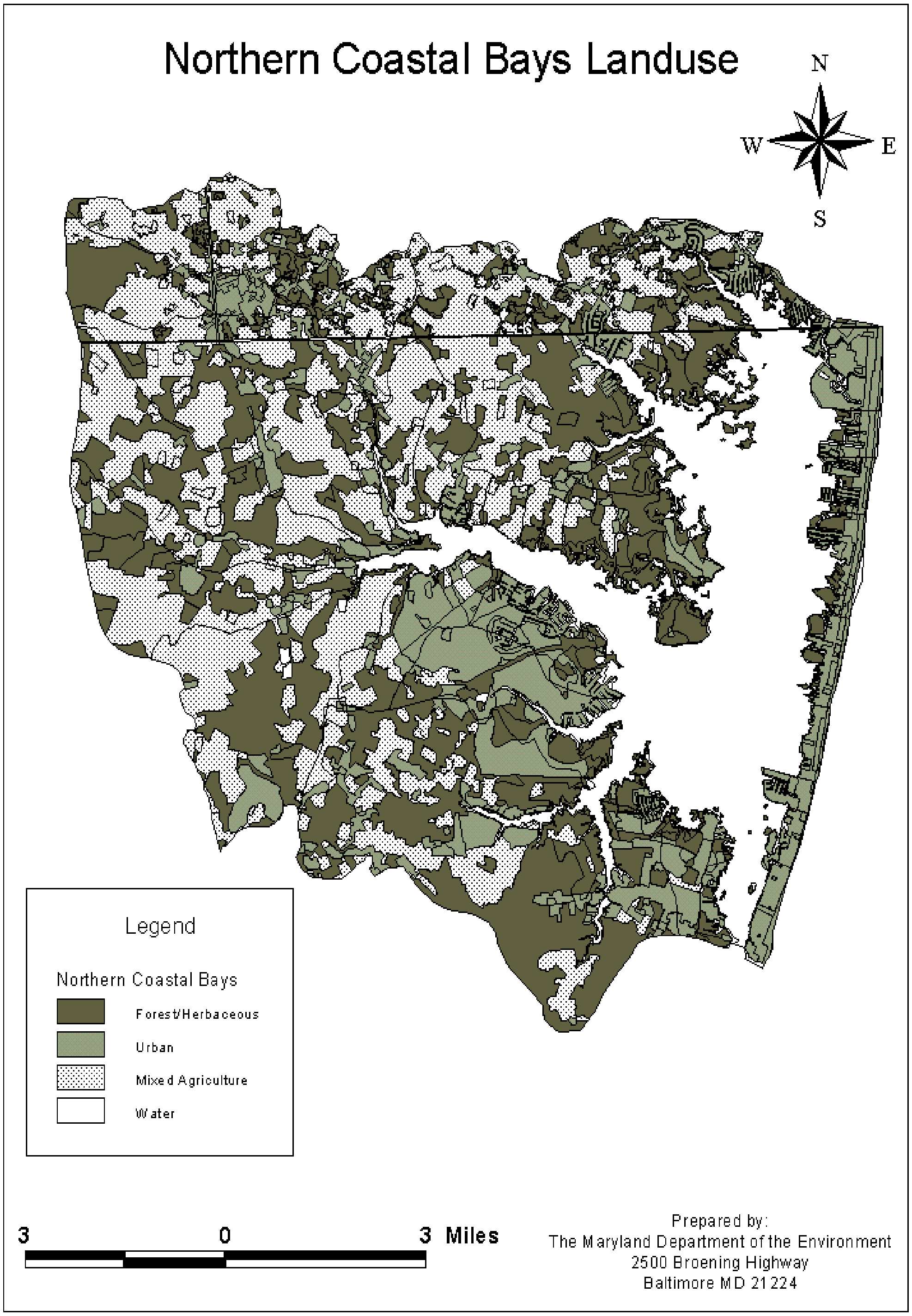

Figure 2: Land Use in the Northern Coastal Bays Drainage Basin

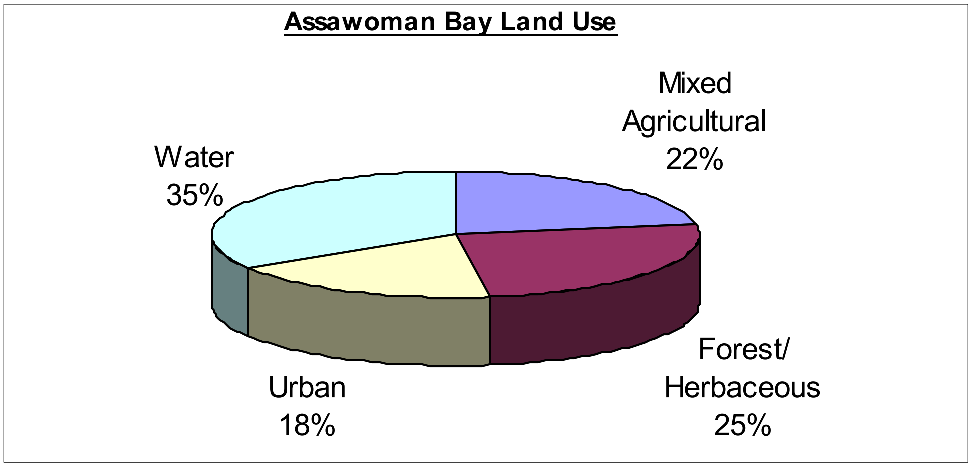

Figure 3a: Land Use in the Assawoman Bay Watershed

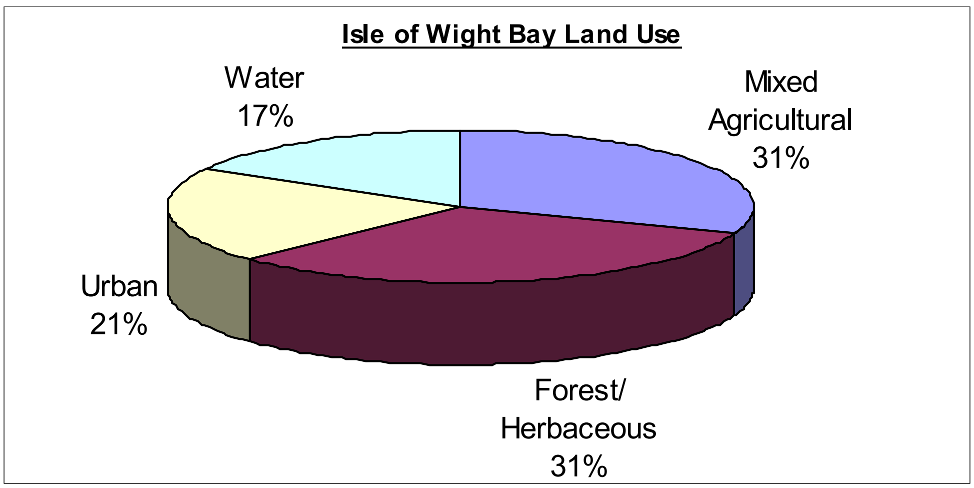

Figure 3b: Land Use in the Isle of Wight Bay Watershed (including the St. Martin River)

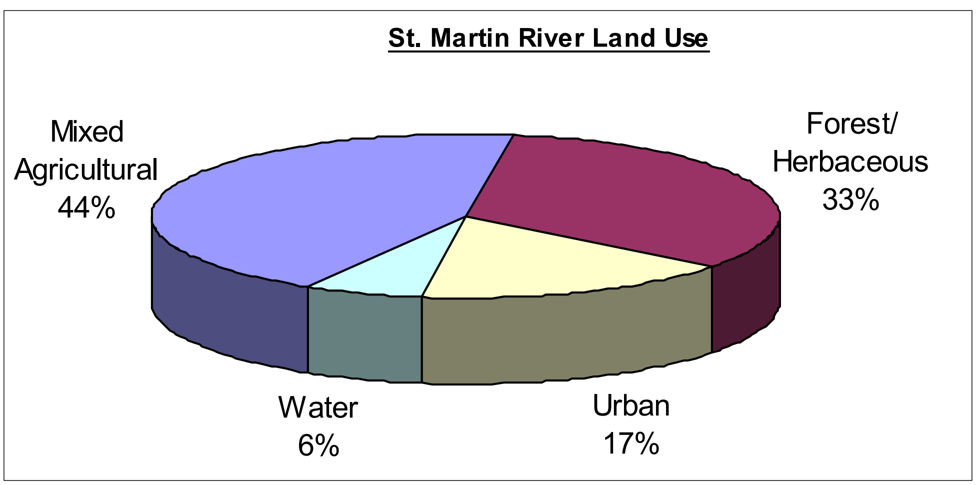

Figure 3c: Land Use in the St. Martin River Watershed

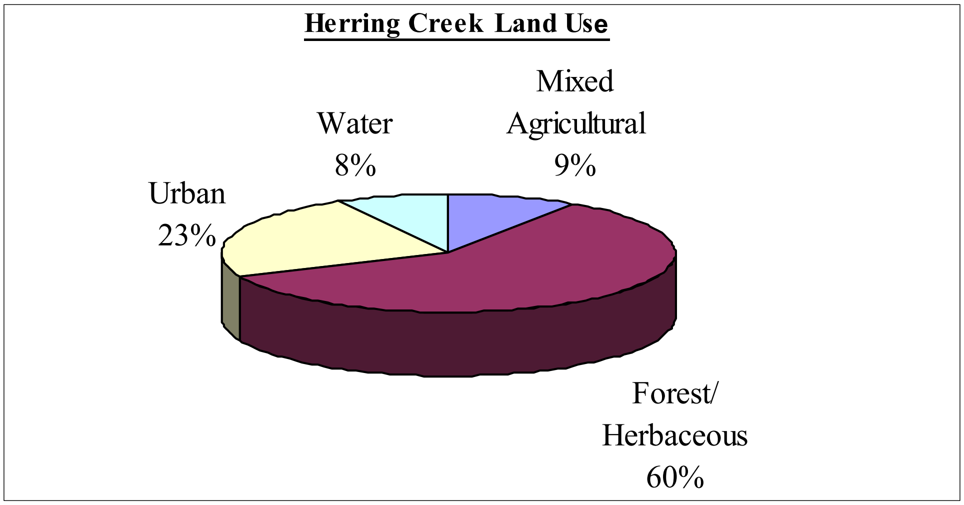

Figure 3d: Land Use in the Herring Creek Watershed

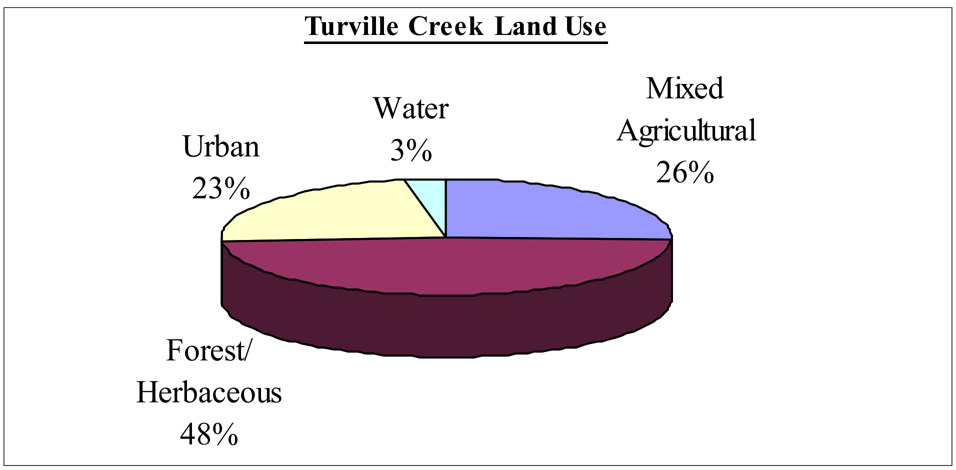

Figure 3e: Land Use in the Turville Creek Watershed

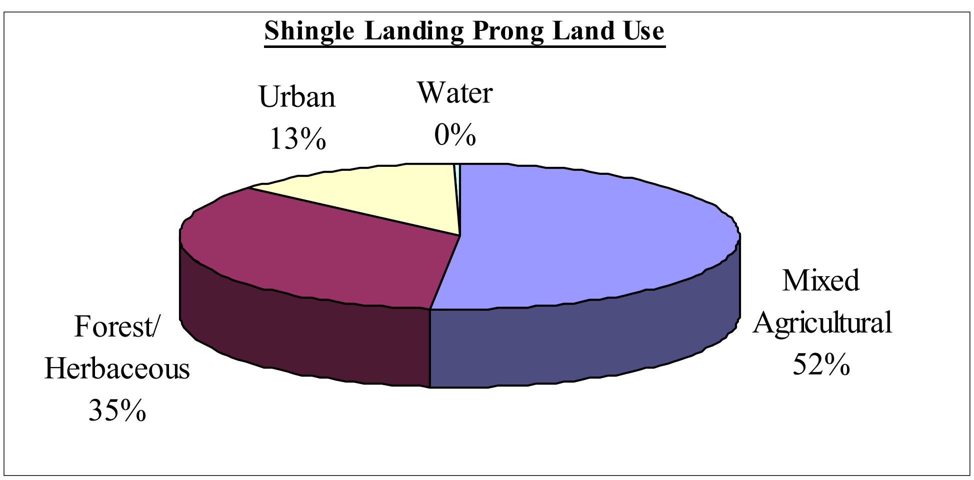

Figure 3f: Land Use in the Shingle Landing Prong Watershed

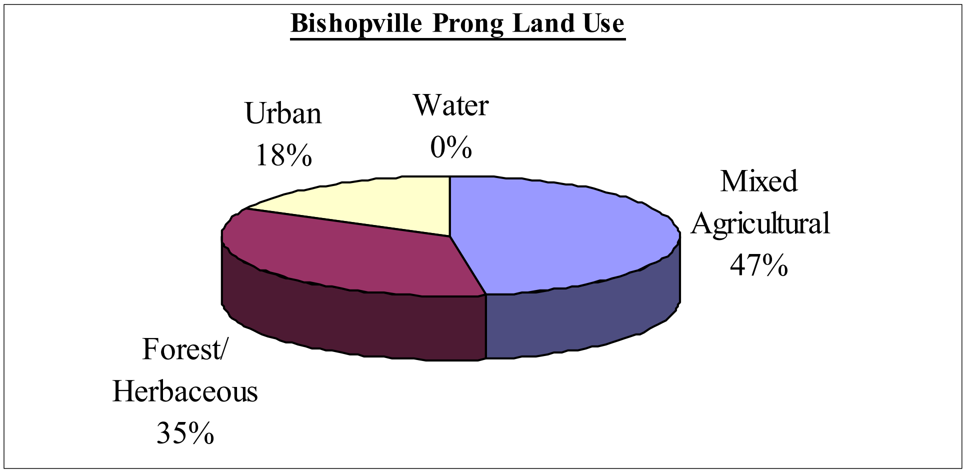

Figure 3g: Land Use in the Bishopville Prong Watershed

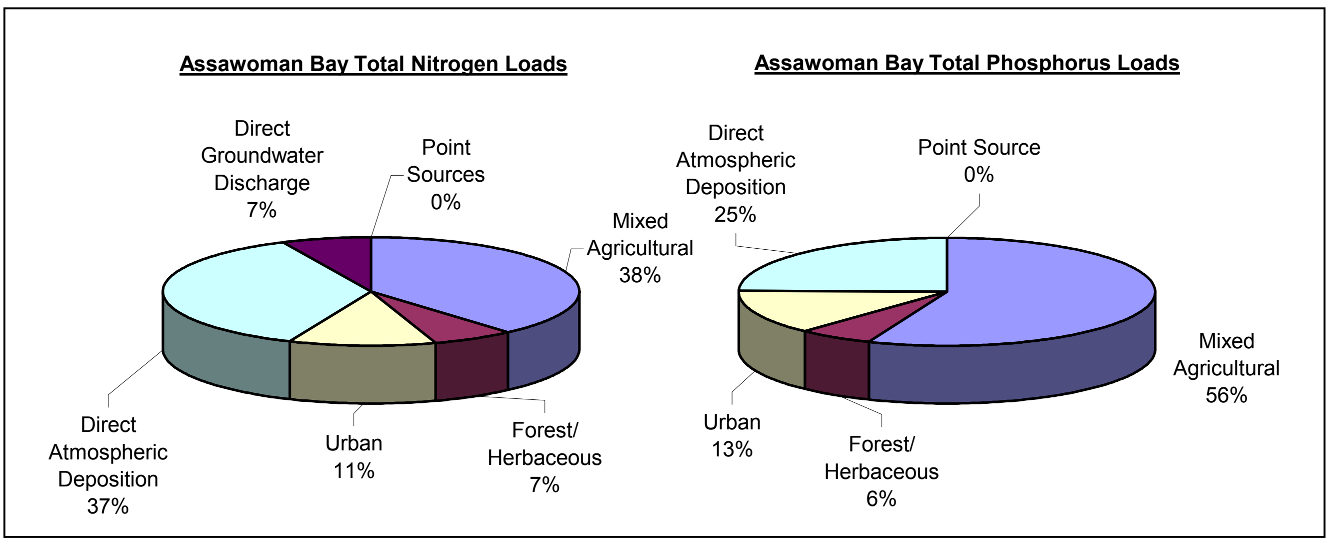

Figure 4a: Average Annual Total Nitrogen and Total Phosphorus Loads Entering Assawoman Bay

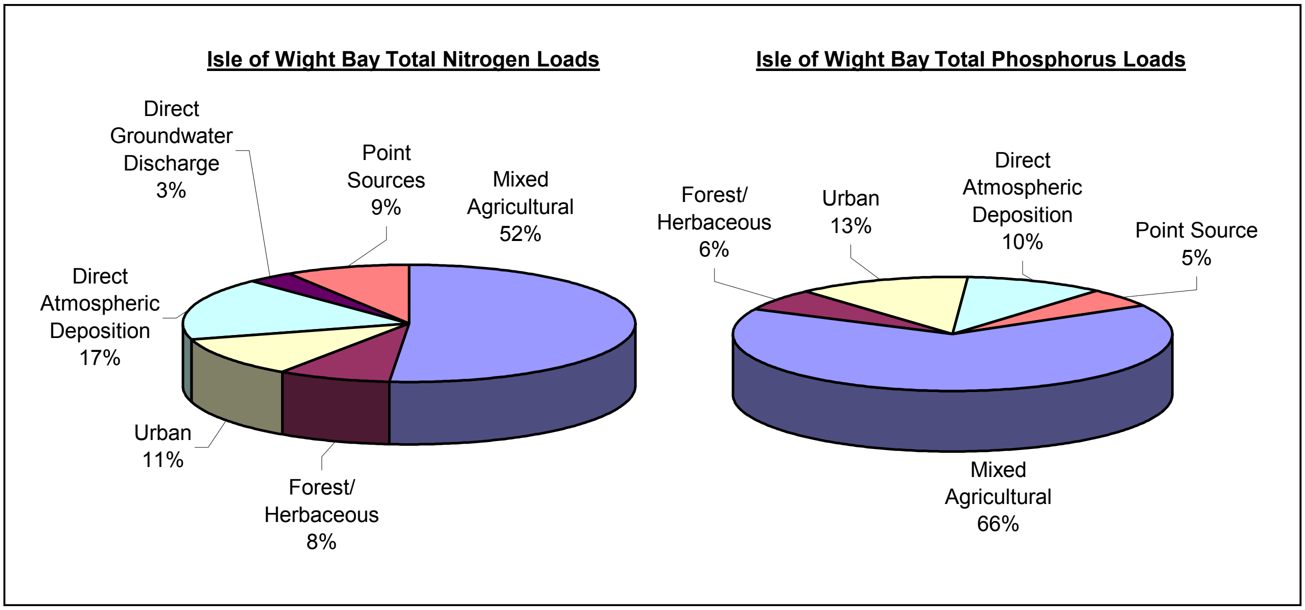

Figure 4b: Average Annual Total Nitrogen and Total Phosphorus Loads Entering Isle of Wight Bay (Including contributions from the St. Martin River)

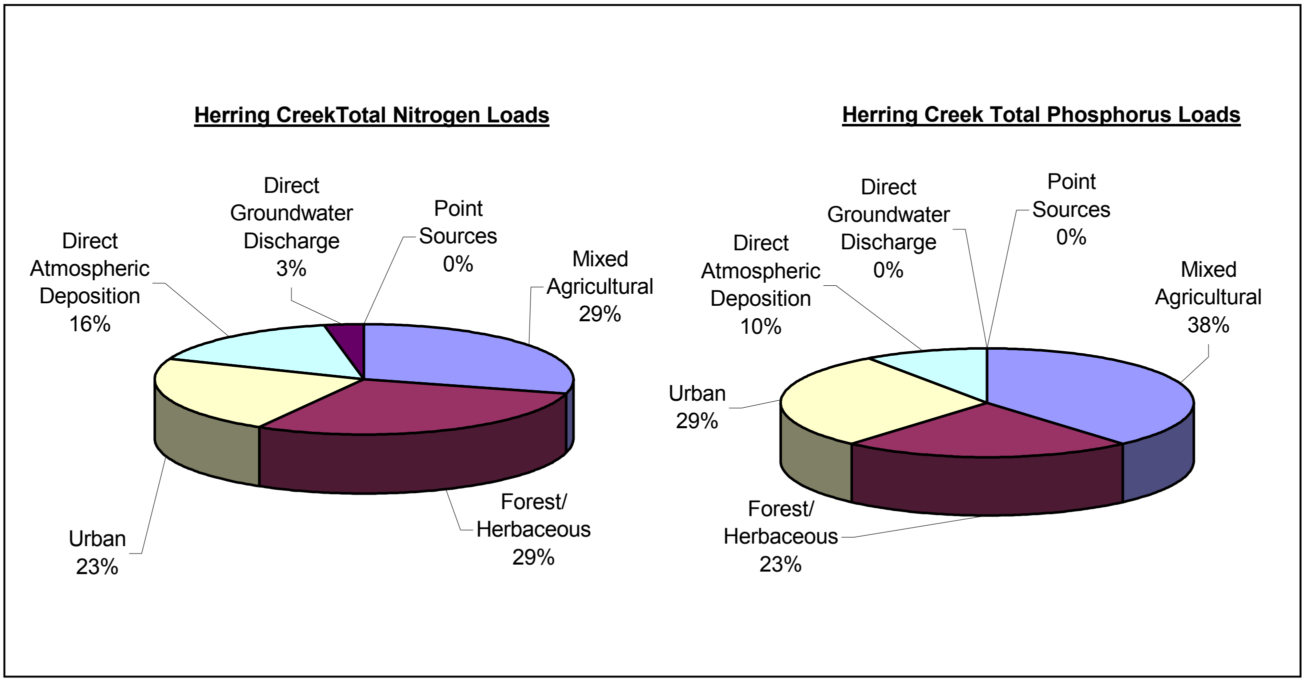

Figure 4c: Average Annual Total Nitrogen and Total Phosphorus Loads Entering Herring Creek

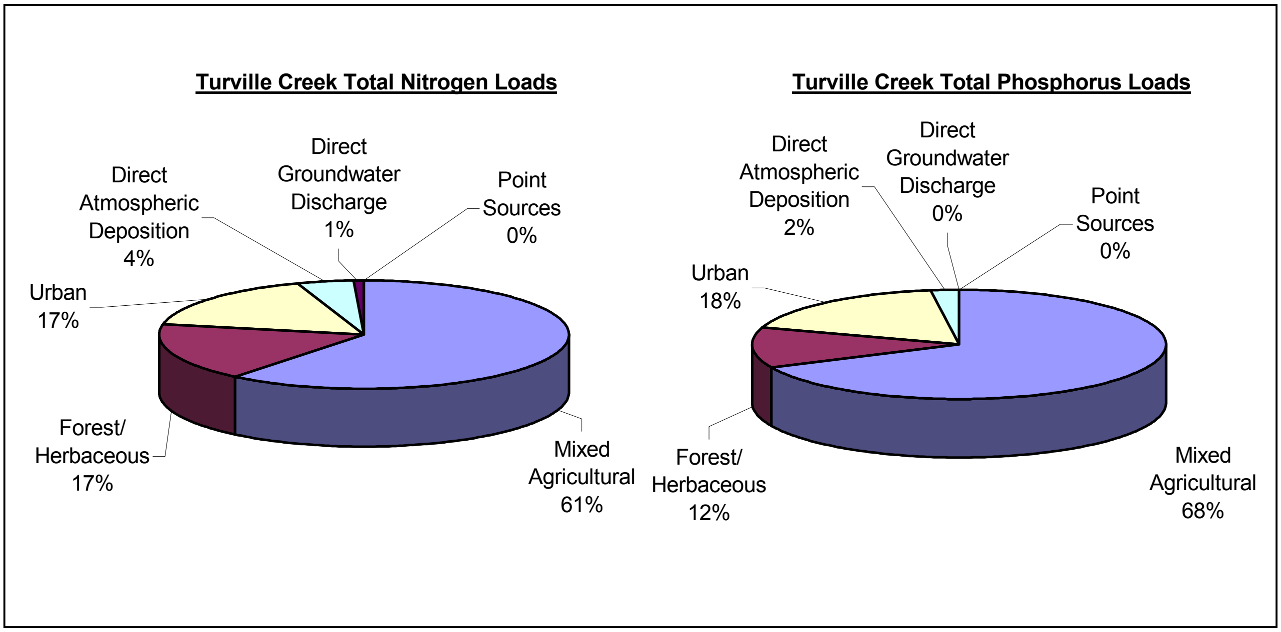

Figure 4d: Average Annual Total Nitrogen and Total Phosphorus Loads Entering Turville Creek

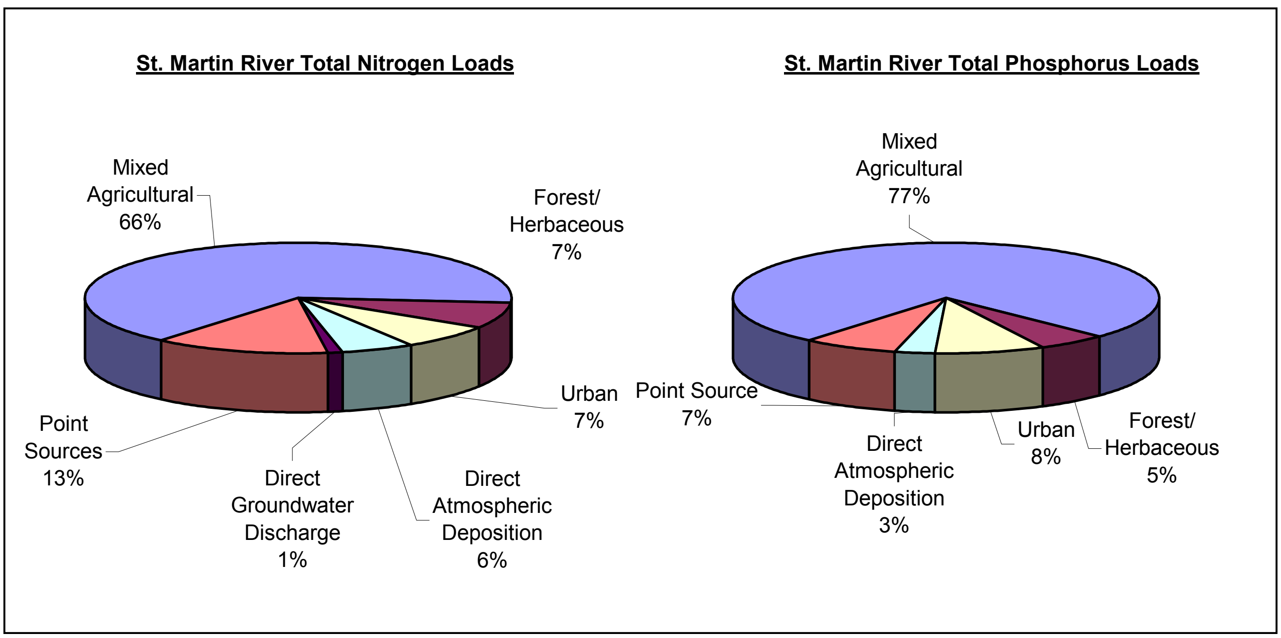

Figure 4e: Average Annual Total Nitrogen and Total Phosphorus Loads Entering the St. Martin River

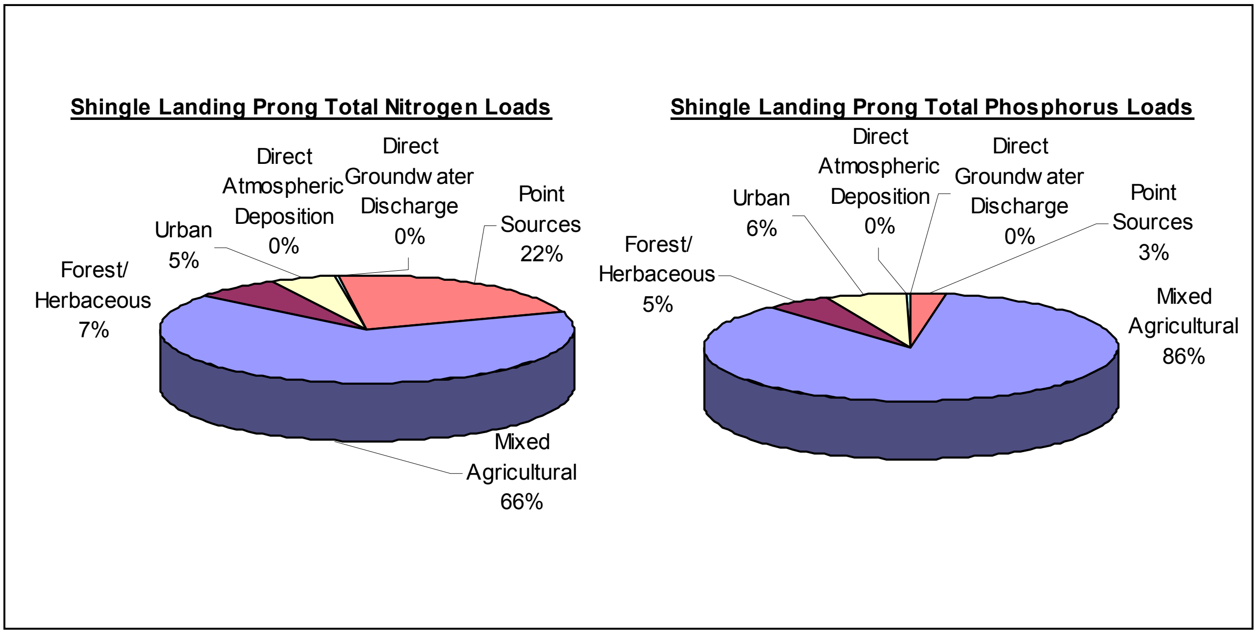

Figure 4f: Average Annual Total Nitrogen and Total Phosphorus Loads Entering Shingle Landing Prong

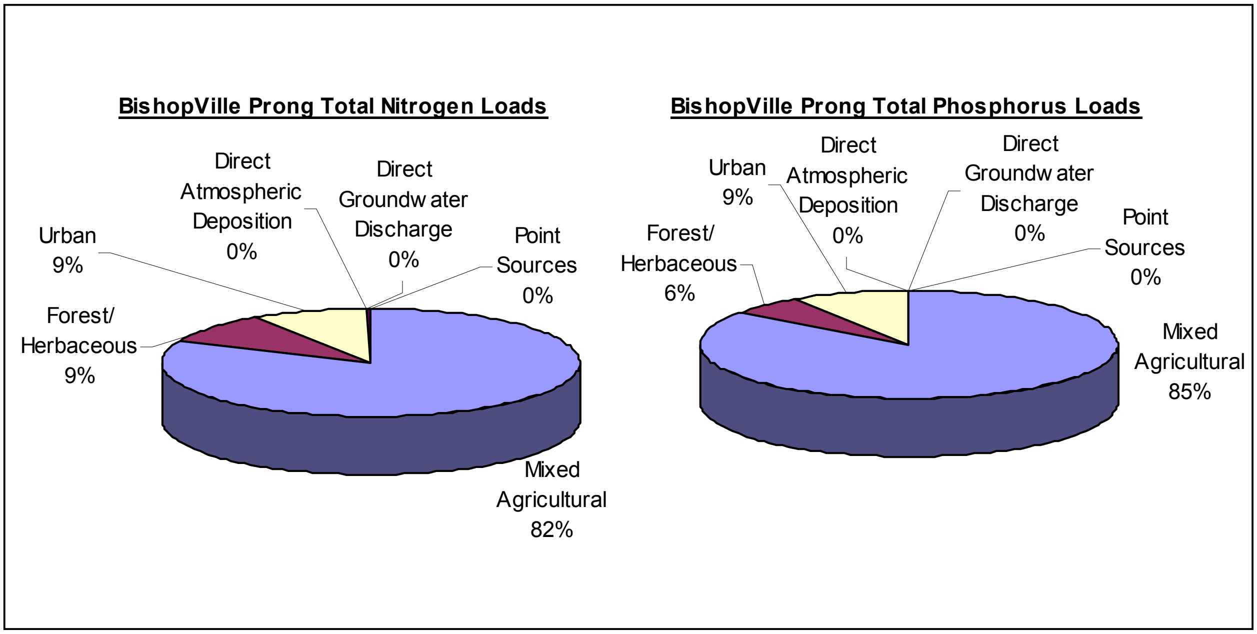

Figure 4g: Average Annual Total Nitrogen and Total Phosphorus Loads Entering Bishopville Prong

2.2 Water Quality Characterization

Four key water quality parameters associated with eutrophication are presented below: chlorophyll *a*, dissolved oxygen, dissolved inorganic nitrogen, and dissolved inorganic phosphorus. Figure 6 through Figure 9 presented below draw upon three data sources: 1998 MDE data, 1998 through 2000 Department of Natural Resources (DNR) data, and 1997 through 1999 Maryland's Coastal Bays Program (MCBP) Volunteer data.

Problems associated with eutrophication are most likely to occur during the low flow period (July - October). During this season there is typically less stream flow available to flush the system, more sunlight to grow aquatic plants, and warmer water temperatures, which are favorable conditions for biological processes of both plant growth and decay of dead plant matter. Because problems associated with eutrophication are usually most acute during this season, the temperature, flow, sunlight, and other parameters associated with this period represent critical conditions for the TMDL analysis. As discussed below, the TMDL analysis also considers other seasons; however, the data collected during the high flow period (February and March) do not show chlorophyll *a* or DO problems. The reader is referred to Figure 5 for the locations of the water quality sampling stations. Figure 6 through Figure 9 present data from the low flow period. Additional data, including that for the high flow periods, are presented in Appendix A.

Figure 6 presents ambient chlorophyll *a* data for low flow conditions (July – October). The figure shows that chlorophyll *a* concentrations in the summer for the open bays typically range between 10 – 20 μg/l. In the St. Martin River proper, concentrations begin to increase upstream to near 50 μg/l with the value at one sampling station reaching almost 100 μg/l. The levels are much greater in Shingle Landing Prong and in Bishopville Prong. Mean values range from 25 - 75 μg/l with a maximum concentration close to 300 μg/l in Bishopville Prong.

Figure 7 presents surface water dissolved oxygen (DO) data for low flow conditions (July – October) that are consistently above the criterion of 5.0 mg/l in the open bays. Although the data is not presented, data currently under review suggests that DO values in the bottom waters of the open bays routinely falls below 5.0 mg/l during the low flow season (Maryland DNR, 2001b).

Figure 7 shows that Herring Creek and Turville Creek (minor tributaries) display evidence of dissolved oxygen concentrations below 5.0 mg/l. For the St. Martin River and Shingle Landing Prong, observed DO levels are at or above 5.0 mg/l. The lowest dissolved oxygen concentrations seen in the system are in Bishopville Prong, near the same locations where high chlorophyll *a* concentrations were observed. It should be noted that this observed data might not reflect the daily minimum DO, which generally occurs very early in the morning after aquatic plant respiration has consumed oxygen during the night when photosynthetic production of oxygen has been absent. That is, in areas of high chlorophyll *a*, a potential exists for a diurnal depletion of DO to occur, which often is not reflected in observed data typically collected at mid-day.

Figure 8 presents the dissolved inorganic nitrogen (DIN) levels measured in the samples collected during low flow conditions. Concentrations in the open bays are very low with slightly higher concentrations around 0.2 mg/l occurring in Isle of Wight Bay. The St. Martin River DIN levels are all below 0.4 mg/l. In the tributaries, Bishopville Prong and Shingle Landing Prong, DIN levels reach 1.5 mg/l. Elevated levels are also observed in Turville Creek (TUV0034).

Figure 9 presents the dissolved inorganic phosphorus data (DIP) as indicated by ortho-phosphate levels measured in samples collected during low flow conditions. As shown in Figure 9 the highest DIP values are in the Bishopville Prong with values reaching up to 0.27 mg/l. The majority of the samples show values under 0.10 mg/l. Elevated levels are also observed in Turville Creek (TUV0034).

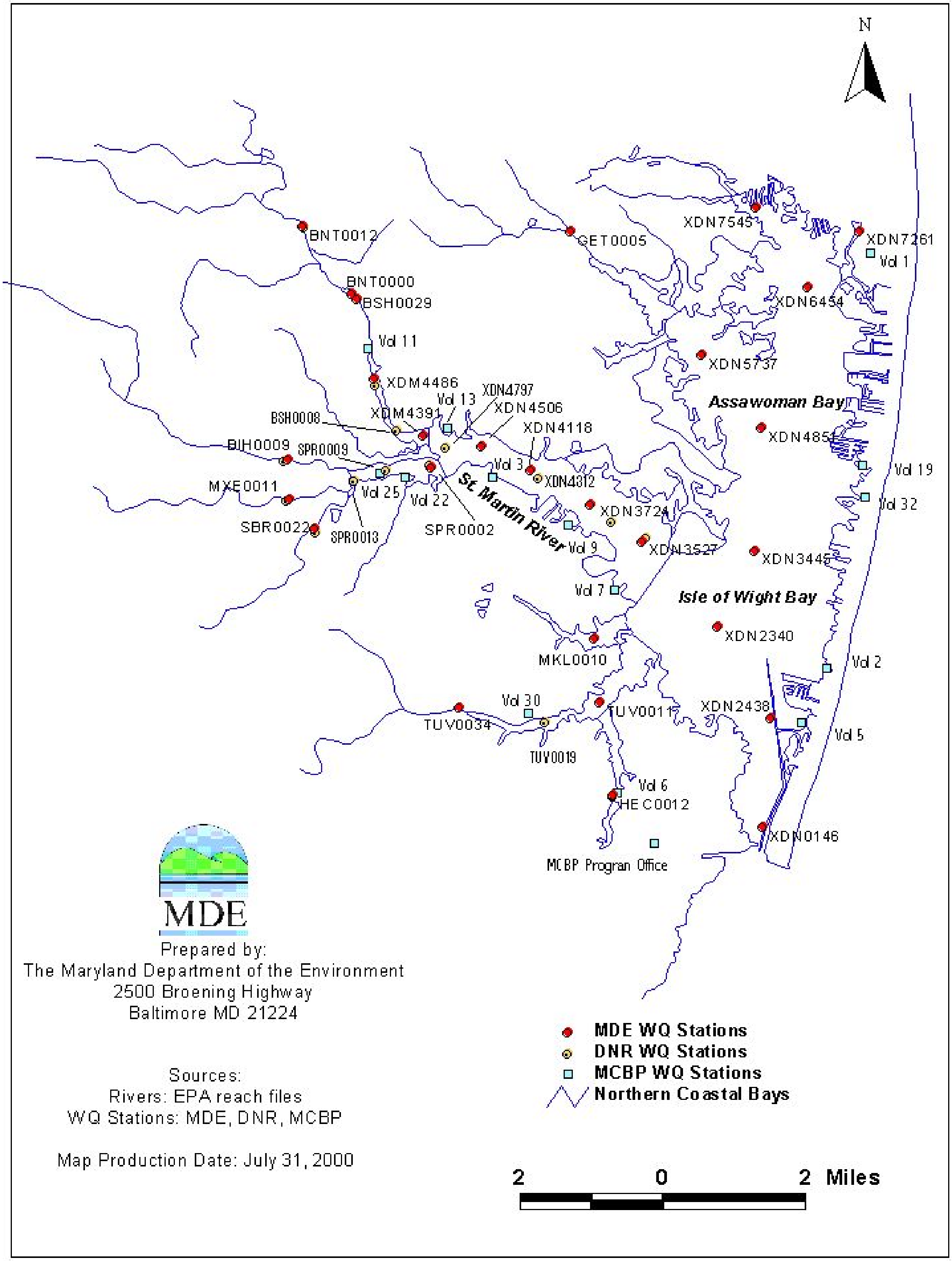

Figure 5: Location Map of the Northern Coastal Bays Water Quality Stations

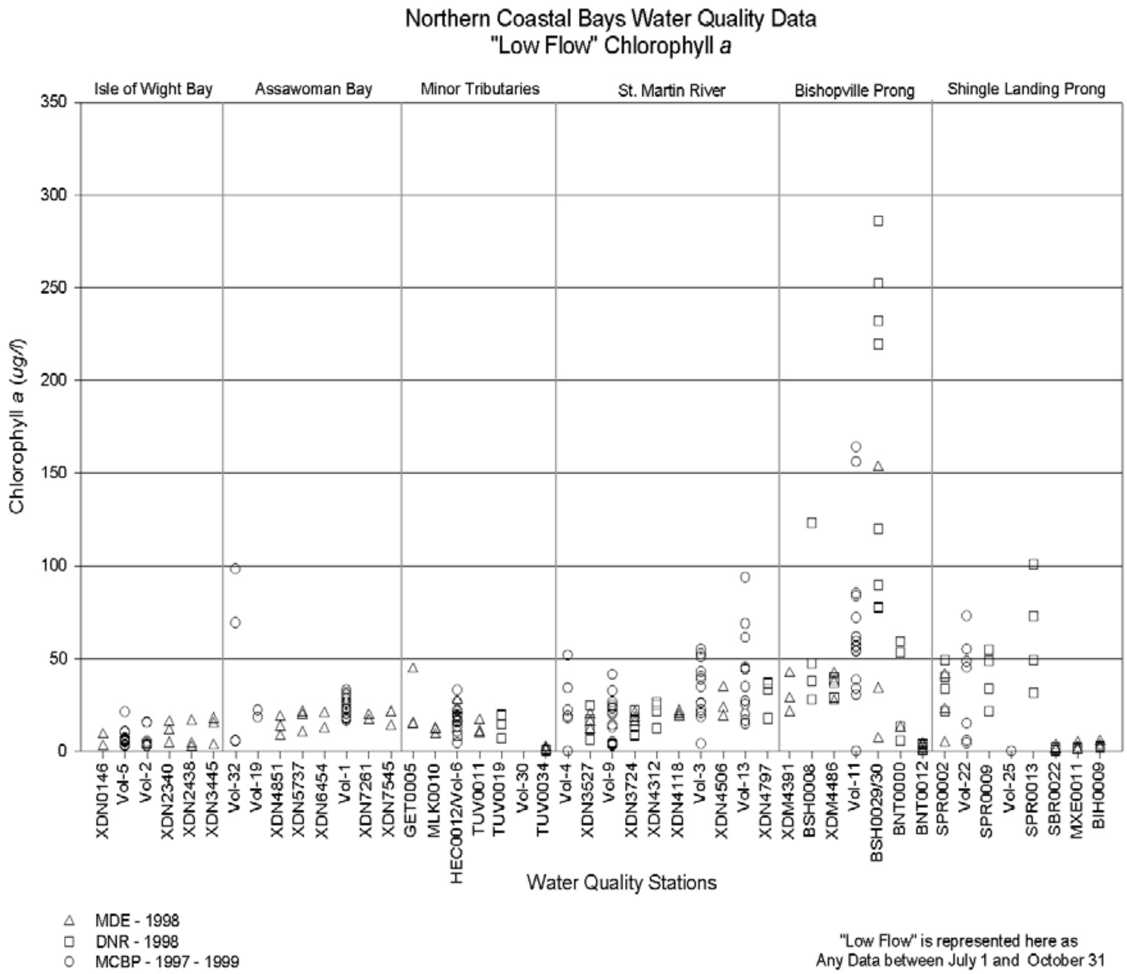

Figure 6: Chlorophyll *a* data for all stations in the Northern Coastal Bays During Low Flow Conditions

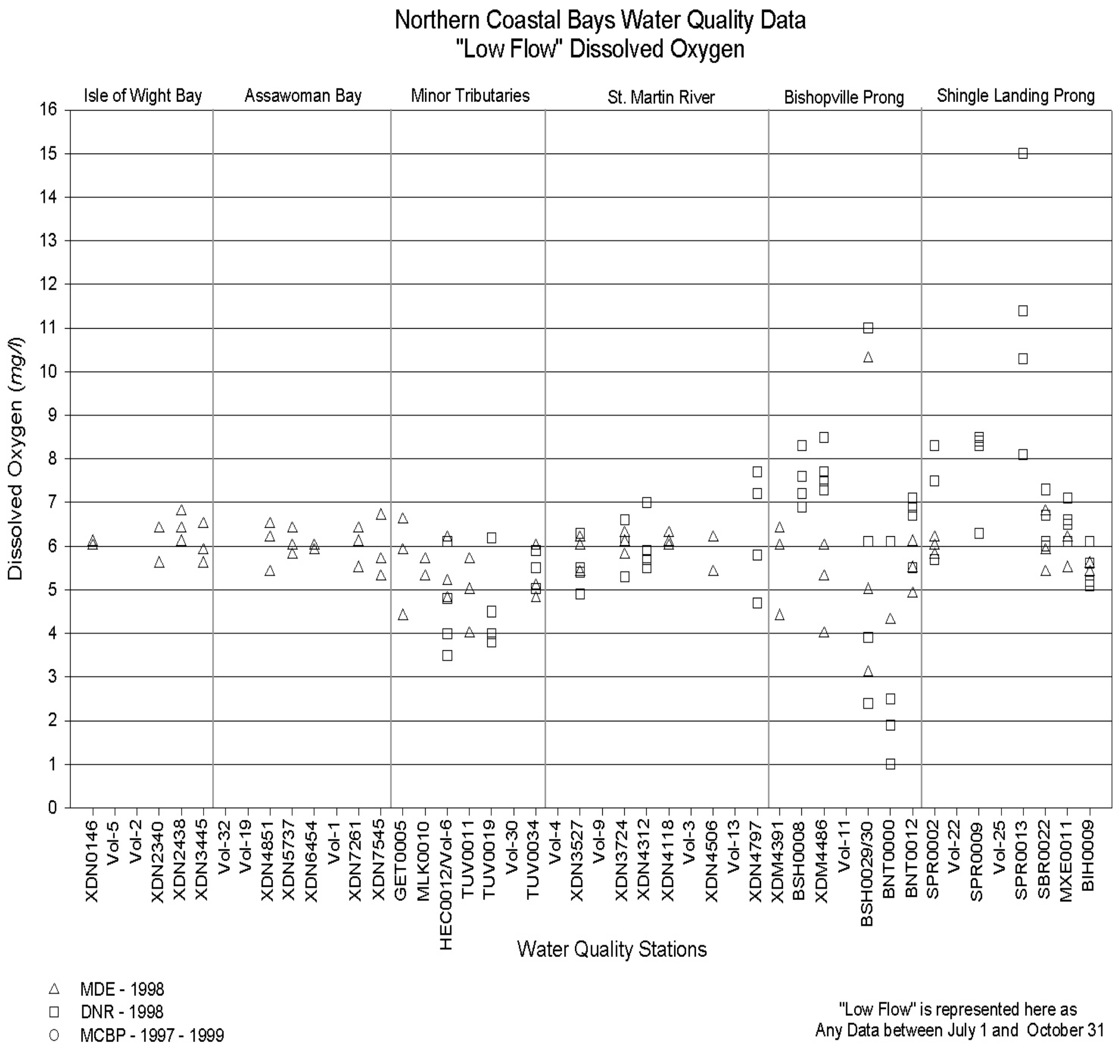

Figure 7: Dissolved Oxygen data for all stations in the Northern Coastal Bays during Low Flow Conditions

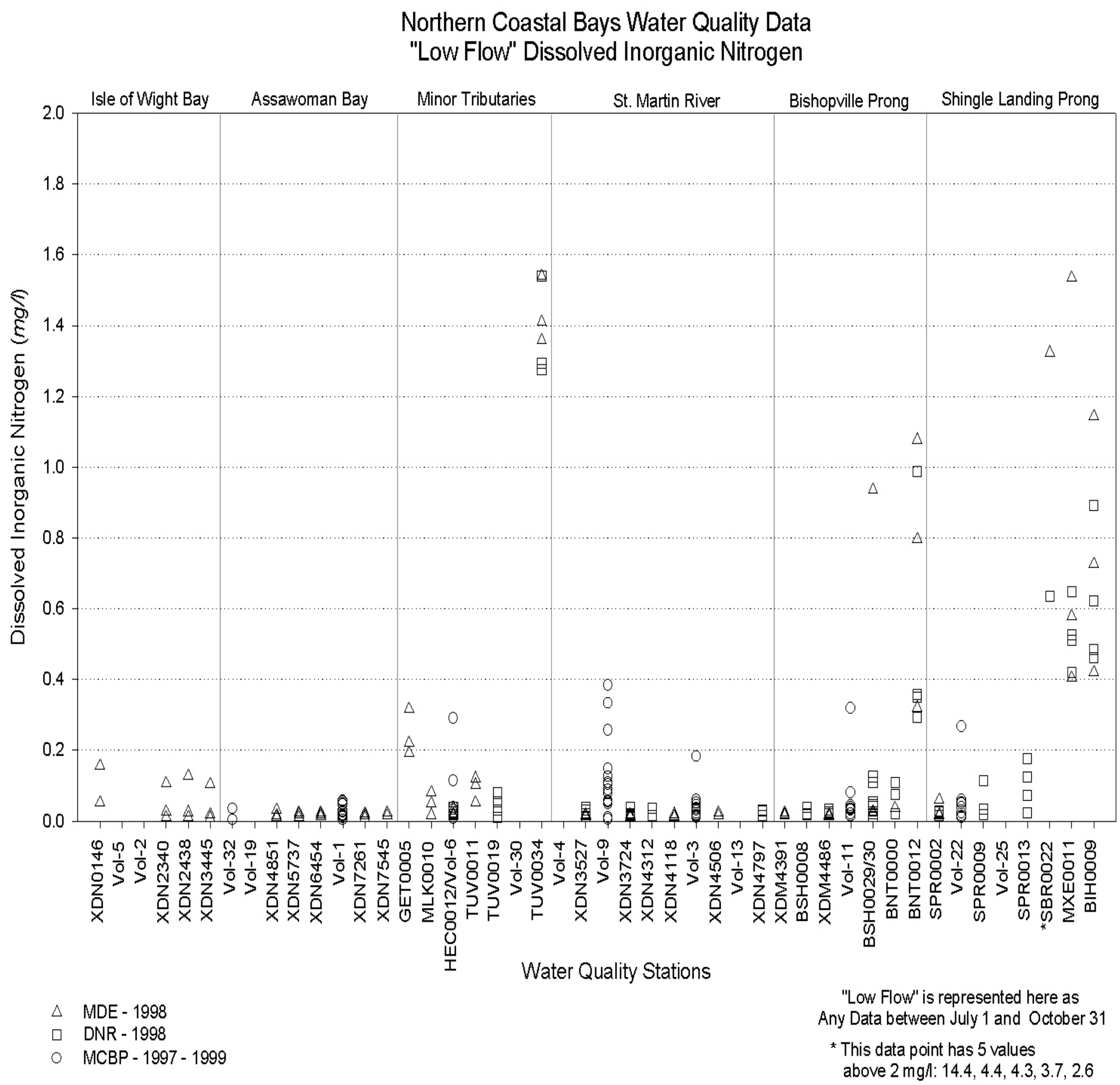

Figure 8: Dissolved Inorganic Nitrogen data for all stations in the Northern Coastal Bays during Low Flow Conditions

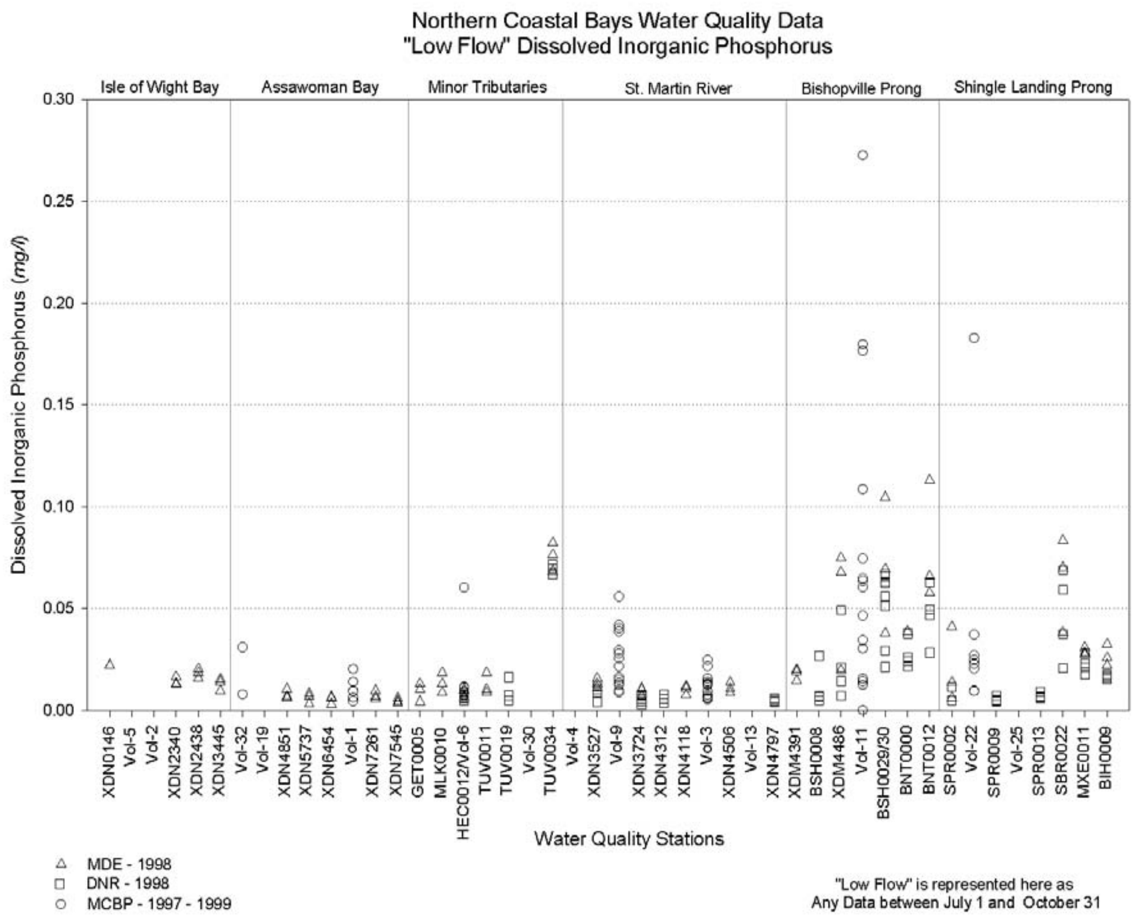

Figure 9: Dissolved Inorganic Phosphorus data for all stations in the Northern Coastal Bays during Low Flow Conditions

2.3 Water Quality Impairment

The Maryland water quality standards Surface Water Use Designation for all estuarine portions and tributaries of the Northern Coastal Bays, is Use II -*Shellfish Harvesting Waters;* except for Bishopville Prong and its tributaries, Shingle Landing Prong and its tributaries, Herring Creek and its tributaries and Ocean City Harbor, which are Designated Use I. Designated Use I waters must "support water contact recreation, fishing, protection of aquatic life and wildlife, and agricultural and industrial water supply." Designated Use II waters are protected for all uses identified for Use I waters and are also protected for shellfish harvesting (oysters, softshell clams, hardshell clams, and brackish water clams), where there are actual or potential areas for shellfish propagation, storage, and gathering for market purposes. The complete details of all designated water uses can be found in the *Code of Maryland Regulations* COMAR, Section 26.08.02.

The water quality impairments in the Northern Coastal Bays system being addressed by this TMDL analysis apply to both Use I and Use II waters. They consist of violations of the numeric criterion for dissolved oxygen (DO), and elevated chlorophyll *a* levels, an indicator of excessive eutrophication. The substances causing these water quality impairments are the nutrients nitrogen and phosphorus.

According to the applicable numeric criterion for DO, concentrations may not be less than 5.0 mg/l at any time (COMAR 26.08.02.03-3A(2)) unless resulting from natural conditions (COMAR 26.08.02.03.A(2)). The applicable narrative water quality criteria pertaining to excessive eutrophication for the designated uses in the Northern Coastal Bays are set forth in COMAR 26.08.02.03 and 26.08.02.02B.

2.3.1 Assawoman Bay and Greys Creek

<u>Assawoman Bay</u>: The chlorophyll *a* concentrations in Assawoman Bay range between 5 and 100 µg/l, with the high values occurring in poorly flushed areas along the shoreline, and lower values in the open waters of the Bay (See Figure 6). The shoreline data was collected by the volunteer monitoring program, under the Maryland Coastal Bays Program. Although this data provides insights regarding near-shore conditions, it is not being used presently for regulatory determinations regarding water quality standards. Dissolved oxygen values are consistently above 5.0 mg/l in surface waters (See Figure 7); however, in bottom water samples collected during DNR fisheries surveys, DO values routinely drop below 5.0 mg/l during summer months (Maryland DNR, 2001b). In summary, data along the shorelines of Assawoman Bay are inconclusive with regard to determining exceedances of water quality standards; however, low DO in the deeper strata of the open waters indicate a violation of standards associated with over-enrichment by nutrients (Maryland DNR, 2001b).

<u>Greys Creek</u>: In bottom water samples collected during DNR fisheries surveys, DO values routinely drop below 5.0 mg/l during summer months. Low DO in the deeper strata of the open waters indicate a violation of standards associated with over-enrichment by nutrients (Maryland DNR, 2001b). Although this data is sufficient to determine impairment, it is not sufficient for conducting the TMDL analysis.

2.3.2 Isle of Wight Bay and Tributaries

<u>Isle of Wight Bay</u>: The chlorophyll *a* concentrations observed in the Isle of Wight Bay area range between 0 and 20 µg/l for the open bay area, and slightly higher peak values along the shoreline of Fenwick Island (See Figure 6). The shoreline data was collected by volunteer monitoring program conducted under the Maryland Coastal Bays Program. Although this data provides insights regarding near-shore conditions, it is not being used presently for regulatory determinations regarding water quality standards. Dissolved oxygen values are consistently above 5.0 mg/l in surface waters (See Figure 7); however, in bottom water samples collected during DNR fisheries surveys, DO values routinely drop below 5.0 mg/l during summer months (Maryland DNR, 2001b). In summary, data along the shorelines of Isle of Wight Bay are inconclusive with regard to determining violations of water quality standards; however, low DO

in the deeper strata of the open waters indicate a violation of standards associated with over-enrichment by nutrients (Maryland DNR, 2001b). Although this data is sufficient to determine impairment, it is not sufficient for conducting the TMDL analysis

Turville Creek: Dissolved inorganic nitrogen and phosphorus values during low flow conditions are elevated in the headwater creek draining to the larger tidal waterbody (TUV0034). The chlorophyll *a* concentrations observed in Turville Creek are below the value of 50 μg/l used as a threshold for determining water quality impairment. However, Figure 7 shows dissolved oxygen data periodically drop below the criterion of 5.0 mg/l, indicating a violation of standards (Maryland DNR, 2001b). The observations are consistent with the after-effects of algal bloom die-offs, in which the bacterial decomposition of algae results in the consumption of dissolved oxygen. In summary, dissolved oxygen data indicate an impairment, which justifies a TMDL analysis.

Herring Creek: Dissolved inorganic nitrogen and phosphorus values are not available in the headwater creek draining to the larger tidal waterbody. However, some values within the larger estuary, after dilution with the estuary, are somewhat elevated (Maryland Coastal Bays Data). The chlorophyll *a* concentrations observed in Herring Creek are below the value of 50 μg/l used as a threshold for determining water quality impairment. However, Figure 7 shows dissolved oxygen data periodically drop below the criterion of 5.0 mg/l, indicating a violation of standards (Maryland DNR, 2001b). The observations are consistent with the after-effects of algal bloom die-offs, in which the bacterial decomposition of algae results in the consumption of dissolved oxygen. In summary, dissolved oxygen data indicate an impairment, which justifies a TMDL analysis.

Manklin Creek: In bottom water samples collected during DNR fisheries surveys, DO values routinely drop below 5.0 mg/l during summer months. Low DO in deeper strata of the open waters indicate a violation of standards associated with over-enrichment by nutrients (Maryland DNR, 2001b). A TMDL is not being established at this time for Manklin Creek due to limitations of the analytical modeling tool.

St. Martin River, Shingle Landing Prong and Bishopville Prong: The chlorophyll *a* concentrations observed in the St. Martin River range between 0 and 40 μg/l for the main transect, and reach levels of 90 μg/l along the shoreline. The shoreline data was collected by the volunteer monitoring program, under the Maryland Coastal Bays Program. Although this data provides insights regarding near-shore conditions, it is not presently being used for regulatory determinations regarding water quality standards.

Values of dissolved oxygen are occasionally observed to drop below 5.0 mg/l during daylight hours near the junction with the upstream tributaries, and near the mouth where deposition of organic matter might be expected to occur. It is reasonable to expect that lower oxygen values, some below 5.0 mg/l, would be observed in early morning hours when diurnal minimum DO occurs. In summary, dissolved oxygen data indicate a boarder-line impairment, which justifies a TMDL analysis.

Shingle Landing Prong: Dissolved inorganic nitrogen and phosphorus values during low flow conditions are elevated in the headwater creeks draining to the larger tidal waterbody (SBR0022, MXE0011, and BIH0009). The chlorophyll *a* concentrations observed in Shingle Landing Prong exceed the value of 50 µg/l, a threshold used by MDE for determining water quality impairment, and reaches an observed peak value of 100 µg/l. Dissolved oxygen data is not observed to drop below the criterion of 5.0 mg/l; however, it is reasonable to expect that oxygen values below 5.0 mg/l would be observed in early morning hours when diurnal minimum DO occurs, due to high concentrations of chlorophyll *a*. In summary, high values of chlorophyll *a*, and expected low dissolved oxygen due to diurnal swings, indicate an impairment, which justifies a TMDL analysis.

Bishopville Prong: Dissolved inorganic nitrogen and phosphorus values during low flow conditions are elevated in the headwater creek draining to the larger tidal waterbody (BNT0012). The chlorophyll *a* concentrations observed in Bishopville Prong exceed the value of 50 µg/l used as a threshold for determining water quality impairment, reaching an observed peak value of 270 µg/l. Dissolved oxygen data is observed to drop below the criterion of 5.0 mg/l. In summary, high values of chlorophyll *a*, and low dissolved oxygen, indicate an impairment, which justifies a TMDL analysis.

3.0 TARGETED WATER QUALITY GOAL

The overall objective of the TMDLs established in this document is to reduce phosphorus and nitrogen loads to levels that are expected to result in meeting water quality criteria associated with eutrophication that support the Use I and Use II designations. Specifically, reduction in the phosphorus and nitrogen loads is intended to control excessive algae growth. Excessive algae growth can lead to violations of the numeric DO criteria, associated fish kills, and the violation of various narrative criteria associated with nuisances, such as odors, and impedance of direct contact use and the loss of habitat for the growth and propagation of aquatic life and wildlife.

In summary, the TMDLs for nitrogen and phosphorus are intended to:

1. Assure that a minimum dissolved oxygen concentration of 5.0 mg/l is maintained throughout the Northern Coastal Bays system; and

2. Resolve violations of narrative criteria associated with excess nutrient enrichment of the Northern Coastal Bays system, as reflected in chlorophyll *a* levels greater than 50 µg/l in the poorly flushed tidal embayments.

4.0 TOTAL MAXIMUM DAILY LOADS AND ALLOCATION

4.1 Overview

This section describes how the nutrient TMDLs and load allocations were developed for the Northern Coastal Bays. The first section describes the modeling framework for simulating nutrient loads, hydrology, and water quality responses. The second and third sections summarize the scenarios that were explored using the model. The assessment investigates water quality responses assuming different stream flow and nutrient loading conditions. The fourth and fifth sections present the modeling results in terms of TMDLs and possible load allocations. The sixth section explains the rationale for the margin of safety. Finally, the pieces of the equation are combined in a summary accounting of the TMDLs for seasonal low flow conditions and for average annual loads.

4.2 Analysis Framework

The computational framework chosen for the Northern Coastal Bays TMDLs was the Water Quality Analysis Simulation Program Version 5.1 (WASP5.1). This water quality simulation program provides a generalized framework for modeling contaminant fate and transport in surface waters and is based on the finite-segment approach (Di Toro *et al.*, 1983). WASP5.1 is supported and distributed by U.S. EPA's Center for Exposure Assessment Modeling (CEAM) in Athens, GA (Ambrose *et al.*, 1988). EUTRO5.1 is the component of WASP5.1 that simulates eutrophication, incorporating eight water quality constituents in the water column and the sediment bed.

The Northern Coastal Bays water quality model was based on a previous model developed by Dr. Winston Lung of the University of Virginia (Lung, 1994). This model was revised and used by MDE for the calculation of these TMDLs. The current model is a depth averaged, two-dimensional model, with relatively large segments, and is implemented in a steady state mode. This mode of using WASP5.1 simulates constant flow, and average waterbody volume over the tidal cycle. The tidal mixing is accounted for using dispersion coefficients, which quantify the exchange of water quality constituents between WASP5.1 model segments. The model simulates an equilibrium state of the waterbody, which in this case, was calibrated to low flow (summer/fall) and high flow (spring) conditions, and applied to low flow, and average flow conditions, described in more detail below.

The spatial domain of the Northern Coastal Bays Eutrophication Model (NCBEM) extends from the Ocean City inlet to the tidal boundaries of most tributaries. The modeling domain is represented by 37 model segments. A diagram of the WASP5.1 model segmentation is presented in Appendix A. It includes Isle of Wight Bay, Assawoman Bay, St. Martin River, Bishopville Prong, Shingle Landing Prong, Church Branch, Turville Creek, Herring Creek, Manklin Creek, and Greys Creek.

The large size of the water quality model segments for Turville Creek, Herring Creek, Manklin Creek, and Greys Creek limits the use of the model. Due to a combination of these modeling limitations, and data limitations, phased TMDLs are being established for Herring Creek, and Turville Creek at this time. This approach is used when an analysis is more uncertain than usual, and places emphasis on taking steps to address the impairments in the near term, while more data is collected to support future evaluations. No TMDLs are being established at this time for Manklin Creek and Greys Creek.

In addition to the limitations imposed by the large water quality model segments that represent the tidal creeks noted above, the model has a single depth layer. Consequently, the results are averaged over the water depth, which limits the model's applicability in the open bays, where low DO in bottom waters is of interest. Due to this limitation, no TMDLs are being proposed for the open bays at this time.

For the St. Martin River system, Herring Creek, and Turville Creek, the water quality model was calibrated to reproduce observed water quality characteristics for both observed low flow and observed high flow conditions. The calibration of the model for these two flow regimes establishes an analysis tool that may be used to assess a range of scenarios for differing flow and nutrient loading conditions. Temporal and spatial data availability as well as temperature and flow measurements were examined to determine the appropriate data to include in each calibration. The low flow calibration uses data from July 1998 to September 1998, and the high flow calibration uses data from April 1998. More information can be found in Appendix A.

The estimation of stream flow used for the calibration of the model was based on an area-flow ratio calculated using 1998 flow data from the United States Geological Survey (USGS) stream gauging station 01485000 in the Pocomoke River near Willards. No active USGS gauging station was in operation in the Northern Coastal Bays basin during the 1998 analysis period. The Pocomoke gage data was considered a reasonable estimate of the flow in the Northern Coastal Bays system due to its similar geology, topography, and proximity to the area. More detailed information on stream flow estimation can be found in Appendix A.

There are two significant point source discharges of nutrients in the Isle of Wight Bay and the St. Martin River watersheds, which were included as explicit point source loads in the modeling analyses. These are the Ocean Pines Service Area Wastewater Treatment Plant (WWTP), and Perdue Farms Inc. in Showell, MD. The Ocean Pines Service Area WWTP discharges directly into the St. Martin River. The Perdue Farms processing plant in Showell discharges into an unnamed tributary of Church Branch, which drains to Shingle Landing Prong, a tributary of the St. Martin River. In 1998, these point sources were contributing about 36,566 lb/yr of nitrogen and 2,313 lb/yr of phosphorus to the St. Martin River System.

Several other point source discharges were considered, but are not directly included in the modeling analyses. The MountAire processing plant, in Delaware on Bishopville Prong of the St. Martin River, only discharges non-contact cooling water. The Ocean City WWTP discharges into the Atlantic Ocean. If it contributes loads, those would be captured at the boundary of the Bay with the Atlantic Ocean. The Perdue hatchery discharge in Bishopville contributes a very small load that does not significantly affect water quality. The points of discharge for the Perdue Hatchery in Bishopville and the MountAire plant in Selbyville are outside the modeling domain. However, the plant discharges are considered as part of the upstream load. See Section 2.1 for a discussion of the source assessment and Appendix A for further discussion of these two plants.

To estimate point source loads for the Ocean Pines WWTP and the Perdue processing plant in Showell for the calibration, 1998 point source discharge data from the MDE point source database was used (MDE, 2000). Additional data from Perdue Farms Inc. was used to estimate loads from the processing plant in Showell (Perdue, 2000). See Appendix A for details.

The method for estimating nonpoint source (NPS) loadings of nitrogen and phosphorus is described in Section 4.3. In brief, low flow and high flow NPS loads used during the model calibration process were derived from concentrations observed during low and high flow sampling in 1998 multiplied by the estimated corresponding flows. Because the loading estimations are based on observed data, which incorporate all sources, they account for all human and natural sources.

The NPS loads for the low flow baseline conditions were derived in the same manner as the low flow loads for the calibration process. The average annual NPS loads were based on unit area loading rates for general land use categories derived in a study conducted in the Maryland Coastal Bays (University of Maryland, 1993). The land use information, to which the unit area loading rates were applied, was based on 1997 Maryland Office of Planning land cover data, 1997 Delaware Office of Planning land cover data, and 1997 Farm Service Agency data. These methods are elaborated upon in Section 4.3 and in Appendix A.

It is important to note that the estimated NPS loads for baseline conditions (for low flow and average annual flow) solely serve as a rough basis by which to compare the NPS reduction needed to reach the TMDL limits. The analysis used to estimate the maximum allowable load to the water body (TMDL) does not depend on the baseline estimate of NPS loads. Thus, any uncertainty in the baseline NPS estimation does not affect the certainty of the estimated annual TMDL.

The nutrient TMDL analyses consist of an assessment of low flow loading conditions for the St. Martin River System, and an assessment of average annual loading conditions for the St. Martin River System and for Herring Creek and Turville Creek. The low flow TMDL analysis investigates the critical conditions under which symptoms of eutrophication are typically most acute, that is, in late summer when flows are low, leading to poor flushing of the system, and when sunlight and temperatures are most conducive to excessive algal production. The average annual TMDL analysis helps control the nutrients that accumulate in the bottom sediments and are cycled into the system during warmer periods.

4.3 Scenario Descriptions

The WASP5.1 model was applied to investigate different nutrient loading scenarios under two stream flow conditions, low flow and average annual flow. Two scenarios were investigated for each flow regime; *baseline conditions*, and *future conditions* associated with TMDLs, yielding a total of four scenarios.

The baseline condition scenarios are intended to provide a point of reference by which to compare the future condition scenarios that simulate conditions of a TMDL. The baseline conditions correspond roughly to the notion of "worst-case conditions" for the given flow regime. For the given flow conditions, the scenarios reflect an approximation of present NPS conditions, and maximum point source flows with estimated concentrations assuming no additional treatment beyond which is currently planned.

The modeling analyses focused on the St. Martin River, Shingle Landing Prong, Bishopville Prong, Turville Creek and Herring Creek. These results provide an explicit basis for the TMDLs in these areas.

Model results also are provided for surface water quality in the open bays. Although the results for the open bays are insightful, and of some value, they do not reflect the water quality in the deeper water where low dissolved oxygen has been a concern. Consequently, as discussed in Section 4.2, the modeling results for the open bays are not being used to establish TMDLs at this time.

<u>First Scenario</u>: (Low Flow Baseline) The first scenario represents the baseline conditions of the stream at a simulated critical low flow in the basin. The scenario simulates a critical condition when the river system is poorly flushed, and sunlight and warm water temperatures are most conducive to creating the water quality problems associated with excessive nutrient enrichment.

The low flow NPS loads were computed as the product of the observed concentrations and estimated critical low flow. The method of estimating the critical low flow is described in Appendix A. The nutrient concentrations from which NPS loads were computed were based on observed data collected during low flow conditions in July, August and September of 1998 (MDE, DNR, MCBP). These low flow NPS loads integrate all natural and human induced sources that contribute to base flow during low flow conditions. An additional load was added to account for direct atmospheric deposition to the water surface. (See Appendix A for further discussion).

The total point source loads were determined on the basis of 1998 plant monitoring records for Ocean Pines WWTP and the Perdue in Showell. Because the Perdue Hatchery in Bishopville and MountAire in Selbyville are outside the modeling domain, they were included as part of the upstream load to Bishopville Prong. Additional technical details are provided in Appendix A.

<u>Second Scenario</u>: (Average Annual Flow Baseline) The second scenario provides an estimate of water quality conditions for average annual loads and flows, which serves as the baseline by which to compare the average annual TMDL (Fourth Scenario). The second scenario simulates a condition when the sunlight and warm water temperatures are most conducive to algal growth, which can lead to water quality problems associated with excessive nutrient enrichment. Because higher stream flows, such as the average flow, typically occur during cooler seasons, the

assumptions of high water temperature and solar radiation used in the analysis are conservative with respect to environmental protection.

The average annual NPS loads were based on land use loading rates derived in a study conducted in the Maryland Coastal Bays (University of Maryland, 1993). The land use information was based on 1997 Maryland Office of Planning land cover data, 1997 Delaware Office of Planning land cover data, and 1997 Farm Service Agency data. The land use loading rates (lb/acre) were multiplied by the acreage of each corresponding land use to estimate surface water loads. Additional loads were added to account for direct atmospheric deposition to the water's surface, and direct groundwater discharge. These methods are elaborated upon in Appendix A.

<u>Third Scenario</u>: (Low Flow Future Condition with TMDL) The third scenario represents the future condition of maximum allowable loads during critical low stream flow. The stream flow is the same as that used in the first scenario. The scenario simulates a condition when the system is poorly flushed due to low flows, and the sunlight and warm water temperatures are most conducive to algal growth. These conditions are critical for causing water quality problems associated with excessive nutrient enrichment.

For the St. Martin River this scenario simulates an estimated 31% reduction in total surface water nonpoint source nitrogen loads. For Shingle Landing Prong this scenario simulates an estimated 31% reduction in total surface water nonpoint source nitrogen loads. For the Bishopville Prong also this scenario simulates an estimated 31% reduction in total surface water nonpoint source nitrogen loads. In addition, a 20% reduction in the direct atmospheric deposition of nitrogen loads to the water's surface throughout the Northern Coastal Bays system, to account for implementation of the Clean Air Act, is factored into the scenario. This scenario accounts for an explicit margin of safety computed as 5% of the NPS load allocation in the St. Martin River and its two tributaries.

The point source loads in the St. Martin River system were not reduced because the Perdue plant was upgraded in 1997 and the Ocean Pines WWTP has limits near the level of technology. The details of the point sources loads are further described in Appendix A, and in the technical memorandum entitled "*Significant Nutrient Point Sources and Nonpoint Sources in the Northern Coastal Bays System*." In this future condition scenario, reductions in sediment nutrient fluxes and sediment oxygen demand (SOD) were estimated based on changes in the nutrient loads to the system. Further discussion is provided in Appendix A.

<u>Fourth Scenario</u>: (Average Annual Future Condition with TMDL) The fourth scenario represents the future condition of maximum allowable loads during average annual flow conditions. The stream flow is the same as that used in the second scenario. This scenario simulates a condition when the sunlight and warm water temperatures are most conducive to algal growth, which can lead to water quality problems associated with excessive nutrient enrichment. These conditions are conservative for this flow regime.

Although nitrogen is not a limiting nutrient in the average annual flow scenario, nitrogen reductions for each of the five tributaries are set at the same percentages as they were for the low flow scenario to correspond to the reductions needed for the low flow scenario. For the St. Martin River this scenario simulates an estimated 19% reduction in total surface water nonpoint source phosphorus loads. For Shingle Landing Prong this scenario simulates an estimated 19% reduction in total surface water nonpoint source phosphorus loads. For Bishopville Prong this scenario simulates an estimated 19% reduction in total surface water nonpoint source phosphorus loads. For the Herring Creek and Turville Creek, this scenario simulates an estimated 13% reduction in total surface water nonpoint source phosphorus loads. In addition, a 20% reduction in the direct atmospheric deposition of nitrogen loads to the water's surface throughout the Northern Coastal Bays system, to account for implementation of the Clean Air Act, is factored into the scenario. This scenario accounts for an explicit margin of safety computed as 5% of the NPS load allocation in the St. Martin River and its two tributaries. Due to the greater uncertainty in the modeling results in Herring Creek and Turville Creek, this scenario accounts for an explicit margin of safety computed as 10% of the NPS load allocation.

The point source loads remained the same as for Scenario 2. The details of the point source loads are described further in Appendix A, and the technical memorandum entitled "*Significant Nutrient Point Sources and Nonpoint Sources in the Northern Coastal Bays System*." In this future condition scenario, reductions in sediment nutrient fluxes and sediment oxygen demand (SOD) were estimated based on changes in the nutrient loads to the system. Further discussion is provided in Appendix A.

4.4 Scenario Results

This section presents the results of the model scenarios described in the previous section. As discussed in Section 4.3, readers should focus their attention on modeling results for the St. Martin River, Shingle Landing Prong, Bishopville Prong, Turville Creek, and Herring Creek.

The NCBEM results for dissolved oxygen (DO) presented in this section are daily average concentrations. The analysis accounted for the effects of diurnal DO fluctuations in the following way. Because over-night respiration of aquatic plants cause a depletion of DO, the water quality endpoint for the analysis of DO is being set as a function of chlorophyll *a* concentration. In St. Martin River, Shingle Landing Prong, and Bishopville Prong, where chlorophyll levels can be as high as 50 µg/l at the TMDL threshold, the water quality endpoint for DO being used in the analysis is 6.0 mg/l. That is, a factor of 1.0 mg/l is added to the water quality criterion of 5.0 mg/l to account for the diurnal fluctuation in DO levels. In Herring Creek and Turville Creek, where chlorophyll *a* is not as significantly elevated (e.g., an average chlorophyll *a* of 25 µg/l or less), a target value of 5.3 mg/l DO is used. Further details are presented in Appendix A.

<u>Baseline Loading Condition Scenarios</u>:

1. *Low Flow:* Simulates critical low stream flow conditions during summer season. Water quality parameters (e.g., nutrient concentrations), which approximate NPS loads at the model boundaries, are based on 1998 observed data. Point source contributions represent maximum

design flows (or approved sewer flows) and estimated concentrations at those flows assuming no additional treatment than presently planned.

2. *Average Annual Flow:* Simulates average annual stream flow conditions. Water quality parameters (e.g., nutrient concentrations) are based on UMCES NPS loading rates. Point source contributions represent maximum design flows (or approved sewer flows) and estimated concentrations at those flows assuming no additional treatment than presently planned.

<u>Scenario 1 Results</u> The following results pertain to the St. Martin River system. Given the limitations of the model for Herring Creek and Turville Creek, a low flow TMDL analysis is not being conducted for them at this time (See Section 4.2, "Analysis Framework").

For the St. Martin River system, dissolved oxygen (DO) and chlorophyll *a* results for the first scenario, representing the baseline condition for summer low flow, are summarized in Figure 10. Under these conditions, the peak chlorophyll *a* level is well above the desired goal of 50 µg/l in both Shingle Landing Prong and Bishopville Prong, reaching a peak value of about 85 µg/l.

Figure 10 shows that values of DO in the St. Martin River system are below the analysis goal of 6.0 mg/l (recall that this analysis goal includes a 1.0 mg/l factor above the 5.0 mg/l DO criterion, which is intended to account for diurnal DO swings). These results indicate that DO concentrations are predicted to fall below the minimum water quality criteria of 5.0 mg/l in Bishopville Prong and in the downstream portion of Shingle Landing Prong due to the diurnal fluctuations.

<u>Scenario 2 Results</u> Dissolved oxygen (DO) and chlorophyll *a* results for the second scenario, representing the baseline condition for average annual flow, are summarized in Figure 11 and Figure 12. Recall that the DO goals, set as a function of expected chlorophyll *a* concentrations under TMDL scenario conditions, are 6.0 mg/l for the St. Martin River system and 5.3 mg/l for Herring Creek and Turville Creek.

Figure 11 shows results for the St. Martin River system. They indicate the peak chlorophyll *a* level is above the desired goal of 50 µg/l in Shingle Landing Prong, reaching a peak value of above 88 µg/l. DO concentrations are predicted to be below the analysis goal of 6.0 mg/l throughout the St. Martin River system.

Figure 12 shows predicted DO level of about 4.5 mg/l in Turville Creek and Herring Creek, which is below the analysis goal of 5.3 mg/l. Note that the model results in Figure 12 are represented by a single dashed line. This is because the computer model represents Herring Creek and Turville Creek as a single model segment.

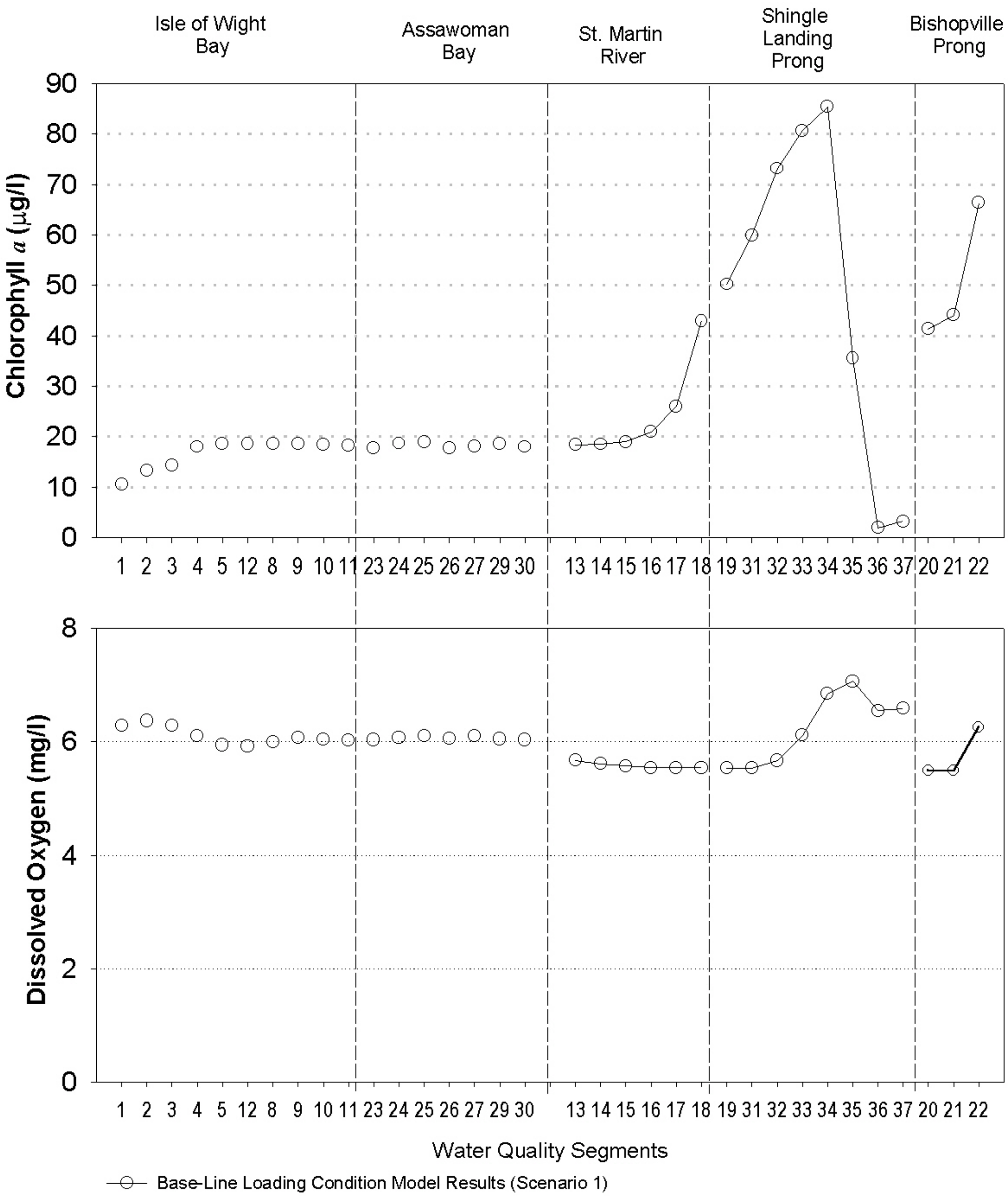

Figure 10: Model Results for the Low Flow Baseline Loading Condition Scenario for Chlorophyll a and Dissolved Oxygen (Scenario 1)

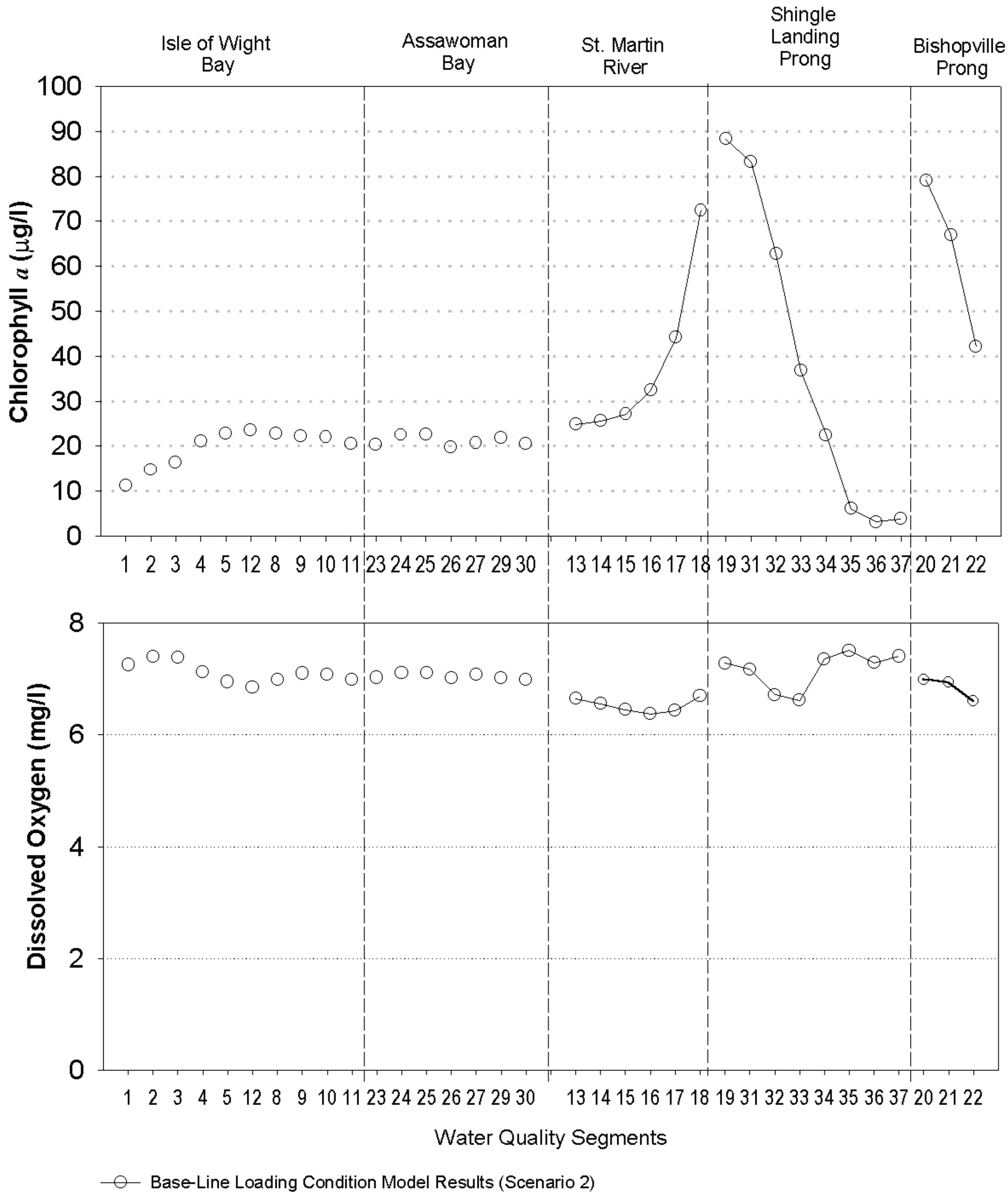

Figure 11: Model Results for the Average Annual Baseline Loading Condition Scenario for Chlorophyll a and Dissolved Oxygen (Scenario 2) – St. Martin River, Bishopville Prong, and Shingle Landing Prong

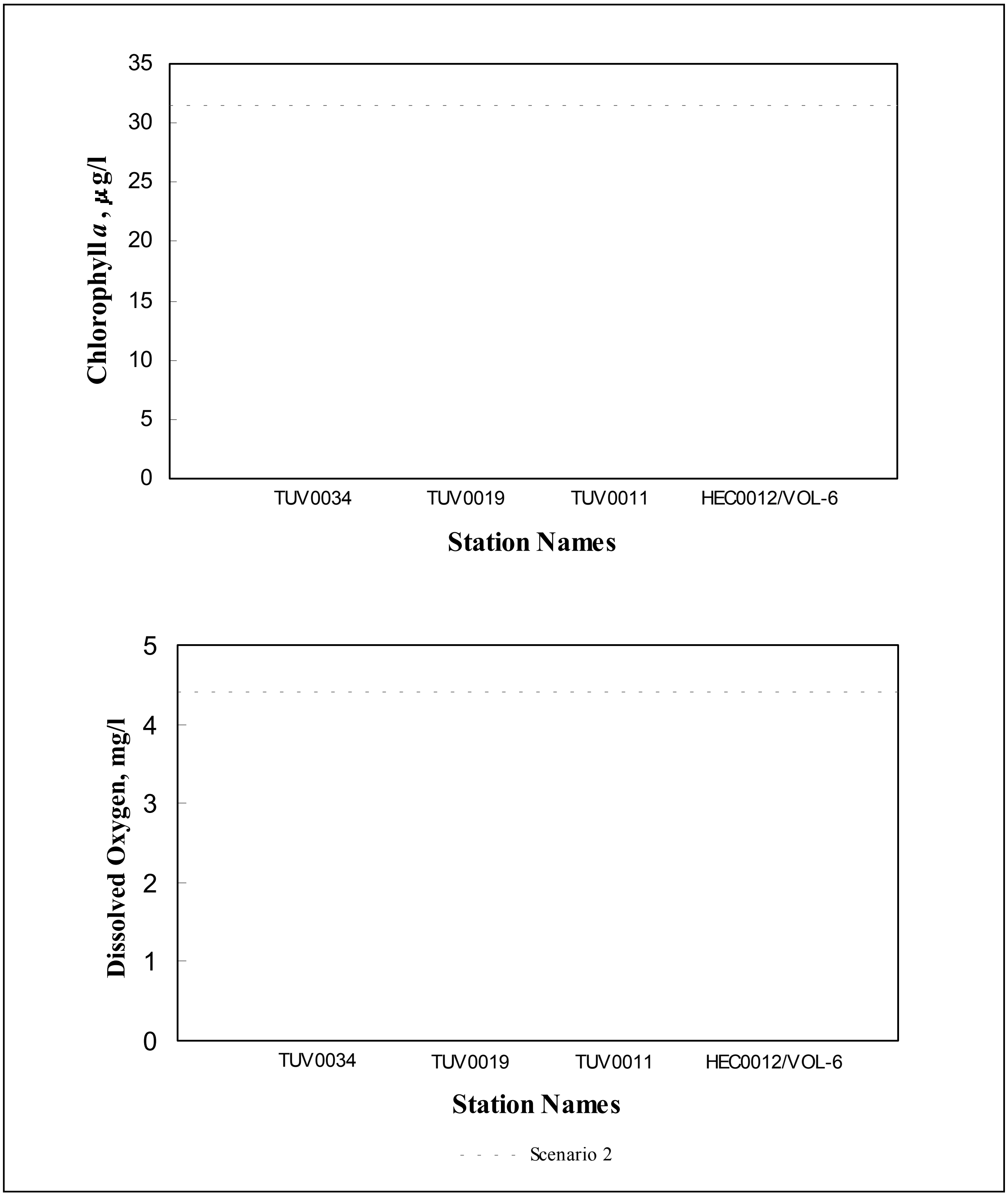

Figure 12: Model Results for the Average Annual Baseline Loading Condition Scenario for Chlorophyll a and Dissolved Oxygen (Scenario 2) – Herring Creek and Turville Creek

NOTE: The dashed-line in Figure 12 presents the water quality model results, which are based on a single model segment for Herring Creek and Turville Creek.

Future Condition Scenarios:

3. *Low Flow:* Simulates the future condition of maximum allowable loads for critical low stream flow conditions during the summer season.

4. *Average Annual Flow:* Simulates the future condition of maximum allowable loads for average annual stream flow conditions.

Scenario 3 Results Dissolved oxygen (DO) and chlorophyll *a* results for the third scenario, representing the maximum allowable loads for summer-time critical low flow, are summarized in Figure 13. Results for the third scenario are summarized in comparison to the associated baseline scenario (solid line & circles). Under the nutrient load reduction conditions described above for this scenario, the results show that chlorophyll *a* concentrations remain just below 50 µg/l in Shingle Landing Prong. Peak values in the St. Martin River and Bishopville Prong are about 40 µg/l.

DO concentrations are predicted to shift upward as a result of simulated nutrient reductions. The minimum DO values are predicted to be above the water quality goal of 6.0 mg/l along the length of both tributaries and the St. Martin River. Recall that the 6.0 mg/l goal is intended to account for a 1.0 mg/l diurnal DO swing.

Again, because of limitations of the model for Herring Creek and Turville Creek, a low flow TMDL analysis is not being conducted at this time (See section 4.2, "Analysis Framework").

Scenario 4 Results Dissolved oxygen (DO) and chlorophyll *a* results for the fourth scenario, representing the maximum allowable loads for summer-time critical low flow, are summarized in Figure 14 and Figure 15. Results for the third scenario are summarized in comparison to the associated baseline scenario. Recall that the DO goals, set as a function of expected chlorophyll *a* concentrations under TMDL scenario conditions, are 6.0 mg/l for the St. Martin River system and 5.3 mg/l for Herring Creek and Turville Creek.

Figure 14 presents the results for the St. Martin River system under the nutrient load reduction conditions described above for this scenario. The results show that chlorophyll *a* concentrations are predicted to shift downward from about a peak of 88 µg/l to about 50 µg/l in the lower section of Shingle Landing Prong. Peak values in the St. Martin River and Bishopville Prong are predicted to be approximately 40 µg/l.

Figure 14 shows that DO concentrations in the St. Martin River system are predicted to shift upward as a result of simulated nutrient reductions. The minimum DO values are predicted to be well above the water quality goal of 6.0 mg/l along the length of both tributaries and the St. Martin River.

Figure 15 shows chlorophyll *a* is predicted to drop slightly below 25 µg/l. The minimum DO values are predicted to meet the water quality goal of 5.3 mg/l for the reduced nutrient conditions

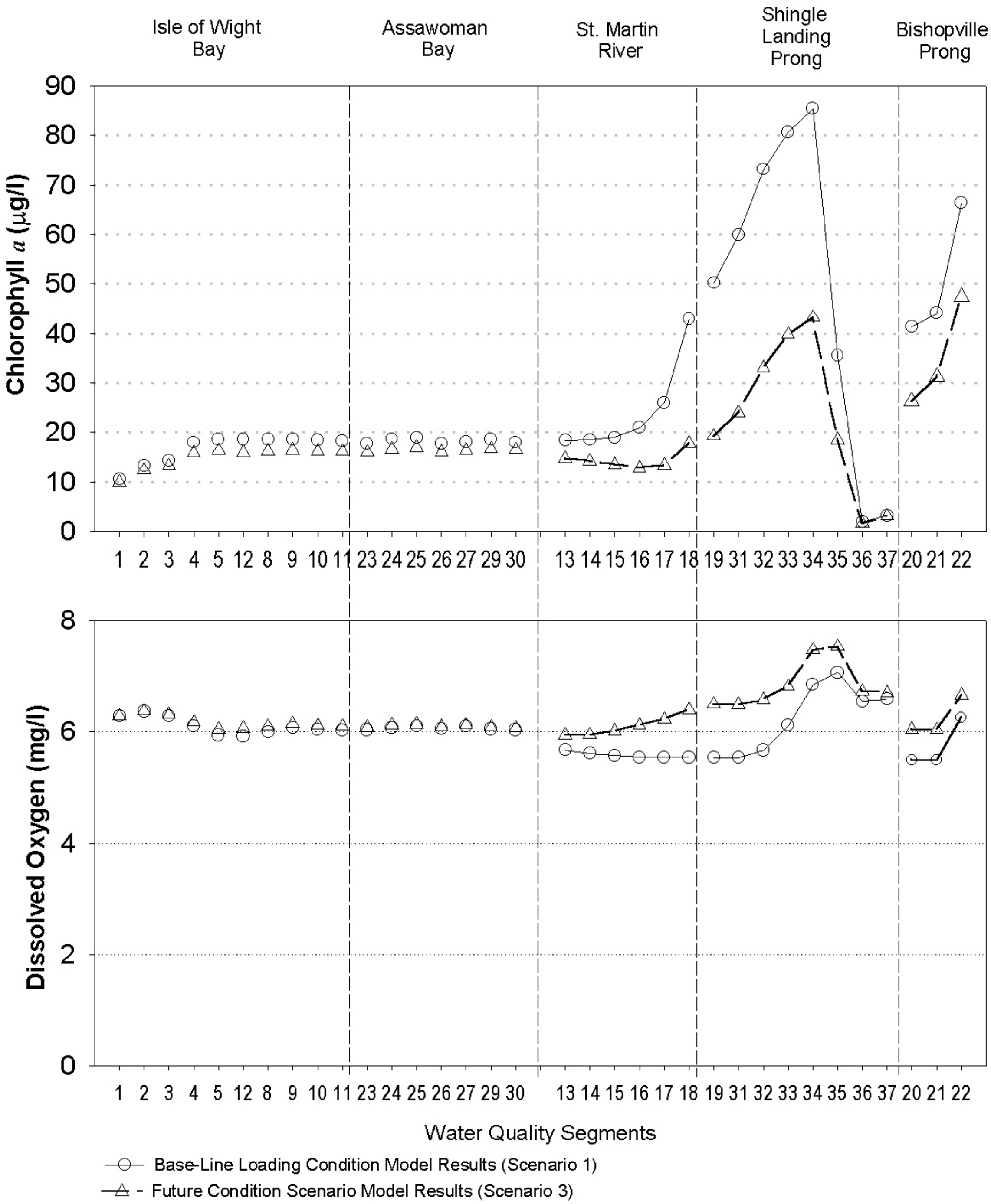

Figure 13: Model Results for the Low Flow Future Condition Scenario for Chlorophyll a and Dissolved Oxygen (Scenario 3)

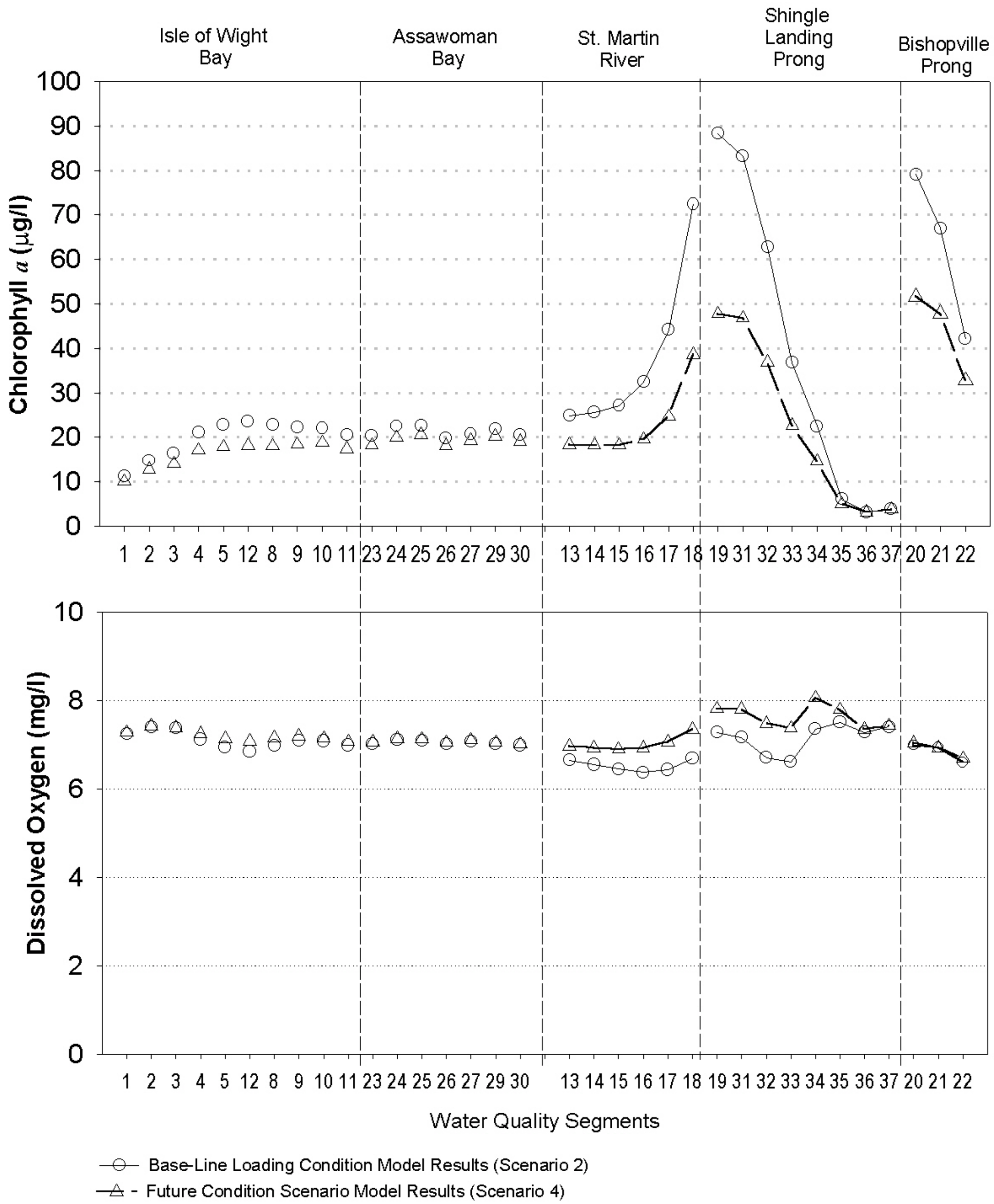

Figure 14: Model Results for the Annual Average Future Condition Scenario for Chlorophyll a and Dissolved Oxygen (Scenario 4) – St. Martin River, Bishopville Prong, and Shingle Landing Prong

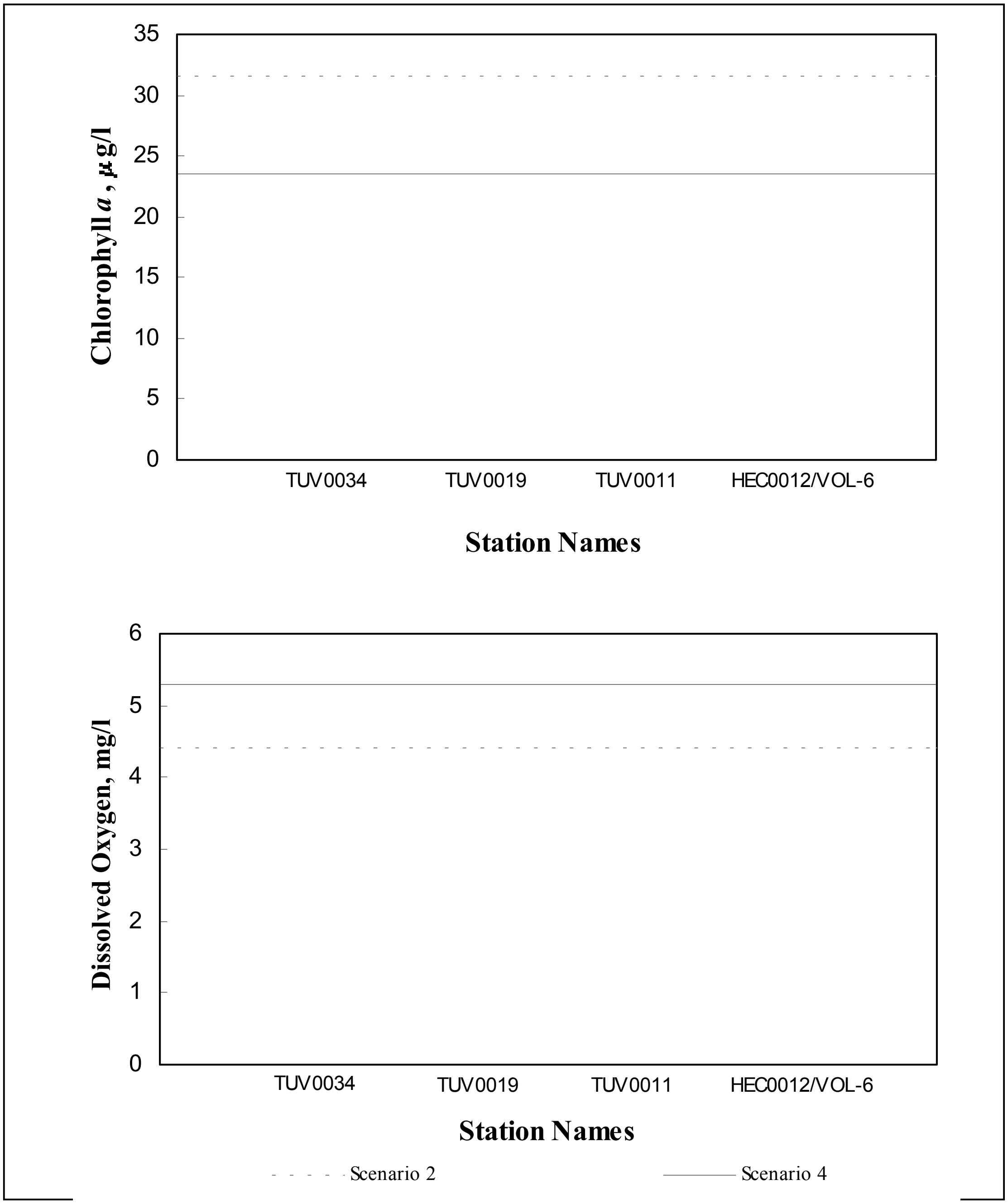

Figure 15: Model Results for the Annual Average Future Condition Scenario for Chlorophyll a and Dissolved Oxygen (Scenario 4) – Herring Creek and Turville Creek

NOTE: The dashed-line in Figure 15 represents the baseline water quality model results, and the solid line represents the TMDL scenario results.

for both Turville Creek and Herring Creek (Solid Line). Again, the water quality goal reflects a factor of 0.3 mg/l that is added to the DO criterion of 5.0 mg/l. This accounts for the diurnal fluctuation of DO in these tidal tributaries under the TMDL conditions when the average chlorophyll *a* is expected to be slightly below 25 μg/l.

4.5 TMDL Loading Caps

This section presents total maximum daily loads (TMDLs) for nitrogen and phosphorus. Because the TMDLs set limits on nitrogen, and because of the way the model simulates nitrogen, it is not necessary to include an explicit TMDL for nitrogenous biochemical oxygen demand (NBOD).

The outcomes for the TMDL analyses are presented in terms of a critical low flow TMDL and an average annual TMDL. The critical season for excessive algal growth in the Northern Coastal Bays is during the summer months, when the river system is poorly flushed. During this critical time, sunlight and warm water temperatures are most conducive to creating the water quality problems associated with excessive nutrient enrichment. The low flow TMDLs are stated in monthly terms because this critical condition occurs for a limited period of time. It should be noted that limits placed on average annual loads are accounted for indirectly in the low flow TMDL as bottom sediment nutrient fluxes and SOD are adjusted to be consistent with reductions in average annual loads (See Appendix A).

4.5.1 TMDL Loading Caps for Herring Creek and Turville Creek

As noted above, due to the limitations of the model for Herring Creek and Turville Creek, a low flow TMDL is not being established at this time (See Section 4.2, "Analysis Framework").

The following annual average TMDLs for nitrogen and phosphorus apply on a multi-year long-term average.

<u>Herring Creek and Turville Creek</u> (Average Annual):

Average Annual TMDLs for Herring Creek:

NITROGEN TMDL 9,547 *lb/year*

PHOSPHORUS TMDL 1,235 *lb/year*

Average Annual TMDLs for Turville Creek:

NITROGEN TMDL 26,272 *lb/year*

PHOSPHORUS TMDL 3,928 *lb/year*

4.5.2 TMDL Loading Caps for the St. Martin River System

The following TMDLs were developed on the basis of results from the WASP simulation model. The low flow TMDLs apply for the summer months, May 1 through October 31.

St. Martin System (Low Flow):

Low Flow TMDLs for the St. Martin River:

NITROGEN TMDL **4,378** ***lb/month***

PHOSPHORUS TMDL **1,908** ***lb/month***

Low Flow TMDLs for Bishopville Prong:

NITROGEN TMDL **665** ***lb/month***

PHOSPHORUS TMDL **109** ***lb/month***

Low Flow TMDLs for Shingle Landing Prong:

NITROGEN TMDL **2,060** ***lb/month***

PHOSPHORUS TMDL **219** ***lb/month***

The following annual average TMDLs for nitrogen and phosphorus apply on a multi-year long-term average.

St. Martin River System (Annual Average):

Average Annual TMDLs for the St. Martin River:

NITROGEN TMDL **222,110** ***lb/year***

PHOSPHORUS TMDL **41,133** ***lb/year***

Average Annual TMDLs for Bishopville Prong:

NITROGEN TMDL **64,946** ***lb/year***

PHOSPHORUS TMDL **9,471** ***lb/year***

Average Annual TMDLs for Shingle Landing Prong:

NITROGEN TMDL	**104,700** ***lb/year***
PHOSPHORUS TMDL	**12,926** ***lb/year***

4.6 Load Allocations Between Point and Nonpoint Sources

The allocations described in this section demonstrate how the TMDLs can be implemented to strive toward achieving water quality standards in the Northern Coastal Bays system. The allocations address geographic distributions of allowable nutrient loads, as well as the distribution between point sources and nonpoint sources.

As noted elsewhere in this document, the only significant point sources are located in the St. Martin River and its tributaries. Herring Creek and Turville Creek solely have allocations to nonpoint sources and the requisite margins of safety. Details of a viable load allocation scheme are described further in the technical memorandum entitled "*Significant Nutrient Point Sources and Nonpoint Sources in the Northern Coastal Bays System*."

4.6.1 Load Allocations for the Herring Creek and Turville Creek

Aside from the margin of safety, the allocations of nutrient loads in Herring Creek and Turville Creek are made solely to nonpoint sources. The allocations are presented for average annual conditions.

<u>Average Annual Conditions</u>

The nonpoint source loads of nitrogen and phosphorus simulated in the average annual TMDL scenario (Scenario 4) represent reductions from the average annual baseline scenario (Scenario 2). Recall that the average annual baseline scenario loads were based on unit area loading rate estimates provided by a University of Maryland study (UMD CEES, 1993). These nonpoint source loads account for both "natural" and human-induced sources. Further discussion of these loading estimates are provided in Appendix A. Details of a viable load allocation scheme are described further in the technical memorandum entitled "*Significant Nutrient Point Sources and Nonpoint Sources in the Northern Coastal Bays System*."

The allocations of average annual nutrient loads in Herring Creek and Turville Creek are made solely to nonpoint sources (Table 1). There are no point source discharges to which allocations can be made at the present time.

Table 1: Average Annual Nonpoint Source Allocations for Herring Creek and Turville Creek

Waterbody Name	Total Nitrogen *(lb/year)*	Total Phosphorus *(lb/year)*
Herring Creek	8,592	1,111
Turville Creek	23,645	3,535

4.6.2 Load Allocations for the St. Martin River System

Aside from the margin of safety, the allocations of nutrient loads in the St. Martin River system are made to both nonpoint sources and point sources. The allocations are presented for both low flow conditions and average annual conditions.

There are two significant point source discharges of nutrients in the Northern Coastal Bays basin[1]. The allocations described in this section demonstrate how the TMDLs can be implemented to achieve water quality standards in the Northern Coastal Bays. Specifically, these allocations show that the sum of nutrient loadings to the Northern Coastal Bays from point and nonpoint sources can be maintained safely within the TMDLs established here.

As described elsewhere in this document, two small point sources in Bishopville Prong are not included explicitly in the WASP modeling framework. Rather, they were considered as part of the load to the upstream boundary of the WASP modeling domain. Consequently, they are not provided explicit allocations, and are included in the load allocation in Bishopville Prong. Future permit decisions for upstream point sources in Bishopville Prong will be set to assure that the load at the upper boundary of the modeling domain does not exceed the threshold for the upstream load, unless other off-setting reductions are achieved, or refined modeling indicates such increases would be protective of the water quality.

<u>Low Flow Allocations</u>:

The nonpoint source loads of nitrogen and phosphorus simulated in the low flow TMDL scenario (Scenario 3) represent reductions from the baseline scenario (Scenario 1). Recall that the baseline scenario loads were based on nutrient concentrations observed in summer 1998 and an estimated critical low stream flow. These nonpoint source loads account for both "natural" and human-induced sources. These loads cannot be separated into specific source categories, because they are based on observed in-stream concentrations.

Point source load allocations for the summer low flow future conditions make up the balance of the total allowable load. This point source load allocation was adopted from the results of model

[1] Two minor point sources discharge upstream of the modeling domain in Bishopville Prong. One is non-contact cooling water, which causes no net change in nutrient load. The other point source is very small. It is addressed indirectly as part of the load at the upstream boundary of the model, rather than as an explicit point source load to the model. The observed 1998 nutrient concentrations are used for this boundary, and thus account for the small upstream discharge. See "Point Source Loadings" in Appendix A for further discussion.

Scenario 3. All significant point sources in the Isle of Wight Bay and the St. Martin River basins are addressed by this allocation and are described further in the technical memorandum entitled "*Significant Nutrient Point Sources and Nonpoint Sources in the Northern Coastal Bays System*." The nonpoint source and point source nitrogen and phosphorus allocations for summer low flow conditions are shown in Table 2 and Table 3 respectively.

Table 2: Summer Low Flow Nonpoint Source Allocations for the St. Martin River and its Significant Tributaries

Waterbody Name	Total Nitrogen *(lb/month)*	Total Phosphorus *(lb/month)*
St. Martin River	1,985	364
Shingle Landing Prong	508	63
Bishopville Prong	632	103

Table 3: Summer Low Flow Point Source Allocations for the St. Martin River and its Significant Tributaries

Waterbody Name	Total Nitrogen *(lb/month)*	Total Phosphorus *(lb/month)*
St. Martin River	2,288	1,525
Shingle Landing Prong	1,525	153
Bishopville Prong	Included in Upstream Load	Included in Upstream Load

Average Annual Allocations:

The nonpoint source loads of nitrogen and phosphorus simulated in the average annual TMDL scenario (Scenario 4) represent reductions from the average annual baseline scenario (Scenario 2). Recall that the average annual baseline scenario loads were based on unit area loading rate estimates provided by a University of Maryland study (UMD CEES, 1993). These nonpoint source loads account for both "natural" and human-induced sources. Further discussion of these loading estimates are provided in Appendix A. Details of a viable load allocation scheme are described further in the technical memorandum entitled "*Significant Nutrient Point Sources and Nonpoint Sources in the Northern Coastal Bays System*."

Point source load allocations for the average annual future conditions make up the balance of the total allowable load. This point source load allocation was adopted from the results of model Scenario 4. All significant point sources in the St. Martin River basin are addressed by this allocation and are described further in Appendix A, and the technical memorandum entitled "*Significant Nutrient Point Sources and Nonpoint Sources in the Northern Coastal Bays System*." The nonpoint source and point source nitrogen and phosphorus allocations for summer low flow conditions are shown in Table 4 and Table 5, respectively.

Table 4: Average Annual Nonpoint Source Allocations for the St. Martin River and its Significant Tributaries

Waterbody Name	Total Nitrogen *(lb/year)*	Total Phosphorus *(lb/year)*
St. Martin River	141,453	21,688
Shingle Landing Prong	71,644	10,541
Bishopville Prong	61,699	8,997

Table 5: Average Annual Point Source Allocations for the St. Martin River and its Significant Tributaries

Waterbody Name	Total Nitrogen *(lb/year)*	Total Phosphorus *(lb/year)*
St. Martin River	73,212	18,303
Shingle Landing Prong	29,285	1,830
Bishopville Prong	Included in Upstream Load	Included in Upstream Load

4.7 Margins of Safety

A margin of safety (MOS) is required as part of a TMDL to account for uncertainties in the knowledge regarding the exact nature and magnitude of pollutant loads from various sources and the ability to predict 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 EPA guidance, the MOS can be achieved through two approaches (EPA, April 1991). One approach is to reserve a portion of the loading capacity as a separate term in the TMDL (i.e., TMDL = WLA + LA + MOS). The second approach is to incorporate the MOS as conservative assumptions used in the TMDL analysis.

Maryland has adopted margins of safety that combine these two approaches. Different approaches have been used in different areas of the Northern Coastal Bays system, depending on the analytical framework used and other considerations. Details of the approach for establishing MOSs for each geographic area are described below.

4.7.1 Margins of Safety for Herring Creek and Turville Creek

Margins of safety, which combine the explicit approach and the implicit approach, have been adopted for Herring Creek and Turville Creek, which drain to Isle of Wight Bay. An explicit 10% MOS has been included for Herring Creek and Turville Creek in recognition that the modeling results are more uncertain due to the large size of the water quality model segment. The explicit margins of safety are summarized in Table 6 for the average annual TMDL.

In addition to the explicit margin of safety, several conservative assumptions were used in the analysis, which provide an additional margin of safety. First, the target dissolved oxygen goal has been set at 5.3 mg/l, rather than 5.0 mg/l, as a conservative assumption. The additional 0.3 mg/l is intended to address potential diurnal variations of DO. Second, the average annual TMDL analysis was conducted under the assumption of summer environmental conditions, despite the more likely scenario of lower water temperatures and solar radiation that typically correspond to periods of higher stream flow. Warmer water temperature and greater solar radiation are more conducive to algal growth and low dissolved oxygen concentrations.

Table 6: Margins of Safety for Average Annual TMDLs for Herring Creek and Turville Creek

Waterbody Name	Total Nitrogen *(lb/year)*	Total Phosphorus *(lb/year)*
Herring Creek	955	124
Turville Creek	2,627	393

4.7.2 Margins of Safety for the St. Martin River System

Following the explicit approach, the load allocated to the MOS for the St. Martin River and tributaries was computed as 5% of the nonpoint source loads. These explicit margins of safety are summarized in Table 7 and Table 8.

In addition to the explicit margins of safety, additional conservative assumptions of the analysis provide implicit margins of safety (for St Martin River System the target dissolved oxygen goal has been set at 6.0 mg/l, rather than 5.0 mg/l). The low flow TMDL analysis uses a combination of environmental parameters (low flow, high solar radiation, high water temperature, all for a sustained period of time) that would rarely occur simultaneously. The average annual TMDL analysis was conducted under the assumption of summer environmental conditions, despite the more likely scenario of lower water temperatures and solar radiation that typically correspond to periods of higher stream flow. Warmer water temperature and greater solar radiation are more conducive to algal growth and low dissolved oxygen concentrations.

Table 7: Margins of Safety (MOS) for Low Flow TMDLs for the St. Martin River and its Significant Tributaries

Waterbody Name	Total Nitrogen *(lb/month)*	Total Phosphorus *(lb/month)*
St. Martin River	105	19
Shingle Landing Prong	27	3
Bishopville Prong	33	6

Table 8: Margins of Safety (MOS) for Average Annual TMDLs for the St. Martin River and its Significant Tributaries

Waterbody Name	Total Nitrogen *(lb/year)*	Total Phosphorus *(lb/year)*
St. Martin River	7,445	1,142
Shingle Landing Prong	3,771	555
Bishopville Prong	3,247	474

4.8 Summary of Total Maximum Daily Loads

The previous sections describe the modeling framework, the modeling scenarios and results in terms of TMDLs, load allocations, and the margins of safety. This section consolidates all of these results into a summary accounting of the TMDLs.

4.8.1 Total Maximum Daily Loads for Herring Creek and Turville Creek

Herring Creek and Turville Creek (Average Annual flow)

The following are the average annual nutrient TMDLs for Herring Creek and Turville Creek.

Herring Creek, Nitrogen (*lb/year*):

TMDL	=	LA	+	WLA	+	MOS
9,547	=	**8,592**	+	**0**	+	**955**

Herring Creek, Phosphorus (*lb/year*):

TMDL	=	LA	+	WLA	+	MOS
1,235	=	**1,111**	+	**0**	+	**124**

Average Daily Loads: On average, the average annual TMDL will result in loads of approximately 26 lb/day of nitrogen, and 3 lb/day of phosphorus.

Turville Creek, Nitrogen (*lb/year*):

TMDL	=	LA	+	WLA	+	MOS
26,272	=	**23,645**	+	**0**	+	**2,627**

Turville Creek, Phosphorus (*lb/year*):

TMDL	=	LA	+	WLA	+	MOS
3,928	=	**3,535**	+	**0**	+	**393**

Average Daily Loads: On average, the average annual TMDL will result in loads of approximately 72 lb/day of nitrogen, and 11 lb/day of phosphorus.

4.8.3 Total Maximum Daily Loads for the St. Martin River System

St. Martin River System (Low flow)

The following are the critical low flow nutrient TMDLs, applicable from May 1 – Oct. 31, for the St. Martin River System.

St. Martin River, Nitrogen (*lb/month*):

TMDL	=	LA	+	WLA	+	MOS
4,378	**=**	**1,985**	**+**	**2,288**	**+**	**105**

St. Martin River, Phosphorus (*lb/month*):

TMDL	=	LA	+	WLA	+	MOS
1,908	**=**	**364**	**+**	**1,525**	**+**	**19**

Where:

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

Average Daily Loads: On average, the low flow TMDL will result in loads of approximately 144 lb/day of nitrogen, and 63 lb/day of phosphorus, applicable from May 1 – Oct. 31.

Bishopville Prong, Nitrogen (*lb/month*):

TMDL	=	LA	+	WLA	+	MOS
665	**=**	**632**	**+**	**0**	**+**	**33**

Bishopville Prong, Phosphorus (*lb/month*):

TMDL	=	LA	+	WLA	+	MOS
109	**=**	**103**	**+**	**0**	**+**	**6**

Average Daily Loads: On average, the low flow TMDL will result in loads of approximately 22 lb/day of nitrogen, and 4 lb/day of phosphorus, applicable from May 1 – Oct. 31.

Shingle Landing Prong, Nitrogen (*lb/month*):

TMDL	=	LA	+	WLA	+	MOS
2,060	=	508	+	1,525	+	27

Shingle Landing Prong, Phosphorus (*lb/month*):

TMDL	=	LA	+	WLA	+	MOS
219	=	63	+	153	+	3

Average Daily Loads: On average, the low flow TMDL will result in loads of approximately 68 lb/day of nitrogen, and 7 lb/day of phosphorus, applicable from May 1 – Oct. 31.

St. Martin River System (Average Annual)

The following are the average annual nutrient TMDLs for the St. Martin River System.

St. Martin River, Nitrogen (*lb/yr*):

TMDL	=	LA	+	WLA	+	MOS
222,110	=	141,453	+	73,212	+	7,445

St. Martin River, Phosphorus (*lb/yr*):

TMDL	=	LA	+	WLA	+	MOS
41,133	=	21,688	+	18,303	+	1,142

Average Daily Loads: On average, the average annual TMDL will result in loads of approximately 607 lb/day of nitrogen, and 113 lb/day of phosphorus.

Bishopville Prong, Nitrogen (*lb/yr*):

TMDL	=	LA	+	WLA*	+	MOS
64,946	=	61,699	+	0	+	3,247

Bishopville Prong, Phosphorus (*lb/yr*):

TMDL	=	LA	+	WLA*	+	MOS
9,471	=	8,997	+	0	+	474

* No explicit allocations are made to two minor point sources that discharge upstream of the modeling domain in Bishopville Prong. See "Point Sources Loadings" in Appendix A for further discussions.

Average Daily Loads: On average, the average annual TMDL will result in loads of approximately 178 lb/day of nitrogen, and 26 lb/day of phosphorus.

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Shingle Landing Prong, Nitrogen (*lb/yr*):

TMDL	=	LA	+	WLA	+	MOS
104,700	=	71,644	+	29,285	+	3,771

Shingle Landing Prong, Phosphorus (*lb/yr*):

TMDL	=	LA	+	WLA	+	MOS
12,926	=	10,541	+	1,830	+	555

Average Daily Loads: On average, the average annual TMDL will result in loads of approximately 287 lb/day of nitrogen, and 35 lb/day of phosphorus.

5.0 PHASED APPROACH

The TMDLs for Herring Creek and Turville Creek are being established under a phased approach. This approach is used when an analysis is more uncertain than usual, and places emphasis on taking steps to address the impairments in the near term, while more data is collected to support future evaluations. The primary distinction between a phased TMDL and a standard TMDL is the adaptive management strategy provided for the phased TMDL, which is presented in Section 6.0.

The adaptive management strategy of the phased TMDL consists of a series of management and evaluation activities to be conducted in the future. In accordance with EPA guidance, schedules are provided regarding the installation and evaluation of control measures, future data collection, and, if needed, additional modeling to refine the present TMDL analysis (EPA, April 1991*a*).

The scheduling is to coordinate all the various activities (water quality restoration and protection measures, monitoring, future evaluations), which are to involve all appropriate local authorities, State and federal agencies. The strategy for the implementation of nutrient control measures, and their subsequent evaluations, are to include: types of controls, the expected pollutant reductions, the time frame within which water quality standards will be met and controls re-evaluated.

The current impairment in Herring Creek and Turville Creek is determined solely by nonpoint sources (NPS). Consequently, the strategy and schedule will focus on best management practices (BMPs) for controlling NPS pollution. The schedule for monitoring and evaluation, as well as existing water quality management frameworks, are described below in the section entitled "Assurance of Implementation"

6.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the nitrogen and phosphorus TMDLs will be achieved and maintained. Because this TMDL document includes several TMDLs that are being established using a phased approach, the section is divided into two subsections. The first subsection addresses the general assurance of implementation, and the second subsection addresses the phased TMDLs for Herring Creek and Turville Creek.

6.1 General Assurance of Implementation

Maryland has several well-established programs that will be drawn upon to assure implementation of the proposed TMDLs. These include the state Nonpoint Source Management Programs under the Clean Water Act Section 319, the state Coastal Nonpoint Pollution Control Programs under Section 6217 of the Coastal Zone Management Act, the Water Quality Improvement Act of 1998 (WQIA), the EPA-sponsored Clean Water Action Plan of 1998 (CWAP), the Comprehensive Conservation Management Plan for Maryland's Coastal Bays (CCMP) developed under Section 320 of the Clean Water Act, and the National Pollutant Discharge Elimination System (NPDES) permitting program under the Clean Water Act. In addition, significant work on evaluating the effectiveness of NPS BMPs has been done by member states of the Bay Program. Based on this work, a technical manual is under development in Maryland, which will provide a consistent basis for detailed implementation planning (Refinement of the March, 1996 "Technical Appendix for Maryland's Tributary Strategies"). Finally, Maryland has adopted procedures to assure that future evaluations are conducted for all TMDLs that are established.

<u>Federal Clean Water Act Section 319 Nonpoint Source Management Programs</u>: The Section 319 Program represents a comprehensive framework for managing nonpoint sources of pollutants. The program supports assessments and reporting of waters of the State that are impaired by nonpoint sources, the documented coordination of a wide array of State programs that jointly constitute a comprehensive nonpoint source management strategy, and the administration of a grant program for the funding of nonpoint source management activities.

<u>Federal Coastal Zone Management Act Coastal Nonpoint Pollution Control Programs</u>: The backbone of the CZM Section 6217 program is the application of management measurements. The 6217 program in Maryland relies on 56 separate management measures for various land use practices. Each management measure has associated enforceable policies and mechanisms (or backup authority) to ensure implementation. If these original management measures fail to produce the necessary water quality improvements, additional management measures must be implemented to address remaining water quality problems.

Management measures are defined as economically achievable measures to control the addition of nonpoint pollution to coastal waters. These measures reflect the greatest degree of pollution reduction achievable using the best available nonpoint pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives.

CZM 6217 management measures focus on five major categories of nonpoint source pollution:

- Agricultural runoff
- Urban runoff
- Silvicultural (forestry) runoff
- Marinas and recreational boating
- Stream channelization and channel modification, dams, and streambank and shoreline erosion.

The state has also developed management measures for wetlands, riparian areas, and vegetated treatment systems that apply generally to various categories of nonpoint source pollution.

The federal program requires that each state program have enforceable policies and mechanisms for most of the management measures, this insures the authority to implement the Best Management Practices (BMPs). The state is also required to track the program's implementation and effectiveness. A tracking system is currently under development.

State Water Quality Improvement Act: Maryland's WQIA requires that comprehensive and enforceable nutrient management plans be developed, approved and implemented for all agricultural lands throughout Maryland. This act specifically requires that nitrogen management plans be developed and implemented by 2004, and plans for phosphorus be implemented by 2005. In support of this, and other agricultural water quality management efforts, Maryland's Agricultural Cost Share Program (MACS) funding is available for Best Management Practices (BMPs) in this watershed. Similarly, the Low Income Loans for Agricultural Conservation (LILAC) program is available to provide financial assistance.

Federal Clean Water Action Plan: Maryland's CWAP initiative has been implemented in a coordinated manner with the State's 303(d) process for identifying impaired waters. All Category I watersheds identified in Maryland's Unified Watershed Assessment process under the CWAP coincide with the approved 303(d) list of impaired waters for 1998. The State has given a high-priority for funding assessment and restoration activities to these watersheds. In coordination with local governments, Maryland has recently conducted and documented a watershed characterization for Isle of Wight Bay (Shanks, 2001). An associated Watershed Restoration Action Strategy (WRAS) is presently under development.

Maryland Coastal Bays Program: In 1999 the Maryland Coastal Bays Program (MCBP) released its Comprehensive Conservation Management Plan (CCMP) for Maryland's Coastal Bays (MCBP, 1999). The MCBP was created in 1996 to assist the region in developing a comprehensive plan to restore and protect Maryland's Coastal Bays. The Program is a partnership among the towns of Ocean City and Berlin; Worcester County; Maryland's Departments of Natural Resources, Agriculture, Environment, and Planning; U.S. National Park Service; and the U.S. Environmental Protection Agency. The CCMP delineates goals, actions needed to complete those goals, and strategies needed to complete each action for four different areas: water quality, fish and wildlife, recreation and navigation, and community and economic development. The water quality goals and actions will help assure that nutrient control activities are targeted to areas where nutrient TMDLs have been established.

Federal National Pollutant Discharge Elimination System: The implementation of point source nutrient controls will be executed through the use of NPDES permits. The NPDES permits will have compliance provisions, which provide a reasonable assurance of implementation.

Assured Future Evaluations: Finally, in 1998, Maryland adopted a five-year watershed cycling strategy to manage its waters. Pursuant to this strategy, the State is divided into five regions and management activities will cycle through those regions over a five-year period. The cycle begins with intensive monitoring, followed by computer modeling, TMDL development, implementation activities, and follow-up evaluation. The choice of a five-year cycle is motivated by the five-year federal NPDES permit cycle. This continuing cycle ensures that, within five years of establishing a TMDL, intensive follow-up monitoring will be performed. Thus, the watershed cycling strategy establishes a TMDL evaluation process that assures accountability.

6.2 Assurance of Implementation for Phased TMDLs

As discussed in Section 5.0, a schedule of control actions and data collection for evaluation is an integral part of a phased TMDL. This section is intended to address that aspect of the TMDLs for Herring Creek and Turville Creek.

6.2.1 Plans for Control Measures and Evaluation

Control Measures

Forethought and proactive environmental management has placed Maryland and local authorities in an ideal position to address the concerns in Herring Creek and Turville Creek. As noted in the previous section, two significant frameworks are in place for implementing nonpoint source controls in these watersheds.

First, stewardship of Maryland's Coastal Bays is under the Maryland Coastal Bays Program, which was originally established with resources provided by the National Estuaries Program (NEP). NEP was chartered by the U.S. Congress by Section 320 of the federal Clean Water Act. Within this framework, involving appropriate local, State and federal authorities, a Comprehensive Conservation Management Plan has been developed (Maryland Coastal Bays Program, 1999). This plan includes specific action items, schedules for undertaking those actions, lead agencies for the projects, cost estimates, and the expected benefits of those actions. That plan is herein adopted by reference, and a copy included as part of the TMDL submittal. It will serve as a key starting point for targeting actions needed to make the nonpoint source reductions needed in Herring Creek and Turville Creek to attain water quality standards.

The sections of the CCMP that address nonpoint sources of nutrients are presently summarized to give the reader a sense of the content of the plan that is adopted by reference. They are as follows:

1. Decrease Nutrient Inputs to Groundwater from Residential and Commercial Land Uses. Note that the following examples are in addition to agricultural nutrient management plans, which are presently required by Maryland's 1998 Water Quality Improvement Act (WQIA).

   Examples:

   - Designate the coastal bays watershed as an "Area of Special Concern" to better manage on site sewage disposal systems.
   - Require grounds management professionals to have nutrient management plans, and apply nutrients only as needed.
   - Implement public education on proper lawn and garden practices.

2. Decrease Nutrient Inputs from Stormwater Runoff. Note that the following examples are in addition to State regulations that require erosion and sediment control plans, and storm water management on new development. Maryland has recently refined the State's stormwater regulations and adopted a revised stormwater design manual cited by reference in the regulations.

   Examples:

   - Build new (or retrofit) stormwater management devices in existing developments.
   - Establish policies, including education of road management crews, about road-side ditch management, which are beneficial to nutrient removal.
   - Coordinate the location of stormwater management devices with on site sewage disposal systems.

3. Decrease Nutrient Inputs from Agricultural Sources. Again, these are in addition to actions under the 1998 WQIA, which require nutrient management plans

   Examples:

   - Target increased financial, technical, and educational resources necessary to assist farmers in the Herring Creek and Turville Creek areas.
   - Address adverse effects of agricultural ditches.
   - Take advantage of technological advances that allow for more precise nutrient management planning, such as Precision Farming Techniques.

The second significant framework for implementing nonpoint source controls in the Herring Creek and Turville Creek watersheds is the Watershed Restoration Action Strategy (WRAS) being developed for Isle of Wight Bay. A watershed characterization has been conducted in anticipation of developing the WRAS (Shanks, 2001). The WRAS is being developed in accordance with U.S. EPA guidance on the use of funding for nonpoint source management, under Section 319 of the federal Clean Water Act. More specific plans for control measures will be developed within the context of this WRAS, with stakeholder involvement.

Evaluation

Maryland's Watershed Cycling Strategy was initiated with water quality monitoring in the Coastal Bays Region in 1998. The cycle will return to this region in 2003. At that time, intensive monitoring can be conducted specifically in both the tidal and non-tidal portions of Herring Creek and Turville Creek.

This monitoring will include water quality evaluations, including storm event monitoring to assess the nonpoint source loads to the tidal waters. Because of the nature of nonpoint source controls, and the effect of ground water lag, it is expected that little change in water quality will have occurred at that time. Consequently, the water quality monitoring will constitute additional baseline information from which to measure improvement.

The Watershed Cycling Strategy imposes a follow-up date of 2008 for future monitoring. This provides a natural deadline for evaluating implementation actions. In addition to water quality monitoring similar to that proposed for 2003, the evaluation will also assess the on-land actions that are included in the Isle of Wight Bay Watershed Restoration Action Strategy, which is currently under development.

6.2.1 Schedules for Control Measures and Evaluation

Two key frameworks have been described above for affecting control measures. These are the Maryland Coastal Bays CCMP, and the Isle of Wight Bay WRAS. In addition, a framework for evaluating the control measures, based on collection of data in the field, has been described above. The following is an outline of the schedule for undertaking these activities.

Schedule for Control Measures and Evaluation in Herring Creek and Turville Creek

Activity	Completion Date
Refined Control Measure Planning:	2002
Baseline Water Quality and Loading Evaluation	2003
Adjustments to Herring/Turville TMDLs (if needed)	2006
Follow-up Water Quality and Loading Evaluation	2008
Attainment of Water Quality Standards, as Determined by Water Quality and Loading Evaluations	2013

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Appendix A