Total Maximum Daily Loads of Nitrogen and Phosphorus for the Chicamacomico River Dorchester, Maryland

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List of Abbreviations

BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
CBOD	Carbonaceous Biochemical Oxygen Demand
CEAM	Center for Exposure Assessment Modeling
CHL*a*	Active Chlorophyll
CREM	Chicamacomico River Eutrophication Model
CWA	Clean Water Act
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
EUTRO5.1	Eutrophication Module of WASP5.1
FA	Future Allocation
LA	Load Allocation
MDA	Maryland Department of Agriculture
MDE	Maryland Department of the Environment
MOS	Margin of Safety
NH_3	Ammonia
NO_{23}	Nitrate + Nitrite
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
USGS	United States Geological Survey
WASP5.1	Water Quality Analysis Simulation Program 5.1

PREFACE

Section 303(d) of the federal Clean Water Act (the Act) directs States to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, the State is to establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards.

The Chicamacomico River was identified on the State's 1996 list of WQLSs as impaired by nutrients (nitrogen and phosphorus). This report proposes the establishment of two TMDLs for the Chicamacomico River: one for nitrogen and one for phosphorus.

Once the TMDLs are approved by the United States Environmental Protection Agency (EPA) they will be incorporated into the State's Continuing Planning Process, pursuant to Section 303(e) of the Act. In the future, the established TMDLs will support nonpoint source measures needed to restore water quality in the Chicamacomico River.

EXECUTIVE SUMMARY

This document proposes to establish Total Maximum Daily Loads (TMDLs) for nitrogen and phosphorus in the Chicamacomico River. The Chicamacomico River ultimately drains to the Chesapeake Bay through the Transquaking River, and is a part of the Lower Eastern Shore Tributary Strategy Basin. The river is impaired by the nutrients nitrogen and phosphorus, which cause excessive algal blooms and exceedance of the dissolved oxygen criterion.

The water quality goal of these TMDLs is 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 for the Chicamacomico River will be met. The TMDL was determined using the WASP5.1 water quality model. Maximum loads for total nitrogen and total phosphorus entering the Chicamacomico River are established for both low flow and average annual flow conditions. As part of the TMDL analysis, the model was used to investigate seasonal variations and to establish margins of safety that are environmentally conservative.

The low flow TMDL for nitrogen is 1,621 lb/month, and the low flow TMDL for phosphorus is 27 lb/month. These TMDLs apply during the period May 1 through October 31. The low flow nonpoint source loads for the TMDLs are computed by multiplying the observed base flow concentrations by the estimated critical low flow. The watershed contains no significant point sources to which allocations can be made.

The annual average TMDL for nitrogen is 203,608 lb/yr, and the annual TMDL for phosphorus is 14,007 lb/yr. Allowable loads have been allocated to nonpoint sources considering an appropriate margin of safety. Baseline average annual nonpoint source loads, from which reductions are computed, are based on year-2000 EPA Chesapeake Bay Program watershed model loading rates applied to 1997 landuse acreages. The watershed contains no significant point sources to which allocations can be made.

Three factors provide assurance that these TMDLs will be implemented. First, Maryland has several well-established programs that will be drawn upon, including Maryland’s Tributary Strategies for Nutrient Reductions developed in accordance with the Chesapeake Bay Agreement. Second, Maryland’s Water Quality Improvement Act of 1998 requires that nutrient management plans be implemented for all agricultural lands throughout Maryland. Finally, Maryland has adopted a watershed cycling strategy, which will assure that routine future monitoring and TMDL evaluations are conducted.

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 the impairing substance a water body 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 Chicamacomico River was first placed on the 1996 303(d) list submitted to EPA by the Maryland Department of the Environment. It was identified as being impaired by nutrients due to signs of eutrophication, expressed as low dissolved oxygen. Eutrophication is the over-enrichment of aquatic systems by excessive inputs of nutrients (nitrogen or phosphorus). The nutrients act as a fertilizer leading to excessive aquatic plant growth, which eventually die and decompose, leading to bacterial consumption of dissolved oxygen. For these reasons, this document proposes to establish TMDLs for the nutrients nitrogen and phosphorus in the Chicamacomico River.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

The Chicamacomico River is located in Dorchester County, Maryland (Figure 1). It originates southeast of the East New Market area and finally drains to the Chesapeake Bay through the Transquaking River roughly one mile due north of Bestpitch. The modeling domain of the River is approximately 16.3 miles in length, from its confluence with the Transquaking River to the headwaters upstream of Big Millpond. The Chicamacomico River watershed has an area of approximately 33,017 acres or 51.6 square miles. The land uses in the watershed consist of forest and other herbaceous (21,204 acres or 64.2%), mixed agriculture (10,935 acres or 33.1%), water (564 acres or 1.7%), and urban (314 acres or 1.0%) (based on 1997 Maryland Office of Planning land cover data, and 1997 Farm Service Agency (FSA) data). Figure 2 shows the geographic distribution of the different land uses. Figure 3 shows the relative amounts of the different land uses.

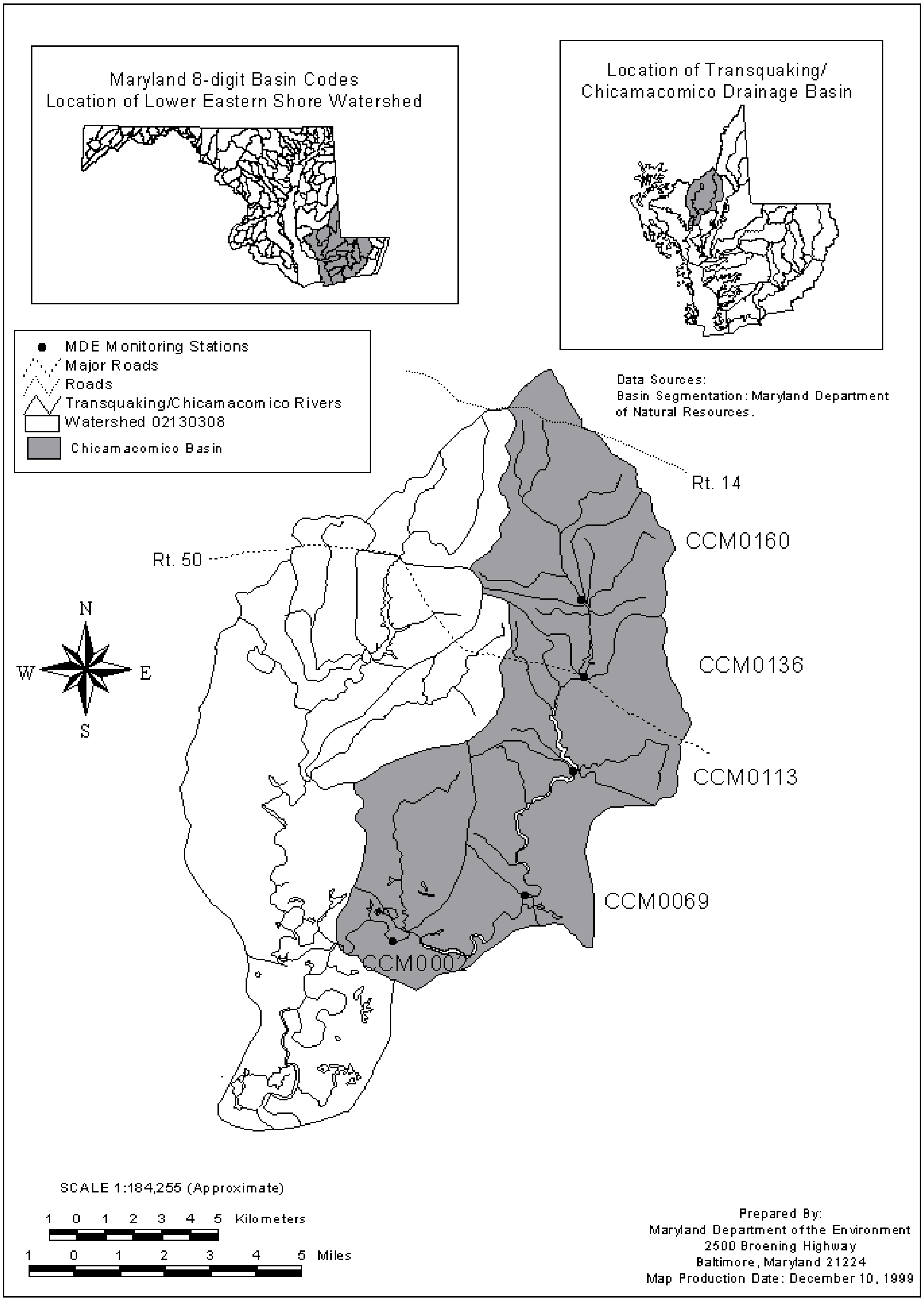


Figure 1 Location Map of the Chicamacomico River Drainage Basin within Maryland

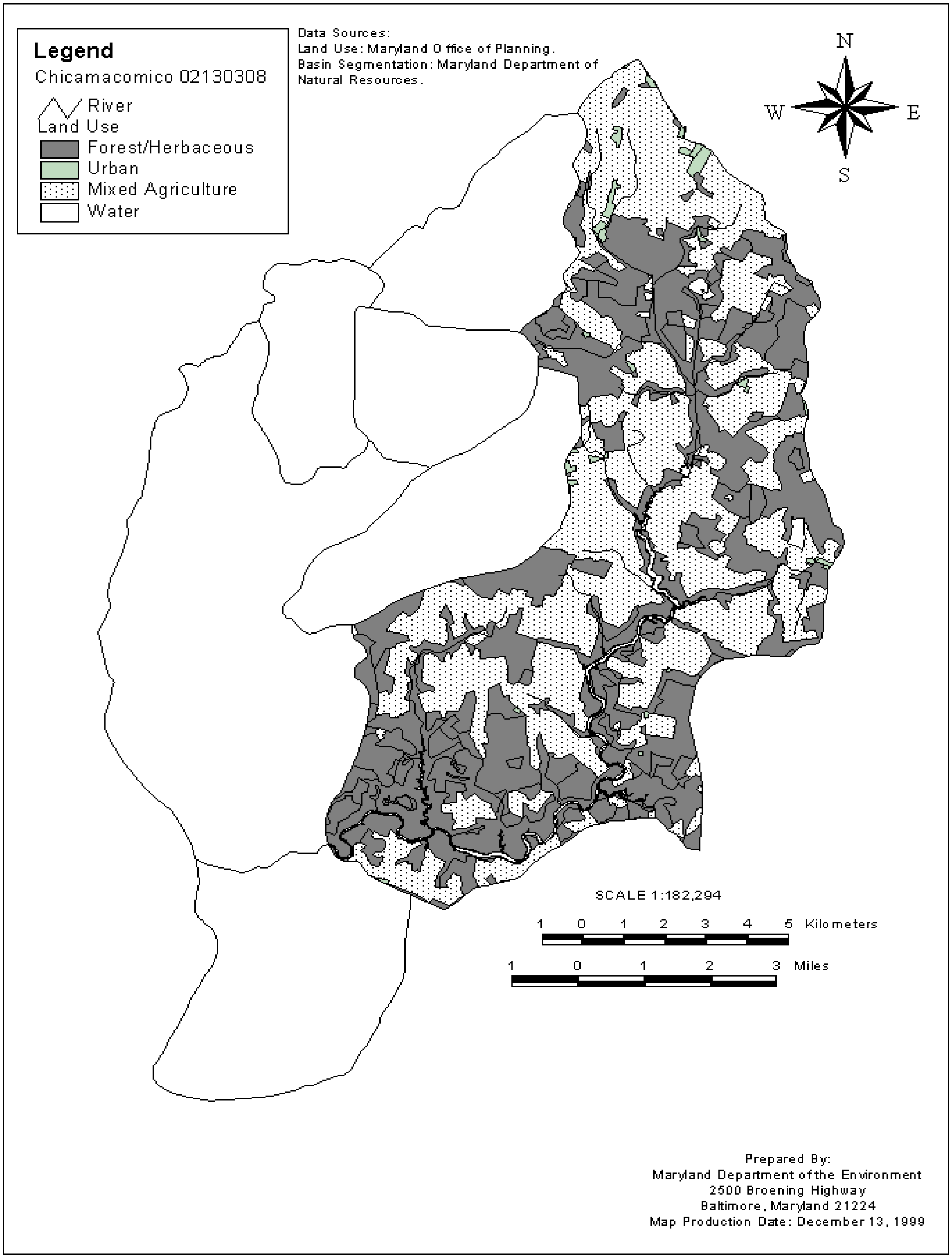


Figure 2: Predominant Land Use in the Chicamacomico River Drainage Basin

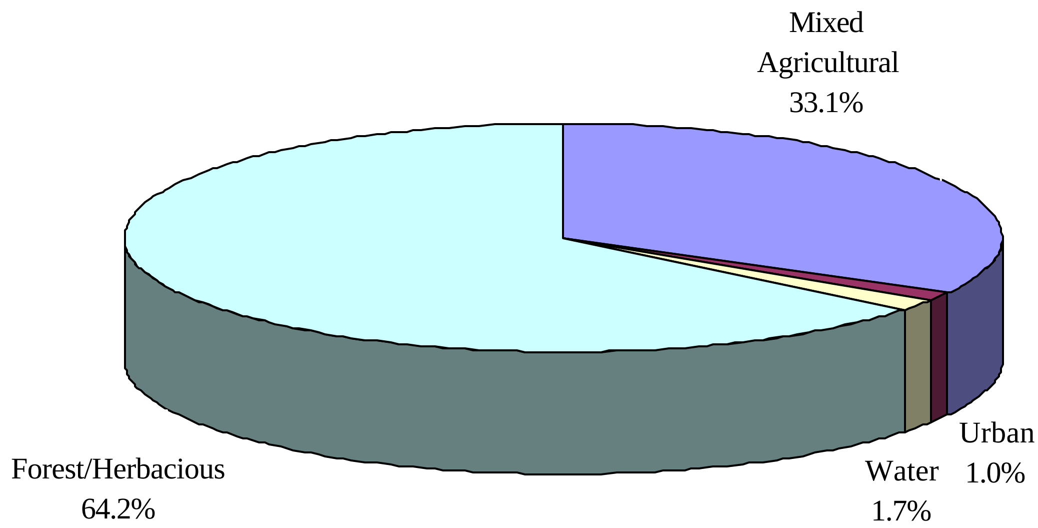
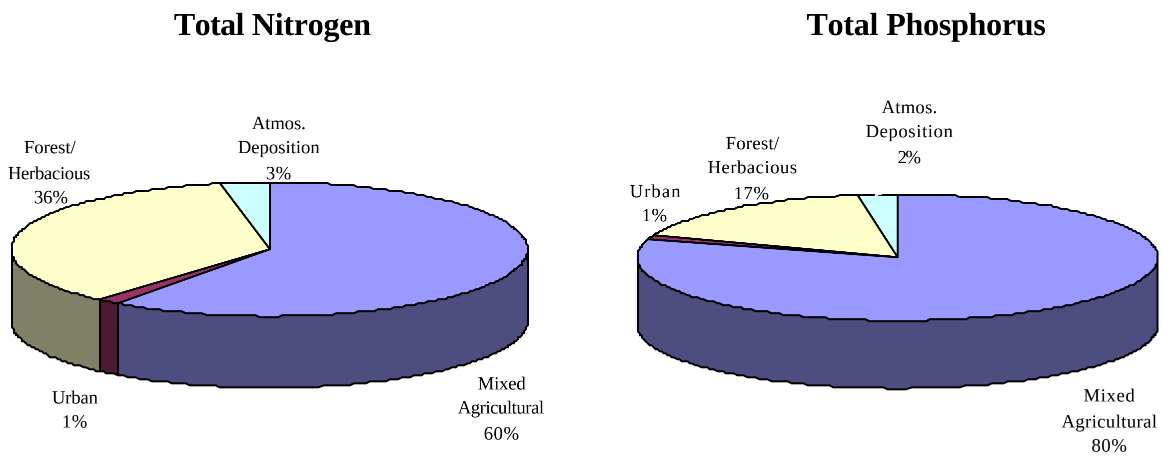


Figure 3: Proportions of Land Use in the Chicamacomico River Drainage Basin

The Chicamacomico River is tidal throughout its navigable reach, which extends from the confluence with the Transquaking to approximately 14.6 miles upstream to an area known as Big Millpond. Big Millpond was previously used as a source of water. A temporary dam was constructed on the upper section of river, but now only a remnant of it remains. Depths of the river range from about 4 inches in the headwaters to greater than 11.5 feet at the confluence of the Transquaking and the Chicamacomico.

In the Chicamacomico River watershed, the estimated average annual total nitrogen load is 259,283 lb/yr, and the total phosphorus load is 19,446 lb/yr (Figure 4). These figures represent loads from nonpoint sources only. There are no significant point sources in the Chicamacomico River watershed that discharge nutrients. The nonpoint source loads were determined using land use loading coefficients. The land use information was based on 1997 Maryland Office of Planning data with refinements to cropland acres, based on 1997 Farm Service Agency data. The total nonpoint source load was calculated by summing all of the individual land use areas and multiplying by the corresponding land use loading coefficients. The loading coefficients were based on the results of the Chesapeake Bay Watershed Model (U.S. EPA, 1996), a continuous simulation model. The EPA Chesapeake Bay Program nutrient loading rates account for direct atmospheric deposition, loads from septic tanks, and loads coming from urban development, agriculture, and forestland.



Note: There are no significant point sources in the watershed (discharging nutrients)

Figure 4: Estimated Annual Nitrogen and Phosphorus Nonpoint Source Loads

2.2 Water Quality Characterization

Four key water quality parameters, chlorophyll *a*, dissolved oxygen, dissolved inorganic nitrogen, and dissolved inorganic phosphorus are presented below. These data were collected by MDE during six water quality surveys conducted in the Chicamacomico River during 1998. Three sets of samples were collected during seasonal low flow periods in summer (21-July-98, 18-Aug-98, 15-Sep-98), and three high flow periods in winter (12-Feb-98, 16-Mar-98, 23-Mar-98). The reader is referred to Figure 1 for the locations of the water quality sampling stations. Table 1 presents the distance of each station from the mouth.

Problems associated with eutrophication are most likely to occur during the summer season (July, August, September). During this season there is typically less stream flow available to flush the system, more sunlight to grow aquatic plants, and warmer 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) does not show chlorophyll *a* or DO problems. The following graphs present data from the low flow period. Additional data, including that for the high flow periods, are presented in Appendix A.

Figure 5 presents a longitudinal profile of chlorophyll *a* data sampled during summer 1998, the low flow period. The sampling region extends from near the confluence of the Chicamacomico River with the Transquaking (Station CCM0002), to within the Big Millpond (CCM0136), and on up to the free-flowing stream above the pond (Station CCM0160). Figure 5 shows that ambient chlorophyll *a* concentrations in the summer are below 50 µg/l, except around 6-8 miles up from the river mouth, where the concentrations reach about 50 µg/l.

A similar longitudinal profile for dissolved oxygen (DO) concentrations is depicted in Figure 6. From the confluence with the Transquaking River to a distance of about 3 miles upstream, the DO levels occasionally fall below the water quality criteria of 5 mg/l. The DO levels are above the criteria from 5 – 12 miles upstream from the confluence. The DO concentrations drop below the criteria of 5 mg/l between stream miles 12-15, and are most depressed inside the Big Millpond, where the concentration is observed to drop as low as 2.1 mg/l.

Table 1: Location of Water Quality Stations

Water Quality Station	Miles from the Mouth of Chicamacomico River	Description
CCM0002	2.49	At Brickhouse Landing, 2 miles above Transquaking River
CCM0069	7.22	Tidal, at Drawbridge Rd. Crossing
CCM0113	11.73	Tidal at New bridge Rd. crossing
CCM0136	14.58	Downstream end of the Big Millpond
CCM0160	16.20	Head Water, above Big Millpond

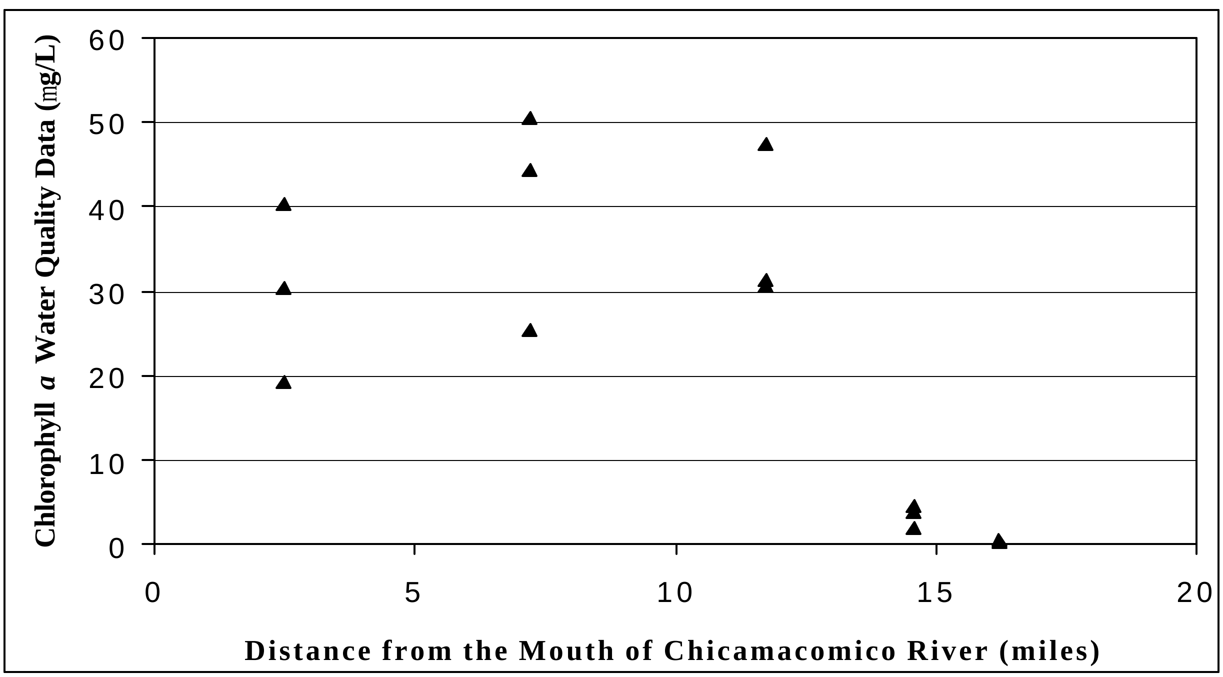


Figure 5: Longitudinal Profile of Chlorophyll *a* Data (Low flow)

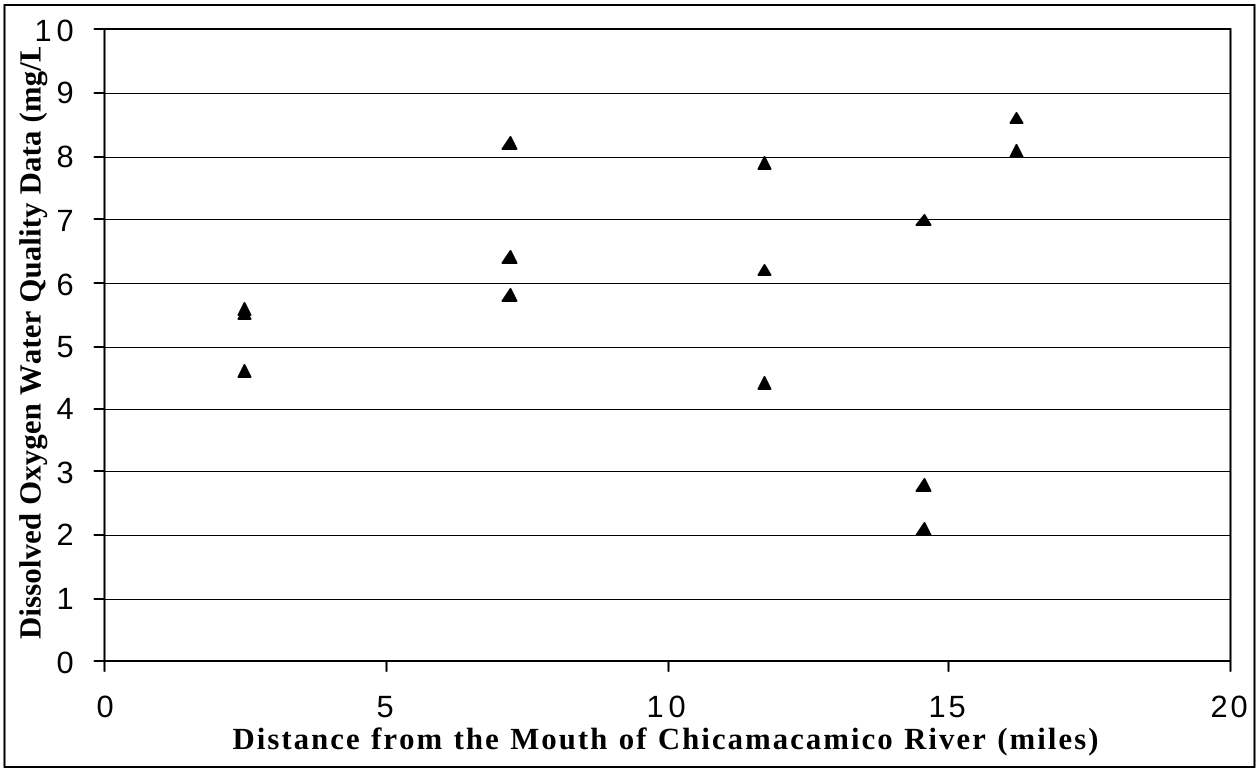


Figure 6: Longitudinal Profile of Dissolved Oxygen

Figure 7 presents a longitudinal profile of dissolved inorganic nitrogen levels measured in the samples collected in 1998, during low flow conditions. The levels are below 0.5 mg/l from the confluence of the Chicamacomico and Transquaking Rivers up-stream to the Big Millpond, then increase to 3.1 mg/l above the pond.

Figure 8 presents a longitudinal profile of dissolved inorganic phosphorus as indicated by ortho-phosphate levels measured in samples collected in 1998, during low flow conditions. Most of the values are at or near the level of detection (0.01 mg/l), with the highest level being 0.05 mg/l at 7 to 12 miles up from the river mouth.

2.3 Water Quality Impairment

The Maryland water quality standards Surface Water Use Designation (COMAR 26.08.02.07) for the Chicamacomico River is Use I - *water contact recreation, fishing, and protection of aquatic life and wildlife.* The water quality impairment of the Chicamacomico River system addressed by this TMDL analysis is a violation of the numeric criteria for dissolved oxygen (DO). The substances causing this water quality violation are the nutrients nitrogen and phosphorus.

According to the numeric criteria for DO for Use I waters, 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 achievement of 5.0 mg/l is expected in the well mixed surface waters of the Chicamacomico River system. The TMDL analysis indicates that nitrogen and phosphorus loadings from nonpoint sources have resulted in DO concentrations below the standard of 5.0 mg/l. The dissolved oxygen concentration in the lower reach of the River occasionally falls below the standard of 5.0 mg/l with severe depletion in the upper reaches inside the Big Millpond, where it has been observed to decrease to a value of 2.1 mg/l.

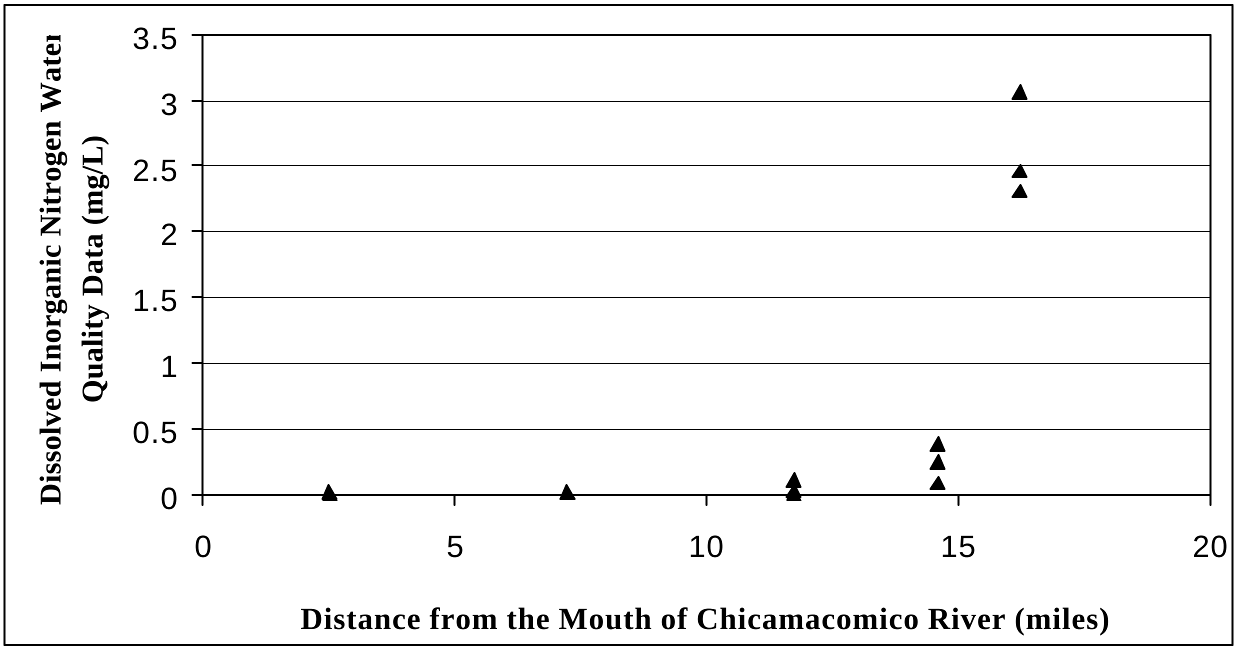


Figure 7: Longitudinal Profile of Dissolved Inorganic Nitrogen Data (Low flow)

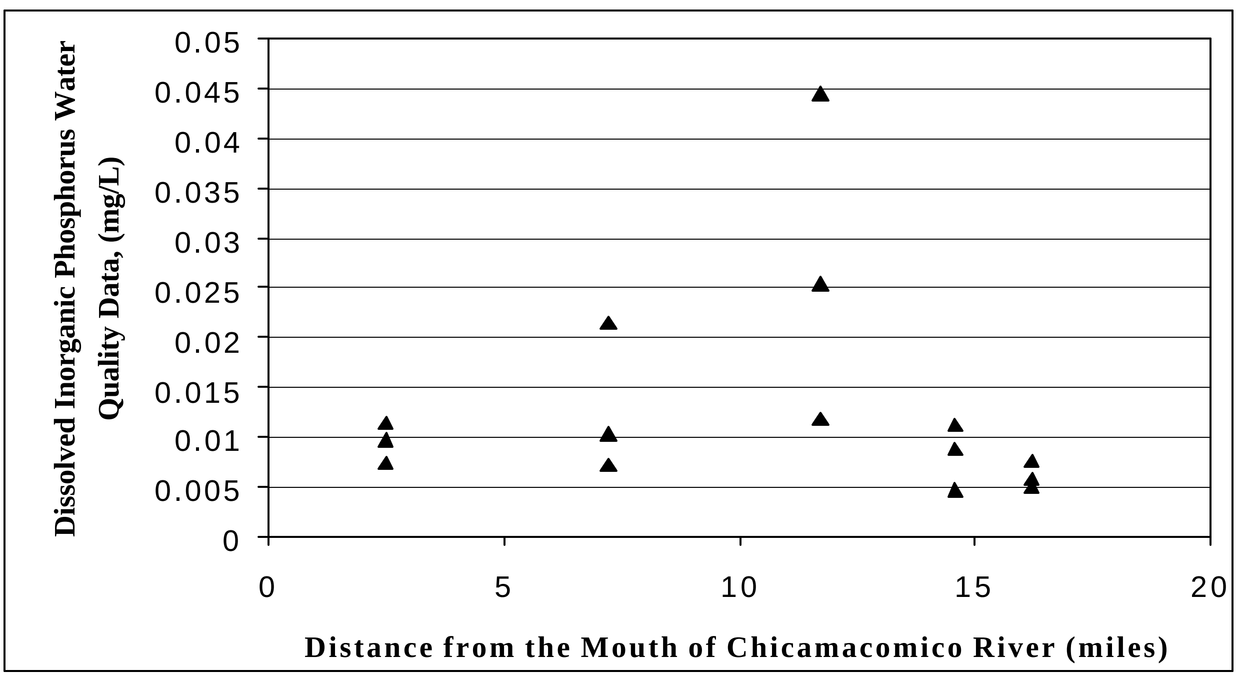


Figure 8: Longitudinal Profile of Dissolved Inorganic Phosphorus Data (Low flow)

3.0 TARGETED WATER QUALITY GOAL

The objective of the nutrient TMDLs established in this document is to assure that the dissolved oxygen criteria support the Use I designation for the Chicamacomico River. Specifically, the TMDLs for nitrogen and phosphorus for the Chicamacomico River are intended to assure that a minimum dissolved oxygen level of 5.0 mg/l is maintained throughout the Chicamacomico River system.

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 Chicamacomico River. 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 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 annual loads.

4.2 Analysis Framework

The computational framework chosen for the Chicamacomico River 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 WASP model was implemented in a steady-state mode. This mode of using WASP simulates constant flow, and average water body volume over the tidal cycle. The tidal mixing is accounted for using dispersion coefficients, which quantify the exchange of conservative substances between WASP model segments. The model simulates an equilibrium state of the water body, which in this case, considered low flow and average flow conditions, described in more detail below.

The spatial domain of the Chicamacomico River Eutrophication Model (CREM) extends from the confluence of the Transquaking River and the Chicamacomico River for about 16.3 miles along the mainstem of Chicamacomico River. This modeling domain, represented by 15 WASP model segments, extends upstream of the Big Millpond. A diagram of the WASP model segmentation is presented in Appendix A.

The nutrient TMDL analyses consist of two broad elements, an assessment of low flow loading conditions, and an assessment of average annual loading. 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 flow TMDL for the Chicamacomico River builds upon an analysis conducted for the Transquaking River, which is downstream. Briefly, an average annual loading limit for the Chicamacomico River was necessary in order to meet water quality standards in the Transquaking River (Transquaking River TMDL analysis, MDE, December 1999). The average annual TMDL analysis for the Chicamacomico River, presented herein, consists of demonstrating that the nutrient loading limits established to meet water quality standards in the Transquaking River are also protective of water quality throughout the Chicamacomico River.

The water quality model was calibrated to reproduce observed water quality characteristics for both observed low flow and observed high flow conditions. Calibration of the model for these two flow regimes establishes an analysis tool that may be used to assess a range of scenarios of differing flow and nutrient loading conditions. Observed water quality data collected during 1998 was used to support the calibration process, as explained further in Appendix A.

The estimation of stream flow used in the critical low flow analyses was based on a regression analysis, which made use of 30 years of data from USGS flow gages in the Delmarva Peninsula region. The average stream flow, estimated to be 18.6 cfs, was based on data from an abandoned USGS gage on the Chicamacomico. The methods used to estimate stream flows are described further in Appendix A.

There are no significant point sources of nutrients in the Chicamacomico watershed. The methods of estimating nonpoint source (NPS) loading are described in Section 4.3. In brief, low flow NPS loads were derived from concentrations observed during low flow sampling in 1998 multiplied by the estimated critical low flows. Because the low flow loading estimations are based on observed data, they account for all human and natural sources. The average annual NPS loads were derived from existing data and results from previous watershed modeling conducted by the EPA Chesapeake Bay Program Office. These methods are elaborated upon in Section 4.3 and in Appendix A.

The concentrations of the nutrients (nitrogen and phosphorus) are modeled in their speciated forms. Nitrogen is simulated as ammonia (NH_3), nitrate and nitrite (NO23), and organic nitrogen (ON). Phosphorus is simulated as ortho-phosphate (PO_4) and organic phosphorus (OP). Ammonia, nitrate and nitrite, and ortho-phosphate represent the dissolved forms of nitrogen and phosphorus. The dissolved forms of nutrients are more readily available for biological processes such as algae growth, which affect chlorophyll *a* levels and dissolved oxygen concentrations. The ratios of total nutrients to dissolved nutrients used in the model scenarios represent values that have been measured in the field. These ratios are not expected to vary within a particular flow regime. Thus, a total nutrient value obtained from these model scenarios, under a particular flow regime, is expected to be protective of the water quality criteria in the Chicamacomico River.

4.3 Scenario Descriptions

The WASP model was applied to investigate different nutrient loading scenarios under two stream flow conditions. These analyses allow a comparison of conditions under which water quality problems exist, with future conditions that project the water quality response to various simulated load reductions of the impairing substances. By modeling both low flow and average annual loadings, the analysis accounts for seasonality, a necessary element of the TMDL development process.

The analyses are grouped according to *base-line conditions*, and *future conditions* associated with TMDLs. Both groups include low flow and average annual loading scenarios, for a total of four scenarios. The base-line conditions are intended to provide a point of reference by which to compare the future scenarios that simulate conditions of a TMDL. The base-line conditions correspond roughly to the notion of "current conditions;" however, this mental picture has limitations. First, there is no such thing as a true "current" condition. Second, the base-line scenarios are typically simulations of unobserved conditions, as opposed to an observed "current" condition. Finally, the notion of "current" is unstable and confusing because there is no single reference point in time over the long process of TMDL analysis, review and approval.

First Scenario: The first scenario represents the base-line conditions of the stream at a simulated critical low flow in the river. The method of estimating the critical low flow is described in Appendix A. 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 nutrient concentrations for the first scenario were computed using observed data collected during low flow conditions of July and August of 1998. The low flow NPS loads were computed as product of the observed concentrations and estimated critical low flow. These low flow NPS loads integrate all natural and human induced sources, including direct atmospheric deposition, loads from septic tanks, which are associated with river base flow during low flow conditions.

Second Scenario: The second scenario represents a base-line condition of the stream at average flow and average annual loading rate. Summer water temperatures and solar radiation values are used as conservative assumptions. The total nonpoint source loads were calculated using loading rates from the EPA Chesapeake Bay Program Phase IV watershed model. The loading rates represent edge-of-stream contributions assuming Best Management Practice (BMP) implementation at levels consistent with expected progress in year-2000. Land use, to which these loading rates were applied, was calculated using 1997 MOP data, and adjusted using 1997 FSA crop acre data. The nutrient loads account for contributions from atmospheric deposition, septic tanks, cropland, pasture, feedlots, forest, and urban land.

Third Scenario: 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. This scenario simulates an estimated 9% reduction in controllable loads of total nitrogen in the head waters draining to the Big Millpond (watershed segment 1), in addition to reductions associated with the Fourth Scenario. This scenario accounts for a margin of safety computed as

5% of the NPS load allocation. In this future condition scenario, reductions in nutrient fluxes and sediment oxygen demand (SOD) were estimated based on the percentage reduction of organic matter settling to the bottom. Further discussion of this scenario is provided in Appendix A.

Fourth Scenario: The fourth scenario represents the future condition of maximum allowable average annual loads *necessary to meet water quality standards in the Transquaking River*. The nutrient loading used in this scenario is atypical. Rather than being the limit needed to meet water quality needs of the Chicamacomico River, the loading was determined by a previous analysis to meet water quality standards in the Transquaking River (MDE, 1999). This scenario demonstrates that the water quality standards are also met throughout the Chicamacomico River.

The stream flow for the fourth scenario is the same as that used in the second scenario (base line for average annual load). Summer water temperatures and solar radiation values are used as conservative assumptions. Water quality characteristics, and fluxes, at the boundaries of the modeling domain, that is, at the confluence of Chicamacomico and Transquaking, are set to match the base-line conditions established by the Transquaking River TMDL. Note that water quality standards were already being met throughout the Chicamacomico River in the baseline condition (Second scenario). Thus, the additional loading limits associated with the fourth scenario are applied in order to be consistent with the previously established TMDL for Transquaking. This said, the limits on the average annual loads also contribute to meeting the water quality standards for the critical low flow conditions.

The fourth scenario simulates an estimated 35% reduction in controllable loads of total nitrogen and total phosphorus from the baseline in the second scenario. This scenario accounts for a margin of safety computed as 3% of the NPS load allocation. In the future condition scenario, reductions in nutrient fluxes and sediment oxygen demand (SOD) were estimated based on the percentage reduction of organic matter settling to the bottom. Further discussion of this scenario is provided in Appendix A and in a technical memorandum entitled *"Significant Nutrient Nonpoint Sources in the Chicamacomico River Watershed."*

4.4 Scenario Results

This section describes the results of the model scenarios described in the previous section. The CREM results presented in this section are daily minimum dissolved oxygen (DO) concentrations. These minimum DO concentrations account for diurnal fluctuations caused by photosynthesis and respiration of algae.

Base-line Condition Scenarios:

1. *Low Flow:* Simulates critical low stream flow conditions during summer season. Water quality parameters (e.g., nutrient concentrations) are based on 1998 observed data.

2. *Average Annual Flow:* Simulates average stream flow conditions, with average annual nonpoint source loads estimated on the basis of 1997 land use, and projected year-2000 nutrient loading rates from the EPA Chesapeake Bay watershed model (See Appendix A).

Results for the first scenario, representing the base-line condition for summer low flow, are summarized in Figure 9. Under these conditions, the peak chlorophyll *a* level is about equal to the desired goal of 50 µg/l. However, DO concentrations are expected to fall below the minimum water quality criteria of 5.0 µg/l both near the river mouth and in the Big Millpond. Scenario 3, presented below, establishes maximum allowable loads that address these apparent DO problems.

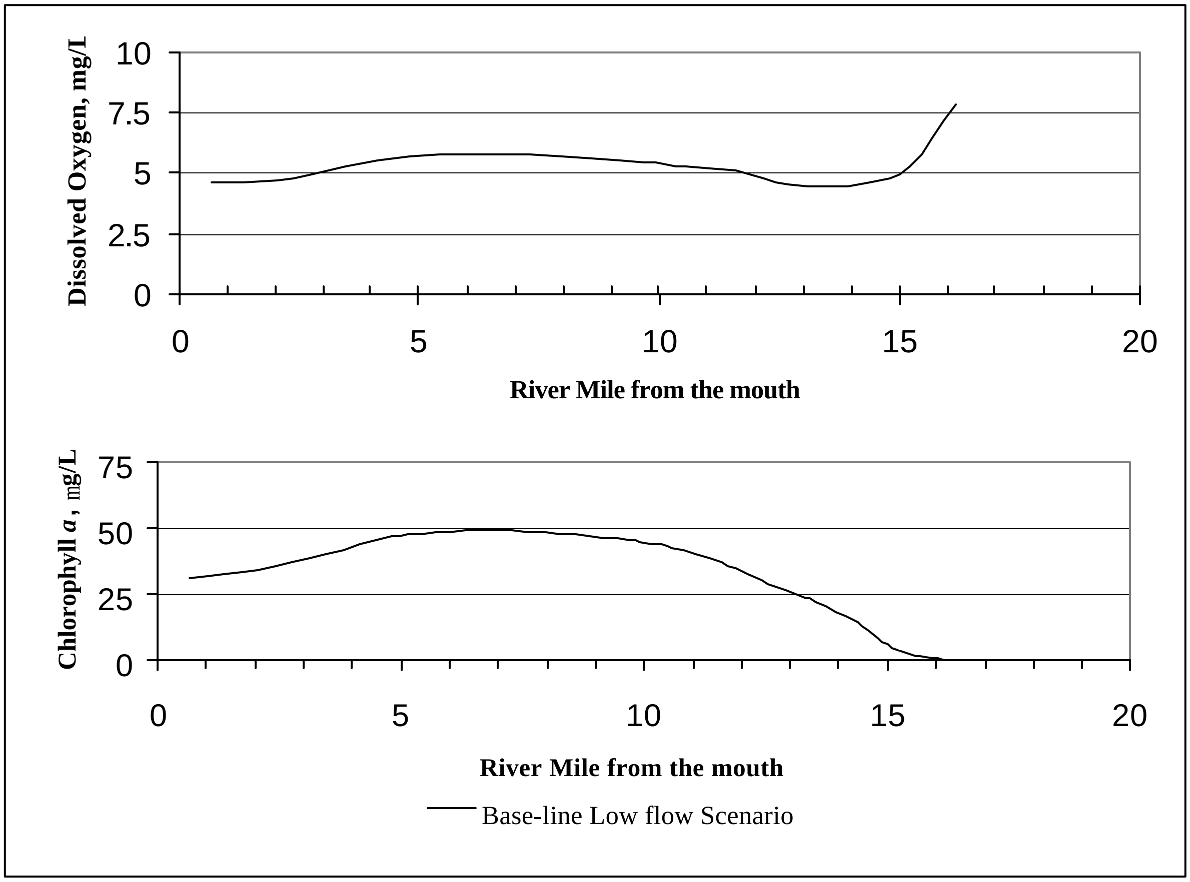


Figure 9: Model Results for the Base-line Low Flow Scenario for Chlorophyll *a* and Dissolved Oxygen (Scenario 1)

Results for the second scenario, representing the base-line condition for average stream flow and average annual loads, are summarized in Figure 10. Under these conditions, chlorophyll *a* concentrations remain well below the desired goal of 50 µg/l, and DO concentrations remain above 5.0 dissolved oxygen µg/l throughout the length of the river. Although no water quality standards violations are indicated for the baseline conditions, loads from the Chicamacomico have been shown to contribute to violations of water quality criteria downstream in the Transquaking River. Scenario 4, presented below, simulates average annual loading limits placed on the Chicamacomico River to meet downstream needs. As one would expect, Scenario 4 indicates all water quality criteria are met throughout the length of the river.

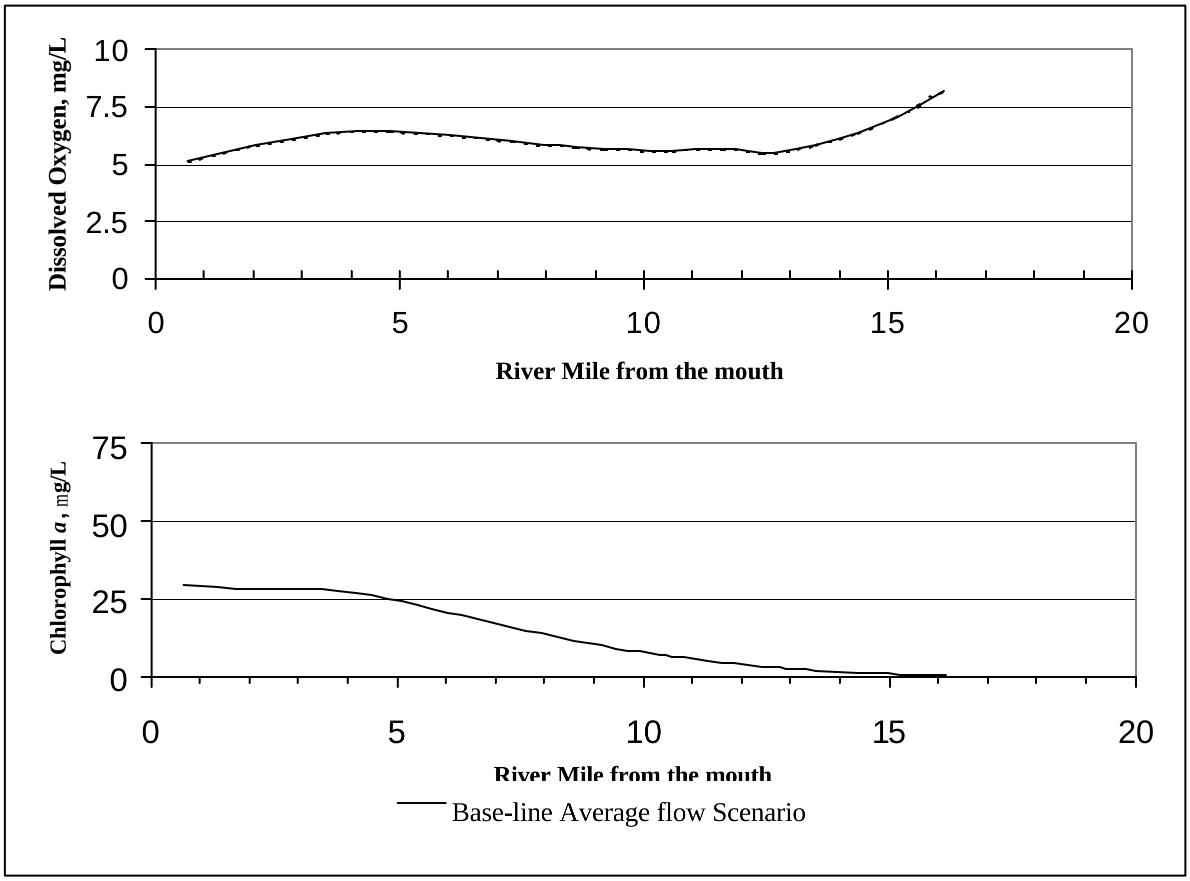


Figure 10: Model Results for the Base-line Average Flow Scenario for Chlorophyll *a* and Dissolved Oxygen (Scenario 2)

Future Condition TMDL Scenarios:

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

4. *Average Annual Flow:* Simulates the future condition of maximum allowable loads under average stream flow and average annual loading conditions to meet down-stream water quality in the Transquaking River.

Results for the third scenario (dotted line), representing the maximum allowable loads for summer-time critical low flow, are summarized in comparison to the appropriate baseline scenario (solid line) in Figure 11. Under the nutrient load reduction conditions described above for this scenario, the results show that chlorophyll *a* concentrations remain well below 50 µg/L along the entire length of the Chicamacomico River. For dissolved oxygen (DO), the comparison shows that the nutrient load reductions result in an upward shift in DO. Figure 11 (dotted line) indicates that the minimum DO along the length of the river is just above the water quality criterion of 5.0 mg/L.

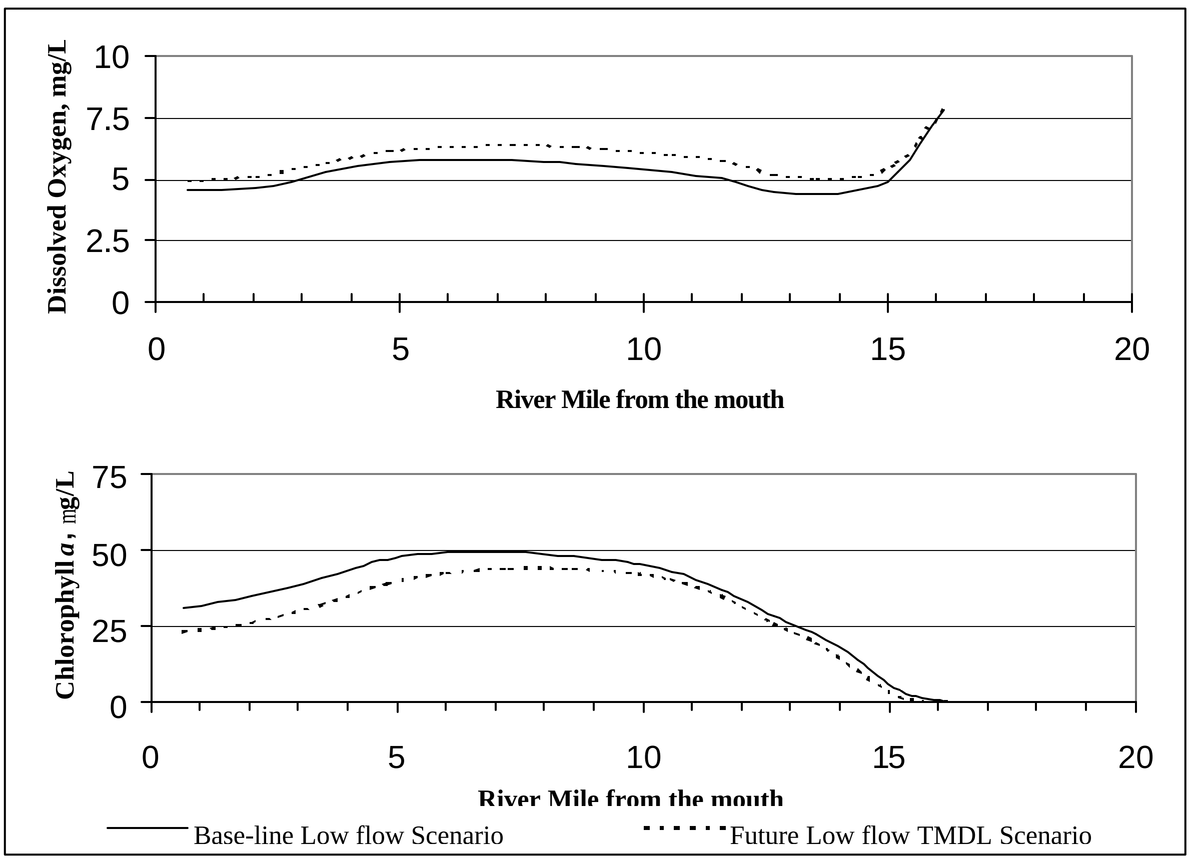


Figure 11: Model Results for the Future Low Flow Scenario for Chlorophyll *a* and Dissolved Oxygen (Scenario 3)

Results for the fourth scenario (dotted line), representing the maximum allowable loads for average annual flow, are summarized in comparison to the appropriate baseline scenario (solid line) in Figure 12. Under the load reduction conditions described above for this scenario, the results show that chlorophyll *a* concentrations remain well below 50 µg/L along the entire length of the Chicamacomico River. For dissolved oxygen (DO), the comparison shows that the minimum DO that occurs along the length of the river remains just above the water quality criterion of 5.0 mg/L for both scenarios. Although this comparison makes it appear that the average annual nutrient limit makes no difference, it is important to note that the average annual nutrient limits for the Chicamacomico serve two purposes. First, the limit is necessary to protect downstream waters (Transquaking River). Second, the limit contributes to meeting summer critical conditions.

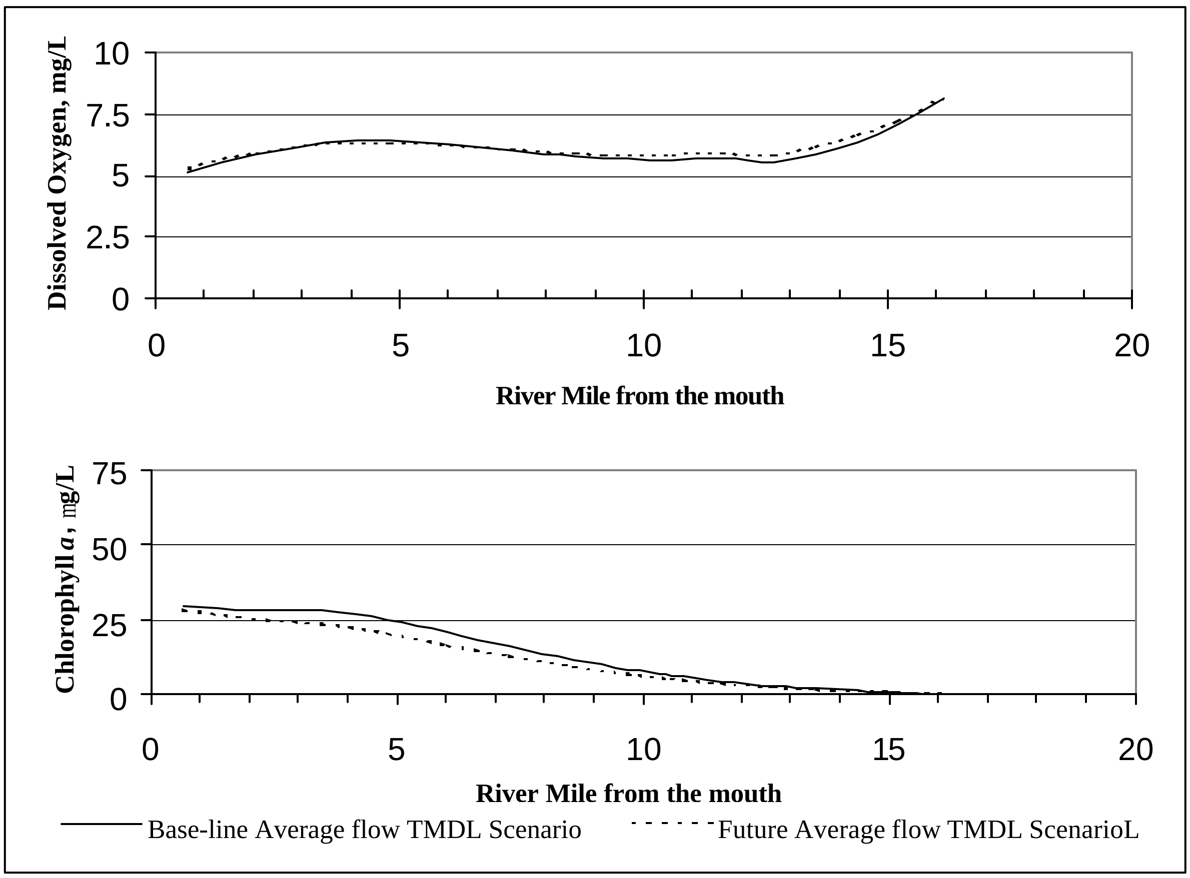


Figure 12: Model Results for the Future Average Flow TMDL Scenario for Chlorophyll *a* and Dissolved Oxygen (Scenario 4)

4.5 TMDL Loading Caps

This section presents total maximum daily loads (TMDLs) for nitrogen and phosphorus. The outcomes are presented in terms of the critical low flow TMDL, and average annual TMDL. The critical season for excessive algal growth in the Chicamacomico River 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 these critical conditions occur for a limited period of time. It should be noted that limits placed on average annual loads are accounted for indirectly by adjusting bottom sediment nutrient fluxes and SOD to be consistent with reductions in average annual loads (See Appendix A). For the summer months, May 1 through October 31, the following TMDLs apply:

Low Flow TMDL:

NITROGEN TMDL **1,621** ***lb/month***

PHOSPHORUS TMDL **27** ***lb/month***

The average annual TMDLs are being established for two purposes. First, they are designed to protect water quality in the Transquaking River, downstream of the Chicamacomico. Second, loading limits on average annual loads contribute to resolving water quality problems observed in the low flow critical season. The annual average TMDLs for nitrogen and phosphorus are:

Average Annual TMDL:

NITROGEN TMDL **203,608** ***lb/year***

PHOSPHORUS TMDL **14,007** ***lb/year***

Because the TMDLs set limits on nitrogen, and because of the way the model simulated nitrogen, it is not necessary to also include a TMDL for nitrogenous biochemical oxygen demand (NBOD), to protect the dissolved oxygen standards in the river.

4.6 Load Allocations Between Point Sources and Nonpoint Sources

The watershed that drains to the Chicamacomico River has no significant point source discharges of nutrients. Hence, for both the low flow and average annual TMDLs, the entire allocation is being made to nonpoint sources, except for the margin of safety.

<u>Low Flow Allocations</u>:

The nonpoint source loads of nitrogen and phosphorus simulated in the third scenario represent reductions from the baseline scenario. Recall that the baseline scenario loads were based on nutrient concentrations observed in summer 1998. These nonpoint source loads, based on observed concentrations, account for both "natural" and human-induced components and cannot be separated into specific source categories.

There are no significant point source discharges of nutrients in the watershed. Consequently, waste load allocations are set at zero. The nitrogen and phosphorus allocations for summer low flow conditions are presented in Table 2.

Table 2: Summer Low Flow Allocations

	Total Nitrogen *(lb/month)*	**Total Phosphorus *(lb/month)***
Nonpoint Source	1,540	25
Point Source	0	0

Average Annual Allocations:

The average annual nonpoint source nitrogen and phosphorus allocations are represented as estimated year 2000 loads, with a 35% reduction in controllable total nitrogen and total phosphorus loads. The nonpoint source loads that were assumed in the model account for both "natural" and human-induced components. As was discussed in the "Scenario Descriptions" section of this document, the loads were based on year 2000 loading rates from the Chesapeake Bay Model (U.S. EPA, 1996), and 1997 land use.

There are no significant point source discharges of nutrients in the watershed. Consequently, the waste load allocations are set to zero. The nitrogen and phosphorus allocations for the average annual TMDLs are shown in Table 3 below.

Table 3: Average Annual Allocations

	Total Nitrogen *(lb/yr)*	**Total Phosphorus *(lb/yr)***
Nonpoint Source	197,500	13,587
Point Source	0	0

4.7 Margins of Safety

A margin of safety (MOS) is required as part of a TMDL in recognition of many uncertainties in the understanding and simulation of water quality in natural systems. For example, knowledge is incomplete regarding the exact nature and magnitude of pollutant loads from various sources and the specific impacts of those pollutants on the chemical and biological quality of complex, natural water bodies. 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. Following the first approach, the load allocated to the MOS was computed as 5% of the nonpoint source loads for nitrogen and phosphorus for the low flow TMDL. Similarly, a 3% MOS was included in computing the average annual TMDLs.

In addition to these explicit set-aside MOSs, additional safety factors are built into the TMDL development process. Note that the results of the model scenario for the critical low flow case indicate a chlorophyll *a* concentration that is around 50 µg/l. In the absence of other factors, a generally acceptable range of peak chlorophyll *a* concentrations is between 50 and 100 µg/l. For the present TMDLs, MDE has elected to use the more conservative peak concentrations of 50 µg/l. Table 4 presents the margin of safety incorporated in low flow and average flow TMDL.

Another MOS is that the fourth model scenario, for average flow, was run under the assumption of summer temperature and summer solar radiation. When the water is warmer and more sunlight is present, there will be more algal growth and a higher potential for low dissolved oxygen concentrations. The model was also run under steady-state conditions, for 150 days, assuming continuous average flows and loads. It is unlikely that these flows and loads will actually be seen for such an extended period of time during the summer. The higher temperatures and solar radiation are conservative assumptions that represent significant margin of safety.

Table 4: Summer Expected Low Flow and Annual Margins of Safety (MOS)

	Total Nitrogen	Total Phosphorus
MOS Low Flow	81lb/month	2 lb/month
MOS Average Flow	6,108 lb/yr	420 lb/yr

4.8 Summary of Total Maximum Daily Loads

The critical low flow TMDLs, applicable from May 1 – Oct. 31 for the Chicamacomico River follow:

For Nitrogen (*lb/month*):

TMDL	**=**	**LA**	**+**	**WLA**	**+**	**MOS**
1,621	**=**	**1,540**	**+**	**0**	**+**	**81**

For Phosphorus (*lb/month*):

TMDL	**=**	**LA**	**+**	**WLA**	**+**	**MOS**
27	**=**	**25**	**+**	**0**	**+**	**2**

The average annual TMDLs for Chicamacomico River follow:

For Nitrogen (*lb/yr*):

TMDL	=	LA	+	WLA	+	MOS
203,608	=	**197,500**	+	**0**	+	**6,108**

For Phosphorus (*lb/yr*):

TMDL	=	LA	+	WLA	+	MOS
14007	=	**13,587**	+	**0**	+	**420**

Where:

TMDL = Total Maximum Daily Load
LA = Nonpoint Source
MOS = Margin of Safety
WLA = Point Source

Average Daily Loads:

On average, the low flow TMDLs will result in loads of approximately 54 lb/day of nitrogen and 1 lb/day of phosphorus. And, on average the annual TMDLs will result in loads of approximately 558 lb/day of nitrogen and 38 lb/day of phosphorus.

5.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the nitrogen and phosphorus TMDLs will be achieved and maintained. For both TMDLs, Maryland has several well-established programs that will be drawn upon: the Water Quality Improvement Act of 1998 (WQIA), the Clean Water Action Plan (CWAP) framework, and the State's Chesapeake Bay Agreement's Tributary Strategies for Nutrient Reduction. Also, Maryland has adopted procedures to assure that future evaluations are conducted for all TMDLs that are established.

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 nutrient management plans for nitrogen be developed and implemented by 2002, and plans for phosphorus to be done by 2005.

Maryland’s CWAP has been developed in a coordinated manner with the State's 303(d) process. All Category I watersheds identified in Maryland's Unified Watershed Assessment process are totally coincident with the impaired waters list for 1996 and 1998 approved by EPA. The State is giving a high-priority for funding assessment and restoration activities to these watersheds.

In 1983, the states of Maryland, Pennsylvania, and Virginia, the District of Columbia, the Chesapeake Bay commission, and the U.S. EPA joined in a partnership to restore the Chesapeake Bay. In 1987, through the Chesapeake Bay Agreement, Maryland made a commitment to reduce nutrient loads to the Chesapeake Bay. In 1992, the Bay Agreement was amended to include the development and implementation of plans to achieve these nutrient reduction goals. Maryland’s resultant Tributary Strategies for Nutrient Reduction provide a framework that will support the implementation of nonpoint source controls in the Lower Eastern Shore Tributary Strategy Basin, which includes the Chicamacomico River watershed. Maryland is in the forefront of implementing quantifiable nonpoint source controls through the Tributary Strategy efforts. This will help to assure that nutrient control activities are targeted to areas in which nutrient TMDLs have been established.

It is reasonable to expect that non-point source loads can be reduced during low-flow conditions. While the low-flow loads cannot be partitioned specifically into contributing sources, the sources themselves can be identified. These sources include dissolved forms of the impairing substances from groundwater, the effects of agricultural ditching and animals in the stream, and deposition of nutrients and organic matter to the stream bed from higher flow events. When these sources are controlled in combination, it is reasonable to achieve non-point source reductions of the magnitude identified by this TMDL allocation.

Finally, Maryland uses 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 every five years intensive follow-up monitoring will be performed. Thus, the watershed cycling strategy establishes a TMDL evaluation process that assures accountability.

REFERENCES

Ambrose, Robert B., Tim A. Wool, James A. Martin. "The Water Quality Analysis Simulation Program, Wasp5.1". Environmental Research Laboratory, Office Of Research And Development, U.S. Environmental Protection Agency. 1993.

Code of Maryland Regulations, 26.08.02.

Di Toro, D.M., J.J. Fitzpatrick, and R.V. Thomann "Documentation for Water Quality Analysis Simulation Program (WASP) and Model Verification Program (MVP)." EPA/600/3-81-044. 1983.

Thomann, Robert V., John A. Mueller "Principles of Surface Water Quality Modeling and Control, " HarperCollins Publisher Inc., New York, 1987.

U.S. EPA, "Technical Guidance Manual for Developing Total Maximum Daily Loads, Book2: Streams and Rivers, Part 1: Biochemical Oxygen Demand/ Dissolved Oxygen and Nutrients/ Eutrophication," Office of Water, Washington D.C., March 1997.

U.S. EPA Chesapeake Bay Program, "Chesapeake Bay Program: Watershed Model Application to Calculate Bay Nutrient Loadings: Final Findings and Recommendations," and Appendices, 1996.

APPENDIX