Total Maximum Daily Loads of Nitrogen and Phosphorus for the Wicomico Creek Wicomico and Somerset Counties, Maryland

Prepared by:

Maryland Department of the Environment
2500 Broening Highway
Baltimore, MD 21224

Submitted to:

Watershed Protection Division
U.S. Environmental Protection Agency, Region III

1650 Arch Street
Philadelphia, PA 19103-2029

EPA Submittal: December 11, 2000
EPA Approval: January 29, 2001

Table of Contents

List of Figures

List of Tables

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
WCEM	Wicomico Creek Eutrophication Model
CWA	Clean Water Act
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
EUTRO5.1	Eutrophication Module of WASP5.1
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
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
WLA	Waste Load Allocation
WQLS	Water Quality Limited Segment

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.

Wicomico Creek 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 Wicomico Creek: 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 control measures needed to restore water quality in Wicomico Creek.

EXECUTIVE SUMMARY

This document proposes to establish Total Maximum Daily Loads (TMDLs) for nitrogen and phosphorus in Wicomico Creek. Wicomico Creek ultimately drains to the Chesapeake Bay through Wicomico River and is a part of the Lower Eastern Shore Tributary Strategy Basin. The creek 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 Wicomico Creek will be met. The TMDL was determined using the WASP5.1 water quality model. Maximum loads for total nitrogen and total phosphorus entering Wicomico Creek 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 1,017 lb/month, and the low flow TMDL for phosphorus is 38 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. Allowable loads have been allocated to nonpoint sources only considering an appropriate margin of safety because the watershed contains no permitted point sources to which allocations can be made.

The average annual TMDL for nitrogen is 104,584 lb/yr, and the average annual TMDL for phosphorus is 6,008 lb/yr. 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 land use acreages. The watershed contains no permitted point sources to which allocations can be made. Therefore, allowable loads have been allocated to nonpoint sources only considering an appropriate margin of safety.

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.

Wicomico Creek was first identified on the 1996 303(d) list submitted to EPA by the Maryland Department of the Environment. It was listed 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 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 the nutrients nitrogen and phosphorus in Wicomico Creek.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

Wicomico Creek is located within Somerset and Wicomico Counties, Maryland and is bisected by the counties' border (Figure 1). Its headwaters originate at the impoundment spillage of Allen Pond, which is fed by Passerby Creek and Barkley Branch. It finally drains to the Chesapeake Bay through the Wicomico River. The creek is approximately seven miles (11.2 km) in length. The Wicomico Creek watershed has an area of approximately 19,961 acres (31.2 sq. miles). The land uses in the watershed consist of forest and other herbaceous (12,495 acres or 62.6%), mixed agriculture (5,840 acres or 29.3%), water (413 acres or 2.1%), and urban (1,214 acres or 6.1%), based on 1997 Maryland Office of Planning land use/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.

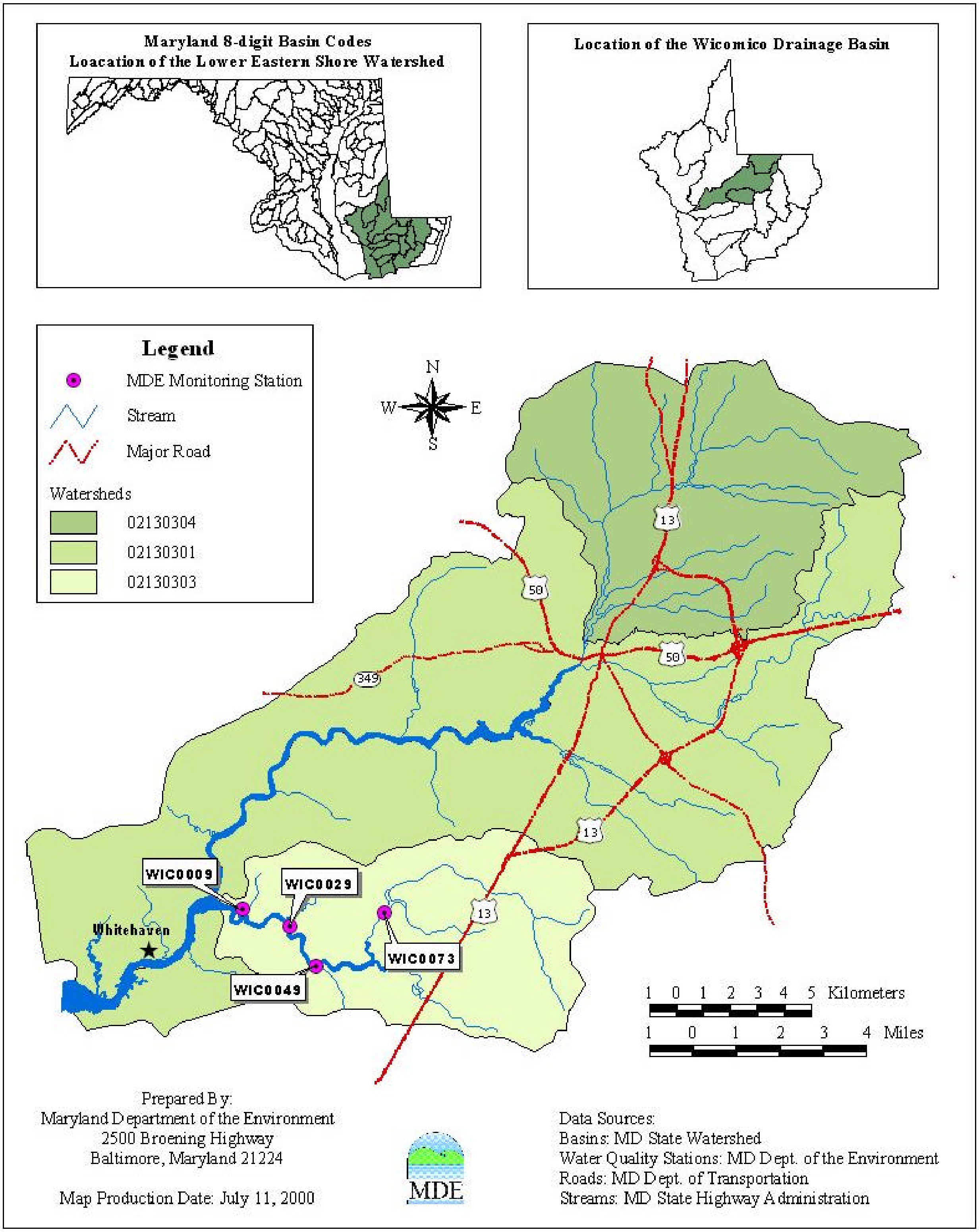

Figure 1: Location Map of the Wicomico Creek Drainage Basin within Maryland

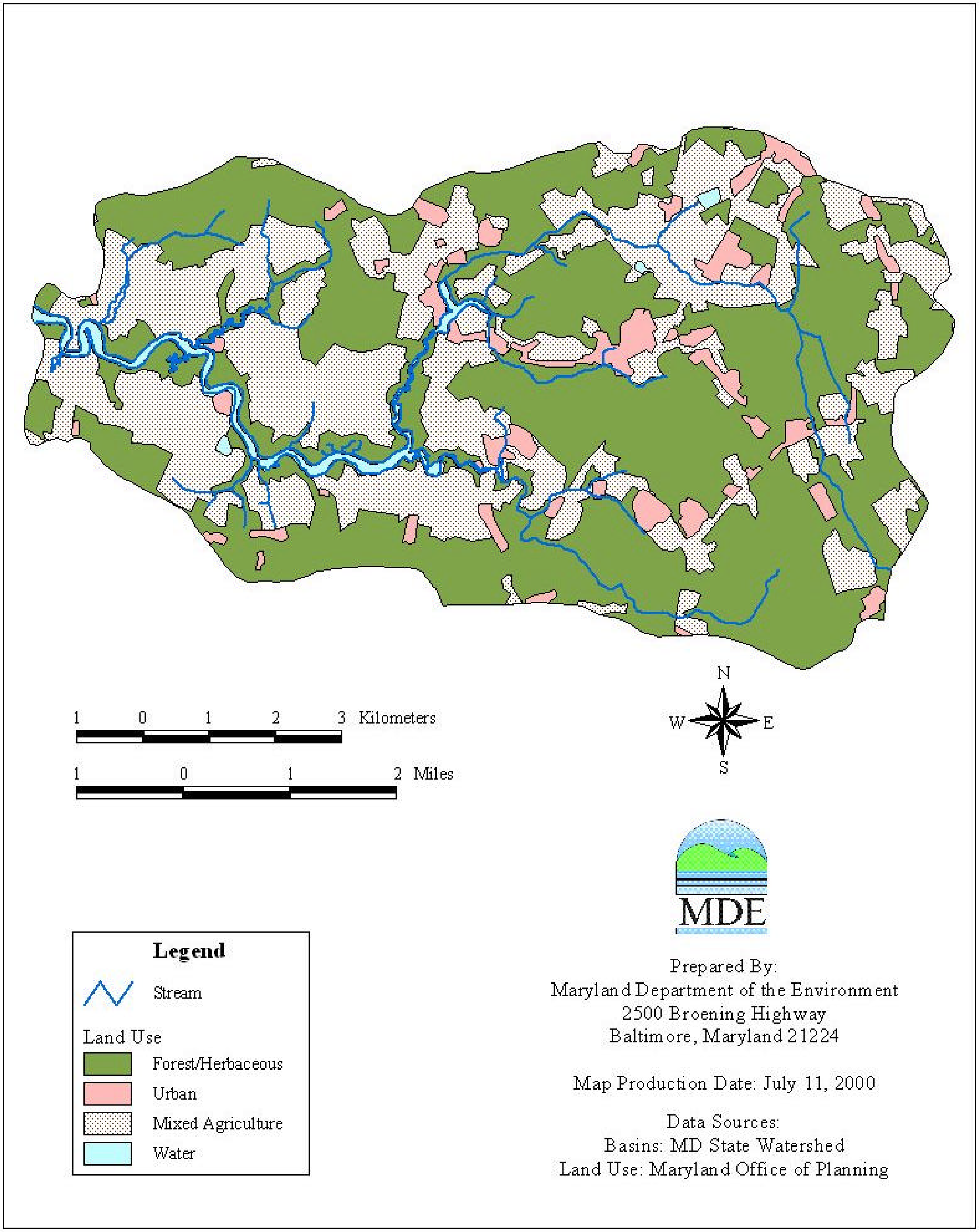

Figure 2: Predominant Land Use in the Wicomico Creek Drainage Basin

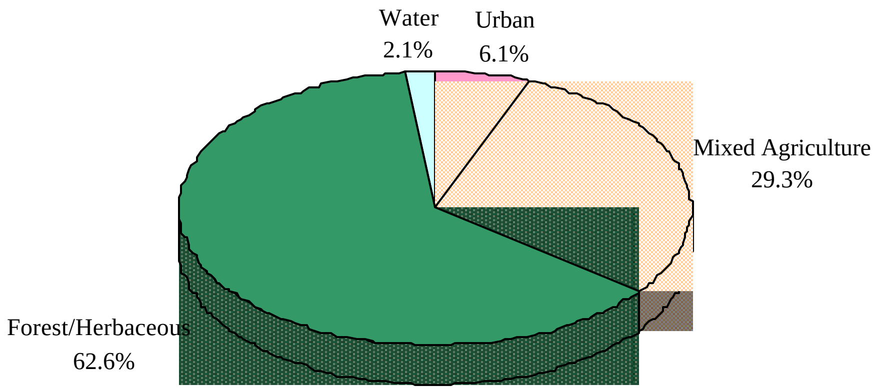

Figure 3: Proportions of Land Use in the Wicomico Creek Drainage Basin

Wicomico Creek is tidal throughout its navigable reach, which extends from the confluence with Wicomico River approximately seven miles upstream to the impound spillage of Allen Pond. The pond serves as the head of tide of the creek, which is free flowing upstream of Allen Pond and tidal downstream of the pond impoundment. The creek experiences limited tidal flushing, which causes higher rates of sediment deposition that elevates the bottom of the creek and thereby decreases its volume capacity. The depth of the creek ranges from about six inches (0.14 m) at the headwaters to greater than 26 feet (6.9 m) at the confluence of Wicomico Creek and Lower Wicomico River.

The watershed supports a high density of mixed agriculture, including beef cattle and poultry operations in its upper region. Many of the row crops in the Wicomico Creek basin receive poultry waste as fertilizer. The upstream area of the basin also has numerous ditches, which are used to drain agricultural land.

In the Wicomico Creek watershed, the estimated total nitrogen load is 131,438 lb/yr, and the total phosphorus load is 8,207 lb/yr. The percentages of the various land uses contributing to these loads are shown in Figure 4. These figures represent loads from nonpoint sources only. There are no permitted point sources in the 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 of 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 Chesapeake Bay loading rates represent edge-of-stream loads for the year 2000 assuming Best Management Practice (BMP) implementation at levels consistent with current progress and account for atmospheric deposition, and loads from septic tanks, urban development, agriculture, and forestland.

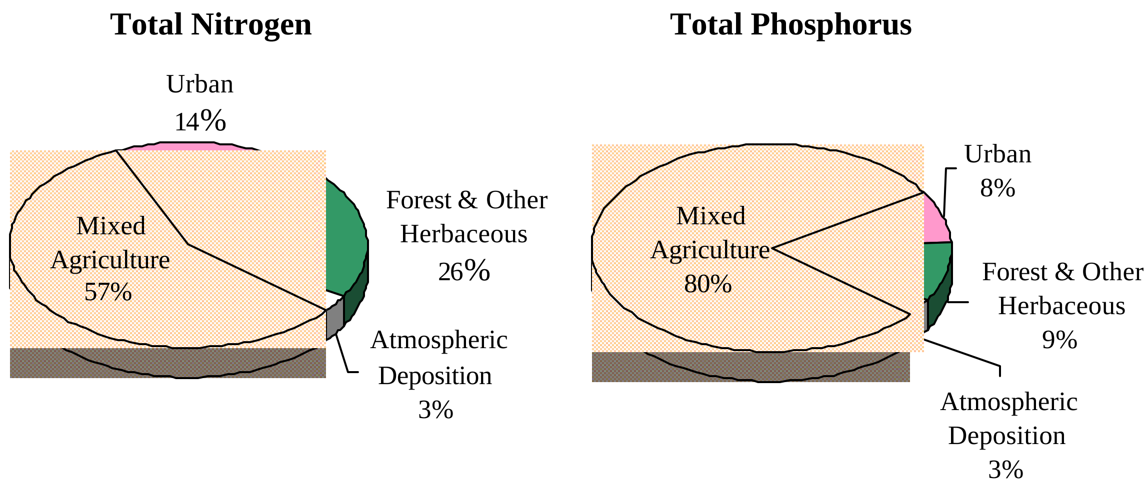

Figure 4: Percentages of Average Annual Nitrogen and Phosphorus Nonpoint Source Loads

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 Wicomico Creek during 1998. Three sets of samples were collected during seasonal low flow periods in summer (28-July-98, 24-Aug-98, 22-Sep-98), and three high flow periods in winter (18-Feb-98, 11-Mar-98, 01-April-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.

Table 1: Location of Water Quality Stations

Water Quality Station	Miles from the Mouth of the Wicomico River
WIC0009	1.10
WIC0029	2.10
WIC0049	4.09
WIC0073	6.09

Problems associated with eutrophication are most likely to occur during the summer season (July, August, and 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, March, and April) 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 period, 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 covers the entire tidal portion of Wicomico Creek from its confluence with Wicomico River (one mile below Station WIC0009) up to the discharge from Allen Pond (Station WIC0073). Figure 5 shows that ambient chlorophyll *a* concentrations in the summer increase downstream of Allen Pond. Concentrations reach their maximum at the 4.1 mile mark, then taper off towards the mouth of the creek. At the 4.1 mile mark concentrations exceed 50 µg/l, with a maximum concentration of about 75 µg/l.

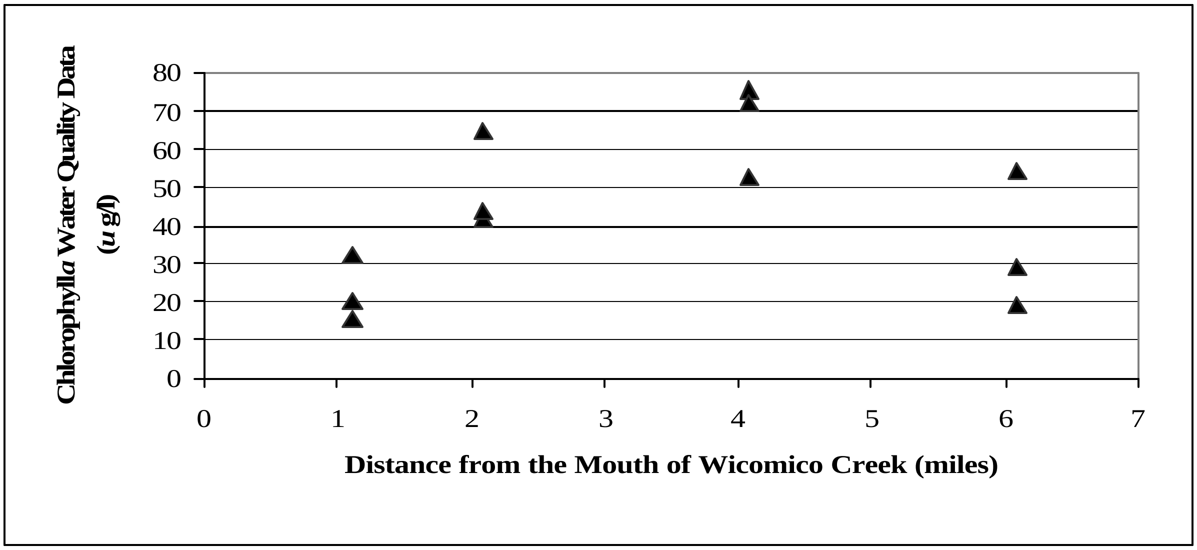

Figure 5: Longitudinal Profile of Chlorophyll *a* Data (Low Flow)

A similar longitudinal profile for dissolved oxygen (DO) concentrations is depicted in Figure 6. With the exception of one low value just below Allen Pond, the data show a general downward trend in concentrations as the water flows down towards the mouth of the creek. The DO levels occasionally fall below the water quality criterion of 5.0 mg/l.

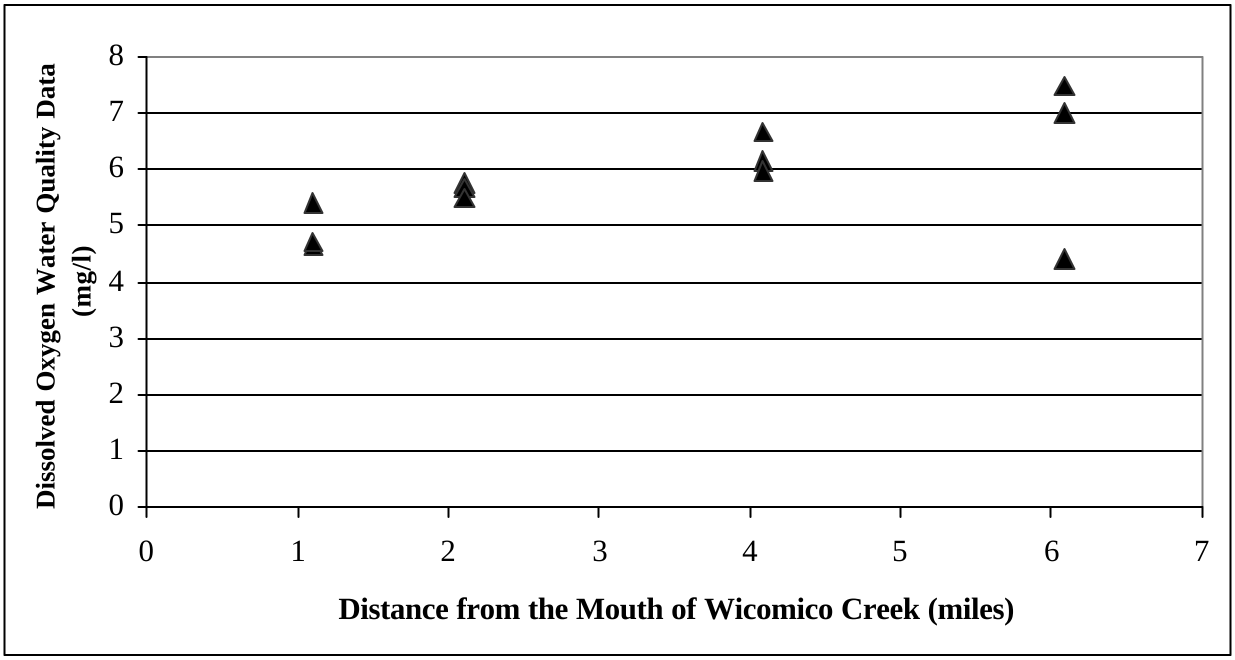

Figure 6: Longitudinal Profile of Dissolved Oxygen Data (Low Flow)

Figure 7 presents a longitudinal profile of dissolved inorganic nitrogen (DIN) levels measured in the samples collected in 1998 during low flow conditions. The levels are generally below 0.04 mg/l throughout the stream system with several observations around 0.1 mg/l. The “U shape” of the profile is consistent with the slightly “mound-shaped” chlorophyll *a* profile, suggesting that the consumption of DIN support the growth of algae.

Figure 8 presents a longitudinal profile of dissolved inorganic phosphorus (DIP) as indicated by ortho-phosphate levels measured in samples collected in 1998, during low flow conditions. All values fall in the range between 0.015 to 0.027 mg/l. Again, as in the DIN profile, the “U-shape” of the profile is consistent with the slightly “mound-shaped” chlorophyll *a* profile, suggesting that the consumption of DIP supports the growth of algae.

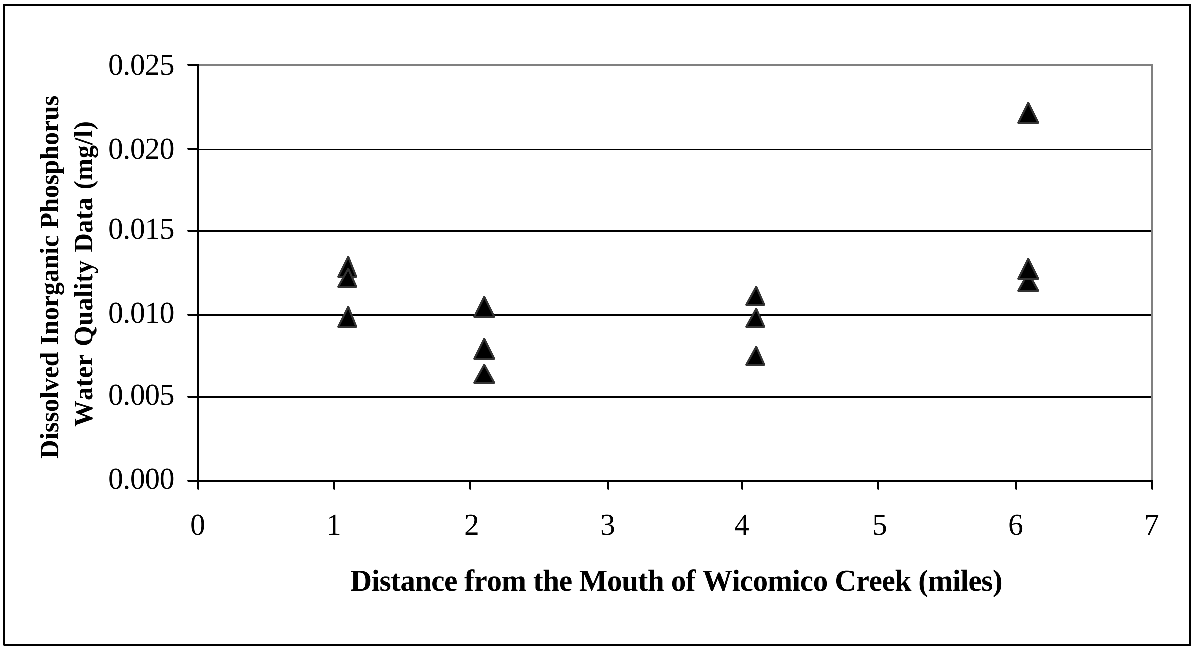

Figure 7: Longitudinal Profile of Dissolved Inorganic Nitrogen Data (Low Flow)

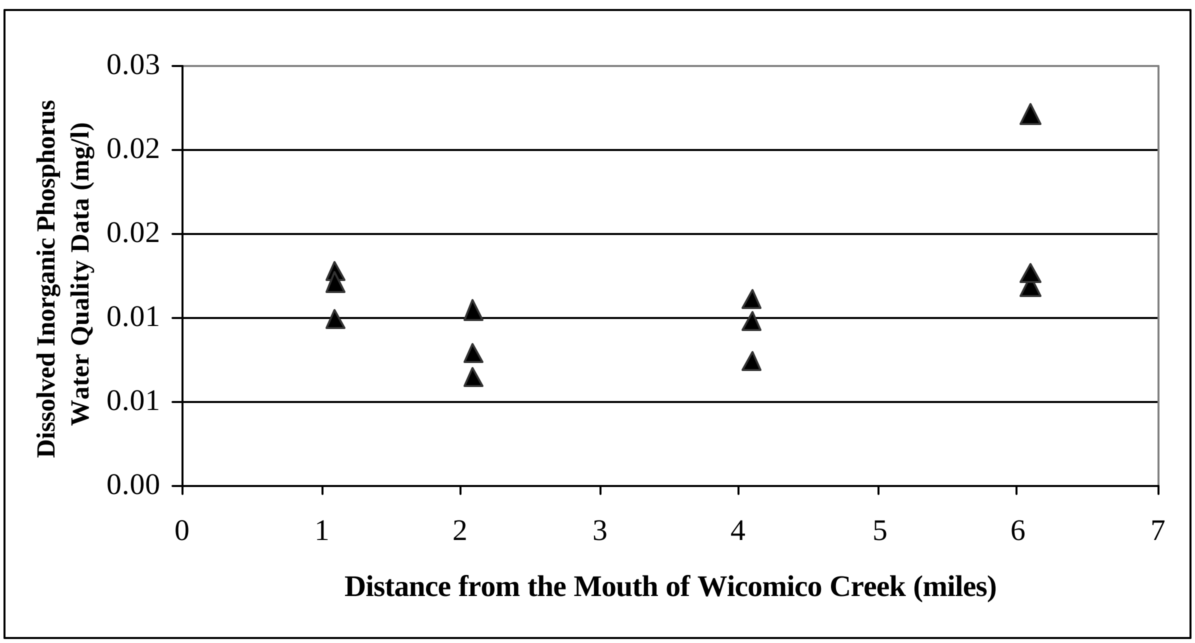

Figure 8: Longitudinal Profile of Dissolved Inorganic Phosphorus Data (Low Flow)

2.3 Water Quality Impairment

The water quality impairment of Wicomico Creek addressed by these TMDLs consists of violations of the applicable numeric dissolved oxygen (DO) criterion and general water quality criteria.

Wicomico Creek, as a tributary of the Wicomico River above the ferry crossing at Whitehaven, has been designated as a Use I water body, pursuant to which it is protected for water contact recreation, fishing, aquatic life and wildlife. See COMAR 26.08.02.07. Use I waters are subject to a DO criterion of not less than 5 mg/l at any time (COMAR 26.08.02.03A(2)). The dissolved oxygen concentration in the upper and lower reaches of Wicomico Creek occasionally falls below the criterion of 5.0 mg/l.

Maryland's General Water Quality Criteria prohibit pollution of waters of the State by any material in amounts sufficient to create a nuisance or interfere directly or indirectly with designated uses. See COMAR 26.08.02.03B(2). Excessive eutrophication, indicated by elevated levels of chlorophyll *a*, can produce nuisance levels of algae and interfere with designated uses such as fishing and swimming. The chlorophyll *a* concentration in the upper reaches of Wicomico Creek range between 50 and 75 μg/l. These levels have been associated with excessive eutrophication.

Violations of the dissolved oxygen and general water quality standards in Wicomico Creek are the result of over-enrichment by the nutrients nitrogen and phosphorus.

3.0 TARGETED WATER QUALITY GOAL

The objective of the nitrogen and phosphorus TMDLs established in this document is to assure that the dissolved oxygen levels support the Use I designation for Wicomico Creek and to control nuisance algal blooms. Specifically, the TMDLs for nitrogen and phosphorus for Wicomico Creek are intended to assure that a minimum dissolved oxygen level of 5.0 mg/l is maintained throughout the Wicomico Creek system and to reduce peak chlorophyll *a* levels (a surrogate for algal blooms) to below 50 μg/l. The dissolved oxygen level is based on specific numeric criteria for Use I waters set forth in the Code of Maryland Regulations 28.08.02. The chlorophyll *a* water quality level is based on the designated use of the Wicomico Creek and guidelines set forth by Thomann and Mueller (1987) and by the EPA *Technical Guidance Manual for Developing Total Maximum Daily Loads, Book 2, Part* (1997). These guidelines acknowledge that it is acceptable to maintain chlorophyll *a* levels below a maximum of 100 μg/l, with a goal of less than 50 μg/l.

4.0 TOTAL MAXIMUM DAILY LOADS AND ALLOCATION

4.1 Overview

This section describes how the nutrient TMDLs and load allocations were developed for Wicomico Creek. 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 Wicomico Creek 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 WASP5.1 model was implemented in a steady-state mode. This mode of using WASP5.1 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 WASP5.1 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 Wicomico Creek Eutrophication Model (WCEM) extends from the confluence of Wicomico Creek with Wicomico River for about seven miles up to the discharge of Allen Pond. Seven WASP5.1 model segments represent this modeling domain. Concentrations of relevant water quality parameters, observed in 1998 coming from Allen Pond, serve as the model's upstream boundary. A diagram of the WASP5.1 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 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 stream flow used in the critical low flow analysis was based on data from three USGS gages near the Wicomico Creek basin. Flow was estimated by averaging 1998 summer low flow data from these three gages and computing a flow to area ratio that was then multiplied by the area of each subwatershed. The average stream flow was estimated using a similar methodology based on the same three USGS gages by averaging 1984 to 1987 annual flow data. This time period was selected because the average load calculation was based on the Chesapeake Bay Program Watershed Model, which was run using precipitation from the period of 1984 to 1987. The methods used to estimate stream flows are described further in Appendix A.

Nonpoint source (NPS) loads were derived from the concentrations observed during low flow sampling in 1998 multiplied by the estimated critical low flows. The low flow loading estimations are based on observed data and thus 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 plus nitrite (NO_{23}), 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 Wicomico Creek.

4.3 Scenario Descriptions

The WASP5.1 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 the 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 creek. The method of estimating the critical low flow is described in Appendix A. The scenario simulates a critical condition when the creek 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 the low flow conditions of July, August and September of 1998. The low flow NPS loads were computed as the 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, and loads stemming from septic tanks, urban development, agriculture, and forestland, that generate base flow during low flow conditions.

Second Scenario: The second scenario provides an estimate of water quality conditions for average annual loads and flows, which serve as the base-line from which the average annual TMDL is computed (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, like 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 stream flow was estimated by averaging data from three USGS stream gages for the period 1984 to 1987. This period was chosen to be consistent with the hydrologic period used by the Chesapeake Bay Program Watershed Model. The methods used to estimate stream flows are described further in Appendix A.

The 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. The land use information was based on 1997 Maryland Office of Planning land use/land cover data and adjusted using 1997 FSA crop acre data. The loading coefficients were based on the results of the Chesapeake Bay Model (U.S. EPA, 1996), a continuous simulation model. The Chesapeake Bay loading rates represent edge-of-stream loads, for the year 2000 assuming Best Management Practice (BMP) implementation at levels consistent with current progress, and account for atmospheric deposition, and loads from septic tanks, urban development, agriculture, and forestland.

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.

The scenario simulates a condition when the creek system is poorly flushed due to low flows and when 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.

This scenario simulates an estimated 30% reduction in controllable NPS loads of nitrogen and phosphorus in subwatershed three and four of the Wicomico Creek basin. This scenario accounts for a margin of safety computed as 5% of the NPS load allocation. In this future condition scenario, reductions in sediment nutrient fluxes and sediment oxygen demand (SOD) were estimated based on the percentage reduction of organic matter available to settle to the bottom, which was computed as a function of the nutrient reductions. Further discussion is provided in Appendix A.

Fourth Scenario: The fourth scenario provides an estimate of future conditions of maximum allowable average annual loads. The scenario uses an average annual stream flow as in Scenario 2. The 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, like 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.

This scenario simulates an estimated 35% reduction in controllable NPS loads of nitrogen and phosphorus in subwatersheds one, two, four, and five and a 55% reduction in controllable NPS loads of nitrogen and phosphorus in subwatershed three of the Wicomico Creek watershed. A 3% margin of safety was also included for the nonpoint source load calculation. Reductions in nutrient sediment fluxes and sediment oxygen demand (SOD) were estimated based on the percentage reduction of organic matter settling to the bottom, computed as a function of the nutrient reduction. Details of nonpoint source load reductions are described further in the technical memorandum entitled "*Significant Nutrient Nonpoint Sources in the Wicomico Creek Watershed*". Further discussion of this scenario is provided in Appendix A.

4.4 Scenario Results

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

Base-line Loading 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 annual stream flow conditions, with base-line annual nonpoint source loads computed on the basis of 1997 land use and year 2000 loading rates (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 above the desired goal of 50 µg/l, reaching a peak value of about 57 µg/l. DO concentrations are not expected to fall below the minimum water quality criterion of 5.0 mg/l at the headwaters but are very close to the criterion near the confluence with Wicomico River.

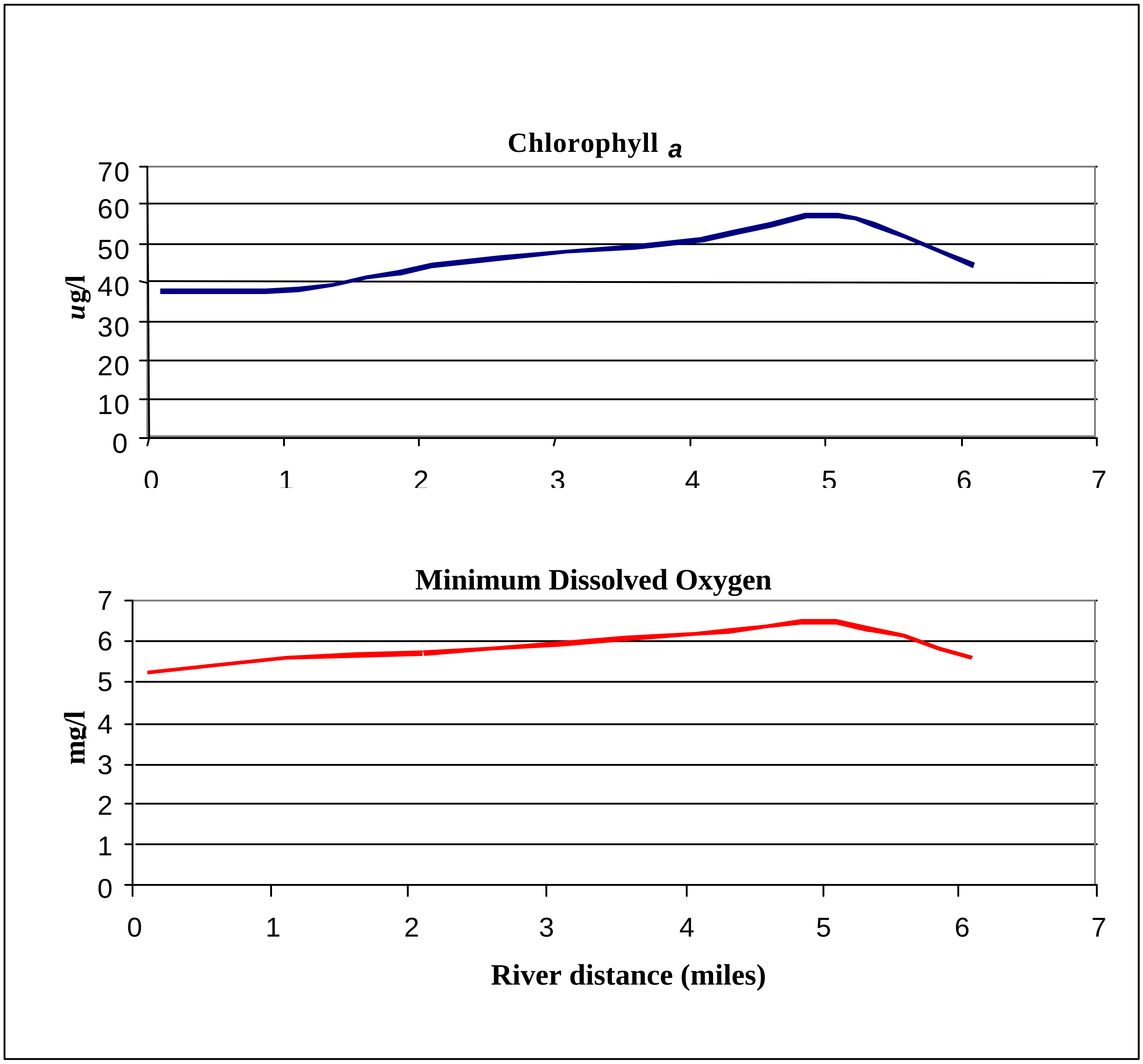

Figure 9: Model Results for the Low Flow Baseline Scenario for Chlorophyll *a* and Dissolved Oxygen (Scenario 1)

Results for the second scenario, representing the base-line condition for the average stream flow and average loads, are summarized in Figure 10. Under these conditions, the chlorophyll *a* concentrations are also above the desired goal of 50 µg/l and DO concentrations remain above 5.0 mg/l throughout the length of the creek.

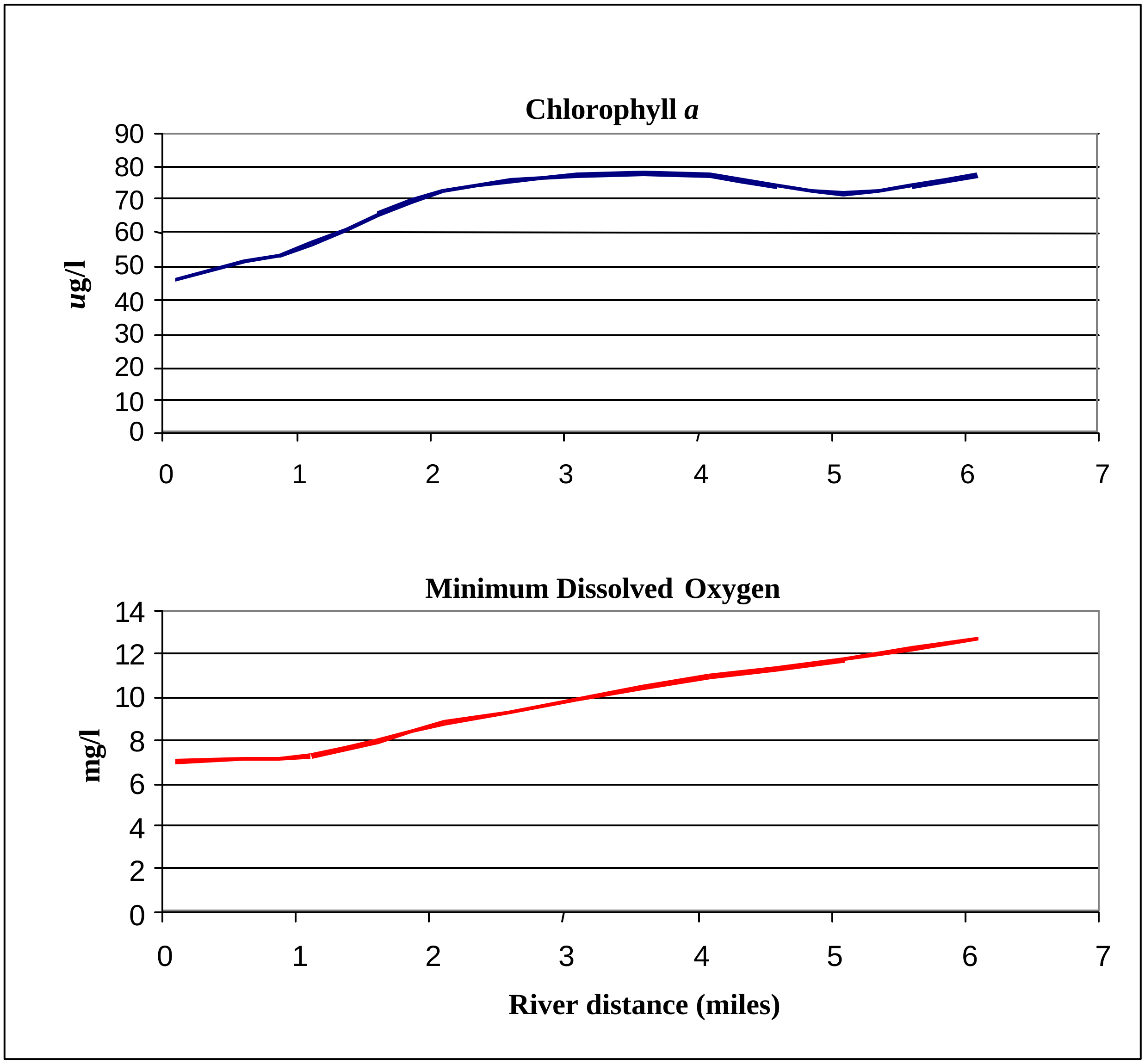

Figure 10: Model Results for the Average Flow Baseline Scenario for Chlorophyll *a* and Dissolved Oxygen (Scenario 2)

<u>Future Condition Scenarios:</u>

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 annual loads under average annual stream flow and loading conditions.

Results for the third scenario (dotted line), representing the maximum allowable loads for summer 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 below 50 µg/l along the entire length of Wicomico Creek. For dissolved oxygen (DO), the comparison shows that the DO along the length of the creek remains above the water quality criterion of 5.0 mg/l for both scenarios.

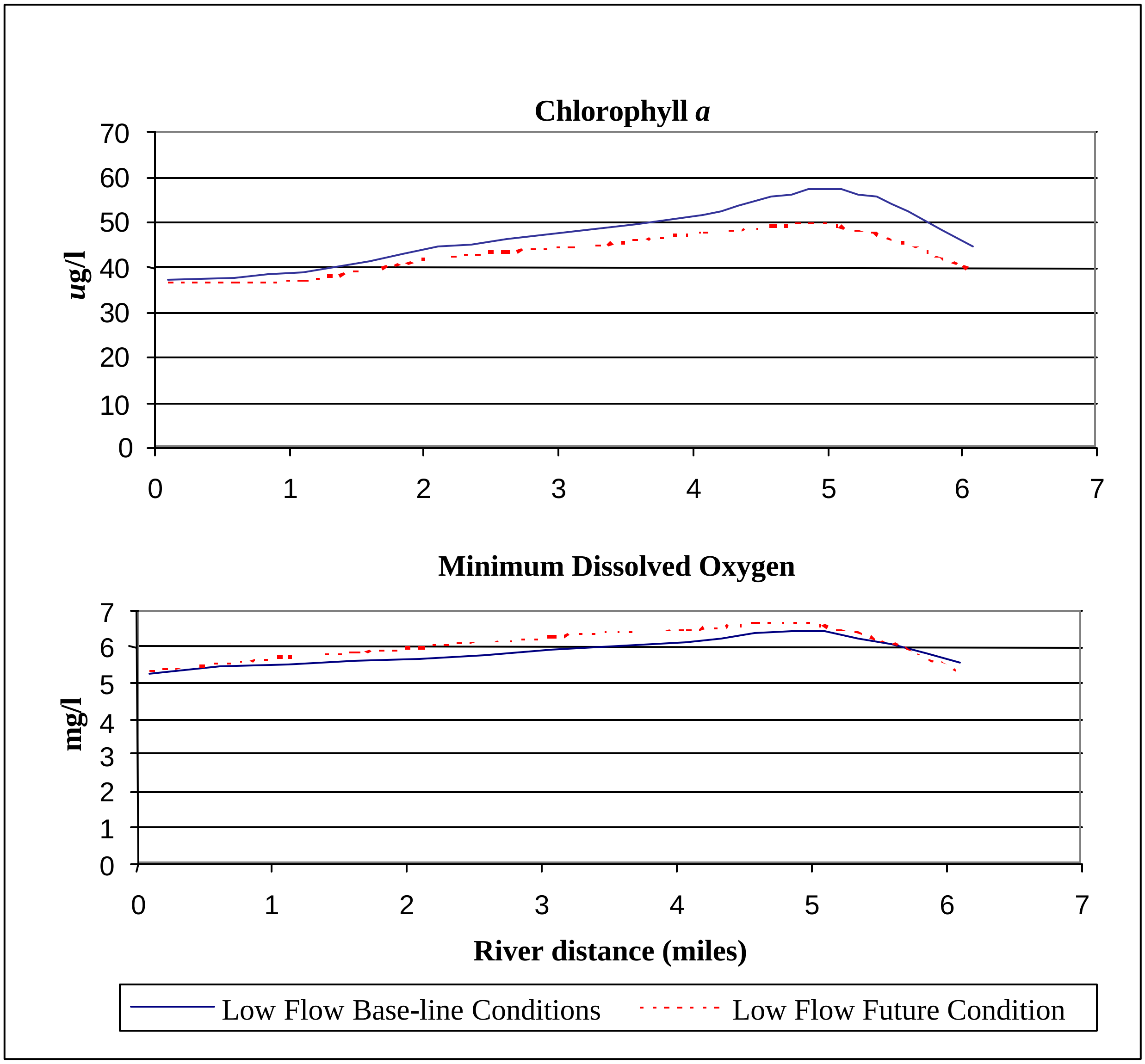

Figure 11: Model Results for the Low Flow Future Condition Scenario for Chlorophyll *a* and Dissolved Oxygen (Scenario 3)

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 below 50 µg/l along the entire length of Wicomico Creek. For dissolved oxygen (DO), the comparison shows that the DO along the length of the creek remains above the water quality criterion of 5.0 mg/l for both scenarios.

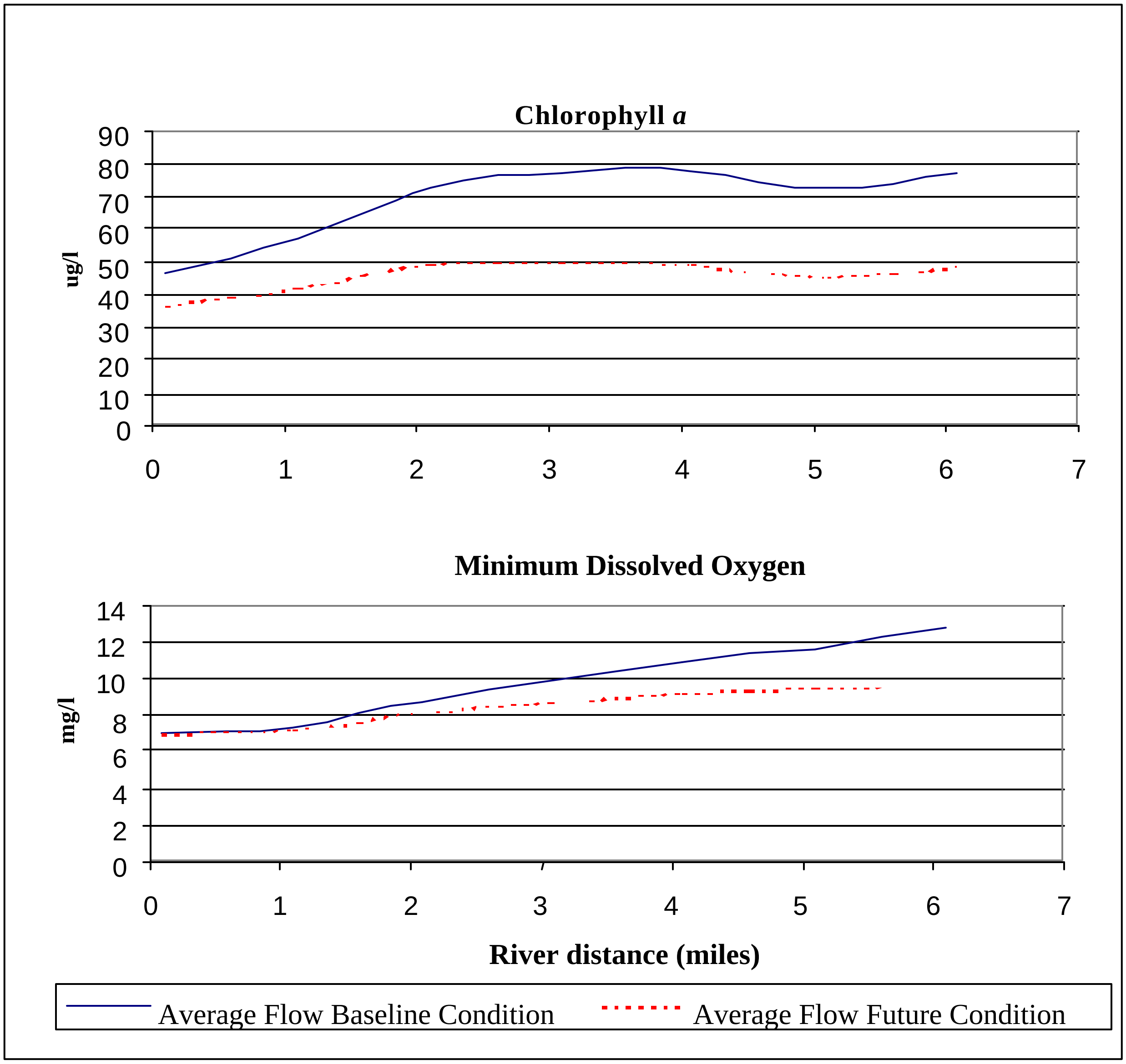

Figure 12: Model Results for the Average Flow Future Condition Scenario for Chlorophyll *a* and Dissolved Oxygen (Scenario 4)

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 low flow TMDL and average annual TMDL. The critical season for excessive algal growth in Wicomico Creek is during the summer months, when the creek 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 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 TMDLs:

NITROGEN TMDL 1,017 *lb/month*

PHOSPHORUS TMDL 38 *lb/month*

The average annual TMDLs for nitrogen and phosphorous are:

Average Annual TMDLs:

NITROGEN TMDL 104,584 *lb/year*

PHOSPHORUS TMDL 6,008 *lb/year*

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).

4.6 Load Allocations between Point Sources and Nonpoint Sources

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

Low Flow Allocations:

The nonpoint source loads of nitrogen and phosphorus simulated in the third scenario represent reductions from the base-line scenario. Recall that the base-line 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 permitted 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	1,017	38
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 nitrogen and phosphorus NPS loads in subwatersheds one, two, four and five and a 55% reduction in controllable NPS loads in subwatershed three of the Wicomico Creek watershed. 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 permitted 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.

Table 3: Average Annual Allocations

	Total Nitrogen *(lb/yr)*	**Total Phosphorus *(lb/yr)***
Nonpoint Source	104,584	6,008
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. These explicit nitrogen and phosphorus margins of safety are summarized in Table 4.

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

	Total Nitrogen	Total Phosphorus
MOS Low Flow	48 lb/month	2 lb/month
MOS Average Flow	3,046 lb/yr	175 lb/yr

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.

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 300 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 a significant margin of safety.

4.8 Summary of Total Maximum Daily Loads

The critical low flow TMDLs, applicable from May 1 – Oct. 31, for Wicomico Creek follow:

For Nitrogen (*lb/month*):

TMDL	=	LA	+	WLA	+	MOS
1,017	=	969	+	0	+	48

For Phosphorus (*lb/month*):

TMDL	=	LA	+	WLA	+	MOS
38	**=**	**36**	**+**	**0**	**+**	**2**

The average annual TMDLs for Wicomico Creek follow:

For Nitrogen (*lb/yr*):

TMDL	=	LA	+	WLA	+	MOS
104,584	**=**	**101,538**	**+**	**0**	**+**	**3,046**

For Phosphorus (*lb/yr*):

TMDL	=	LA	+	WLA	+	MOS
6,008	**=**	**5,833**	**+**	**0**	**+**	**175**

Where:

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

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), and the EPA-sponsored Clean Water Action Plan of 1998 (CWAP), 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 these nutrient management plans be developed and implemented by 2004. Maryland's CWAP has been developed in a coordinated manner with the State's 303(d) process. All Category I waters 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 has given a higher 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 Eastern Shore Tributary Strategy Basin, which includes Wicomico Creek 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 nonpoint 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 nonpoint source reductions of the magnitude identified by this TMDL allocation.

Finally, Maryland has recently 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 National Pollutant Discharge Elimination System (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.

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 (WASP5.1) 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, Book 2: 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.