Total Maximum Daily Loads of Nitrogen and Phosphorus for the Bohemia River Cecil County, 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 2000
EPA Approval: January 2001

Table of Contents

List of Figures .... *i*

List of Tables .... *i*

List of Abbreviations .... *ii*

PREFACE .... *iii*

EXECUTIVE SUMMARY .... *iv*

1.0 INTRODUCTION *1*

2.0 SETTING AND WATER QUALITY DESCRIPTION *1*

2.1 General Setting and Source Assessment **1**

2.2 Water Quality Characterization **4**

2.3 Water Quality Impairment **8**

3.0 TARGETED WATER QUALITY GOAL *8*

4.0 TOTAL MAXIMUM DAILY LOADS AND ALLOCATION *9*

4.1 Overview **9**

4.2 Analysis Framework **9**

4.3 Scenario Descriptions **10**

4.4 Scenario Results **11**

4.5 TMDL Loading Caps **13**

4.6 Load Allocations Between Point Sources and Nonpoint Sources **14**

4.7 Margins of Safety **15**

4.8 Summary of Total Maximum Daily Loads **15**

5.0 ASSURANCE OF IMPLEMENTATION *16*

REFERENCES *18*

APPENDIX A *A1*

Report Version: January 16, 2001

List of Figures

Figure 1: Location Map of the Bohemia River Drainage Basin within Maryland 2
Figure 2: Predominant Land Use in the Bohemia River Drainage Basin.......................................3
Figure 3: Proportions of Land Use in the Bohemia River Drainage Basin....................................4
Figure 4: Longitudinal Profile of Chlorophyll *a* Data (Low flow)...6
Figure 5: Longitudinal Profile of Dissolved Oxygen Data (Low flow)..6
Figure 6: Longitudinal Profile of Dissolved Inorganic Nitrogen Data (Low flow)........................7
Figure 7: Longitudinal Profile of Dissolved Inorganic Phosphorus Data (Low flow)...................7
Figure 8: Model Results for the Base-line Low Flow Scenario for Chlorophyll *a* and Dissolved Oxygen (Scenario 1) 12
Figure 9: Model Results for the Future Low Flow Scenario for Chlorophyll *a* and Dissolved Oxygen (Scenario 2) 13

List of Tables

Table 1: Location of Water Quality Stations 5
Table 2: Summer Low Flow Allocations..14
Table 3: Summer Expected Low Flow Margins of Safety (MOS) 15

List of Abbreviations

BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
BREM	Bohemia River Eutrophication Model
CBOD	Carbonaceous Biochemical Oxygen Demand
CEAM	Center for Exposure Assessment Modeling
CHL*a*	Active Chlorophyll
CWA	Clean Water Act
DE	Delaware
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphorus
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
EUTRO5.1	Eutrophication Module of WASP5.1
FA	Future Allocation
INPRG	Input Program/Based on Streeter Phelps equation
LA	Load Allocation
MDA	Maryland Department of Agriculture
MDE	Maryland Department of the Environment
MD	Maryland
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 Bohemia 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 Bohemia 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 control measures needed to restore water quality in the Bohemia River.

EXECUTIVE SUMMARY

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

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 Bohemia River will be met. The TMDLs for the nutrients nitrogen and phosphorus were determined using the WASP5.1 water quality model. Loading caps for total nitrogen and total phosphorus entering the Bohemia River are established for low flow conditions. Because of outstanding questions regarding the nature of algae production in this water body during cold weather conditions, when stream flows are higher, MDE will consider average annual TMDLs at a later date.

The low flow TMDL for nitrogen is 1,201 lbs/month, and the low flow TMDL for phosphorus is 154 lbs/month. These TMDLs apply during the period May 1 through October 31. The allowable loads have been allocated between point and nonpoint sources. The nonpoint sources are allocated 794 lbs/month of total nitrogen, 49 lbs/month of total phosphorus. The point source is allocated 365 lbs/month of nitrogen, 102 lbs/month of phosphorus. The explicit margins of safety make up the remainder of the nitrogen and phosphorus allocations.

Four factors provide assurance that these TMDLs will be implemented. First, NPDES permits will play a role in assuring implementation. Second, 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. Third, Maryland’s Water Quality Improvement Act of 1999 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 Bohemia River was first identified on the 1996 303(d) list submitted to EPA by the Maryland Department of the Environment (MDE). It was listed as being impaired by nutrients due to signs of eutrophication, expressed as high chlorophyll *a* level. 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 Bohemia River.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

The Bohemia River is mainly located in Cecil County, Maryland (Figure 1), with some small tributaries of the headwaters located in New Castle County, Delaware. It originates west of the Middletown Area and US Rt.301, and finally drains to the Chesapeake Bay through the Big Elk River roughly four miles due south of Town Point. The modeling domain of the River is approximately 10 miles in length, from its confluence with the Big Elk River to the headwaters upstream of Maryland/Delaware state line (See Appendix A, Figure A7). The Bohemia River watershed has an area of approximately 35,544 acres or 55.5 square miles. The land uses in the watershed consist of forest and other herbaceous (7,448 acres or 21 %), mixed agriculture (22,782 acres or 64%), water (3,194 acres or 9%), and urban (2,120 acres or 6.0%) (Maryland landuse is based on based on 1997 Maryland Office of Planning land cover data with crop acres refined using 1997 Farm Service Agency (FSA) data, Delaware landuse is based on 1997 Delaware Office of State Planning Coordination). Figure 2 shows the geographic distribution of the different land uses. Figure 3 shows the relative amounts of the different land uses.

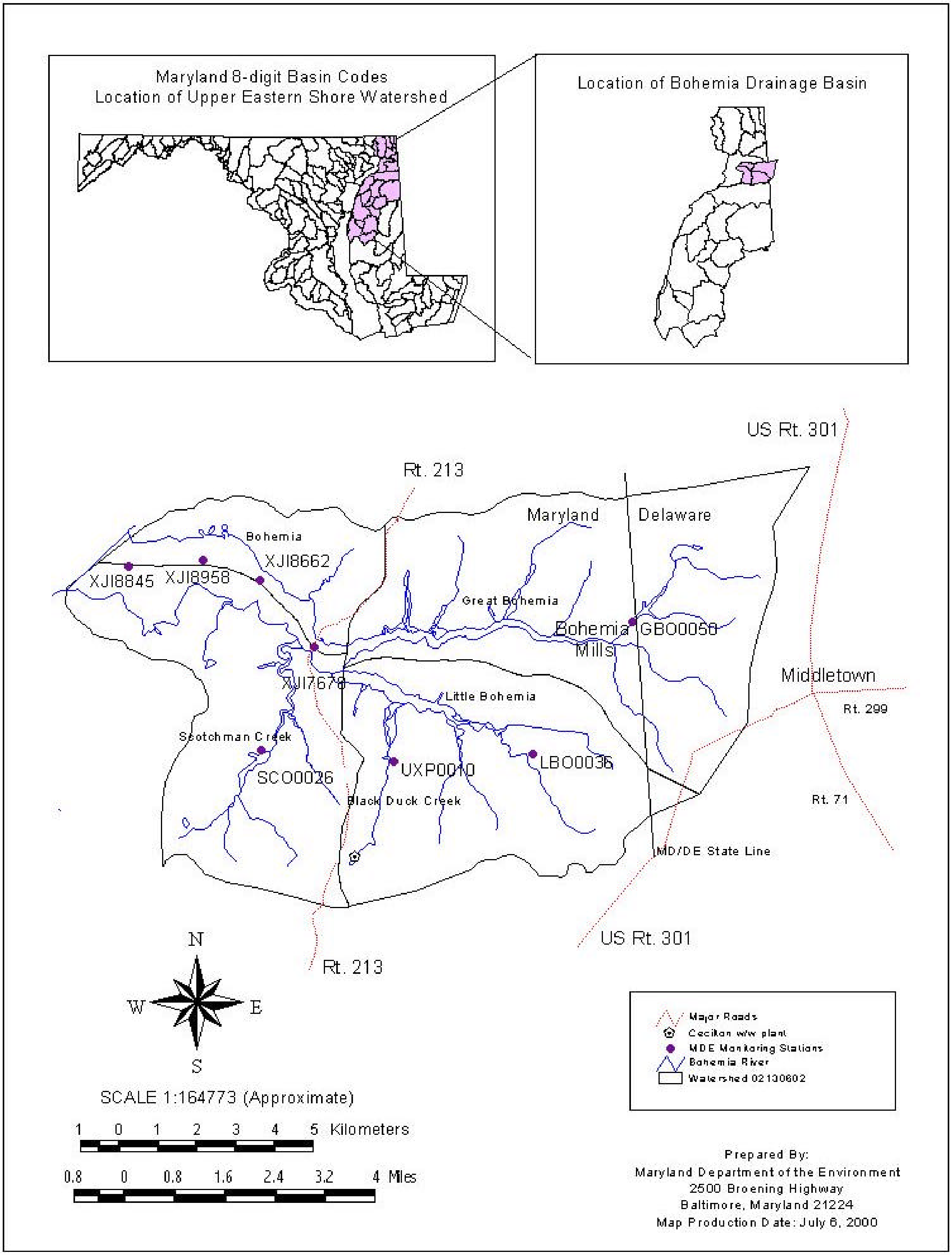

Figure 1: Location Map of the Bohemia River Drainage Basin within Maryland

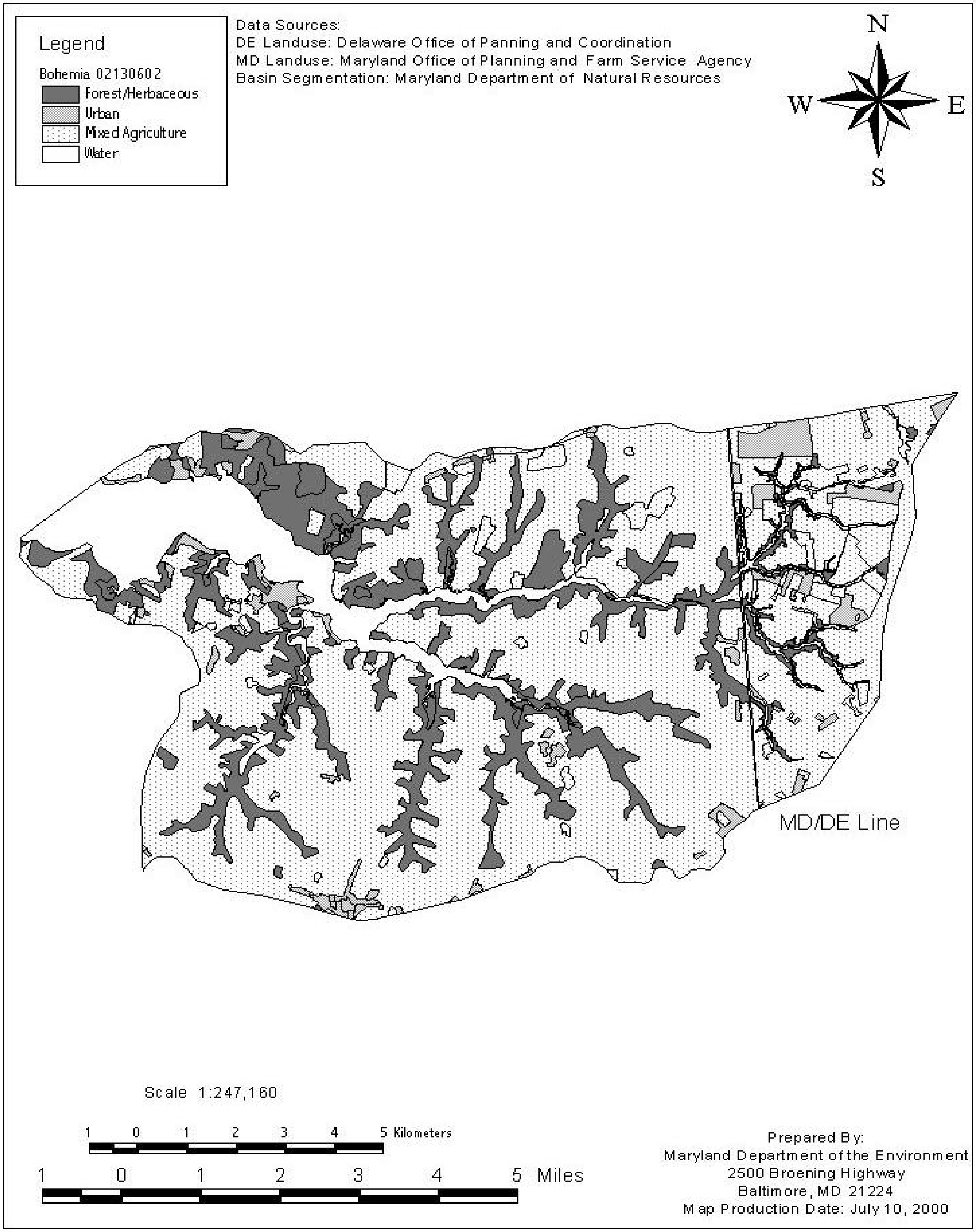

Figure 2: Predominant Land Use in the Bohemia River Drainage Basin

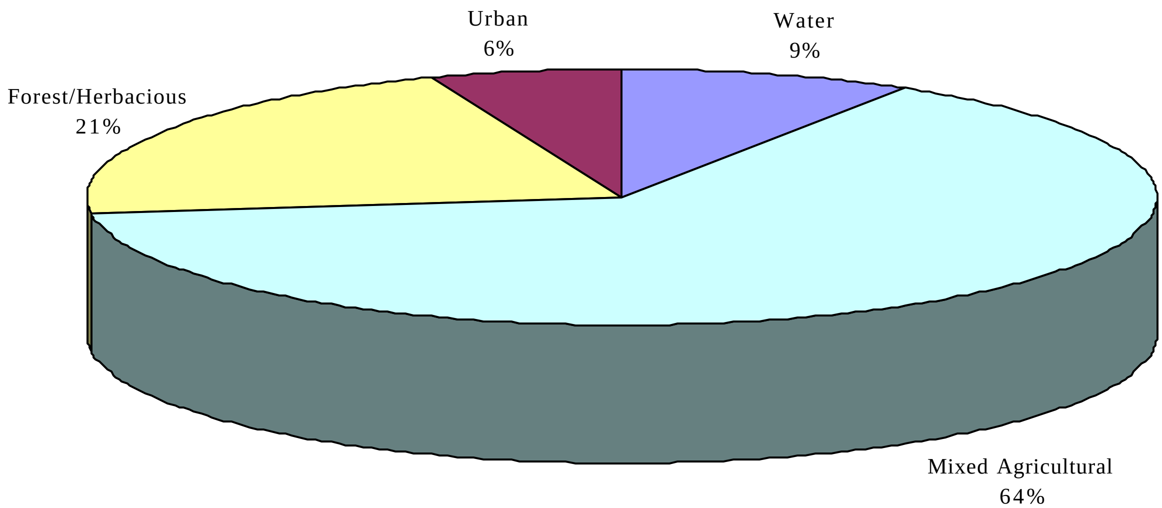

Figure 3: Proportions of Land Use in the Bohemia River Drainage Basin

The Bohemia River is tidal throughout its navigable reach, which extends from the confluence with the Big Elk River to approximately 9 miles upstream to an area known as Bohemia Mills. At about 3.5 miles from the mouth a major branch, called Little Bohemia, joins the Bohemia River, which is called the Great Bohemia upstream of this branch. Depths of the river range from about 6 inches in the headwaters to greater than 5.5 feet at the confluence of Big Elk and Bohemia Rivers.

There is one minor point source, the Cecilton Wastewater Treatment Plant (WWTP), located near the town of Cecilton, contributing nutrient loads to the watershed.

2.2 Water Quality Characterization

Four water quality parameters associated with the observed impairment of the Bohemia River, 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 Bohemia River during 1999. Three sets of samples were collected during seasonal low flow periods in summer (27-July-99, 25-Aug-99, 28-Sep-99), and three high flow periods in winter (24-Mar-99, 20-April-99, 18-May-99). 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 sun light 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. 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 1999, the low flow period. The sampling region extends from near the confluence of the Bohemia River with the Big Elk (Station XJI9438), to within a small pond (GBO0050) at MD/DE State Line. Figure 5 shows that most of the time chlorophyll *a* concentrations in the summer are below the level of 50 μg/l except near the head of the river where the concentrations reach above 50 μg/l. Under critical condition, the chances of exceedance of the threshold value of 50 μg/l could be higher.

A similar longitudinal profile for dissolved oxygen (DO) concentrations is depicted in Figure 6. It shows that the observed DO levels along the whole stretch of the river do not fall below the standard of 5.0 mg/l. The average DO along the river length is greater than 6.0 mg/l.

Figure 6 presents a longitudinal profile of dissolved inorganic nitrogen levels measured in the samples collected in 1999, during low flow conditions. The levels of most samples are below 0.8 mg/l for most of the river stretch with the exceptions of several samples near the mouth of the river, where concentrations are observed to reach values greater than 1.5 mg/l.

Figure 7 presents a longitudinal profile of dissolved inorganic phosphorus as indicated by ortho-phosphate levels measured in samples collected in 1999, during low flow conditions. Half of the observations are below the level of detection (0.01 mg/l). Again concentrations are observed to increase towards the mouth of the river, where they reach a maximum of 0.05 mg/l.

Table 1: Location of Water Quality Stations

Water Quality Station	Miles from the Mouth of Bohemia River	Description
XJI9438	-	At Confluence of Big Elk River and Bohemia River
XJI8845	0.47	Mid-channel, between Town Pt. and Veazey Cove. Depth ~ 5.5 ft.
XJI8958	1.67	Mid-channel, between Battery Pt. and Bohemia Vista Marina. Depth ~ 9 ft.
XJI8662	2.63	At marker R 2 Depth ~ 10 ft.
XJI7678	4.03	Rte 213 bridge. In channel near marina. Depth 24 ft.
GBO0050	9.63	Old Telegraph Road crossing, below pond on Great Bohemia Creek.
SCO0026	-	Road crossing on Frazers Lake Rd., below Mill Pond. (Scotchman Creek)
UXP0010	-	Bridge crossing on Bohemia Church Road. First Stream east of Rt. 213 (Black Duck Creek).
LBO0036	-	Road crossing at Bohemia Church Road. First stream west of Church Rd (Little Bohemia Creek)

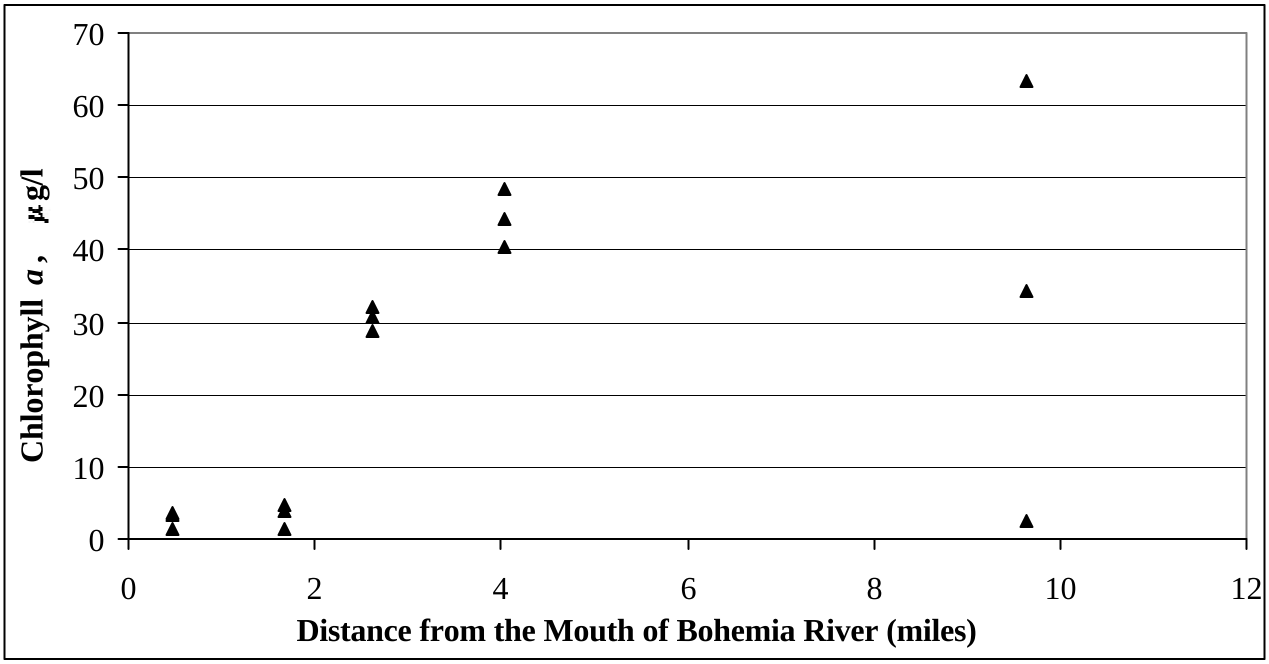

Figure 4: Longitudinal Profile of Chlorophyll *a* Data (Low flow)

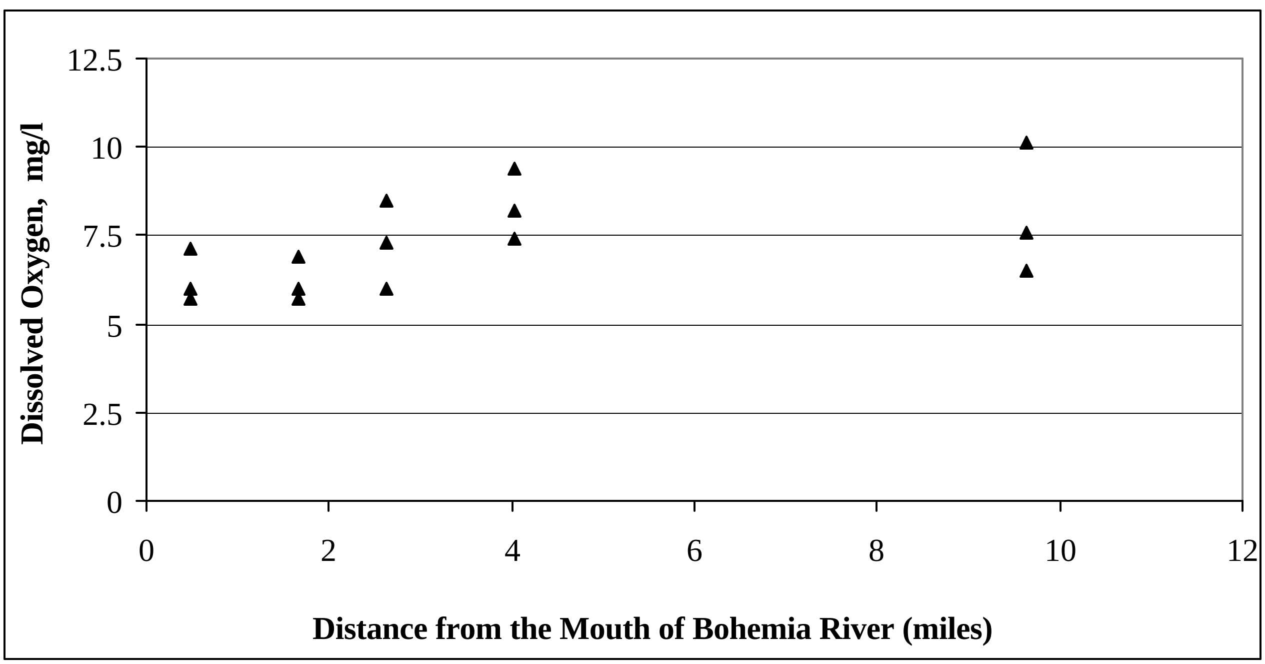

Figure 5: Longitudinal Profile of Dissolved Oxygen Data (Low flow)

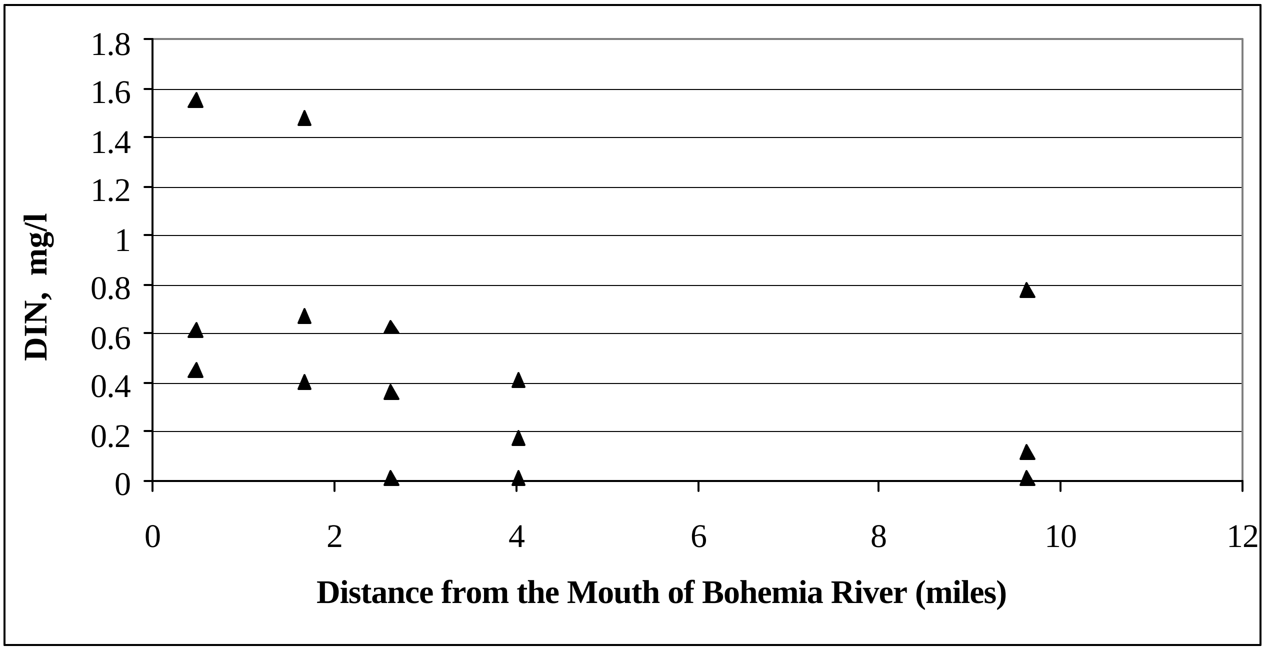

Figure 6: Longitudinal Profile of Dissolved Inorganic Nitrogen Data (Low flow)

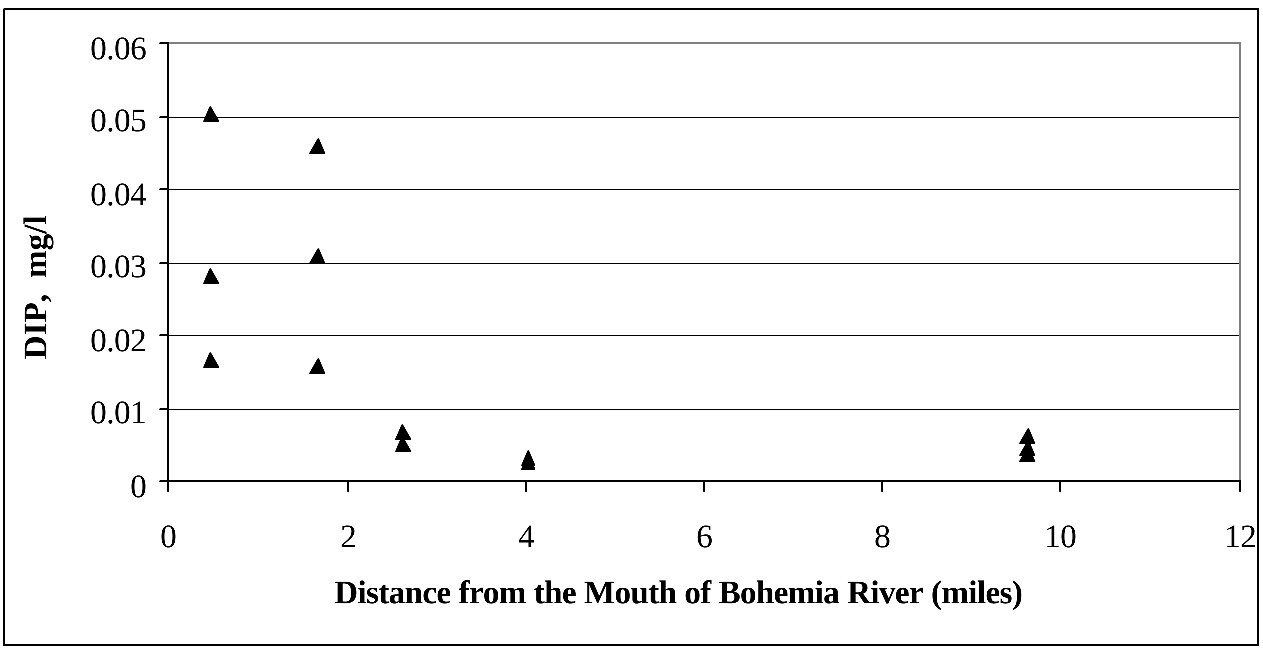

Figure 7: Longitudinal Profile of Dissolved Inorganic Phosphorus Data (Low flow)

2.3 Water Quality Impairment

The Maryland water quality standards Surface Water Use Designation (COMAR 26.08.02.07) for the Bohemia River is Use I - *water contact recreation, fishing, and protection of aquatic life and wildlife.* The water quality impairment of the Bohemia River system being addressed by this TMDL analysis consists of a higher than acceptable level of chlorophyll *a*. 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 Bohemia River system.

Maryland's general water quality criteria prohibit pollution of waters of the State by any material in amounts sufficient to create nuisance or interfere with designated uses (COMAR 26.08.02.03B2). The TMDL analysis indicates that nitrogen and phosphorus loadings from nonpoint sources have resulted in chlorophyll *a* concentrations above the desired level of 50 µg/l. The chlorophyll *a* concentration in the upper reach of the River occasionally exceeds the desired level of 50 µg/l.

3.0 TARGETED WATER QUALITY GOAL

The objective of the nutrient TMDLs established in this document is to assure that the chlorophyll *a* levels support the Use I designation for the Bohemia River. Specifically, the TMDLs for nitrogen and phosphorus for the Bohemia River are intended to:

1. Assure that a minimum dissolved oxygen level of 5.0 mg/l is maintained throughout the Bohemia River system, and
2. Reduced peak chlorophyll *a* levels (a surrogate for algal blooms) to below 50 µg/l throughout the Bohemia River system.

Specifically, the TMDLs for nutrients for the Bohemia River are intended to assure that a minimum dissolved oxygen level of 5.0 mg/l is maintained throughout the Bohemia River 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 (COMAR) 28.08.02. The chlorophyll *a* water quality level is based on the designated uses of the Bohemia River, 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 1 (1997). These guidelines acknowledge it is acceptable to maintain chlorophyll *a* concentrations 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 the Bohemia 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 low flow conditions.

4.2 Analysis Framework

The computational framework chosen for the Bohemia 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 of 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. These conditions are described in more detail below.

The spatial domain of the Bohemia River Eutrophication Model (BREM) extends from the confluence of the Big Elk River and the Bohemia River for about 10 miles along the mainstem of Bohemia River. This modeling domain, represented by 11 WASP model segments, extends upstream of the MD/DE State Line. A diagram of the WASP model segmentation is presented in Appendix A.

The nutrient TMDL analyses presented here consist of an assessment of low flow loading conditions. 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 sun light and temperatures are most conducive to excessive algal production.

The water quality model was calibrated to reproduce water quality characteristics for observed low flow conditions. Observed water quality data collected during 1999 was used to support the calibration process, as explained further in Appendix A.

The estimation of stream flow used in the low flow calibration was based on the flows of four nearby USGS stations. An average flow for each individual USGS gage was calculated by obtaining an average value over three low flow months (July, August, September) for the entire range of the flow data available. A ratio of flow to drainage area was calculated for each of the USGS gages and then an average of all the four flow to area ratios was determined. The flow for each subwatershed was then determined by multiplying the flow to area ratio by its individual area. The 7Q10 flow (critical low flow) for the subwatersheds were also derived using the same method as described for the low flow calibration using 7Q10 flows of the four USGS stations. The methods used to estimate stream flows are described further in Appendix A.

There is one minor point source in the Bohemia River basin, Cecilton WWTP. This source is located near the headwaters of the free-flowing tributary, Black Duck Creek. The flow is very small, 0.08 mgd, and its impact on the mainstem of the Bohemia River is minimal. The methods of estimating nonpoint source (NPS) loadings are described in Section 4.3. In brief, low flow NPS loads were derived from concentrations observed during low flow sampling in 1999 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 point source loads were based on the maximum permitted flow loads from the source.

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 Bohemia River.

4.3 Scenario Descriptions

The WASP model was applied to investigate different nutrient loading scenarios under low 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.

The analyses are grouped according to *base-line conditions,* and *future conditions* associated with TMDLs. 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 sun light 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, August and September of 1999. 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, loads from septic tanks, which are associated with river base flow during low flow conditions. For point source loads, these base-line conditions assume maximum allowable flow (based on maximum approved water and sewer plan flow) and appropriate parameter concentrations expected to occur at that flow.

Second Scenario: The second 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 31% reduction in controllable loads of total nitrogen and phosphorus from the entire watershed. 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 on to the bottom. The point source loads assume maximum allowable flow (based on maximum approved water and sewer plan flow) and appropriate parameter concentrations expected to occur at that flow. Details of this modeling activity are described further in the technical memorandum entitled *"Significant Nutrient Point Sources in the Bohemia River Watershed"* and Appendix A.

4.4 Scenario Results

This section describes the results of the model scenarios described in the previous section. The BREM 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:

Low Flow: Simulates critical low stream flow conditions during summer season. Water quality parameters (e.g., nutrient concentrations) are based on 1999 observed data. Point source loads assume maximum approved water and sewer plan flow and appropriate parameter concentrations expected to occur at that flow (0.08 mgd at Cecilton WWTP).

Results for the first scenario, representing the base-line condition for summer low flow, are summarized in Figure 9. From Figure 9 it is clear that, the peak chlorophyll *a* level reaches to levels of 60 µg/l under critical condition of temperature and flows near the head of the river. Scenario 2, presented below, establishes maximum allowable loads that address these apparent DO problems.

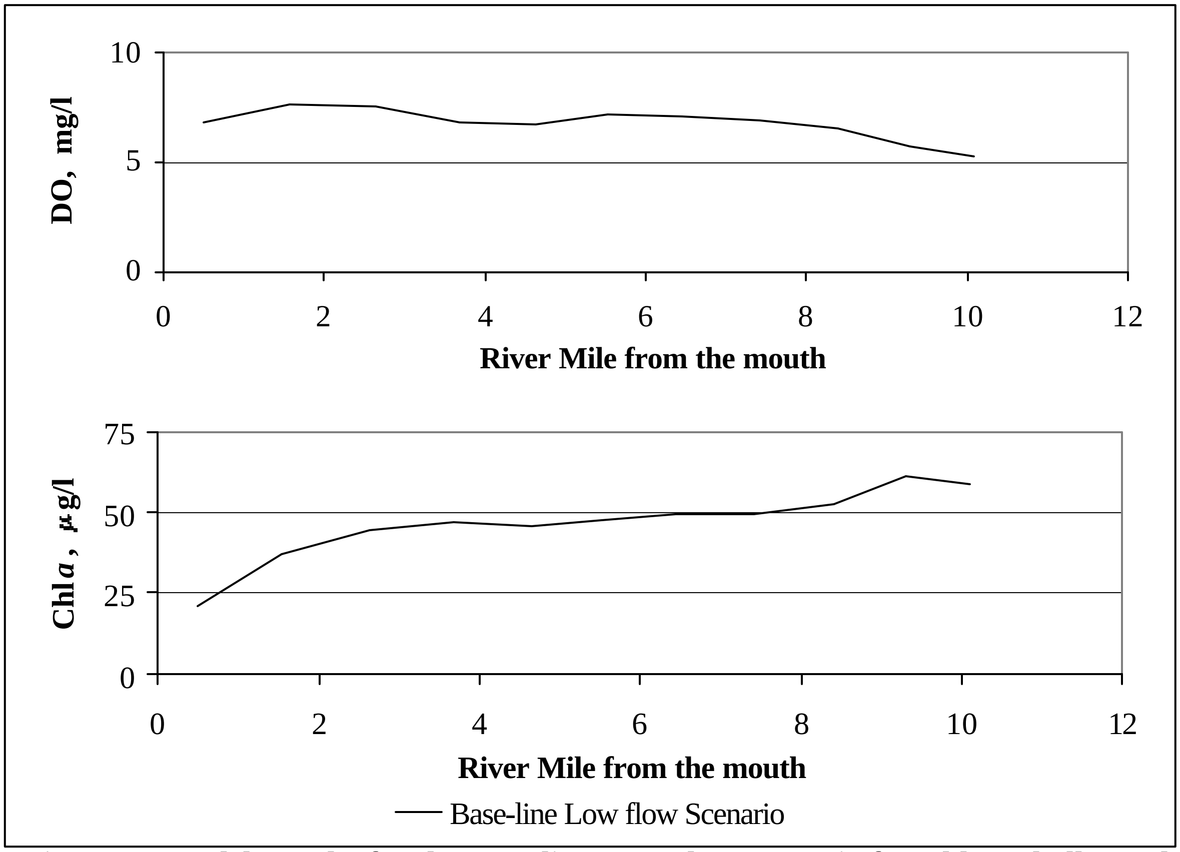

Figure 8: Model Results for the Base-line Low Flow Scenario for Chlorophyll *a* and Dissolved Oxygen (Scenario 1)

<u>Future Condition TMDL Scenarios:</u>

Low Flow: Simulates the future condition of maximum allowable loads for critical low stream flow (7Q10) conditions during summer season to meet the water quality in the Bohemia River.

Results for the second 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 10. Under the nutrient load reduction conditions described above for this scenario, the results show that chlorophyll *a* concentrations reduce down to levels of 50 µg/l along the entire length of the Bohemia River. Figure 11 (dotted line) indicates that the minimum concentrations of DO along the length of the river are well above the water quality criterion of 5.0 mg/l.

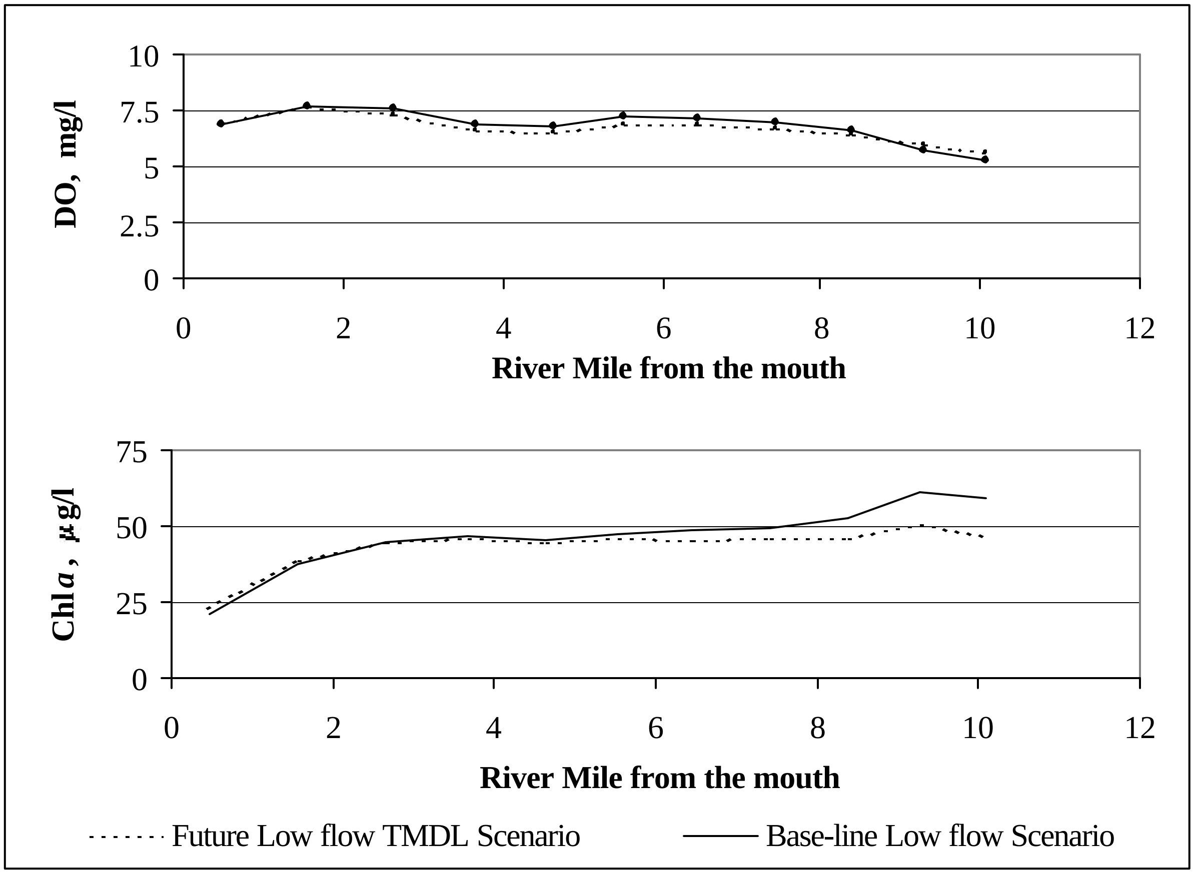

Figure 9: Model Results for the Future Low Flow Scenario for Chlorophyll *a* and Dissolved Oxygen (Scenario 2)

4.5 TMDL Loading Caps

This section presents total maximum daily loads (TMDLs) for nitrogen and phosphorus applicable during critical low flow conditions. The critical season for excessive algal growth in the Bohemia River is during the summer months, when the river system is poorly flushed[1]. During this critical time, sun light 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 additional limits are accounted for indirectly by adjusting bottom sediment nutrient fluxes and SOD to be consistent with reductions in the low flow loads (See Appendix A).

1. Elevated levels of chlorophyll *a* have been observed during cooler periods of higher flow. This phenomenon remains under investigation

For the summer months, May 1 through October 31, the following TMDLs apply:

Low Flow TMDL:

NITROGEN TMDL **1,201 *lbs/month***

PHOSPHORUS TMDL **154 *lbs/month***

The nitrogen species as modeled by WASP5.1 include the consumption of oxygen through nitrification. Thus, an additional TMDL for nitrogenous biochemical oxygen demand (NBOD) is not necessary to protect dissolved oxygen standards in the river.

4.6 Load Allocations Between Point Sources and Nonpoint Sources

The allocations described in this section demonstrate how the TMDL can be implemented to achieve water quality standards in the Bohemia River. Specifically, these allocations show that the sum of nitrogen and phosphorus nutrient loadings to the Bohemia River from existing point and nonpoint sources can be maintained safely within the TMDL established here.

<u>Low Flow Allocations</u>:

The nonpoint source loads of nitrogen and phosphorus simulated in the second scenario represent reductions from the baseline scenario. Recall that the baseline scenario loads were based on nutrient concentrations observed in summer 1999. 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 is one minor point source, Cecilton WWTP, that discharges nutrients in the watershed. An allocation has been made to this point source based on its maximum permitted loading of the nutrients. Point Source allocations are described further in the technical memorandum entitled *"Significant Nutrient Point Sources in the Bohemia River Watershed"* and Appendix A. The nitrogen and phosphorus allocations for summer low flow conditions are presented in Table 2.

Table 2: Summer Low Flow Allocations

	Total Nitrogen *(lbs/month)*	**Total Phosphorus *(lbs/month)***
Nonpoint Source	794	49
Point Source	365	102

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 = LA + WLA + MOS). The second approach is to incorporate the MOS as conservative assumptions used in the TMDL analysis.

Maryland has adopted margins of safety for these TMDLs using the above approach. Following the 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

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 60 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 3 presents the margin of safety incorporated in low flow and average flow TMDL.

Table 3: Summer Expected Low Flow Margins of Safety (MOS)

	Total Nitrogen	**Total Phosphorus**
MOS Low Flow	42 lbs/month	3 lbs/month

4.8 Summary of Total Maximum Daily Loads

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

For Nitrogen (*lbs/month*):

TMDL	**=**	**LA**	**+**	**WLA**	**+**	**MOS**
1,201	**=**	**794**	**+**	**365**	**+**	**42**

For Phosphorus (*lbs/month*):

TMDL	**=**	**LA**	**+**	**WLA**	**+**	**MOS**
154	**=**	**49**	**+**	**102**	**+**	**3**

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 TMDLs will result in loads of approximately 78 lbs/day of nitrogen and 8 lbs/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.

The implementation of point source nutrient controls will be executed through the use of NPDES permits. The NPDES permit for the Cecilton WWTP will have compliance provisions, which provide a reasonable assurance of implementation.

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 Upper Eastern Shore Tributary Strategy Basin, which includes the Bohemia 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 A