Total Maximum Daily Loads of Phosphorus for the Marshyhope Creek, Dorchester and Caroline Counties, Maryland

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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
CHLa	Chlorophyll *a*
CBP	Chesapeake Bay Program
DIN	Dissolved Inorganic Nitrogen
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
EUTRO5.1	Eutrophication Module of WASP5.1
FA	Future Allocation
LA	Load Allocation
MCEM	Marshyhope Creek Eutrophication Model
MDA	Maryland Department of Agriculture
MDE	Maryland Department of the Environment
MOS	Margin of Safety
NBOD	Nitrogenous Biochemical Oxygen Demand
NH_3	Ammonia
NO_{2-3}	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
The Act	Clean Water Act
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WASP5	Water Quality Analysis Simulation Program 5
WLA	Waste Load Allocation
WQLS	Water Quality Limited Segment
WWTP	Waste Water Treatment Plant

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 water body can receive without violating water quality standards.

The Marshyhope Creek was identified on the State's 1996 list of WQLSs as impaired by nutrients. This report proposes the establishment of a phosphorus TMDL for the Marshyhope Creek.

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 point and nonpoint source (NPS) control measures needed to restore water quality in the Marshyhope Creek.

EXECUTIVE SUMMARY

This document proposes to establish a Total Maximum Daily Load (TMDL) for phosphorus in Marshyhope Creek. Marshyhope Creek ultimately drains to the Chesapeake Bay through the Nanticoke River, and is part of the Lower Eastern Shore Tributary Strategy Basin. Although Marshyhope Creek was initially listed for nutrients in general, the TMDL analysis indicates that phosphorus is the nutrient that limits algal growth. Thus, limits are established only for phosphorus to decrease the severity of algal blooms and reduce the potential for failing to meet the dissolved oxygen criterion whereby the designated uses for Marshyhope Creek will be met.

The TMDL was determined using the WASP5.1 water quality model. The modeling work indicated that phosphorus caused excessive algal growth when the stream flow was low. Therefore a loading cap on phosphorus entering Marshyhope Creek is established for low flow conditions. The model was used to investigate seasonal variations, leading to the conclusion that establishing an annual average TMDL is not supported by the present analytical framework.

The low flow TMDL for phosphorus is 767 lb/month, which applies during the period May 1 through October 31. The allowable loads have been allocated between point and nonpoint sources. The nonpoint sources are allocated 249 lb/month. The point sources are allocated 415 lb/month. A future allocation and explicit margin of safety make up the balance of the allocation.

Four factors provide assurance that this TMDL will be implemented. First, NPDES permits will play a major 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 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 future monitoring of Marshyhope Creek 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 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. Water quality standards are 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 can be either narrative statements or numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

Marshyhope 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. Eutrophication is the over enrichment of aquatic systems by excessive inputs of nutrients especially nitrogen and phosphorus. The nutrients act as a fertilizer leading to the excessive growth of aquatic plants, which eventually die and decompose, leading to bacterial consumption of dissolved oxygen. Analyses indicate that the algae growth is limited by the availability of phosphorus. For this reason, it is possible to eliminate the impairment by limiting the amount of phosphorus that enters the waterbody, without regard to loadings of other nutrients. Accordingly, the Department proposes to establish a TMDL for phosphorus in Marshyhope Creek.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

Marshyhope Creek (Figure 1) is located within Dorchester and Caroline Counties, Maryland with its headwaters in Sussex and Kent Counties, Delaware. It drains into the Nanticoke River approximately 2.2 miles (≈ 3.5 kilometers) southwest of Sharptown. The Nanticoke River itself drains directly into the Chesapeake Bay. The Creek is approximately 60 kilometers (≈38 miles) in length, from its confluence with the Nanticoke River to the upper reaches of the headwaters. Marshyhope Creek watershed has an area of approximately 138,485 acres (560 km^2). As seen in figures 2a and 2b, the land use in the watershed, consists of mixed agriculture (67,813 acres or 49%), with other areas being under forest (62,055 acres or 45%) and urban (7,677 acres or 5%). The land use is based on 1997 Maryland Office of Planning land cover data, 1997 Delaware Office of State Planning land cover data, and 1997 Farm Service Agency (FSA) information. Figure 3 shows the relative amounts of the different land uses.

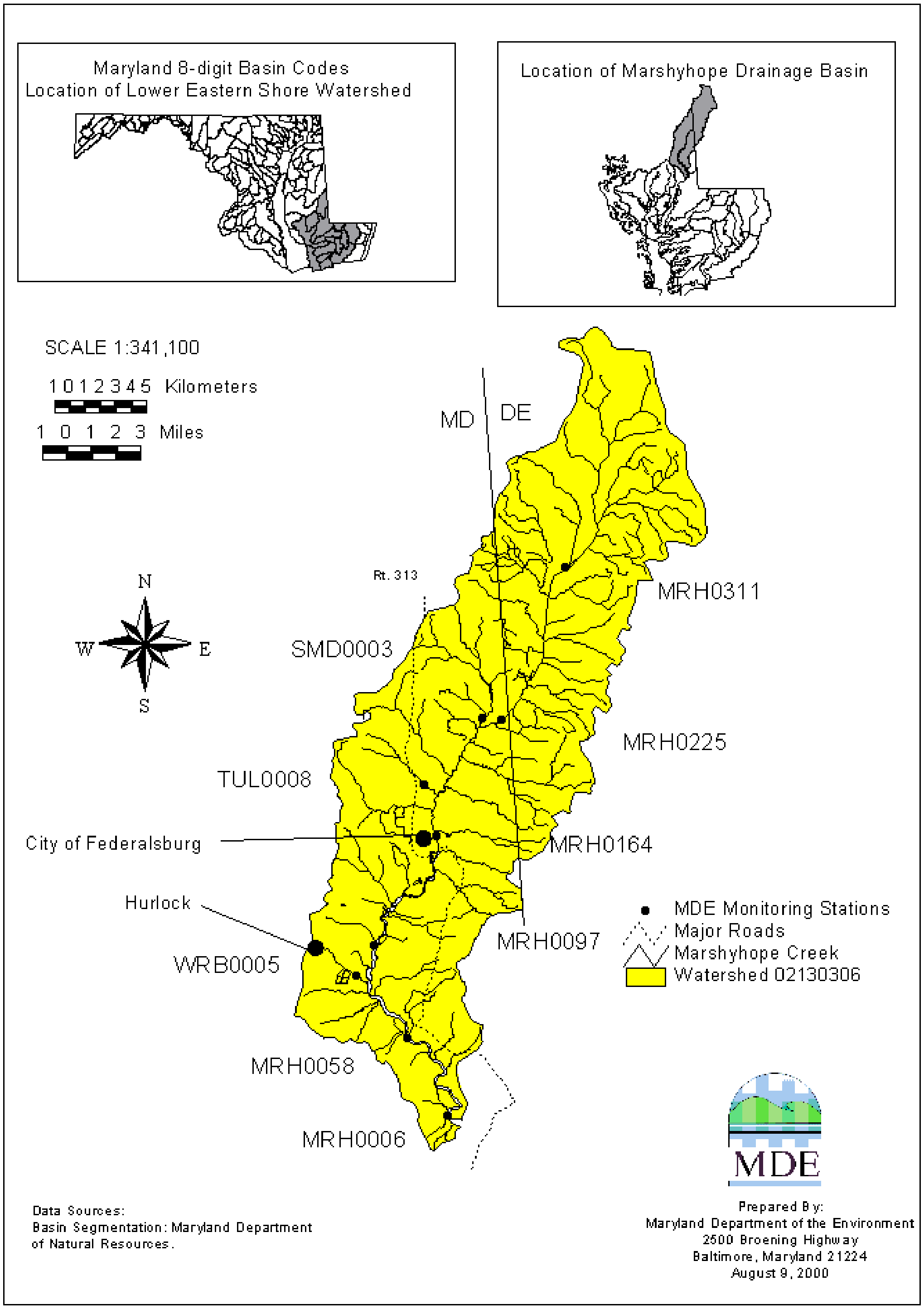


Figure 1: Location Map of the Marshyhope Creek Drainage Basin within Maryland and Delaware Including Location of MDE Water Qualituy Monitoring Stations

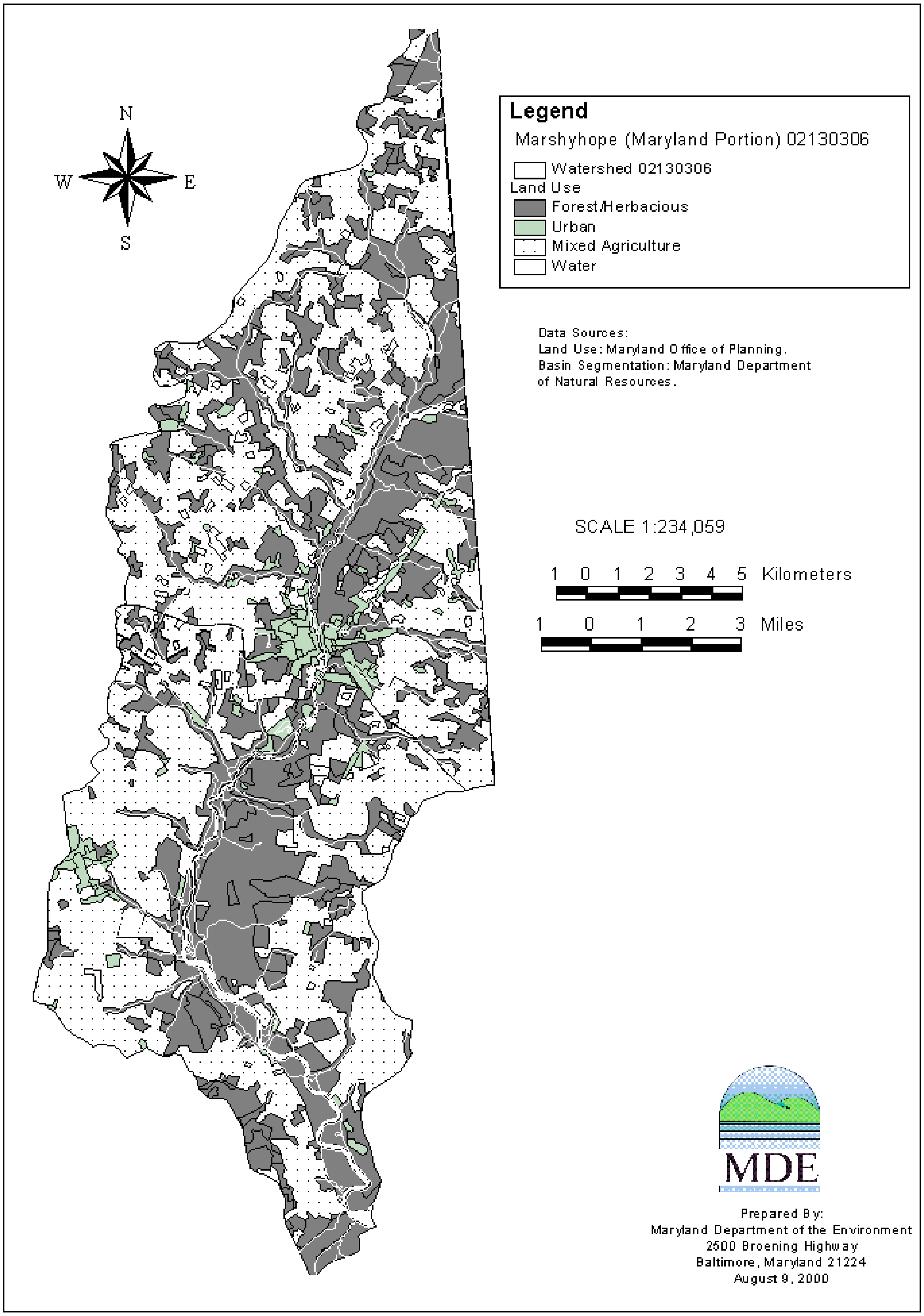


Figure 2a: Predominant Land Use in the Marshyhope Creek (Maryland Side) Drainage Basin

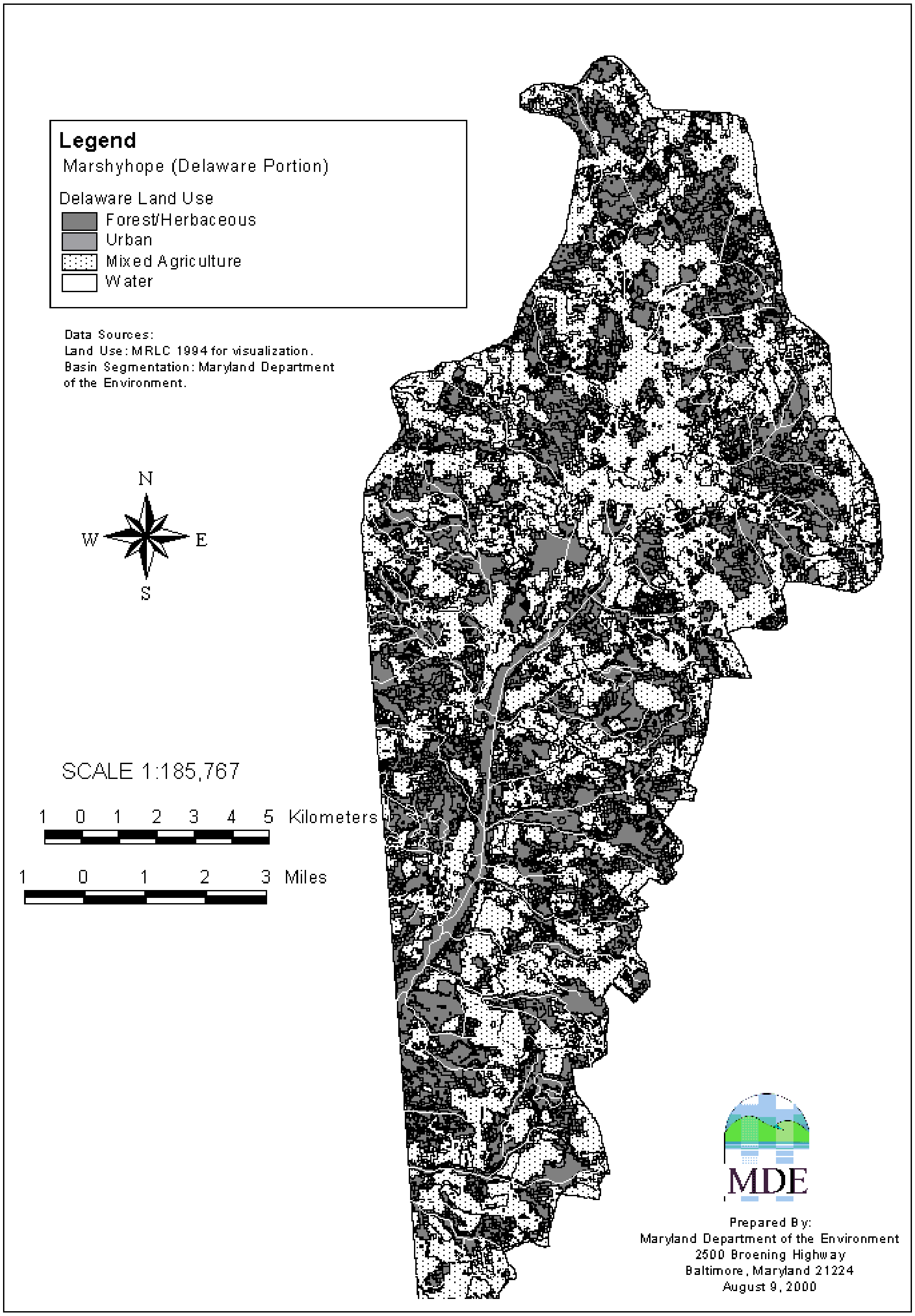


Figure 2b: Predominant Land Use in the Marshyhope Creek (Delaware Side) Drainage Basin

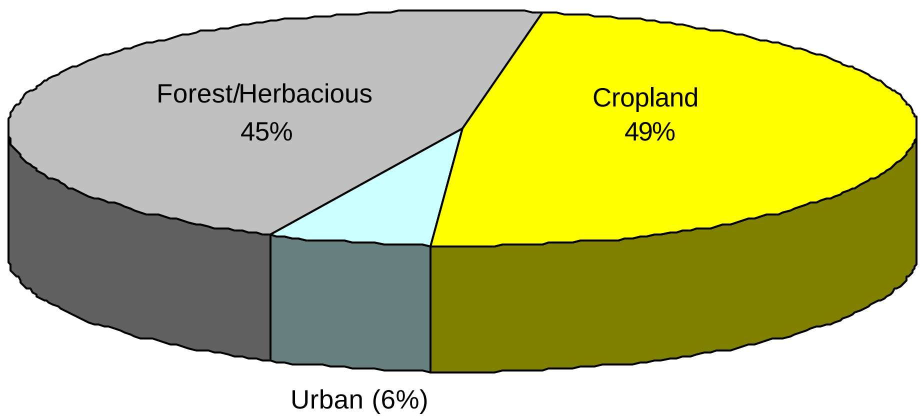


Figure 3: Estimated Land Use in the Marshyhope Creek Drainage Basin

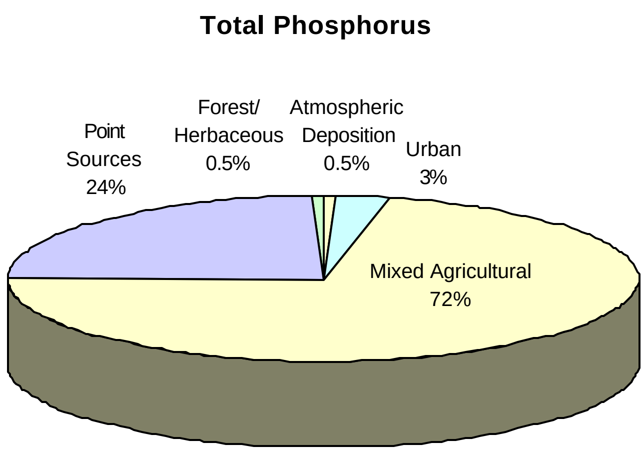
The tidal section of Marshyhope Creek extends from the mouth of the creek for approximately 10 miles upstream to a point approximately 1.4 miles north of the Town of Federalsburg. The navigable reach extends from the mouth up to the crossing with route 313 for all boats (recreational and commercial fisheries that need at least 3 feet depth) and up to about ¼ mile south of the Town of Federalsburg for recreational fishing purposes (small boats that need virtually no depth to navigate). Depths of the creek range from about 0.5 ft (0.15 meters) near the headwaters to greater than 26.2 ft (8 meters) in the tidal zone prior to the creek's confluence with the Nanticoke River. Widths can vary from 82 ft (25 meters) at the headwaters to 1,098 ft (355 meters) at the mouth.

The upper region of the watershed supports a high density of poultry operations augmented by row crop agriculture. Poultry waste is applied as fertilizer to the crops, which consist mainly of corn and soybeans. In this area, the Army Corps of Engineers has channeled the creek, to drain non-tidal wetlands in order to accommodate agricultural functions. A few miles downstream of the channeled part of the creek, just after the DE-MD border, starts the Idylwild State Wildlife Management Area. This is an area of approximately 30,000 acres of uninhabited wetlands and forest, which extends from the DE-MD border down to the head of tide. Below this region, beginning at Smithville, the land use becomes predominantly residential until up to the Town of Federalsburg, which is a higher density urban area. Downstream of Federalsburg there is a mix of forest and crop lands with limited poultry growing, except in the region of Walnut Landing, where there are many poultry operations and concentrated feeding operations, mostly swine.

In Marshyhope Creek watershed, the estimated annual average total nitrogen load is 1,778,694 lb/yr (808,497 kg/yr), and the total phosphorus load is 149,028 lb/yr (67,740 kg/yr). The NPS component of this total nitrogen load accounts for 1,653,028 lb/yr (751,376 kg/yr), and the NPS phosphorus load is 112,226 lb/yr (51,011 kg/yr). Figure 4 shows the relative amounts of nitrogen and phosphorus point and NPS loadings. The NPS 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 annual average NPS 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 Model (U.S. EPA, 1996), a continuous simulation model. The Chesapeake Bay Program loading rates represent edge of stream loads for the year 2000 assuming Best Management Practices (BMP) implementation at levels consistent with current progress, and account for atmospheric deposition, loads from septic tanks, and loads coming from urban development, agriculture, and forestland. (See Section 4.3 and Appendix A for further discussion on nonpoint sources).

MDE considered four current point sources that discharge within the Marshyhope Creek watershed, and a fifth potential future discharge (Allen Foods). These four point sources are: Hurlock WWTP, Federalsburg WWTP, Col. Richardson High School WWTP and W.O. Whyteley and Sons Company. Information was reviewed from discharge monitoring reports stored in MDE's point source database. Of the four current discharges, the W. O. Whiteley discharge (NPDES Permit MD0061255), of less than an average of one gallon per day, was considered to be insignificant. The TMDL analysis accounts for the possibility that the Allen Foods processing facility, which currently directs its wastewater to the Hurlock Waste Water Treatment Plant (WWTP), could choose to build a separate treatment plant and pursue a permit to discharge directly to the waters of the State. This was done by having the volume of discharge assumed in the TMDL computer model simulation at the location of the Hurlock plant be sufficient to account for both the needs of Hurlock and Allen Foods.

During 1998, the time period used to calibrate the simulation model, loads from Hurlock (including Allen Foods), Federalsburg and Colonel Richardson High School WWTPs, were estimated to contribute 125,666 lb/yr (57,120 kg/yr) of nitrogen and 36,802 lb/yr (16,726 kg/yr) of phosphorus.



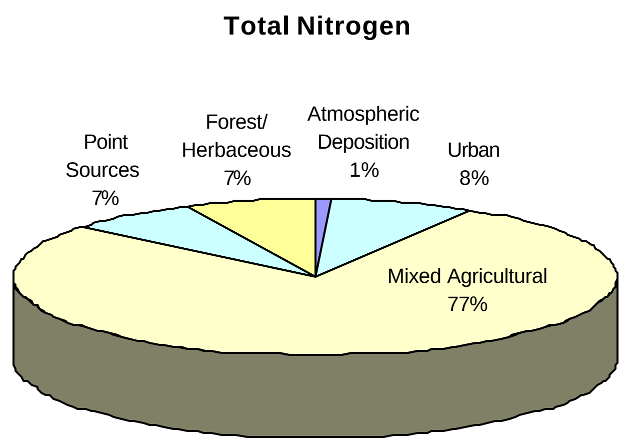


Figure 4: Estimated Annual average Nitrogen and Phosphorus Point and Nonpoint Source Loads

2.2 Water Quality Characterization

Four water quality parameters associated with the observed impairment of Marshyhope Creek, chlorophyll *a* (Chla) , dissolved oxygen (DO), dissolved inorganic nitrogen (DIN), and dissolved inorganic phosphorus (DIP), are presented in figures 5 through 8 below. These data were collected by MDE during six water quality surveys conducted in the Marshyhope Creek during 1998. Three sets of samples were collected during seasonal low flow periods in summer (15-July-98, 5-Aug-98, 9-Sept-98), and three high flow periods in winter (16-Feb-98, 25-Mar-98, 8-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 of the creek.

Table 1: Location of Water Quality Monitoring Stations along Main Branch of Marshyhope Creek

Water Quality Station	Kilometers from Mouth of Marshyhope Creek
MRH0006	1.1
MRH0058	9.6
MRH0097	17.1
MRH0164	27.3
MRH0225	38.1
MRH0311	49.6

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 dead plant matter decay. 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 periods, are presented in Appendix A.

Figure 5 presents a longitudinal profile of chlorophyll *a* data collected during summer 1998, the low flow period. The sampling region covers the entire tidal portion of the Marshyhope Creek, from its confluence with the Nanticoke River (Station MRH0006), and includes four free-flowing stations above the Town of Federalsburg. Ambient chlorophyll *a* concentrations during the low period are below 50 μg/L in the upstream waters, but significantly greater between the mouth of the creek and the 15-mile mark, where mean values are about 65 μg/L, with an observed maximum of 111 μg/L.

A similar longitudinal profile for DO concentrations is depicted in Figure 6. As the data indicates, during low flow, most of the stations show DO levels above the standard. The higher values between the mouth and the 15-mile mark correspond with high chlorophyll *a* values, suggesting elevation due to the effects of photosynthetic activity, and the potential for diurnal DO depletion. But at two stations upstream of the head of tide, the DO levels are fairly close to the water quality standard of 5.0 mg/l. Low DO values might be expected to occur naturally in the wetlands setting of the Idylwild State Wildlife Management Area.

Figure 7 presents a longitudinal profile of DIN measured as ammonia plus nitrate plus nitrite levels in the samples collected in 1998, during low flow conditions. The concentration of inorganic nitrogen remains fairly low throughout the length of the creek with values ranging between 0.012 mg/l and 2.5 mg/l. These lower values indicate possible consumption of nutrients due to temperature increase and therefore *chlorophyll a* growth. The highest values are located near the Federalsburg WWTP discharge point.

Figures 8 presents a longitudinal profile of DIP, as indicated by ortho-phosphate levels measured in samples collected during the summer 1998 surveys. During high flow, very low concentrations at the headwaters were found to increase rapidly downstream but not to exceed 0.06 mg/l after the Wrights Branch junction (High flow DIP is shown in figure A6 of Appendix A). During low flow, measured concentrations are at or near the level of detection (0.01 mg/l), also indicating possible consumption due to chlorophyll *a* growth.

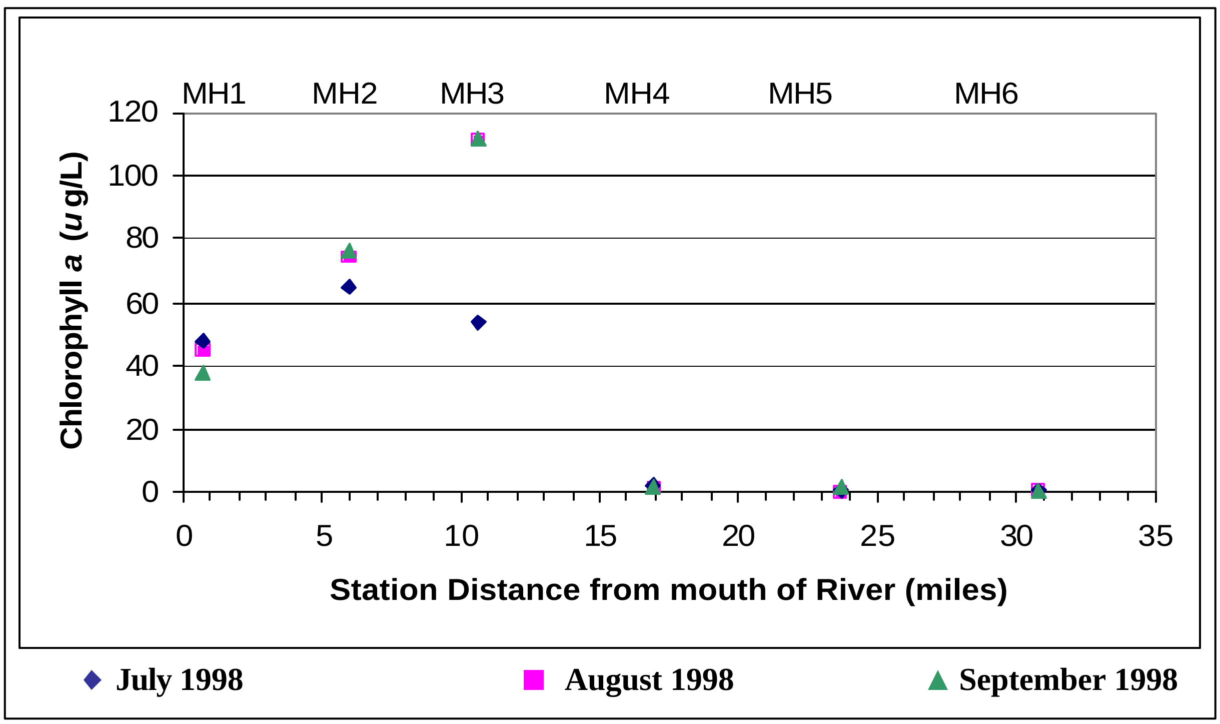


Figure 5: Longitudinal Profile of Chlorophyll *a* Data (Low Flow)

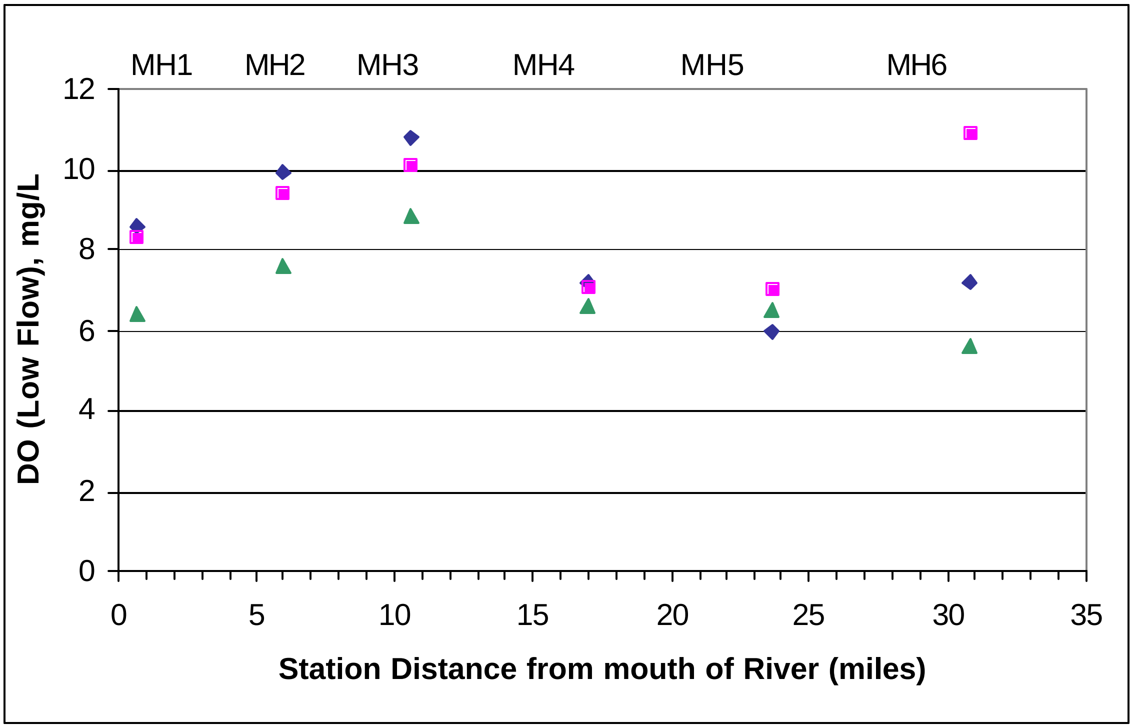


Figure 6: Longitudinal Profile of Dissolved Oxygen Data (Low Flow)

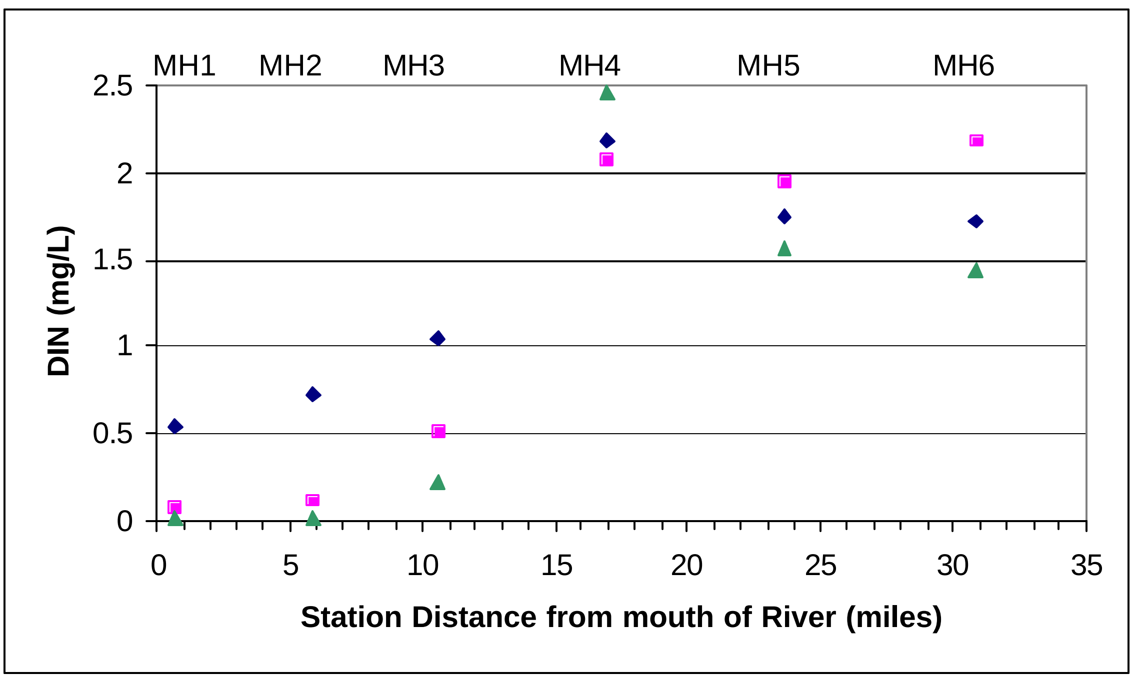


Figure 7: Longitudinal Profile of Dissolved Inorganic Nitrogen Data (Low Flow)

◆ **July 1998** ■ **August 1998** ▲ **September 1998**

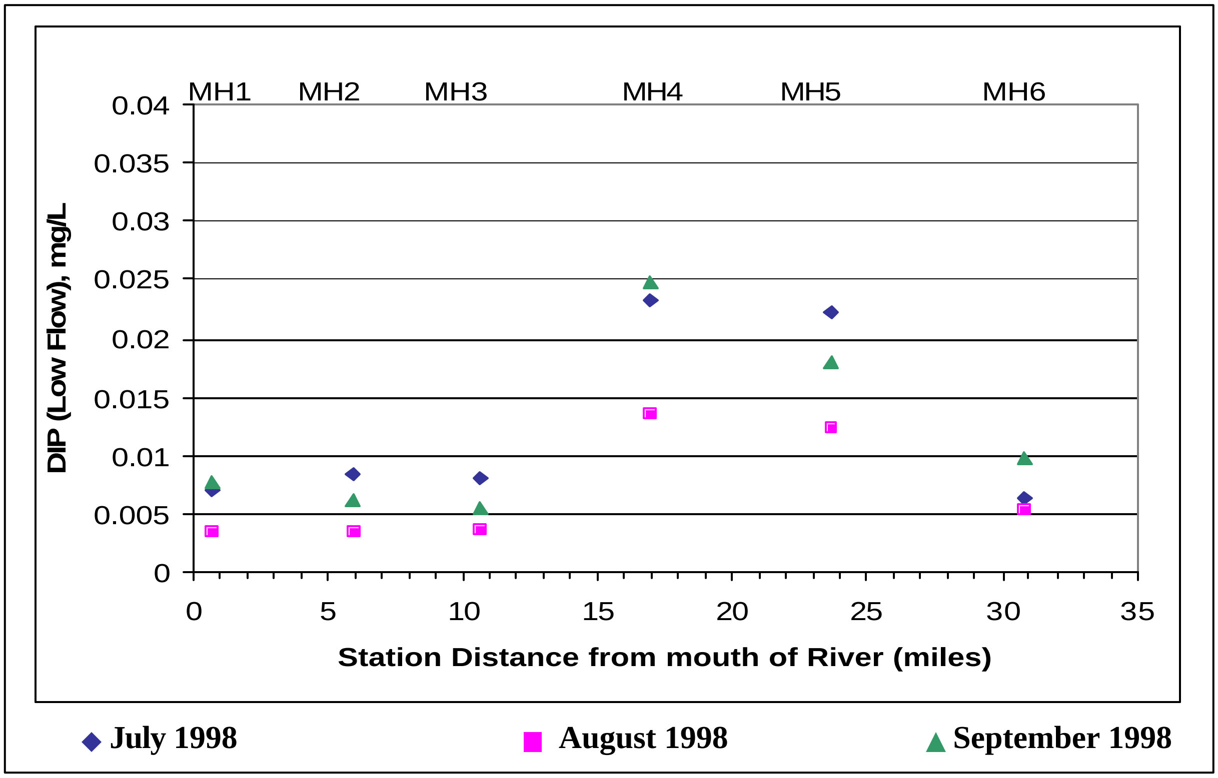


Figure 8: Longitudinal Profile of Dissolved Inorganic Phosphorus Data (Low Flow)

2.3 Water Quality Impairment

The Maryland water quality standards Surface Water Use Designation (COMAR 26.08.022.07) for the Marshyhope Creek is Use I – *water contact recreation, fishing, and protection of aquatic life and wildlife.* The water quality impairment of the Marshyhope Creek system being addressed by this TMDL analysis consists of an over enrichment of nutrients. Nutrient loadings from both point and nonpoint sources have resulted in higher than acceptable chlorophyll *a* concentrations. Although observed dissolved oxygen concentrations are not below the minimum criteria of 5.0 mg/l in any of the samples taken during the 1998 survey, high concentrations of chlorophyll *a* suggest the possibility of low DO concentrations as a result of diurnal variations in oxygen due to algal respiration during non-daylight hours.

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 Marshyhope Creek range between 40 and 110 µg/l. These levels have been associated with excess eutrophication.

3.0 TARGETED WATER QUALITY GOAL

The objective of the phosphorus TMDL established in this document is to assure that the dissolved oxygen criteria support the Use I designation for Marshyhope Creek and to control nuisance algal blooms. Specifically, the TMDL for phosphorus for the Marshyhope Creek are intended to assure that a minimum dissolved oxygen level of 5.0 mg/l is maintained throughout the Marshyhope 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 Marshyhope 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 (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 TMDL and load allocations for point sources and nonpoint sources were developed for Marshyhope Creek. The second section describes the modeling framework for simulating nutrient loads, hydrology, and water quality responses. The third and fourth 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 fifth and sixth sections present the modeling results in terms of a TMDL, and allocate the TMDL between point sources and nonpoint sources. The seventh section explains the rationale for the margin of safety. Finally, the pieces of the equation are combined in a summary accounting of the TMDL for seasonal low flow conditions and for annual loads.

4.2 Analysis Framework

The computational framework chosen for the Marshyhope Creek TMDL 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, Georgia (Ambrose *et al.*, 1993). EUTRO 5.1 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 Marshyhope Creek Eutrophication Model (MCEM) extends from the confluence of Marshyhope Creek and the Nanticoke River for about 38 miles along the mainstem of the Marshyhope Creek. No tributaries of the Marshyhope Creek were included in the modeling domain. The modeling domain, represented by 23 WASP model segments, extends upstream beyond the state border of Maryland and Delaware. A diagram of the WASP model segmentation is presented in Appendix A. Freshwater flows and NPS loadings from these subwatersheds are taken into consideration by dividing the drainage basin into 39 subwatersheds and assuming that flows and loadings are direct inputs to the MCEM.
The nutrient TMDL analysis consists of two broad elements, an assessment of low flow loading conditions, and an assessment of annual average 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. The calibration of the model for these two flow regimes establishes an analysis tool that may be used to assess a range of scenarios with differing flow and nutrient loading conditions. Observed water quality data collected during 1998 was used to support the calibration process, as explained further in the "Nonpoint Source Loadings" section of 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 the USGS flow gage (Station # 1488500) located near Adamsville, Delaware. The estimation of the annual average flow in the Marshyhope Creek builds upon an analysis of historical flow data from the same USGS station using the period of record from 1984 –1987. This time period is consistent with that used in the Chesapeake Bay Program Watershed Model, which provides annual average loading rates by landuse type. The methods used to estimate stream flows are described further in the "Freshwater Flows" section of Appendix A.

There were three significant point sources of nutrients in the Marshyhope Creek watershed during 1998 when data was collected to support the model calibration. These are the municipal wastewater treatment plants for the Towns of Hurlock, and Federalsburg, and a small discharge from Colonel Richardson Middle & High School. There is an additional industrial point source, the W. O. Whitley and Sons Company. This industrial point source has a negligible discharge and was not considered for calculations purposes. MDE point source discharge data was used to estimate point source loads for the 1998 calibration. (See Section 2.1, *General Setting and Source Assessment* for further discussion).

The methods of estimating NPS loadings 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 annual average 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 the “Nonpoint Source Loadings” section of 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 (NO2-3), 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 Marshyhope Creek.

4.3 Scenario Descriptions

The WASP model was applied to investigate different nutrient loading scenarios under various 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 annual average loadings, the analyses account for seasonality, a necessary element of the TMDL development process. However, the analysis demonstrates that the establishment of an annual average TMDL for Marshyhope Creek is not supported by the present modeling framework.

The analyses are grouped according to *baseline conditions*, and *future conditions*. Both groups typically include low flow and annual average loading scenarios, for a total of four scenarios. However, for the Marshyhope Creek analysis, a fourth scenario was omitted for reasons discussed below.

The baseline conditions are intended to provide a point of reference by which to compare the future scenarios that simulate the conditions of the TMDL. Defining this baseline for comparison with the TMDL outcome is preferred to trying to establish a “current condition.” The baseline is defined in a consistent way among different TMDLs, and does not vary in time. Where as, the alternative of using a “current condition” has the drawback that it changes over time, which creates confusion. It is “current” at one point in time for a given TMDL, but development and review often take several years; by the time the TMDL is done, the “current” condition is no longer current. Also, what constitutes “current” for one TMDL, is different for another TMDL developed at a later time. To avoid this confusion we use “baseline” scenario.

The baseline conditions for Nonpoint Source loads typically reflect an approximation of loads during the calibration monitoring time-frame, in this case 1998. Baseline point source loads are typically estimated under the assumption of maximum approved water and sewer plan flows, and either present permitted concentrations or estimates of expected concentrations at such flow. As such, the baseline conditions often reflect a fixed potential future critical condition, which approximates a maximum future loading assuming no control actions. Specific baseline loading assumptions for the point sources are presented in the "Point Source Loadings" section of Appendix A.

First Scenario: The first scenario represents the baseline conditions of the stream at a simulated critical low flow in the creek. The method of estimating the critical low flow is described in the "Freshwater Flows" section of 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 nonpoint source nutrient concentrations for the first scenario were computed using the observed data collected during the low flow conditions of July and August of 1998, which were also used in the calibration of the model. The low flow nonpoint source loads were computed as the product of the observed concentrations and estimated critical low flow. These low flow nonpoint source loads integrate all natural and human induced sources, including direct atmospheric deposition, loads from septic tanks, which are associated with creek base-flow during low flow conditions. For point sources loads, these baseline conditions assume maximum allowable flow and appropriate parameter concentrations expected to occur at that flow (see "Point Source Loadings" of Appendix A for more details).

Second Scenario: The second scenario represents baseline conditions of the stream at average flow and annual average 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. The 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. A detailed description of this scenario can be found in Appendix A.

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 40% reduction from the baseline conditions scenario controllable nonpoint source loads in the Marshyhope Creek watershed. This reduction in nonpoint source loads includes a margin of safety computed as 5% of the NPS load allocation. The point source loads were set at a level necessary to meet water quality standards. 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. Further discussion of this scenario is provided in Appendix A.

Fourth Scenario: A fourth scenario is typically conducted by MDE when the baseline conditions annual average loading scenario indicates water quality problems (second scenario). Because that was not the case for Marshyhope Creek, an annual average TMDL analysis is not being conducted at this time. Thus a fourth scenario is omitted from this documentation.

4.4 Scenarios Results

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

Baseline Conditions Loading Scenarios:

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

Second Scenario (Annual average flow): Simulates historical annual average stream flow condition under summer environmental conditions. Assumes baseline annual average nonpoint source loads, and maximum point source design flow and load (1998 data).

Results for the first scenario, representing the baseline conditions for summer critical low flow, are summarized in Figure 9. Under these conditions, the peak chlorophyll *a* level is above the desired goal of 50 µg/l downstream of the junction of Wrights Branch and Marshyhope Creek. However, DO concentrations are not expected to fall below the minimum water quality criterion of 5.0 mg/l throughout the length of the creek.

Results for the second scenario, representing the baseline conditions for the annual average stream flow and average 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 mg/l throughout the length of the creek. Analogous average flow analyses, using a steady state water quality model, have been used in the past to establish baseline conditions impairment from which to estimate an annual average maximum loading limit. However, in this case, no water quality impairment is indicated by the *annual average flow scenario* (Second Scenario). As a consequence, the establishment of an annual average TMDL is not supported by the present analytical framework.

Although an explicit annual average TMDL is not established through this analysis, year-around limits of loads to these waters are assured in two ways. First, Maryland's voluntary commitment to the nutrient management goals of the Chesapeake Bay Agreement helps to control the upper limit on nutrient loads. Second, the nonpoint source limits established for the six-month period (May – October) by the low flow TMDL can only be achieved by implementing controls that place practical limits on loads over the entire year.

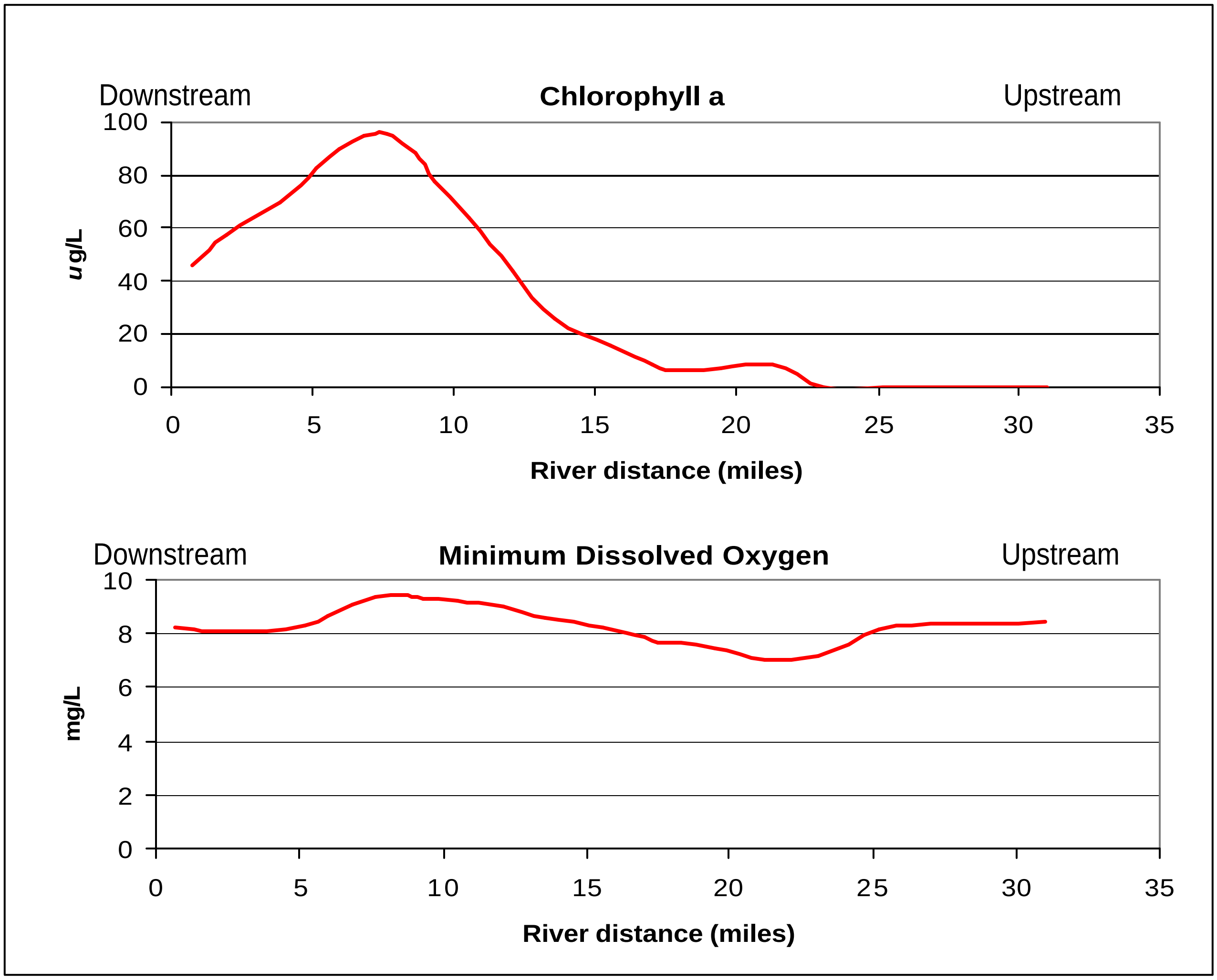


Figure 9: Model Results for the Low Flow Baseline Conditions Scenario for Chlorophyll *a* and Dissolved Oxygen (Scenario 1)

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

<u>Third Scenario (Low Flow)</u>: Simulates the future condition of maximum allowable loads for critical low stream flow conditions during summer season.

Results for the third scenario (dotted line), representing the maximum allowable load for summer-time critical low flow, are summarized in comparison to the appropriate baseline conditions 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 the Marshyhope Creek. For dissolved oxygen (DO), the comparison shows that the nutrient load reductions result in almost no change, maintaining the DO concentration above the water quality criterion of 5.0 mg/l along the length of the creek.

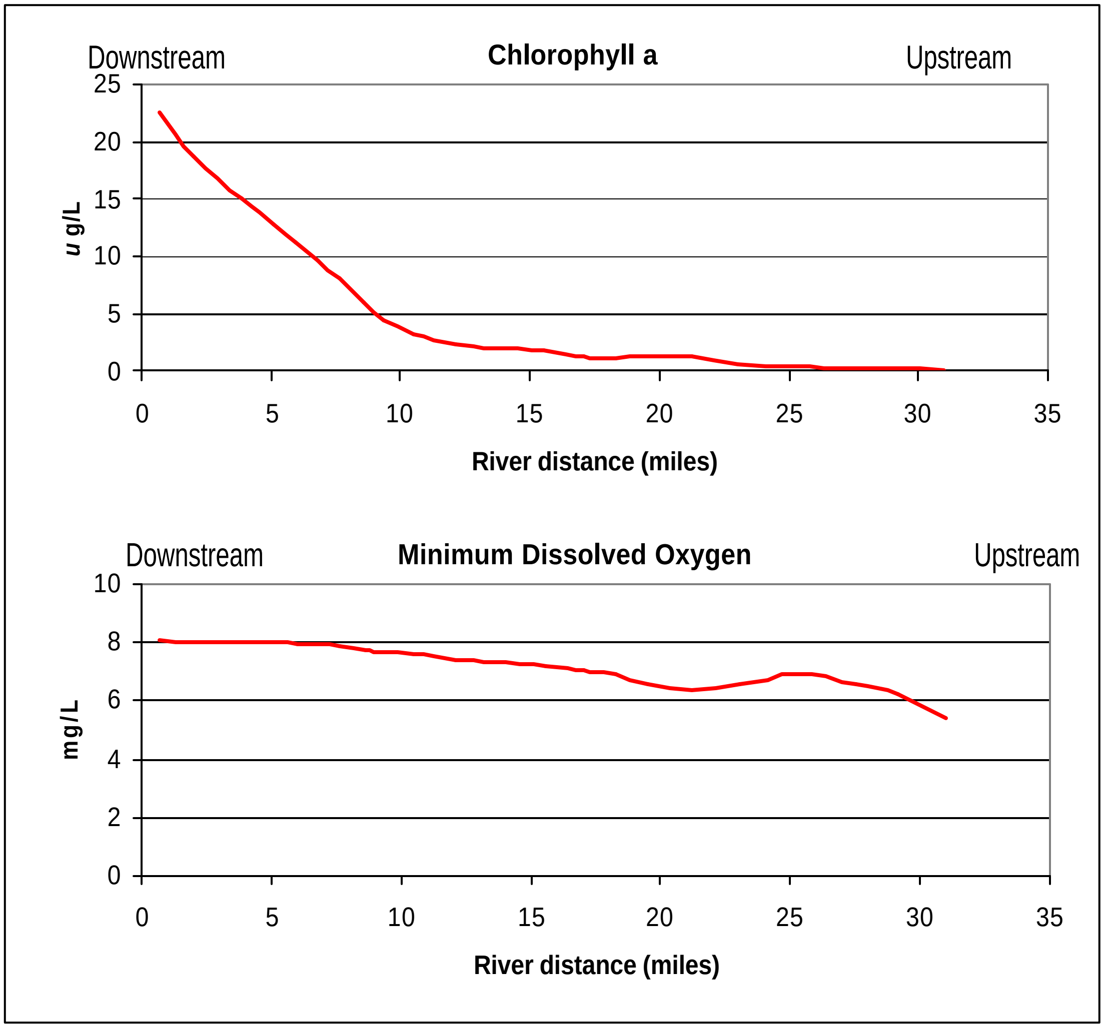


Figure 10: Model Results for the Annual Average Flow Baseline Conditions Scenario for Chlorophyll *a* and Dissolved Oxygen (Scenario 2)

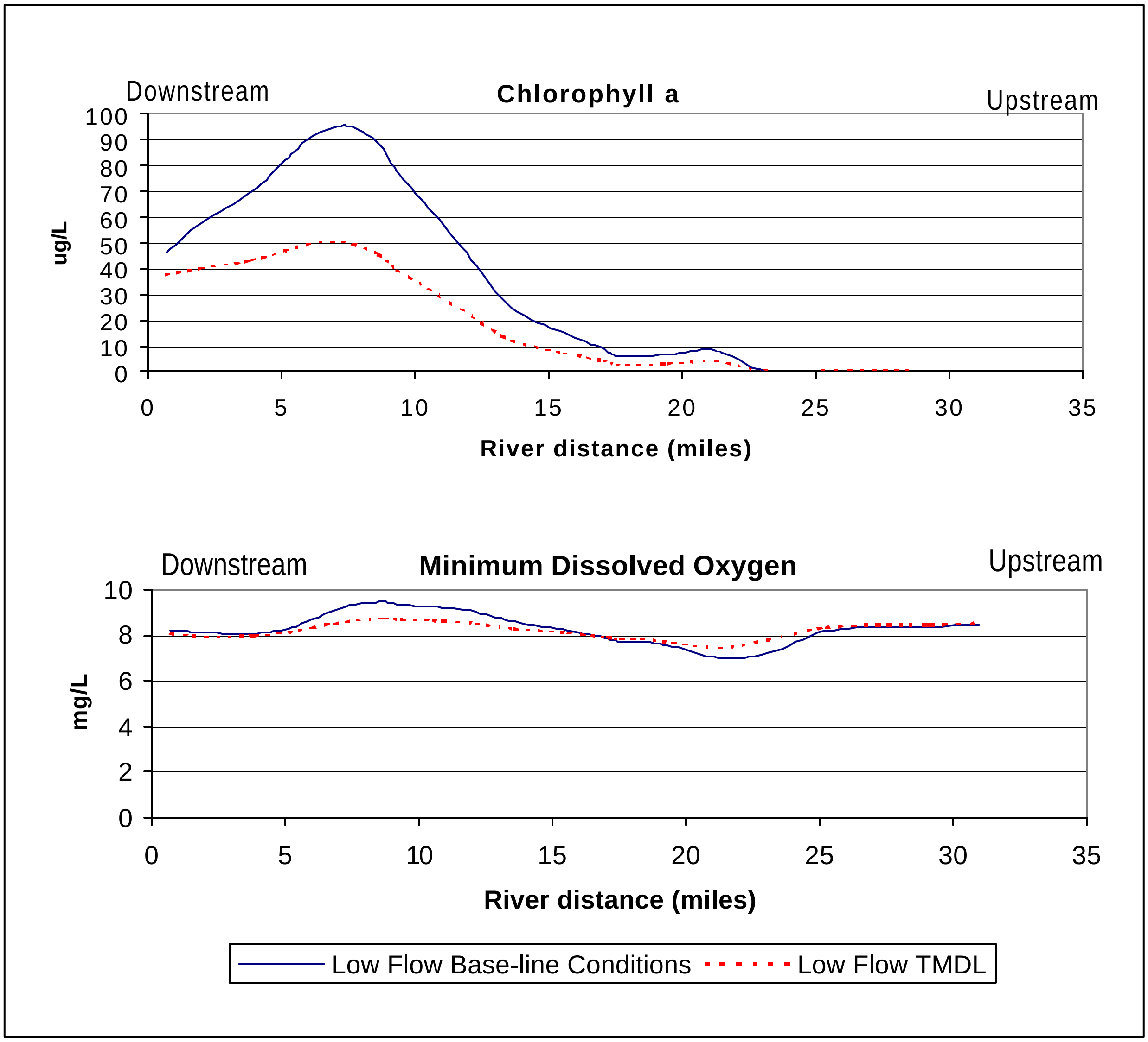


Figure 11: Model Results for the Low Flow Future Conditions Scenario for Chlorophyll *a* and Dissolved Oxygen (Scenario 3)

4.5 TMDL Loading Caps

This section presents the Total Maximum Daily Load (TMDL) for phosphorus for critical low flow conditions. The critical season for excessive algal growth in Marshyhope Creek is during the summer months, when the creek is poorly flushed. During this time, sunlight and warm water temperatures are most conducive to creating the water quality problems associated with excessive nutrient enrichment. The low flow TMDL is stated in monthly terms because these critical conditions occur for limited periods of time.

For the months, May 1 through October 31, the following TMDL applies:

Low Flow TMDL:

PHOSPHORUS TMDL **767 *lb/month***

4.6 Load Allocations Between Point Sources and Nonpoint Sources

The watershed that drains to Marshyhope Creek has three significant permitted point source discharges of nutrients. The allocations described in this section demonstrate how the TMDL can be implemented to achieve water quality standards in Marshyhope Creek. Specifically, these allocations show that the sum of phosphorus loadings to Marshyhope Creek from existing point and nonpoint sources can be maintained safely within the TMDL established here.

Low Flow TMDL Allocations:

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

Point source load allocations for the summer low flow baseline conditions make up the balance of the total allowable load. This point source load allocation was adopted from results of model scenario 3. All significant point sources are addressed by this allocation and are described further in the technical memorandum entitled *"Significant Nutrient Point and Nonpoint Sources in the Marshyhope Creek Watershed."* The NPS and point source phosphorus allocations for summer critical low flow conditions are shown in Table 2.

Table 2: Summer Low Flow Allocations

	Total Phosphorus *(lb/month)*
Nonpoint Source	249
Point Source	415

4.7 Future Allocation and Margins of Safety

Future allocations represent surplus assimilative loading capacity that is either currently available, or projected to be available due to planned implementation of environmental controls. The future allocations have been computed as the difference between the allowable load at the discharge point of the Hurlock WWTP for a flow of 1.5 mgd versus 2.0 mdg. The future summer low flow phosphorus Future Allocations are given in Table 3.

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 that combine these two approaches and does so for this TMDL. Following the first approach, the load allocated to the MOS was computed as 5% of the NPS load (13 lb/month) for 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 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 TMDL, MDE has elected to use the more conservative peak concentrations of 50 µg/l.

Table 3: Summer Critical Low Flow Margins of Safety and Future Allocations

	Total Phosphorus *(lb/month)*
Margins of Safety	13
Future Allocations	90

4.8 Summary of Total Maximum Daily Loads

The critical low flow TMDL for Marshyhope Creek, applicable from May 1 – Oct. 31 follows:

For Phosphorus (*lb/month*):

TMDL	**=**	**LA**	**+**	**WLA**	**+**	**FA**	**+**	**MOS**
767	**=**	**249**	**+**	**415**	**+**	**90**	**+**	**13**

Where:

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

<u>Average Daily Loads</u>:

On average, the low flow TMDL will result in loads of approximately 26 lb/day of phosphorus.

5.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the phosphorus TMDL will be achieved and maintained. 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), 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 sources nutrient controls will be executed through the use of NPDES permits. The NPDES permits for Hurlock and Federalsburg WWTP will require stricter limits. The NPDES permits in Marshyhope Creek 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 phosphorus be developed and implemented by 2005. Maryland’s CWAP has been developed in a coordinated manner with the State's 303(d) process. All CWAP 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 NPS controls in the Lower Eastern Shore Tributary Strategy Basin, which includes the Marshyhope Creek watershed. Maryland is in the forefront of implementing quantifiable NPS 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.

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Appendix A