Total Maximum Daily Loads of Nitrogen and Phosphorus for Mattawoman Creek in Charles County and Prince George's County, Maryland

Prepared by:

Maryland Department of the Environment
1800 Washington Boulevard
Baltimore, MD 21230

Submitted to:

Watershed Protection Division
U.S. Environmental Protection Agency, Region III
1650 Arch Street
Philadelphia, PA 19103-2029

January 2004

Submittal Date: January 21, 2004
Approval Date: January 5, 2005
Document version: January 15, 2005

Table of Contents

List of Figures

List of Tables

List of Abbreviations

$7Q_{10}$	7-day consecutive lowest flow expected to occur every 10 years
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
CBOD	Carbonaceous Biochemical Oxygen Demand
CEAM	Center for Exposure Assessment Modeling
CHL *a*	Active Chlorophyll
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
CWAP	Clean Water Action Plan
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
LA	Load Allocation
MCEM	Mattawoman Creek Eutrophication Model
MDA	Maryland Department of Agriculture
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
MD	Maryland
mg	Milligrams
MGD	Million Gallons per Day
MOS	Margin of Safety
NH_4^+	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
µg	Micrograms
USGS	United States Geological Survey
WASP5.1	Water Quality Analysis Simulation Program 5.1
WLA	Waste Load Allocation
WQIA	Water Quality Improvement Act
WWTP	Wastewater Treatment Plant
WQLS	Water Quality Limited Segment

EXECUTIVE SUMMARY

This document proposes to establish Total Maximum Daily Loads (TMDLs) for nitrogen and phosphorus in Mattawoman Creek (basin number 02-14-01-11). Mattawoman Creek ultimately drains to the Chesapeake Bay, and is a part of the Lower Potomac Tributary Strategy Basin. The river is impaired by the nutrients nitrogen and phosphorus, which cause excessive algal blooms and low dissolved oxygen. Mattawoman Creek was identified first in 1996 as being impaired by nutrients due to signs of eutrophication (expressed as high chlorophyll *a* levels), suspended sediments, and in 2002 for evidence of impacts to biological communities. The suspended sediments and biological impairments will be addressed at a later date.

Excess nutrients in an aquatic system act as a fertilizer - algal growth is promoted, the algae ultimately dies and decomposes, leading to bacterial consumption of dissolved oxygen. 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 Mattawoman Creek will be met. The TMDLs for the nutrients nitrogen and phosphorus were determined using the WASP 5.1 water quality model. Loading caps for total nitrogen and total phosphorus entering Mattawoman Creek are established for low flow and average annual flow conditions.

Low Flow Condition:

The low flow TMDL for nitrogen is 1,544 lbs/month. This TMDL is applied during the period May 1 through October 31. The allowable loads have been allocated between point and nonpoint sources. The nonpoint sources are allocated 164 lbs/month of total nitrogen. The point sources are allocated 1,366 lbs/month of nitrogen. The low flow TMDL for phosphorus is 411 lbs/month. This TMDL is applied during the period May 1 through October 31. The allowable loads have been allocated between point and nonpoint sources. The nonpoint sources are allocated 5 lbs/month of phosphorus. The point sources are allocated 404 lbs/month of phosphorus. Explicit future allocations and margins of safety make up the balance of these allocations.

Average Annual Flow Condition:

The average annual flow TMDL for nitrogen is 217,986 lbs/year. This TMDL is applied for the average annual flow condition. The allowable loads have been allocated between point and nonpoint sources. The nonpoint sources are allocated 116,699 lbs/year of total nitrogen. The point sources are allocated 85,784 lbs/year of nitrogen. The average annual flow TMDL for phosphorus is 18,167 lbs/year. This TMDL is applied for the average annual flow condition. The allowable loads have been allocated between point and nonpoint sources. The nonpoint sources are allocated 5,304 lbs/year of total phosphorus. The point sources are allocated 11,786 lbs/year of total phosphorus. Explicit future allocations and margins of safety make up these balance of the allocations.

Four factors provide assurance that these TMDLs will be implemented. First, National Pollutant Discharge Elimination System (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 (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing 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.

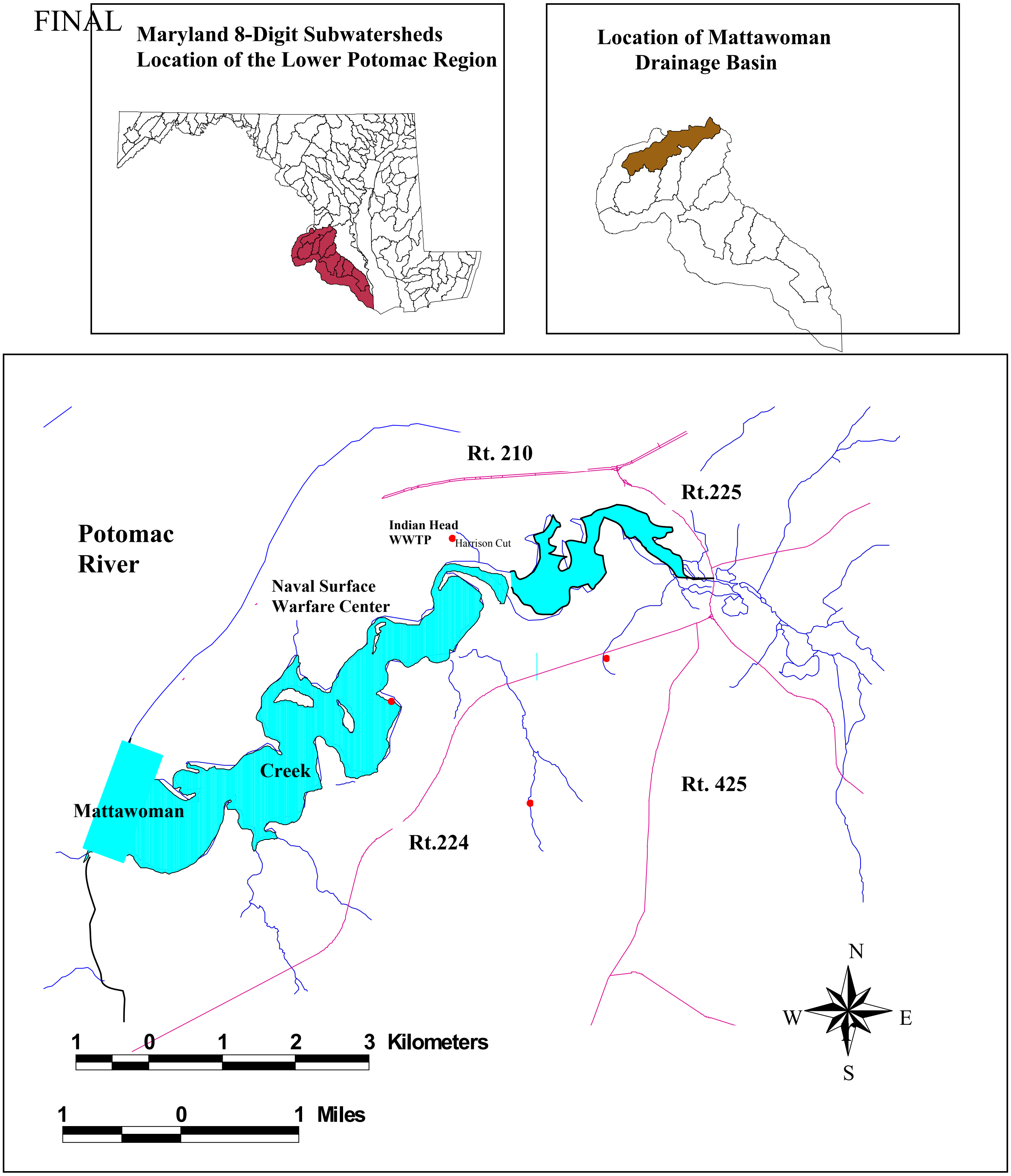
TMDLs are established to achieve and maintain water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include activities such as swimming, drinking water supply, 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.

Mattawoman Creek (basin number 02-14-01-11) 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* levels), suspended sediments, and evidence of biological impacts. Eutrophication is the over-enrichment of aquatic systems by excessive inputs of nutrients (nitrogen and/or phosphorus). The nutrients act as a fertilizer leading to excessive growth of aquatic plants, which eventually die and decompose, leading to bacterial consumption of dissolved oxygen. For these reasons, this document proposes to establish TMDLs for the nutrients nitrogen and phosphorus in Mattawoman Creek. The suspended sediments and biological impairments will be addressed at a later date.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

Mattawoman Creek is a shallow, tidally-influenced embayment of the Potomac Estuary, located approximately 38 miles downstream of Chain Bridge, Washington, D.C (Figure 1). The length of Mattawoman Creek is 23.5 miles, with 62,474 acres drainage area. The volume of the creek is about 360 million cubic feet, with average depth of 5 feet. The land uses in the watershed consist of forest and other herbaceous (36,614 acres or 59%), mixed agriculture (7,282 acres or 12%), urban (16,036 acres or 26%) and water/wetland (2,542 acres or 3%) (Figures 2 and 3). The land use is based on 2000 Maryland Department of Planning (MDP) land cover data, and Farm Service Agency (FSA) information. Figure 2 shows the geographic distribution of the different land uses. Figure 3 illustrates the relative amounts of the different land uses.



Data Sources:
Watersheds: MD Department of Natural Resources
Roads: State Highway Administration

MDE
Prepared By
Maryland Department of the Environment
1800 Washington Blvd
Baltimore, MD 21230
:

Figure 1: Location of the Mattawoman Creek Drainage Basin and Mattawoman Creek Eutrophication Model (MCEM) Study Area

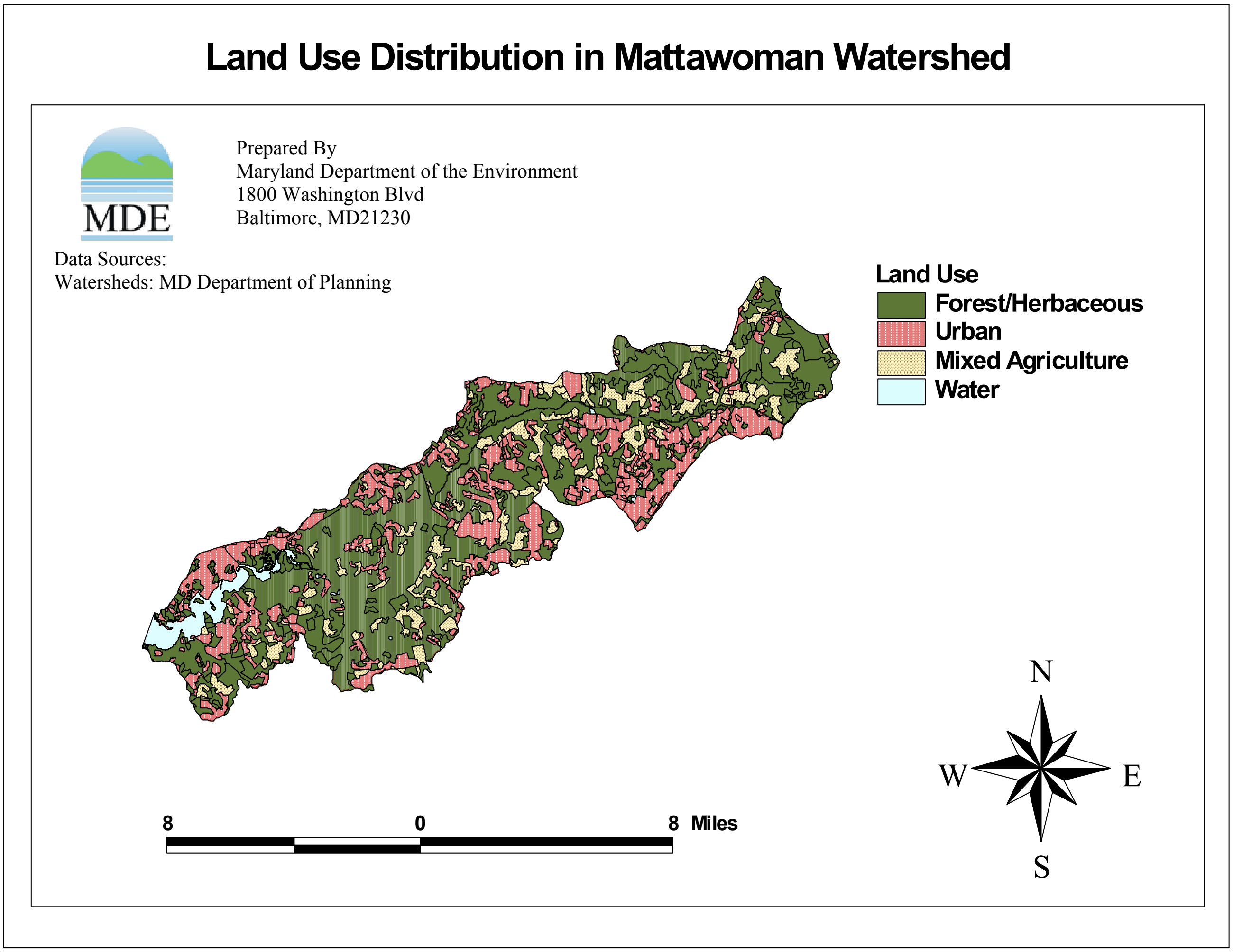


Figure 2: Predominant Land Use in the Mattawoman Creek Drainage Basin

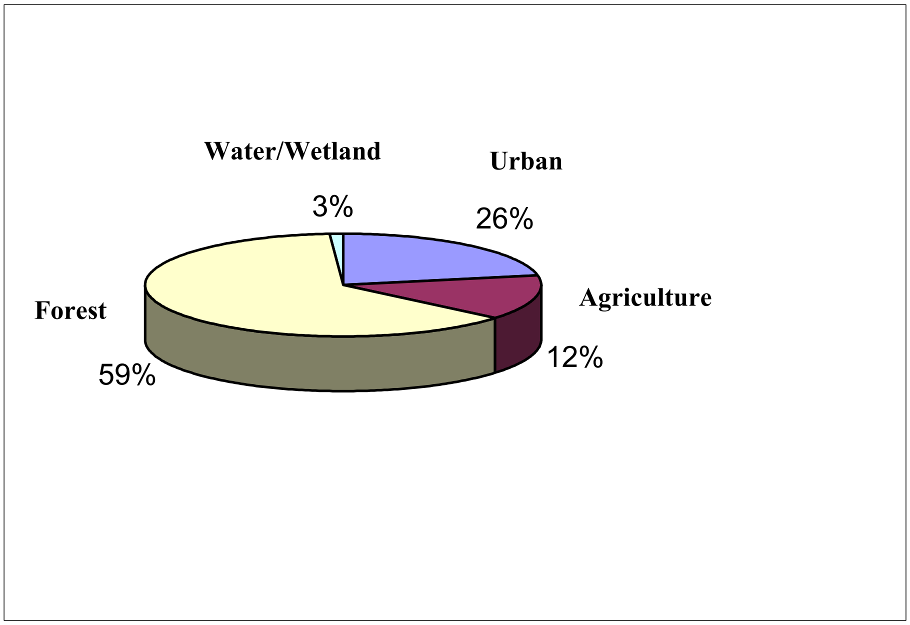


Figure 3: Proportions of Land Use in the Mattawoman Creek Drainage Basin

There are several point sources on the Mattawoman Creek watershed (Figure 4). The Town of Indian Head Wastewater Treatment Plant (WWTP), located at Harrison Cut, a tributary of Mattawoman Creek about 5.0 river miles from the mouth of the Creek, is the major point source with a design capacity of 0.5 million gallons per day (MGD). There are three other point sources in the watershed with smaller load contribution: Lackey High School (0.009 MGD), Brandywine Receiving Station (0.009 MGD) and Lingafelt Residence (0.00045 MGD). The estimated annual nutrient loadings for Mattawoman Watershed are 340,845 lbs for total nitrogen and 26,828 lbs for total phosphorus. These values were estimated based on 2001 Discharge Monitoring Data, 2000 MDP land use data and EPA's Chesapeake Bay Watershed Model loading coefficient (Phase 4.3). A detailed breakdown for all the major contributors for nutrient loadings is illustrated in Figure 5.

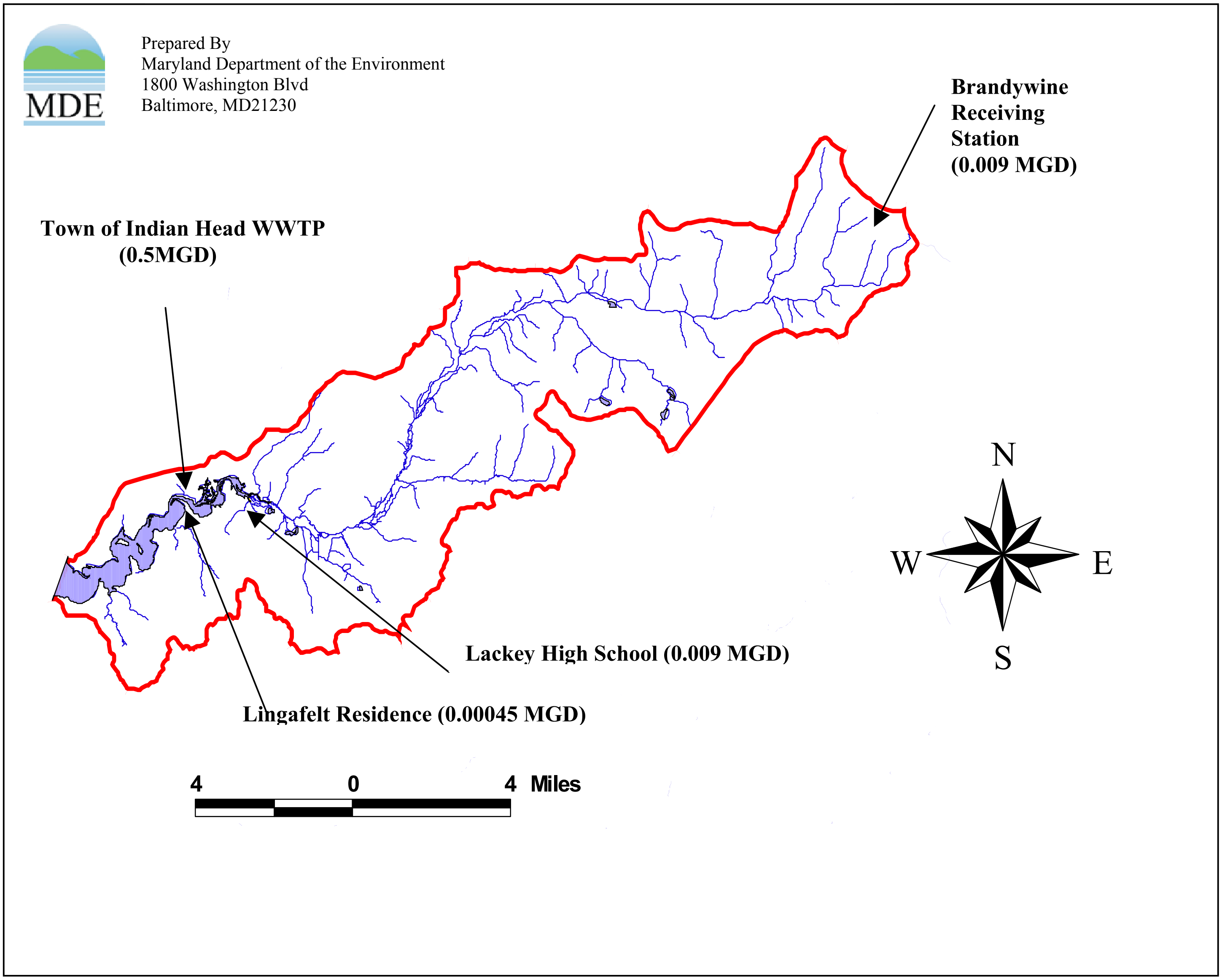
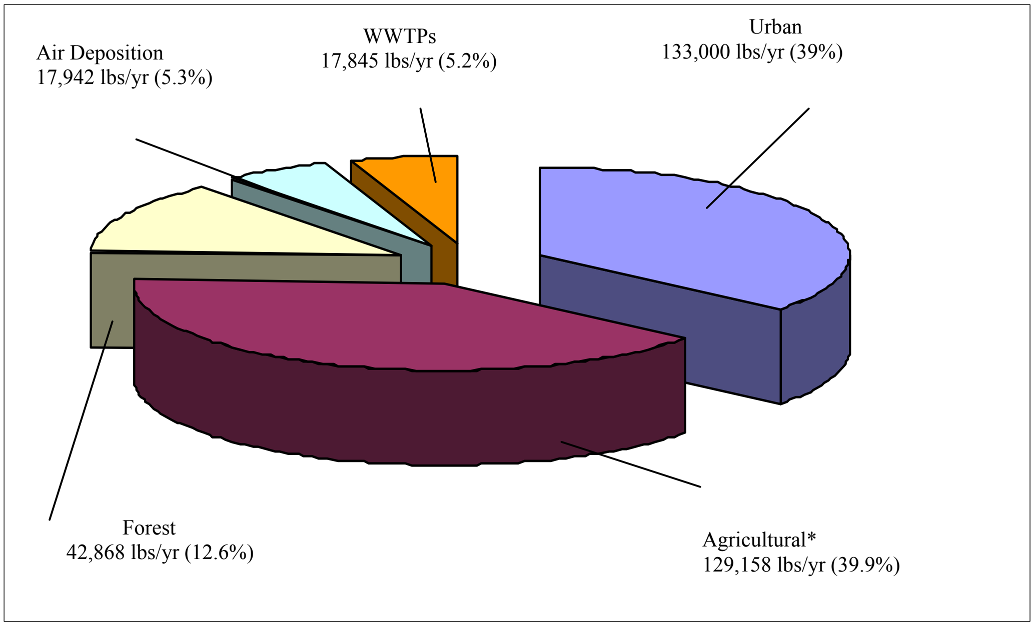
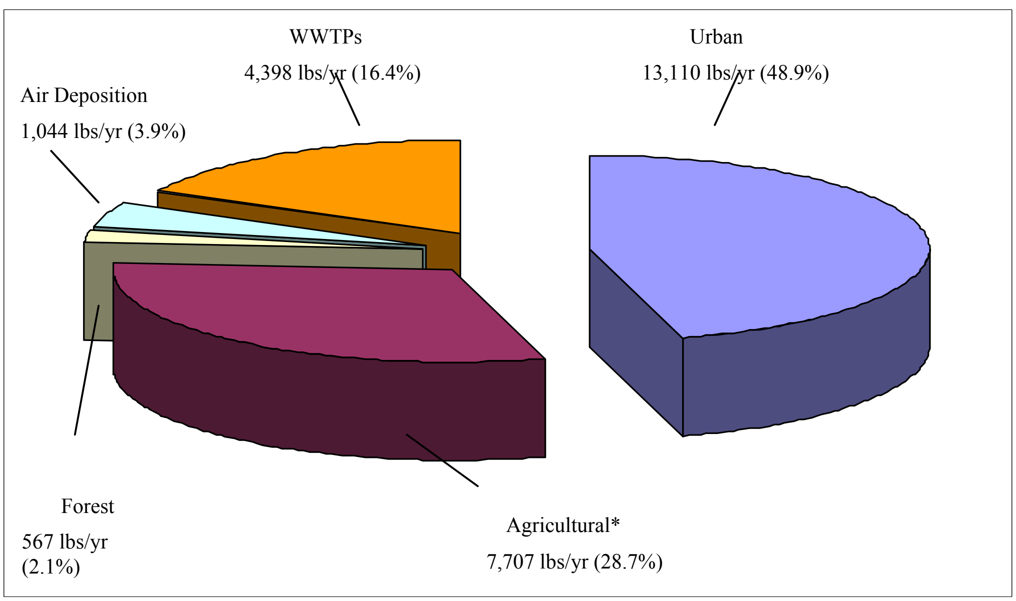


Figure 4. Locations of Wastewater Treatment Plants on Mattawoman Creek Watershed

Total Nitrogen



Total Phosphorus



*Including loads estimated from barren land and wetland

Figure 5: Estimated Annual Nitrogen and Phosphorus Loads

2.2 Water Quality Characterization

Two water quality parameters associated with the observed impairment of Mattawoman Creek, chlorophyll *a* and dissolved oxygen (DO) are presented below. Data from two of the water quality monitoring stations on Mattawoman Creek (MAT0016 and MAT0078, see Figures 6, 7 and Table 1 for their locations) indicate that there have been chronic water quality impairments on parts of Mattawoman Creek (Figure 8). Problems associated with eutrophication are most likely to occur during the summer season. 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. In order to perform the analysis, more recent data has been collected by MDE during surveys conducted in Mattawoman Creek during 2001 and 2002 (Figures 9 and 10).

Because of the generally level to moderate sloping topography and a soil texture consisting mostly of sandy soil in the drainage basin, minimum stream velocity is commonly observed during the low flow season and indicators of eutrophication are usually found in the boundary between the tidal and non-tidal portion of the Creek (between Harrison Cut and Route 225). Figures 9 and 10 present a longitudinal profile of chlorophyll *a* and DO data from the low flow periods of 2001 and 2002. High chlorophyll *a* concentrations (158 µg/l) as well as low DO (4.5 mg/l) were observed on August 2001 at the Station HSC0002, which is located between the outfall of Town of Indian Head WWTP, and the confluence between Harrison Cut and Mattawoman Creek. Another low DO (4.3 mg/l) concentration was observed at Station MAT0076 in August 2002. These observations have confirmed that the segments near these areas possess a great potential for eutrophication problems under critical low flow conditions.

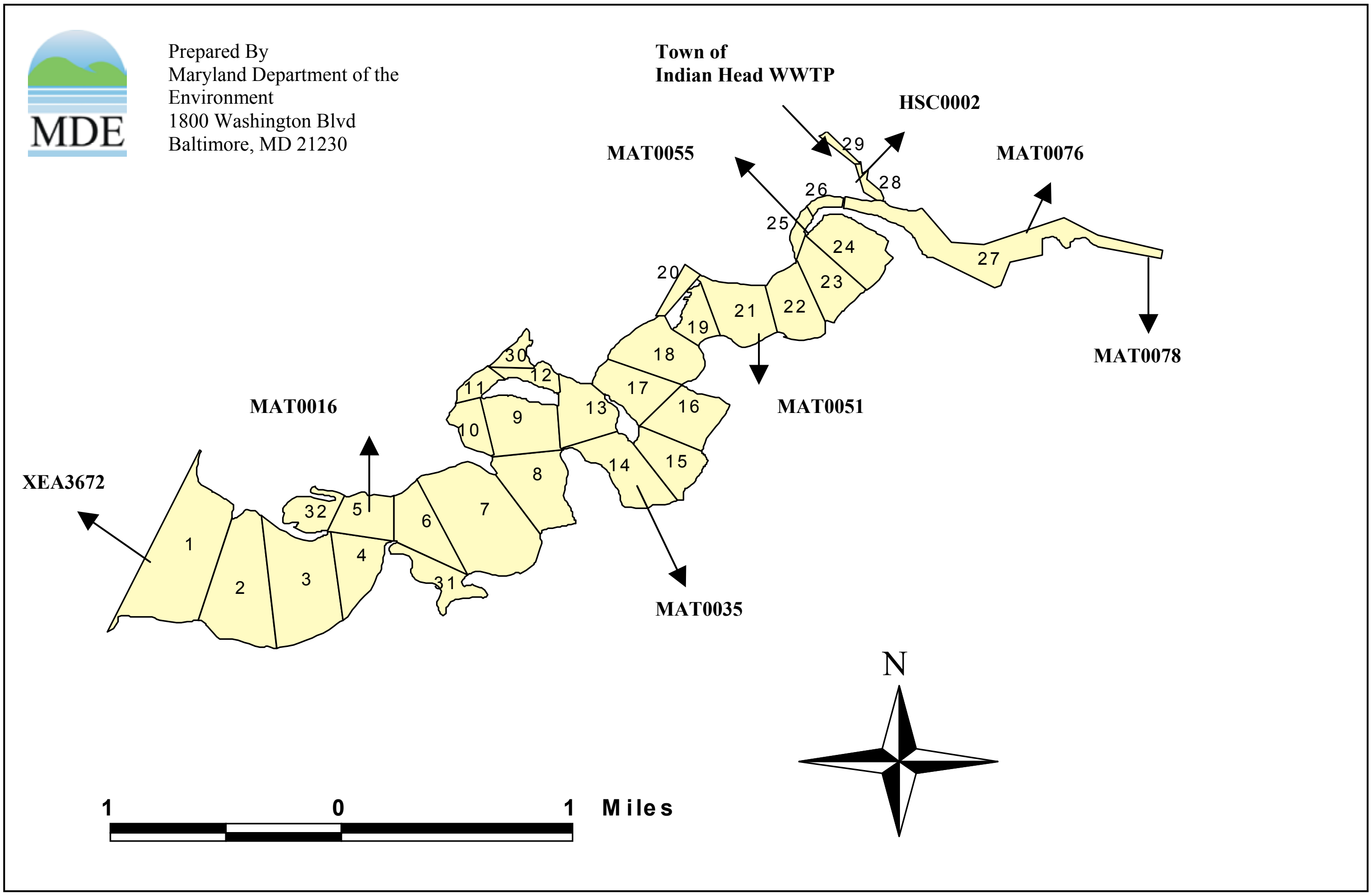


Figure 6. Locations of Water Quality Stations Referenced in MCEM Segments.

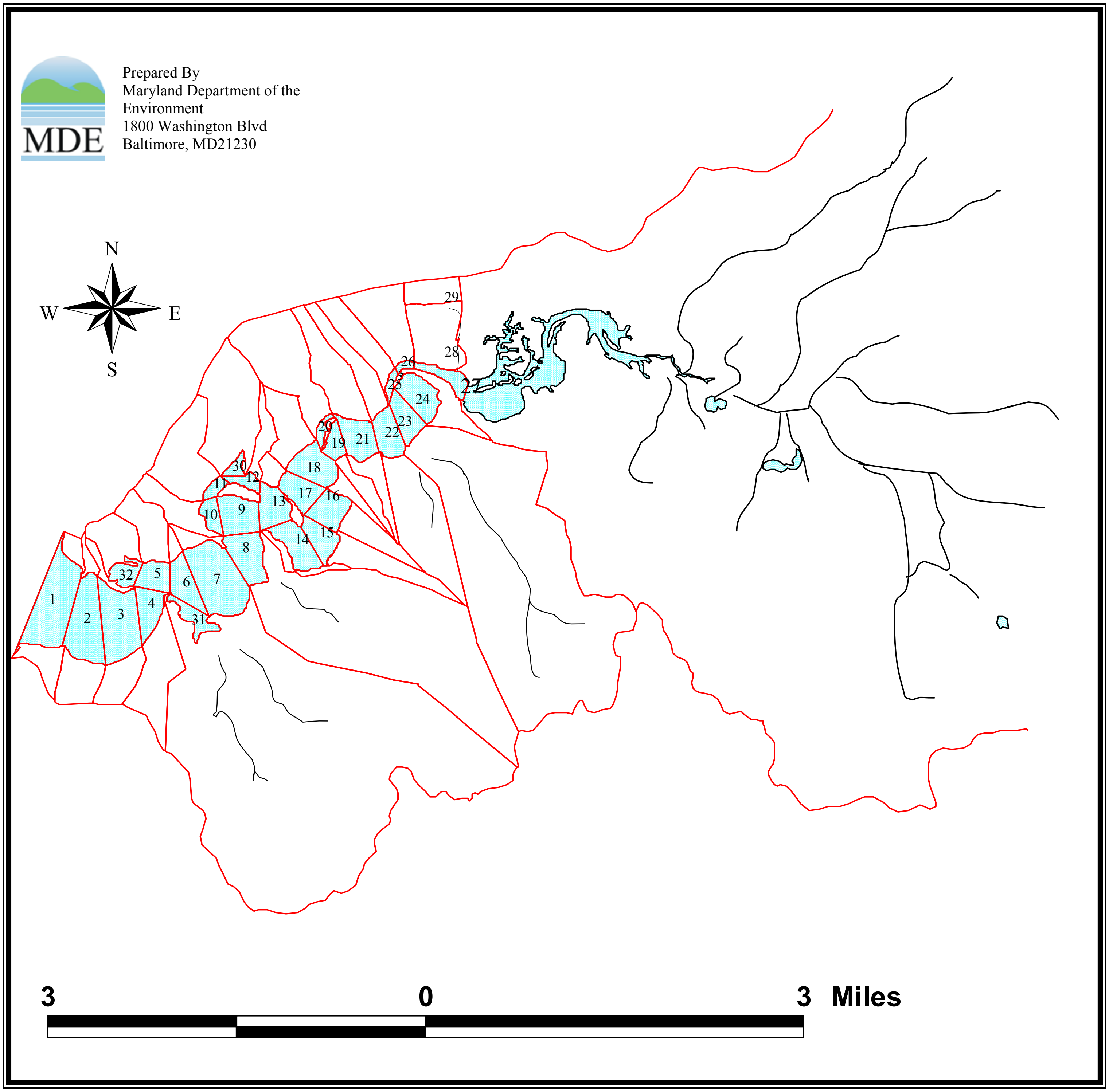
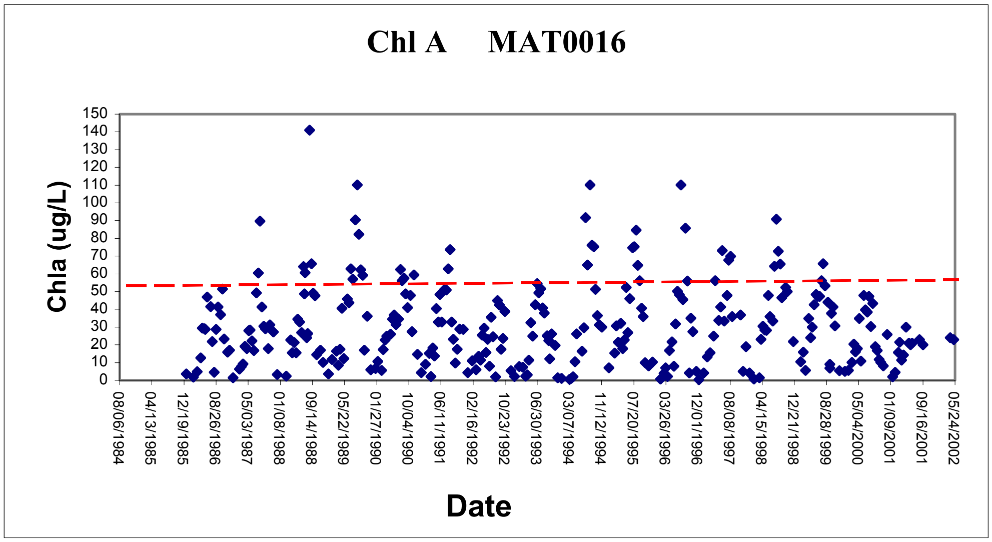


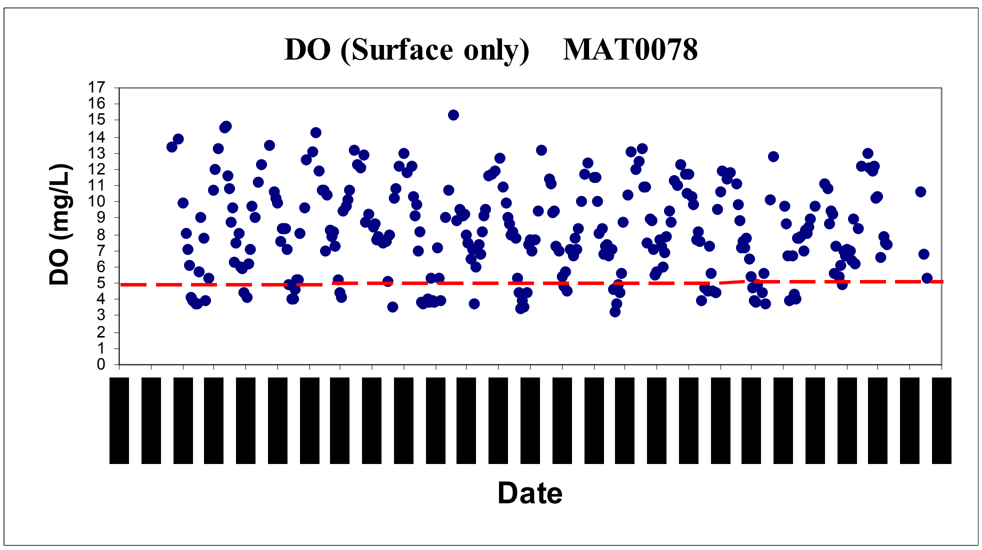
Figure 7. MCEM Segments and their Associated Subwatersheds.

Table 1. Locations of Water Quality Stations Referenced in 2001 MDE Survey.

Water Quality Station	Location	Distance from the Mouth (mile)
XEA 3672	38^{o} 33.557' N latitude 77^{o}12.753' W longitude	0
MAT0016	38^{o} 33.921' N latitude 77^{o} 11.660' W longitude	1.2
MAT0035	38^{o} 34.117' N latitude 77^{o} 10.591' W longitude	2.9
MAT0051	38^{o} 34.972' N latitude 77^{o} 10.005' W longitude	4.2
MAT0055	38^{o} 35.309' N latitude 77^{o} 09.201' W longitude	4.5
HSC0002	38^{o} 35.580' N latitude 77^{o} 09.411' W longitude	5.2
MAT0076	38^{o} 35.813' N latitude 77^{o} 08.088' W longitude	5.6
MAT0078*	38^{o} 35.317' N latitude 77^{o} 07.133' W longitude	6.1

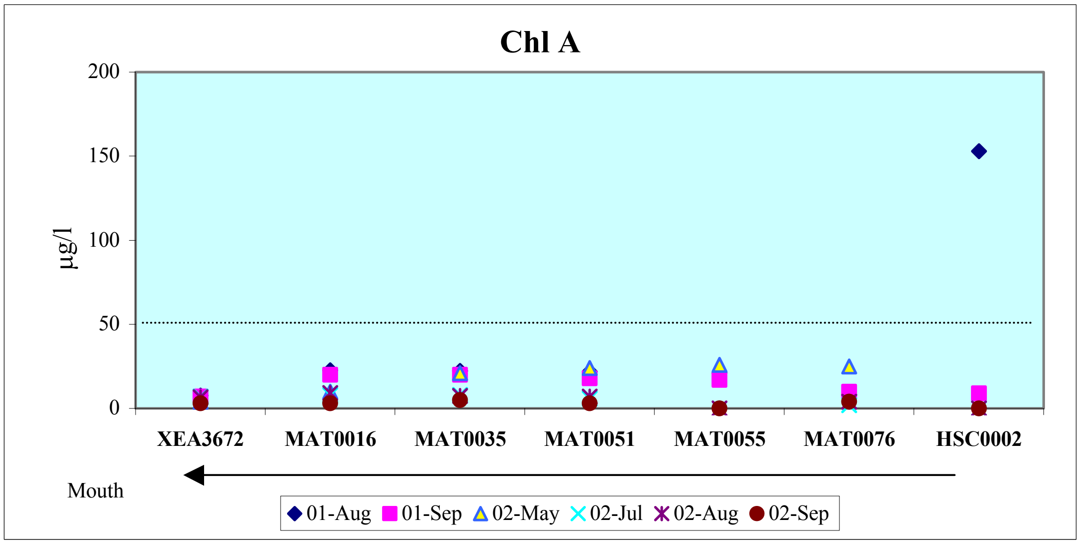
* Historical water quality monitoring station, not included in 2001 MDE survey.





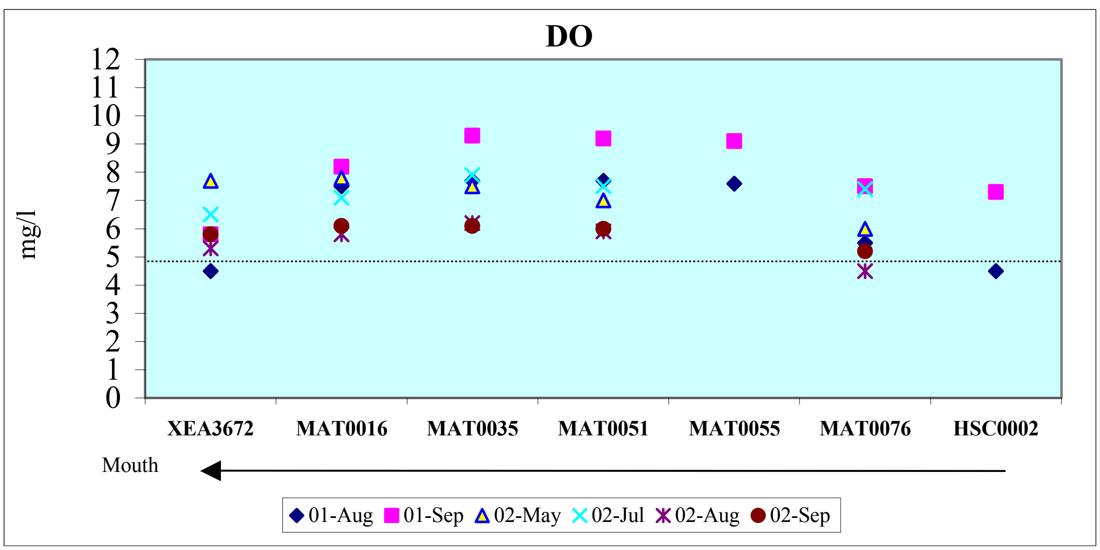
*The dashed line represents water quality goals (chlorophyll *a*) or criteria (DO).

Figure 8: Historical Chlorophyll *a* and Dissolved Oxygen Data from Two Water Quality Monitoring Stations on Mattawoman Creek



*The dashed line is the targeted water quality goal.

Figure 9: Longitudinal Profile of Chlorophyll *a* Data (Low flow)



*The dashed line is the targeted water quality criterion.

Figure 10: Longitudinal Profile of Dissolved Oxygen Data (Low flow)

2.3 Water Quality Impairment

The Maryland water quality standards Surface Water Use Designation Code of Maryland Regulations ((COMAR) 26.08.02.08M) for Mattawoman Creek is Use I - *water contact recreation, fishing, and protection of aquatic life and wildlife*. The water quality impairment of Mattawoman Creek 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 26.08.02.03A(2)). The achievement of 5.0 mg/l is expected in the well-mixed waters of the Mattawoman Creek 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 26.08.02.03B(2)). Additionally, COMAR 26.08.03.01B(3) recognizes that certain surface waters are eutrophic and all discharges to these surface waters shall be treated as necessary to reduce eutrophic effects. Excessive eutrophication, indicated by elevated levels of chlorophyll *a*, can produce nuisance level of algae and interfere with desired uses such as fishing and swimming. The baseline scenario of TMDL analysis indicates that both nitrogen and phosphorus loadings from point and nonpoint sources have resulted in chlorophyll *a* concentrations occasionally exceeding the desired level of 50 μg/l in parts of the Mattawoman Creek during both low and average annual flow conditions.

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 Mattawoman Creek. Specifically, the TMDLs of nitrogen and phosphorus for Mattawoman Creek are intended to:

1. Maintain a minimum DO level of 5.0 mg/l throughout the Mattawoman Creek system, and
2. Reduce peak chlorophyll *a* levels (a surrogate for algal blooms) to below 50 μg/l throughout the Mattawoman Creek system.

The DO level is based on specific numeric criteria for Use I waters set forth in the COMAR 28.08.02. The chlorophyll *a* water quality level is based on the designated uses of Mattawoman Creek, 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 that 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 Mattawoman 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 (MOS). Finally, the pieces of the equation are combined in a summary accounting of the TMDLs for low flow and average annual flow conditions.

4.2 Analysis Framework

The computational framework chosen for the Mattawoman 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), dividing the water body into a series of segments and accounting for mass balance through various mass transportation and transformation equations. WASP5.1 is supported and distributed by U.S. EPA's Center for Exposure Assessment Modeling (CEAM) in Athens, GA (Ambrose *et al.*, 1993). 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 annual flow conditions. These conditions are described in more detail below.

The spatial domain of the Mattawoman Creek Eutrophication Model (MCEM) extends from the mouth of Mattawoman Creek for about 6 miles (9 km) along the tidal portion of Mattawoman Creek. There are 32 model segments in this WASP modeling domain. A diagram of the WASP model segmentation is presented in Figure 7.

The nutrient TMDL analyses presented here consist of an assessment of low flow loading conditions and a projected loading for average annual flow condition. 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 water quality characteristics for observed low flow conditions. Observed water quality data collected during the 2001 survey was used to support the calibration process, as explained further in Appendix A.

In order to estimate representative flows to be used in MCEM analysis, five U.S. Geological Survey (USGS) gaging stations located on or adjacent the Mattawoman Watershed were selected (please refer to appendix A for the station numbers). A ratio of flow to drainage area was calculated for each of the USGS gages and then an average of all the five 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 $7Q_{10}$ flow (critical low flow) for the subwatersheds were derived from an approach using an inverse distance weighting of flows data. This method was suggested by USGS for the southern region of Maryland. The estimation of stream flow used for the average annual flow condition was also calculated based on the data collected from the same reference USGS gages selected before. The methods used to estimate stream flows are described further in Appendix A.

There are four point sources in the Mattawoman Creek basin, the Town of Indian Head WWTP (design flow capacity 0.5 MGD); Lackey High School (0.009 MGD); Brandywine Receiver Site (0.009 MGD); and Lingafelt Residence (0.00045 MGD). 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 2001 multiplied by the estimated critical low flows. Because the loading estimations are based on observed data, they account for all human and natural sources. The NPS loads in the MCEM also include the non-contact cooling water and the stormwater discharge from the Indian Head Naval Surface Warfare Center. The high flow NPS loading estimation is calculated by multiplying the estimated annual regional nutrient load coefficients for each land use (obtained from EPA Chesapeake Bay Program) with the area of land use in each subwatershed. The point source loads were based on the maximum permitted flow loads from the sources.

The concentrations of nitrogen and phosphorus are modeled in their speciated forms. Nitrogen is simulated as ammonia (NH_4^+), nitrate and nitrite (NO_{23}), and organic nitrogen (ON). Phosphorus is simulated as ortho-phosphate (PO_4) and organic phosphorus (OP). NH_4^+, NO_{23}, and PO_4 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 DO concentrations. The ratios of total nutrients to dissolved nutrients used in the model scenarios represent normalized 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 Mattawoman Creek.

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 *baseline conditions*, and *TMDL conditions* associated with TMDLs. The baseline conditions are intended to provide a point of reference to compare to the future scenario that simulates conditions of a TMDL. Defining this baseline for comparison is preferred to trying to establish a "current condition". The baseline is defined in a consistent way among different TMDL projects, and does not vary in time. The alternative of using a "current condition" has the drawback of changing over time creating confusion. Since the development and review of a TMDL often take years, by the time it is completed, the "current" condition will be no longer valid. To avoid this confusion, we use the term "baseline condition".

Baseline Condition (Low Flow): This first scenario represents the baseline conditions of the stream at a simulated critical low flow in Mattawoman Creek. 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 create the water quality problems associated with excessive nutrient enrichment.

The nutrient concentrations for the first scenario were calculated using observed data collected during low flow conditions of 2001. 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 from septic tanks, which are associated with river base flow during low flow conditions. The NPS loads in the MCEM also include the non-contact cooling water and stormwater runoff from the Indian Head Naval Surface Warfare center. For loads from wastewater treatment plants, these baseline conditions assume maximum permitted flow from the major point source (Town of Indian Head WWTP, 0.5 MGD) with the observed effluent nutrient during 2001 summer (total nitrogen 15 mg/l, total phosphorus 3.7 mg/l) and current permitted biological oxygen demand (BOD) concentration (16 mg/l). The loads from other less significant point sources (Lackey High School, Brandywine Site and the Lingafelt residence) are assumed at their current permitted flows with appropriate parameters expected to occur at that flow period.

TMDL (Low Flow): 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 40% overall reduction in NPS nitrogen and phosphorus input from the watershed. In this future condition scenario, reductions in nutrient fluxes and oxygen demand from the sediment were assumed corresponding to the percentage reduction of nutrient input from the NPS. The point source loads from Town of Indian Head assume maximum design flow at total nitrogen controlled at 10 mg/l and total phosphorus at 3 mg/l. The loads from other less significant point sources (Lackey High School, Brandywine Site and the Lingafelt residence) are assumed at their current permitted flows with appropriate parameters expected to occur at that flow with no additional control. Details of this modeling activity are described further in the technical memorandum entitled *" Nutrient Point Sources in the Mattawoman Creek Watershed"* and Appendix A.

Baseline Condition (Average Annual Flow): This third scenario represents the baseline conditions of the stream at a simulated average annual condition in the Creek. The model predict the stream's response for nutrient input at average annual flow condition. The method of estimating the average annual flow is described in Appendix A.

For loads from wastewater treatment plants, these baseline conditions assume maximum permitted flow from the major point source (Town of Indian Head WWTP, 0.5 MGD) with the observed effluent nutrient from 2001 summer data (total nitrogen of 15 mg/l, total phosphorus of 3.7 mg/l, DO of 6 mg/l) and the current permitted BOD concentration (30 mg/l). The loads from other less significant point sources (Lackey High School, Brandywine Receiving Station and the Lingafelt residence) are assumed at their current permitted flows with appropriate parameters expected to occur at that flow.

The total NPS loads were calculated using loading rates for different land use from the EPA Chesapeake Bay Program Phase 4.3 watershed model and land use information from 2000 MDP data. The nutrient loads account for contributions from atmosphere deposition, agricultural, forest and urban lands. The NPS source loads in the MCEM also include the non-contact cooling water and the stormwater discharge from the Indian Head Naval Surface Warfare Center.

TMDL (Average Annual Flow): This fourth scenario represents the future condition of maximum allowable loads during average annual stream flow condition. The stream flow is the same as that used in the third scenario. This scenario simulates an estimated 40% overall reduction in NPS nitrogen and phosphorus inputs from the watershed. The point source loads assume maximum allowable flow (0.5 MGD) with total nitrogen and total phosphorus at 15 mg/l and 3 mg/l respectively from the Town of Indian Head WWTP. In this future scenario, reductions in nutrient fluxes and oxygen demand from the sediment were adjusted in correspondence to the percentage reduction of nutrient input from the NPS. Details of this modeling activity are described further in the technical memorandum entitled "*Nutrient Point Sources in the Mattawoman Creek Watershed"* and "*Significant Nutrient Nonpoint Sources in the Mattawoman Creek Watershed",* as well as Appendix A.

4.4 Scenario Results

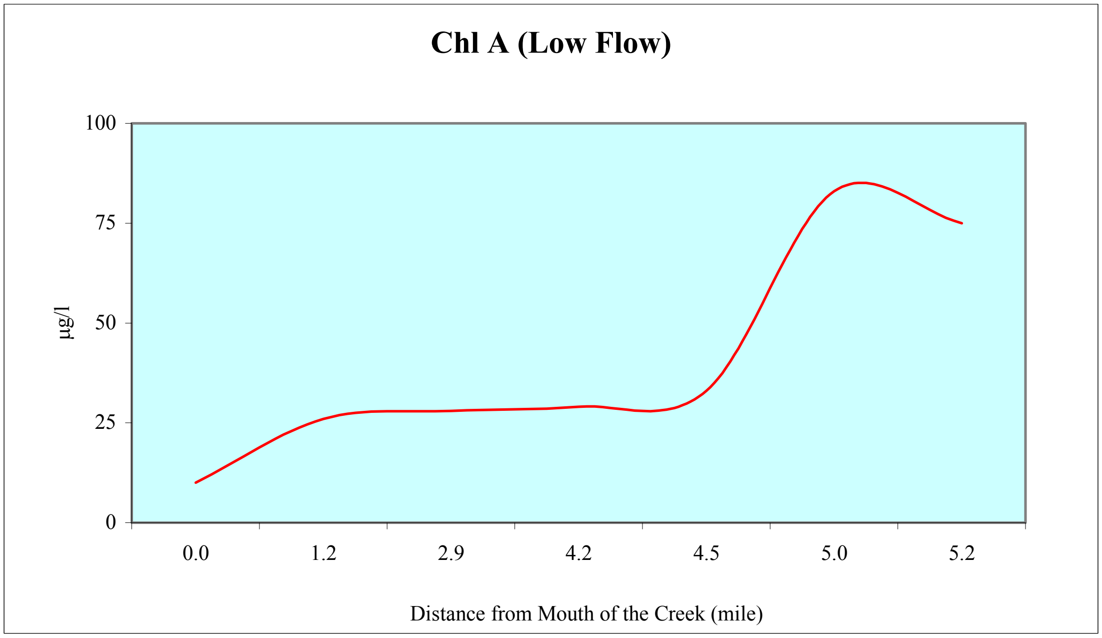
This section describes the results of the model scenarios described in the previous section. The MCEM results presented in this section are daily minimum DO concentrations. These minimum DO concentrations account for diurnal fluctuations caused by photosynthesis and respiration of algae (diurnal swing).

Baseline Condition (Low Flow):

This scenario simulates critical low stream flow ($7Q_{10}$) conditions during the summer season. Point source loads assume maximum approved water and sewer plan flow and observed effluent nutrient concentrations from the Town of Indian Head WWTP (0.5 MGD) during Summer 2001. The loadings from the other three point sources were incorporated with the NPS using the observed water quality parameters (e.g., nutrient concentrations) based on the 2001 survey. Results for this scenario, representing the baseline condition for summer low flow, are illustrated in Figure 11. Figure 11 (A) shows that the peak chlorophyll *a* level is well above 50 µg/l under critical conditions of temperature and flow among the upper segments of the river. On the other hand, even though the DO concentrations in the baseline condition are above the 5 mg/l criterion in all model segments (Figure 11 (B)), there are still potential risks of low DO caused by diurnal manifestation in segments with high chlorophyll *a* level (excessive algae growth). The TMDL scenario, presented later, establishes maximum allowable loads that address these apparent problems.

Baseline

(A)



(B)

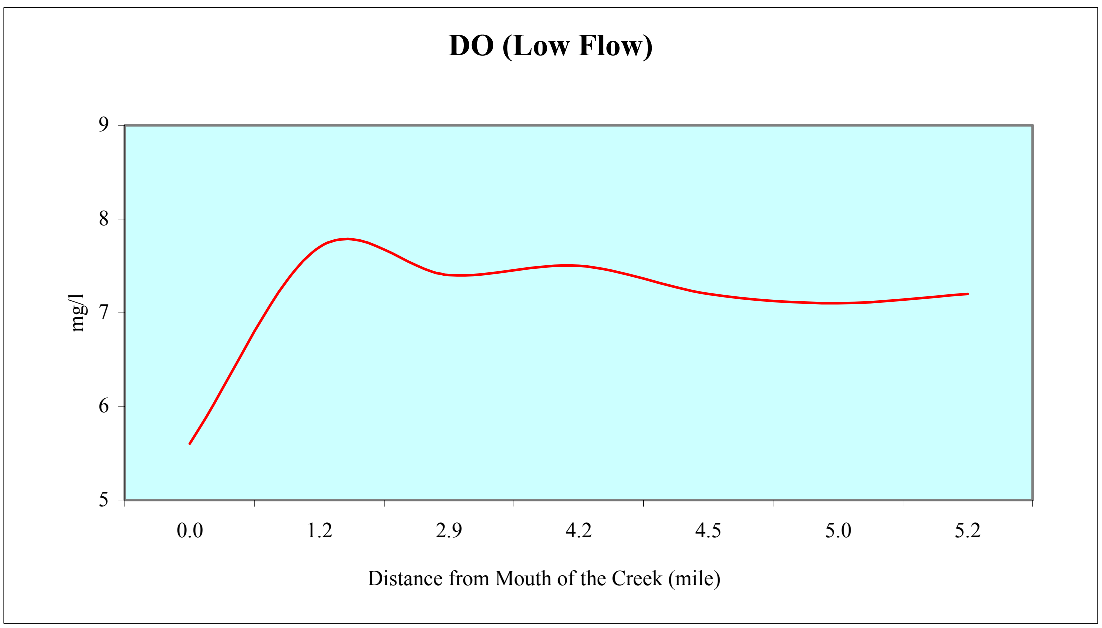


Figure 11: Model Results for the Low Flow Baseline for (A) Chlorophyll *a* and (B) Dissolved Oxygen

TMDL (Low Flow):

The TMDL simulates the future condition of maximum allowable loads for critical low stream flow ($7Q_{10}$) conditions during summer season to meet the water quality standard criteria for Mattawoman Creek. Results for the TMDL are illustrated in comparison to the appropriate baseline condition (solid line) in Figure 12. Under the nutrient load reduction conditions described above for this scenario, the model results show that chlorophyll *a* concentrations are below the levels of 50 µg/l along the entire length of Mattawoman Creek (Figure 12(A)). Results from Figure 12(B) also indicate that the minimum concentrations of DO along the length of the river are above the water quality criterion of 5.0 mg/l. The significant reductions of algae growth in the upper segments predicted in the baseline condition also reduce the risk for the occurrence of potential low DO condition caused by diurnal fluctuations in oxygen.

Baseline Condition (Average Annual Flow):

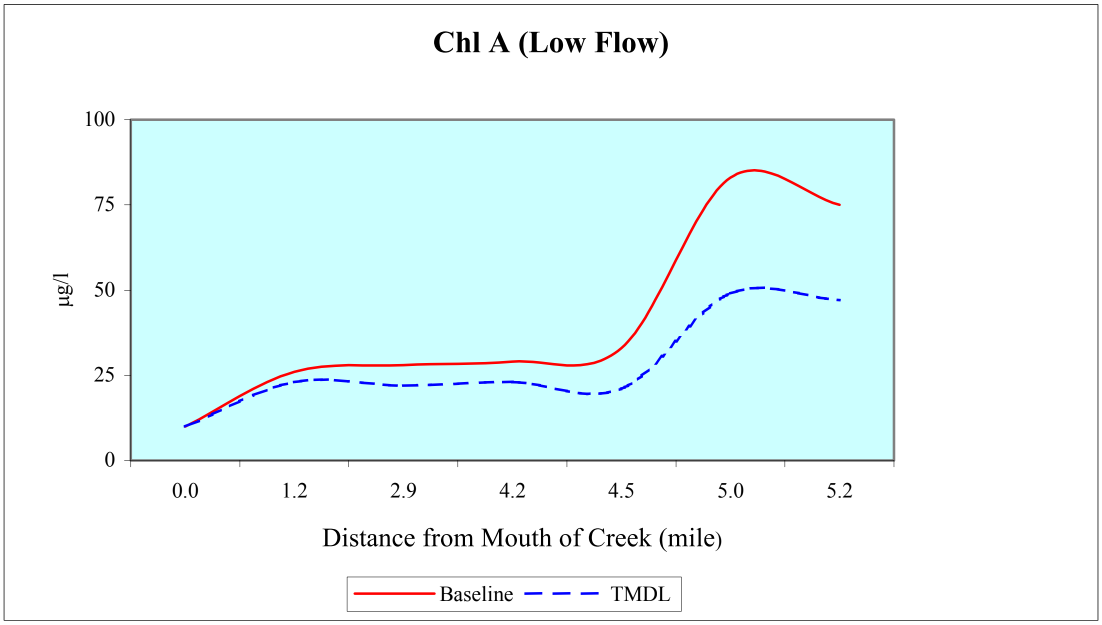
This scenario simulates high stream flow conditions during average annual flow conditions. Nutrient loads are based on loading rates for different land use from the EPA Chesapeake Bay Program Phase IV watershed model and land use information from 2000 MDP data. Point source loads assume maximum approved water and flow and observed effluent nutrient concentrations during Summer 2001 (0.5 MGD at Town of Indian Head WWTP). Results for this scenario, representing the baseline condition for high flow seasons, are illustrated in Figure 13. Figure 13A indicates that the peak chlorophyll *a* level will exceed 50 µg/l under average annual flow condition in the lower to middle segments. The DO level shown in Figure 13 (B) is above the 5.0 mg/l throughout the model segments. This TMDL scenario, presented below, establishes maximum allowable loads that address these apparent problems.

TMDL (Average Annual Flow Condition):

This scenario simulates the future condition of maximum allowable loads for average annual flow conditions to meet the water quality in Mattawoman Creek. Results for the TMDL are illustrated in comparison to the appropriate baseline condition (solid line) in Figure 14. Under the nutrient load reduction conditions described above for this scenario, the results show that chlorophyll *a* concentrations are below the levels of 50 µg/l along the entire length of the model segments (see Figure 14(A)). Results from Figure 14(B) indicate that the minimum concentrations of dissolved oxygen along the length of the river are above the water quality criterion of 5.0 mg/l.

TMDL

(A)



(B)

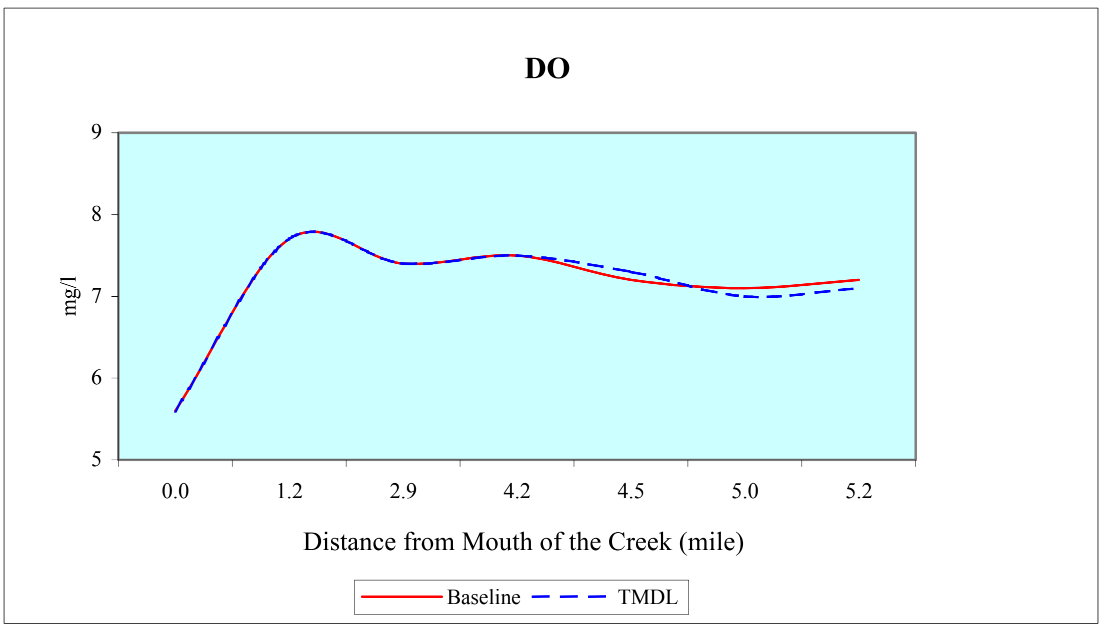
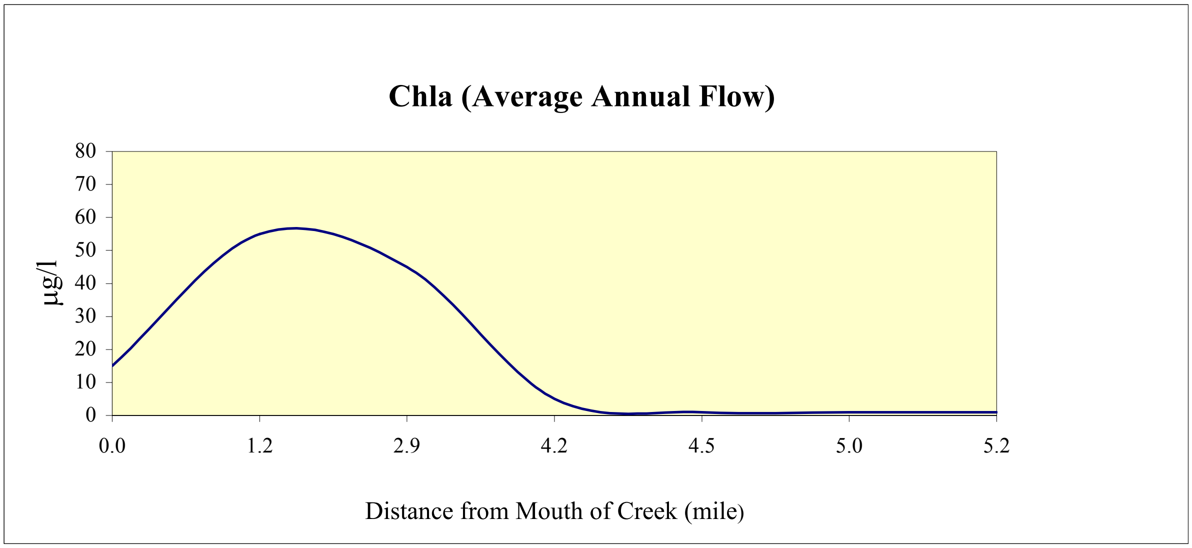


Figure 12: Model Results for the Low Flow TMDL for (A) Chlorophyll *a* and (B) Dissolved Oxygen

Baseline



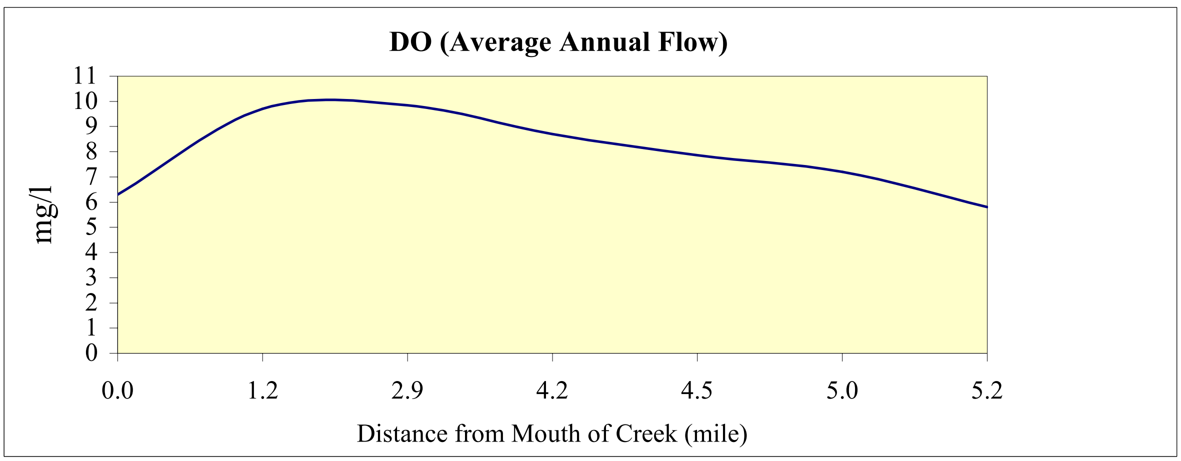
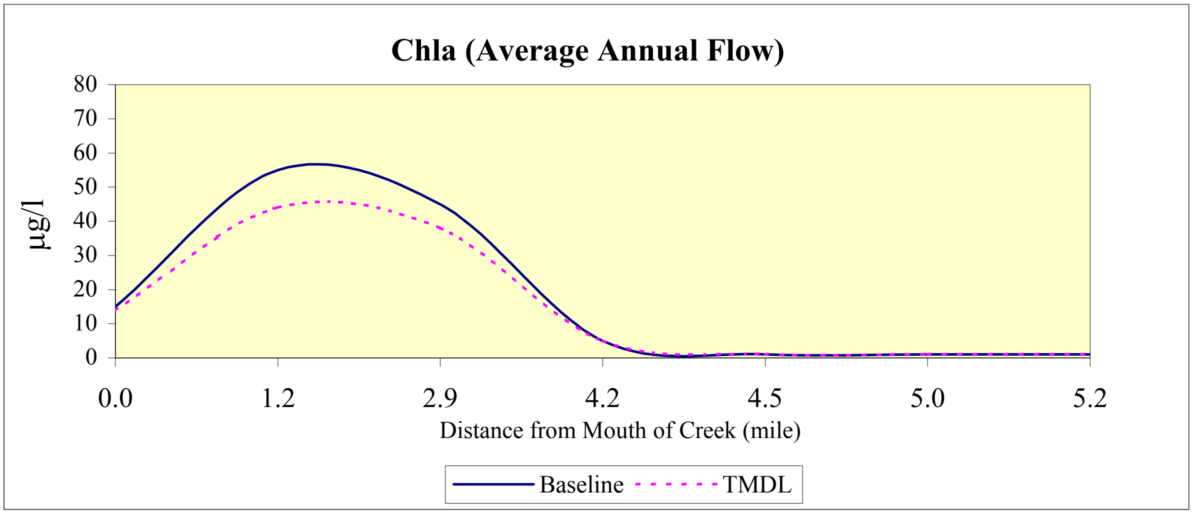


Figure 13: Model Results of Average Annual Flow Baseline for (A) Chlorophyll *a* and (B) Dissolved Oxygen

TMDL



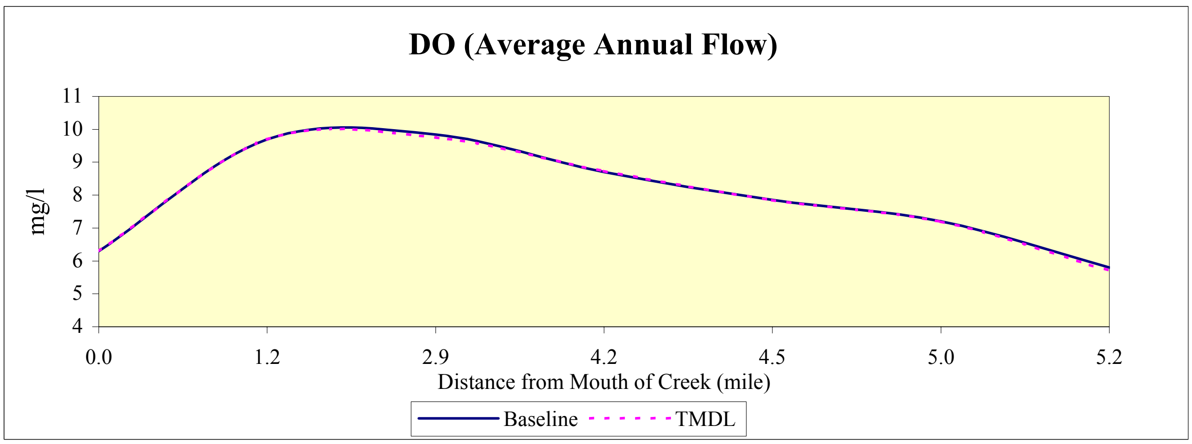


Figure 14: Model Results of Average Annual Flow TMDL for (A) Chlorophyll *a* and (B) Dissolved Oxygen

4.5 TMDL Loading Caps

This section presents the TMDLs of nitrogen and phosphorus applicable during critical low flow conditions. The critical season for excessive algal growth in Mattawoman Creek is during the summer months, when the river system is poorly flushed. During this critical time, sunlight and warm water temperatures are most conducive to creating the water quality problems associated with excessive nutrient enrichment. The low flows TMDLs are stated in monthly terms because these critical conditions occur for a limited period of time.

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

<u>Low Flow TMDL:</u>

NITROGEN **1,544** *lbs/month*

PHOSPHORUS **411** *lbs/month*

For the average annual flow, the following TMDLs apply:

<u>Average Annual Flow TMDL:</u>

NITROGEN **217,986** *lbs/year*

PHOSPHORUS **18,167** *lbs/year*

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 Mattawoman Creek. Specifically, these allocations show that nitrogen and phosphorus nutrient loadings to Mattawoman Creek from existing point sources and nonpoint sources can be maintained safely within the TMDL established here. These allocations demonstrate how these TMDLs could be implemented to achieve water quality standards; however the State reserves the right to revise these allocations provided the allocations are consistent with the achievement of water quality standards.

<u>Low Flow Allocations</u>:

The NPS loads of nitrogen and phosphorus simulated in both future scenarios represent 40% reductions from the baseline scenario. Recall that the baseline scenario loads were calculated through observed nutrient concentrations from the Mattawoman Creek water quality survey conducted in Summer 2001. These low flow NPS loads, based on observed concentrations, account for both "natural" and human-induced components and cannot be separated into specific source categories. There are four wastewater treatment plants, Town of Indian Head WWTP, Lackey High School, Brandywine Receiving Station, and the Lingafelt Residence discharging nutrients in the watershed. Allocations have been made to these point sources based on their maximum permitted discharge flows. Point Source allocations are described further in the technical memorandum entitled "*Nutrient Point Sources in the Mattawoman Creek Watershed"* and Appendix A. To address future developments in the watershed, 5% of the NPS loading used in the MCEM is being assigned to the urban waste load allocation (see section 4.7 for discussion). The nitrogen and phosphorus allocations for low flow conditions are presented in Table 2.

Table 2: Summer Low Flow Allocations

	Total Nitrogen *(Lbs/month)*	**Total Phosphorus *(lbs/month)***
Nonpoint Source	164	5
Point Source	1366	404
FA	9*	1
MOS	5**	1
Total	1544	411

* Representing 5% of the total loads from NPS
** Representing 3% of the total loads from NPS

<u>Average Annual Flow Allocations</u>:

This scenario was performed with an overall 40% load reduction from NPS (for nitrogen reduction: 54% from urban stormwater, 54% from agriculture and 20% from air deposition; for phosphorus reduction: 47 % from urban stormwater, 49 % from agriculture and 20% from air deposition). On the other hand, the point source loadings from wastewater treatment plant will be allocated at the current level. It is concluded that the nutrient values set for these loadings will be adequate for average annual flow TMDL. The NPS and urban stormwater load calculated in the annual flow condition was based on the nutrient loading rates provided by EPA's Chesapeake Bay Program. There are four wastewater treatment plants (Town of Indian Head WWTP, Lackey High School, Brandywine Receiver Site and the Lingafelt Residence) discharging nutrients into the watershed. Allocations have been made to these point sources based on their maximum permitted discharge flows. The load from urban stormwater discharge is incorporated into the point source load as part of the annual waste load allocations. Point source allocations are described further in the technical memorandum entitled "*Nutrient Point Sources in the Mattawoman Creek Watershed"* and Appendix A. To address future developments in the watershed, 5% of the NPS loading used in the MCEM is being assigned to the urban waste load allocation (see section 4.7 for discussion). The nitrogen and phosphorus allocations for average annual flow conditions are presented in Table 3.

Table 3: Average Annual Flow Allocations

	Total Nitrogen *(lbs/year)*	**Total Phosphorus *(lbs/year)***
Nonpoint Source[1]	116,699	5,304
Point Source	85,784	11,786
FA[2]	9,689	673
MOS[3]	5,814	404
Total	217,986	18,167

1. Excluding urban stormwater loads.
2. Representing 5% of the total loads from NPS and urban stormwater.
3. Representing 3% of the total loads from NPS and urban stormwater.

4.7 Future Allocations and Margins of Safety

Future allocations represent assimilative surplus loading capacity that is either currently available, or projected to become available due to planned implementation of environmental controls or other changes. MDE has elected to reserve loads equal to 5% of the current NPS loads to address the future regional development. For comparison, the current future nitrogen allocation reserved for urban stormwater is 9,689 lbs/yr, which is more than 15% of the annual allocation for urban stormwater (61,552 lbs/yr). Compared with the 2% estimated annual growth based on the projection from MDP for this region (39% growth in 20 years), the loads reserved in the FA should be sufficient for future regional development with the acknowledgement that future adjustments of the loadings may be necessary to allow for changes in land use. To further ensure that the future allocation is sufficient, the following methodology was used to check whether the future allocation given in the TMDL is sufficient to address the future development activities. Land use data from the available 1994 and 2000 MDP land use acreages for the Mattawoman Creek watershed were used to estimate loads for these years in the same way that the baseline average annual loads were estimated (see detailed description in Appendix A, page A46). The changes in land use and loads for urban, forest and agricultural land uses from between 1994 and 2000 were then calculated. By subtracting the nutrient load loss from the disappearance of forest and agriculture land use from the gain of load through urban land increase, it was assumed that the result is the load increase due to urban growth activity. This final load was averaged over a six-year period (1994 – 2000) to obtain a gross estimation for annual growth of nutrient load due to urban growth and development activities. For the Mattawoman Creek Watershed, the average TN and TP loads gained through land use change is 1,067 lbs/yr (approximately 11% of annual FA) and 213 lbs/yr (approximately 32% of annual FA). After comparing these loads with the annual future allocations, it is concluded that the future allocation will be adequate until such time as the allocations are revised through a public process.

A margin of safety (MOS) is required as part of a TMDL in recognition of the many uncertainties in 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 these 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 = Load Allocations + Waste Load Allocations + MOS). The second approach is to incorporate the MOS as conservative assumptions used in the TMDL analysis.

Maryland has adopted MOS for these TMDLs by using both a more conservative approach in the modeling process as well as a reserved portion from loading capacity. For instance, the average monthly flows from Town of Indian Head WWTP from May 2002 to March 2003 are 0.36 MGD (source: Discharge Monitoring Report) which account for 80 % of the design flows (0.5 MGD) utilized in baseline and scenario simulations in MCEM. In addition to this conservative approach, additional safety factors are also built into the TMDL development process. 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 reserve 3% of NPS loads (including agriculture, forest, air deposition and urban stormwater) to address the uncertainties faced during the modeling process as well as an additional MOS in the average annual TMDL given the projected maximum chlorophyll *a* at a value of 48 µg/l. Table 3 includes the MOS incorporated in low flow and average flow TMDL.

4.8 Summary of Total Maximum Daily Loads

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

For Nitrogen (*lbs/month*):

TMDL	=	LA	+	WLA	+	FA[1, 2]	+	MOS [3]
1,544	=	164	+	1,366	+	9	+	5

For Phosphorus (*lbs/month*):

TMDL	=	LA	+	WLA	+	FA[1, 2]	+	MOS [3]
411	=	5	+	404	+	1	+	1

The average annual TMDLs, applicable for the average annual flow condition for Mattawoman Creek:

For Nitrogen (*lbs/year*):

TMDL	=	LA[1]	+	WLA	+	FA[2]	+	MOS[3]
217,986	=	116,699	+	85,784	+	9,689	+	5,814

For Phosphorus (*lbs/year*):

TMDL	=	LA[1]	+	WLA	+	FA[2]	+	MOS[3]
18,167	=	5,304	+	11,786	+	673	+	404

1. Excluding urban stormwater loads.
2. Representing 5% of the total loads from NPS and urban stormwater.
3. Representing 3% of the total loads from NPS and urban stormwater.

Where:

TMDL = Total Maximum Daily Load

LA = Load Allocation (Nonpoint Source)

WLA = Waste Load Allocation (Point Source)
= Load (WWTPs) + Load (Urban Stormwater)

MOS = Margin of Safety

FA = Future Allocation

Average Daily Loads:

On average, the low flow TMDLs will result in loads of approximately 51 lbs/day of nitrogen and 14 lbs/day of phosphorus. The average annual flow TMDLs will result in loads of approximately 597 lbs/day of nitrogen and 50 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 National Pollutant Discharge Elimination System (NPDES) permits. The NPDES municipal surface discharge permits for the Town Indian Head WWTP, Lackey High School, Brandywine Receiving Station, Lingafelt Residence will have compliance provisions. The NPDES municipal separate stormwater permits for Charles County and Prince George County will ensure the adoption of best available technologies and best management practices to provide the 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 and phosphorus be developed and implemented.

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 Potomac Tributary Strategy Basin, which includes the Mattawoman 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 NPS 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 NPS 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.

In addition, EPA Region 4 and EPA Region 6 have indicated that reductions in atmospheric contributions will be accomplished over time through existing and proposed Clean Air Act regulatory controls that will ensure significant reduction in airborne nutrient loading on a nationwide basis by reducing atmospheric emissions. Additionally, the following actions taken by EPA and the State of Maryland are also underway to assure the reduction of air deposition:

- To date, EPA has promulgated approximately 100 New Source Performance Standards under Section 111 of the Clean Air Act (CAA), of which about ten directly control nitrogen oxide (NOx) emissions;
- Because NOx is a precursor to ozone, Maryland and other states must apply similar requirements to major stationary sources of NOx emissions, including application of reasonably available control technology;
- The CAA Acid Rain Program specifies a two-part strategy to reduce NOx emissions from coal-fired electric power plants. EPA estimates that this program has resulted in 40% reductions in NOx emission rates from large utility boilers, and additional controls are expected over the next several years;
- In 1994, Maryland and other states signed a Memorandum of Understanding to achieve regional emission reductions of NOx (a.k.a. "OTC NOx Budget Program"). The agreement calls for the adoption of regulations to reduce NOx emissions in 1999 and further reduce emissions in 2003;
- In 1998, EPA issued the "NOx SIP Call" which assigns a cap on summertime NOx emissions to be achieved by 2007;
- In 1999, EPA announced new limits for tailpipe emissions of NOx. These standards would require a 77% emissions reduction in cars over the next ten years;
- The proposed Clear Skies Act of 2003, aimed at power plants, estimates to reduce NOx emissions from Maryland sources by 70% by 2020, and 77% reductions in total NOx emissions in Maryland from 2000 levels. The estimated NOx deposition to the Chesapeake Bay watershed would be reduced up to 20%;
- Maryland and the other Chesapeake Bay states have agreed to incorporate nitrogen reductions resulting from the Clear Skies legislation as part of the overall plan to reduce nutrient loadings to the Bay.

The EPA expects to see reduced emissions as a number of regulations are implemented to control sulfur dioxide and nitrous oxides emissions. These controls for atmospheric emissions are expected to be implemented in phases.

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, 26.08.02.08M, 26.08.02.03-3A(2), 26.08.02.03A(2), 26.08.02.03B(2), 26.08.03.01B(3)

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.

Maryland Department of Planning. 2000 Reference for Land Use.

Nitrogen: Multiple and Regional Impacts," EPA-430-R-01-06

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

U.S. EPA - Chesapeake Bay Program Watershed Model Scenario Output Database, Phase 4.3. Available at www.chesapeakebay.net.

U.S. EPA, "Guidance for water quality based decisions: The TMDL process," Office of Water, Washington D.C., 1991.

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

U.S. EPA, "Nitrogen Oxides (NOx) Reduction under Phase II of the Acid Rain Program Group 1 and Group 2 Boilers", Acid Rain Program; Nitrogen Oxides Emission Reduction Program, Washington D.C., December 1996. (or www.epa.gov/airmarkt/arp/nox/phase2.html)

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 website: www.epa.gov/air/clearskies