Total Maximum Daily Loads of Biochemical Oxygen Demand (BOD), Nitrogen and Phosphorus for Town Creek into which the Town of Oxford Wastewater Treatment Plant Discharges Talbot County, Maryland

FINAL

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TABLE OF CONTENTS

LIST OF FIGURES .... *i*

LIST OF TABLES .... *i*

LIST OF ABBREVIATIONS .... *ii*

EXECUTIVE SUMMARY .... *iv*

1.0 INTRODUCTION *1*

2.0 SETTING AND WATER QUALITY DESCRIPTION *1*

2.1 General Setting and Source Assessment **1**

2.2 Water Quality Characterization **4**

2.3 Water Quality Impairment **8**

3.0 TARGETED WATER QUALITY GOAL *10*

4.0 TOTAL MAXIMUM DAILY LOADS AND ALLOCATION *10*

4.1 Overview **10**

4.2 Analysis Framework **10**

4.3 Scenario Descriptions **14**

4.4 Scenario Results **16**

4.5 TMDL Loading Caps **19**

4.6 Load Allocations between Point Sources and Nonpoint Sources **21**

4.7 Margins of Safety **22**

4.8 Summary of Total Maximum Daily Loads **24**

5.0 ASSURANCE OF IMPLEMENTATION *25*

APPENDIX A *A1*

LIST OF FIGURES

Figure 1: Location Map of the Town Creek Drainage Basin and
Water Quality Monitoring Stations 2
Figure 2: Land Use in the Town Creek Drainage Basin 3
Figure 3: Proportions of Land Use in the Town Creek Drainage Basin 4
Figure 4: Longitudinal Profile of Dissolved Oxygen Data (Low Flow) 6
Figure 5: Longitudinal Profile of Chlorophyll *a* Data (Low Flow) 6
Figure 6: Longitudinal Profile of Dissolved Inorganic Nitrogen Data (Low Flow) 7
Figure 7: Longitudinal Profile of Dissolved Inorganic Phosphorus Data (Low Flow) 8
Figure 8: Sources and Sinks for Dissolved Oxygen in a River 9
Figure 9: Town Creek Model Segmentation 12
Figure 10: Model Results for the Low Flow Scenarios 1, 3 and 4. 18
Figure 11: Model Results for the Average Annual Flow Scenarios 2, 5 and 6. **Error! Bookmark not defined.**
Figure 12: Low Flow TMDL Loading Cap Schematic 20
Figure 13: Average Annual Flow TMDL Loading Cap Schematic 21

LIST OF TABLES

Table 1: Town Creek Low Flow Observed Dissolved Oxygen Concentrations 5
Table 2: Scenarios Loads Comparison 17
Table 3: Summer Low Flow Allocations 22
Table 4: Average Annual Allocations 22
Table 5: Low Flow Margins of Safety (MOS) 23
Table 6: Average Annual Flow Margins of Safety (MOS) 23

LIST OF ABBREVIATIONS

7Q10	7-day consecutive lowest flow expected to occur every 10 years
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
BOD_5	The amount of oxygen consumed by the oxidation of carbonaceous and nitrogenous waste materials over a 5-day period at 20^{o}C.
CBOD	Carbonaceous Biochemical Oxygen Demand
CO_2	Carbon Dioxide
CEAM	Center for Exposure Assessment Modeling
cfs	cubic feet per second
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
CWAP	Clean Water Action Plan
DNR	Maryland Department of Natural Resources
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
EUTRO5.1	Eutrophication Model of WASP5.1
FA	Future Allocation
gpd	Gallons per day
km	Kilometer
LA	Load Allocation
lbs/month	Pounds per month
lbs/year	Pounds per year
MDE	Maryland Department of the Environment
mgd	million gallons per day
mg/l	Milligrams per liter
MOS	Margin of Safety
NBOD	Nitrogenous Biochemical Oxygen Demand
NH_3	Ammonia
$NO_{2,3}$	Nitrate plus nitrite
NPS	Nonpoint Source
NPDES	National Pollutant Discharge Elimination System
PS	Point Source
SOD	Sediment Oxygen Demand
TCEM	Town Creek Eutrophication Model
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
µg/l	Microgram per liter
USGS	United States Geological Survey

WASP5.1	Water Quality Analysis Simulation Program version 5.1
WLA	Waste Load Allocation
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WRAS	Watershed Restoration Action Strategy
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

This document establishes Total Maximum Daily Loads (TMDLs) of biochemical oxygen demand (BOD), nitrogen and phosphorus for Town Creek, which is a part of the Lower Choptank River watershed (02-13-04-03). Town Creek is a tributary of the Tred Avon River that ultimately drains to the Choptank River. The water quality impairments and TMDLs are described below.

The water quality goal of the BOD TMDL is to establish BOD concentration inputs at levels that will ensure the ambient dissolved oxygen (DO) standard of 5.0 mg/l in Town Creek. The TMDL for BOD was determined using the U.S. Environmental Agency's Water Quality Analysis Simulation Program version 5.1 (WASP5.1) water quality model. Maximum loads of BOD entering Town Creek were established for both low flow and average annual flow conditions. As part of the TMDL analysis, the model was used to investigate seasonal variations and to establish margins of safety (MOSs) that are environmentally conservative.

The overall objective of the BOD TMDL established in this document is to determine allowable BOD loads to levels that are expected to result in meeting all water quality criteria that support the designated use. The 7Q10 low-flow conditions TMDL for BOD is 921.1 lbs/month and 11,279.8 lbs/year for the average annual flow conditions.

In addition to the BOD TMDL described above, this document also establishes TMDLs for nitrogen and phosphorus that address the control of stressors causing excessive algal blooms in Town Creek. Analysis reveals that both phosphorus and nitrogen have an impact on chlorophyll *a* concentrations (a surrogate for algal blooms). The water quality goal of the TMDLs for nitrogen and phosphorus is to reduce the high chlorophyll *a* concentrations to an acceptable level consistent with the uses and physical characteristics of Town Creek.

As in the BOD TMDL, the nitrogen and phosphorus TMDLs were determined using the WASP5.1 water quality model. Maximum loads for nitrogen and phosphorus entering Town Creek were established for both low flow and average annual flow conditions. The nitrogen and phosphorus TMDLs are 531.1 lbs/month and 59.3 lbs/month respectively for 7Q10 low-flow conditions, and 6,471.7 lbs/year and 722.7 lbs/year for the average annual flow conditions, respectively.

Several factors provide assurance that these TMDLs of BOD, nitrogen and phosphorus will be implemented. First, NPDES permits will be written to be consistent with the load allocations in the TMDLs. Second, Maryland has adopted a watershed cycling strategy, which will ensure that future water quality monitoring and TMDL evaluations are routinely conducted. In addition, the certainty of implementation of the nonpoint source nitrogen and phosphorus reductions to Town Creek will be enhanced by two specific programs: the Water Quality Improvement Act of 1998 (WQIA), which requires that nutrient management plans be implemented for all agricultural land in Maryland; and the EPA-sponsored Clean Water Action Plan of 1998 (CWAP).

1.0 INTRODUCTION

Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency (EPA)'s 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 waterbody 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.

The Lower Choptank River watershed (02-13-04-03) was first identified on the 1996 303(d) list of water quality limited segments submitted to the EPA by the Maryland Department of the Environment (MDE). The watershed was listed as impaired by nutrients, fecal coliform, and suspended sediment. The list acknowledged that only a portion of the watershed might be impaired, and that with additional information, the spatial boundaries of the impairment could be refined. Water quality data collected in 1998 indicates dissolved oxygen (DO) impairments in Town Creek. Additional analysis revealed also that the Creek is nutrient impaired. These support the 303(d) listing of the Lower Choptank River. This document establishes TMDLs for a portion of the Choptank River watershed: Town Creek, a tributary of the Tred Avon River, which flows into the Choptank River. The TMDLs described in this document were developed to address localized water quality impairments identified within the watershed, specifically biochemical oxygen demand (BOD) and nutrients stressors in Town Creek. The suspended sediment, nutrient and fecal coliform impairments within the other portions of the Lower Choptank River watershed will be addressed separately at a future date.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

Town Creek is part of the Maryland Sub-Watershed identified by the Maryland Department of Natural Resources (DNR) as 02-13-04-03 (Lower Choptank River drainage area). Its headwaters originate in Oxford near the intersection of MD Route 333 with Morris Avenue. It finally drains to the Choptank River through the Tred Avon River. The creek is approximately 1.2 miles (1.9 km) in length. The Town Creek watershed has an area of approximately 597 acres (0.93 sq. miles). As shown in Figure 2 and Figure 3, the predominant land uses in the watershed, based on 1997 Maryland Office of Planning land cover data, consist of open water (143 acres or 24 %), urban (131 acres or 22 %), and mixed agriculture (322 acres or 54 %). In the Town Creek watershed, the baseline average annual total nitrogen load is 11,465 lbs/year, and the estimated average annual phosphorus load is 1,274 lbs/year.

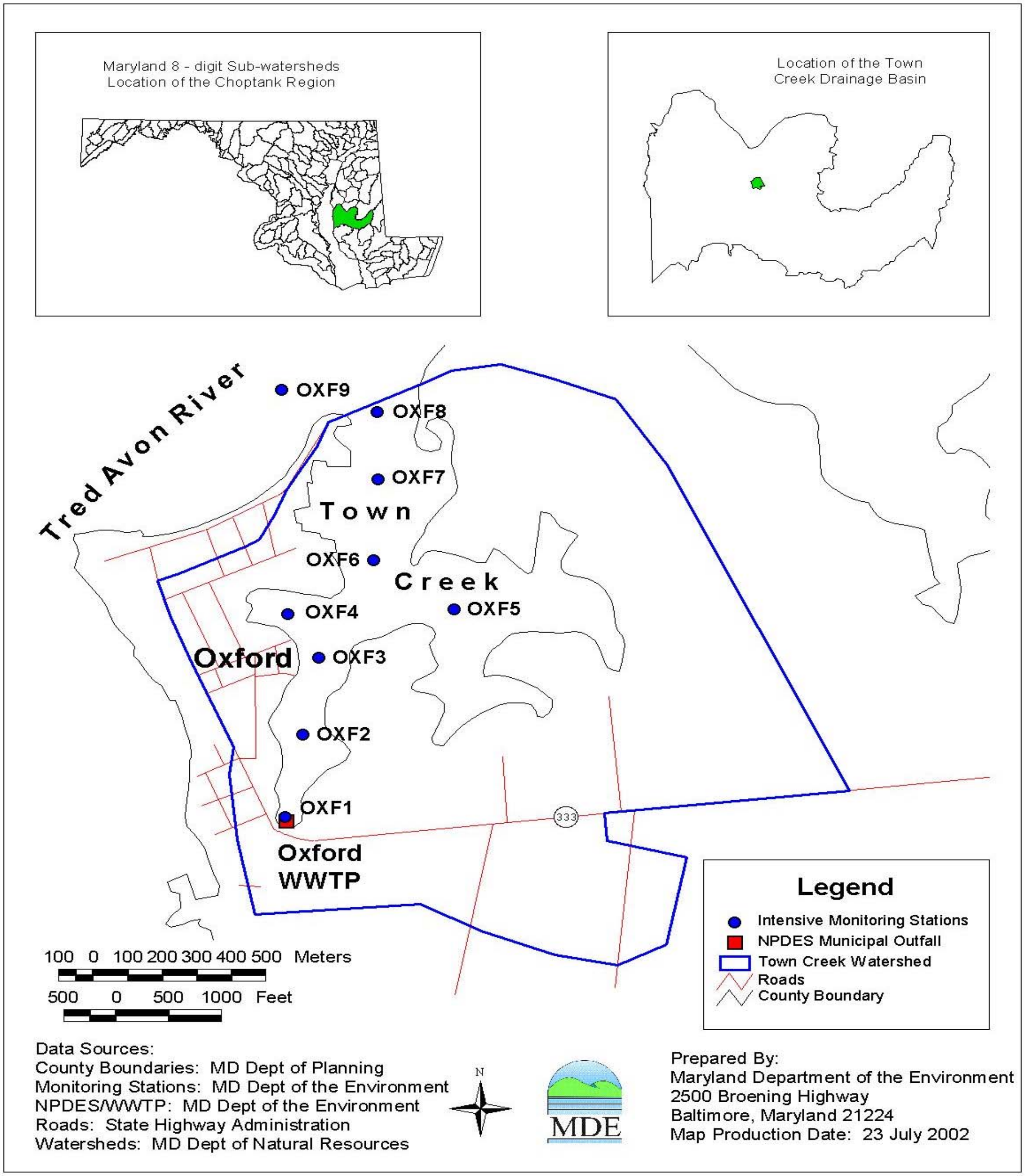

Figure 1: Location Map of the Town Creek Drainage Basin and Water Quality Monitoring Stations

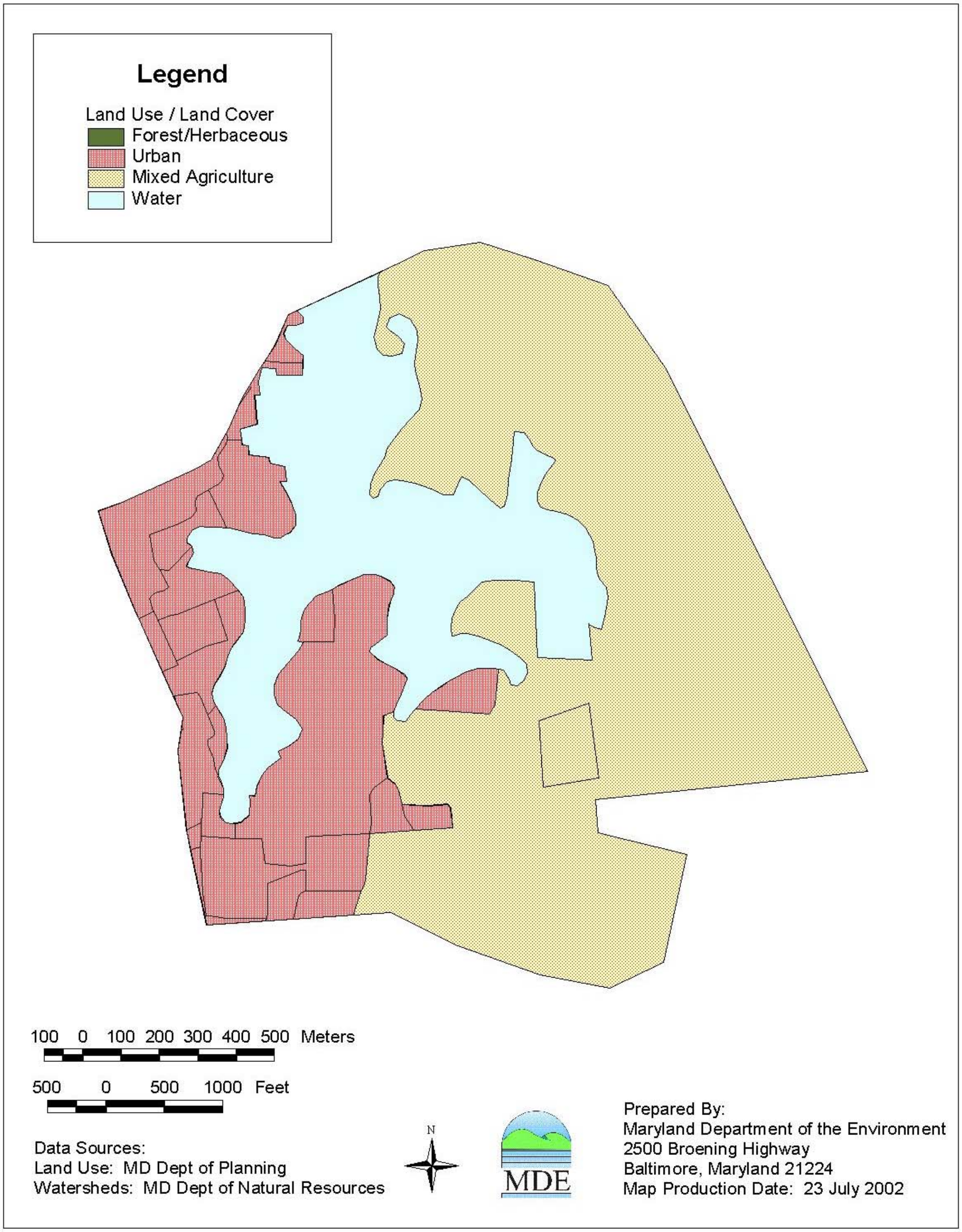

Figure 2: Land Use in the Town Creek Drainage Basin

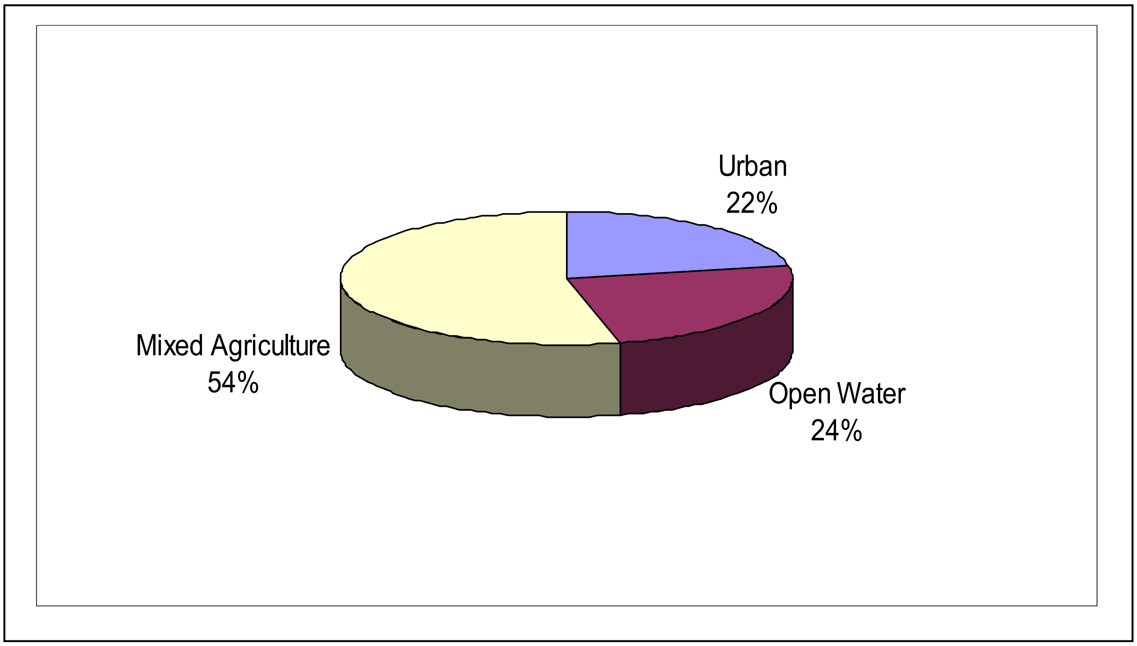

Figure 3: Proportions of Land Use in the Town Creek Drainage Basin

The pollutants of concern for the Town Creek TMDLs are the amount of BOD and nutrients entering the system that results in the low dissolved oxygen and high chlorophyll *a* concentrations immediately below the Town of Oxford Wastewater Treatment Plant (WWTP) discharge point. The facility is permitted through the National Pollution Discharge Elimination System (NPDES) to discharge a maximum flow of 0.208 million gallons per day (mgd) treated domestic wastewater into Town Creek, with effluent quality limits of 30 mg/l BOD_5, 2.0 mg/l total phosphorus and assumed 18 mg/l total nitrogen.

2.2 Water Quality Characterization

The MDE Field Operations Program conducted intensive water quality surveys of Town Creek in 1986, 1988 and 1998. The creek was monitored for salinity, temperature, DO, organic phosphorus and pH in July 1986. In August 1988, it was surveyed for sediment oxygen demand (SOD), DO and salinity, and again for physical, chemical, and biological parameters in July and August 1998. Water quality samples were collected once in July, and twice in August 1998 from a total of ten sampling locations. Eight of these monitoring locations are strategically positioned in Town Creek, one in the Tred Avon River, and one at the Town of Oxford Wastewater Treatment Plant (WWTP) as shown in Figure 1.

The parameters analyzed include DO, BOD, total Kjeldahl nitrogen (TKN), total nitrogen (TN), organic nitrogen, ammonia nitrogen (NH_3), nitrate + nitrite nitrogen (NO_{23}), total phosphorus (TP), organic phosphorus, chlorophyll-a and salinity. Four key water quality parameters, DO, chlorophyll *a*, dissolved inorganic nitrogen (DIN), and dissolved inorganic phosphorus (DIP) are presented in Figure 4 through Figure 7.

Low DO concentration values of 3.0, 3.3, 4.2 and 4.4 mg/l were observed downstream from the WWTP at OXF1, OXF2, OXF3 and OXF6 locations during the 1986 and 1988 monitoring periods. In 1998, DO values of 3.4, 4.2, 4.4, 4.8 and 4.9 mg/l have been recorded at the same locations near the WWTP as shown in Table 1.

Table 1: Town Creek Low Flow Observed Dissolved Oxygen Concentrations

Monitoring Locations →	1986, 1988 and 1998 Observed Dissolved Oxygen (DO) in Town Creek							
	OXF1	OXF2	OXF3	OXF4	OXF5	OXF6	OXF7	OXF8
	Dissolved Oxygen (DO), Mg/l							
07/08/1998	**4.2**	**4.8**	6.0	5.8	5.9	6.0	5.9	6.0
08/17/1998	5.0	6.2	6.1	6.9	8.8	6.6	7.3	7.6
08/26/1998	**3.4**	**4.4**	4.9	5.3	5.5	5.9	5.7	5.9
1998 Average	**4.2**	5.1	5.7	6.0	6.7	6.2	6.3	6.5
08/04/1988	**3.3**	-	-	-	-	6.3	-	7.9
	3.3	-	-	-	-	6.4	-	6.9
	3.0	-	-	-	-	5.0	-	6.5
	-	-	-	-	-	**4.2**	-	5.9
1988 Average	**3.2**	-	-	-	-	5.5	-	6.8
07/21/1986	**4.4**	-	7.1	8.4	6.8	7.5	7.0	6.4
	5.2	-	**3.3**	5.0	6.6	7.1	6.7	6.4
	-	-	6.5	**4.2**	6.7	6.1	5.4	5.9
1986 Average	**4.8**	-	5.6	5.7	6.7	6.9	6.4	6.2

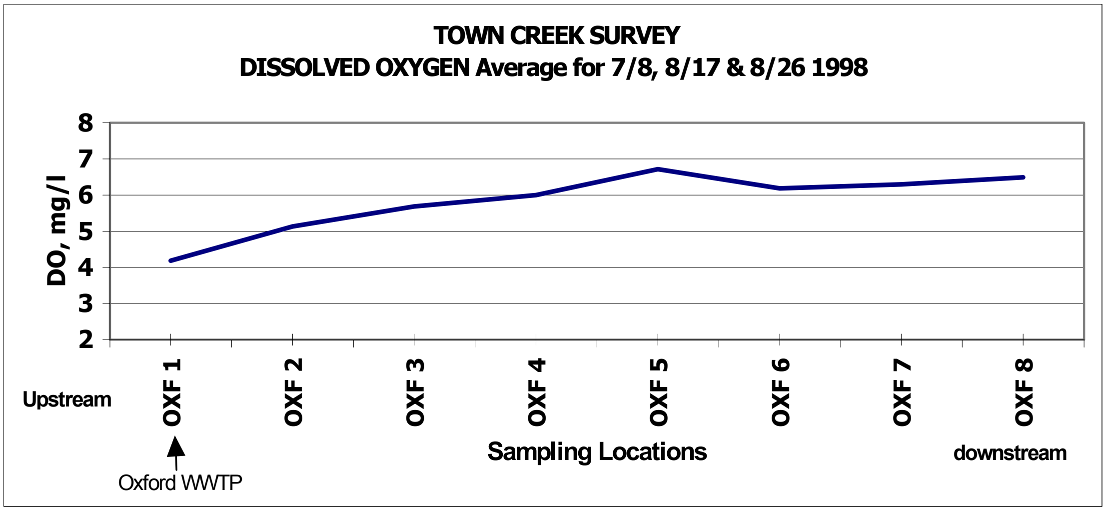

Figure 4: Longitudinal Profile of Dissolved Oxygen Data (Low Flow)

Figure 4 presents a longitudinal profile for DO concentrations with low values just below the Town of Oxford WWTP (OXF1). The data show a general upward trend in DO concentrations as the water flows downstream toward the mouth of the creek.
Problems associated with high chlorophyll *a* levels (a surrogate for algal blooms) are most likely to occur during the summer season (July, August, and September). During this season there is typically less stream flow available to flush the system, more sunlight to grow aquatic plants, and warmer temperatures, which are favorable conditions for biological processes of both plant growth and the decay of dead plant matter. Eutrophication problems are usually most acute during this season, and the period represents critical conditions for the TMDL analysis.

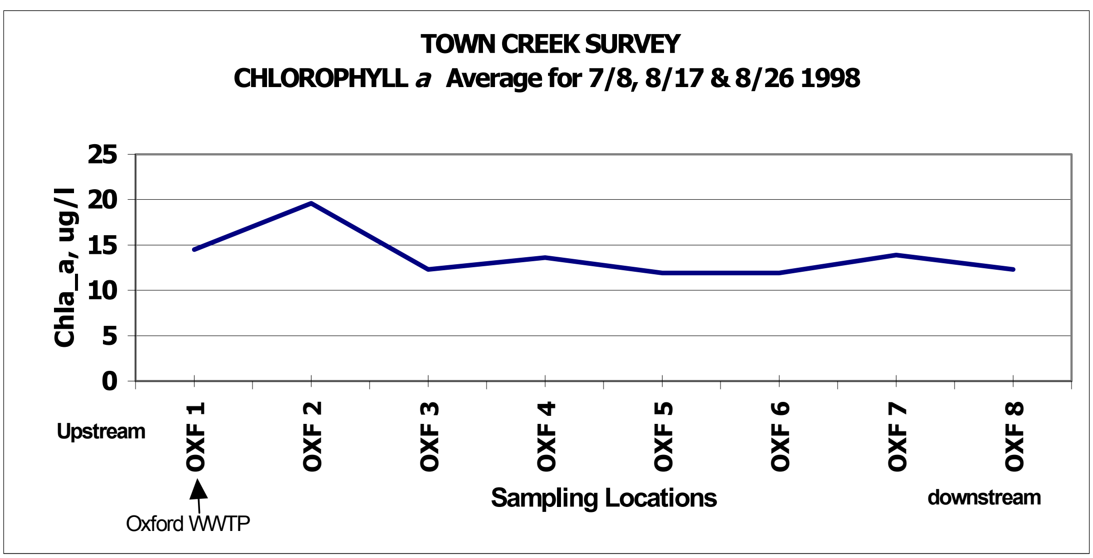

Figure 5: Longitudinal Profile of Chlorophyll *a* Data (Low Flow)

Figure 5 presents a longitudinal profile of chlorophyll *a* data collected during summer 1998 low flow period. The chlorophyll *a* concentrations ranged from 23.6 µg/l below the WWTP to 9.2 µg/l along the Tred Avon River and Town Creek confluence. While the chlorophyll *a* concentrations observed during the 1998 water quality sampling are not high, the Department's analysis revealed that if the Town of Oxford WWTP were to discharge at its full permitted limits, the ambient chlorophyll *a* concentrations just below the WWTP would increase beyond the 50 µg/l mark. It is believed that the nitrogen and phosphorus concentrations entering Town Creek from the WWTP need to be controlled to the extent that they will not cause downstream algal nuisance.

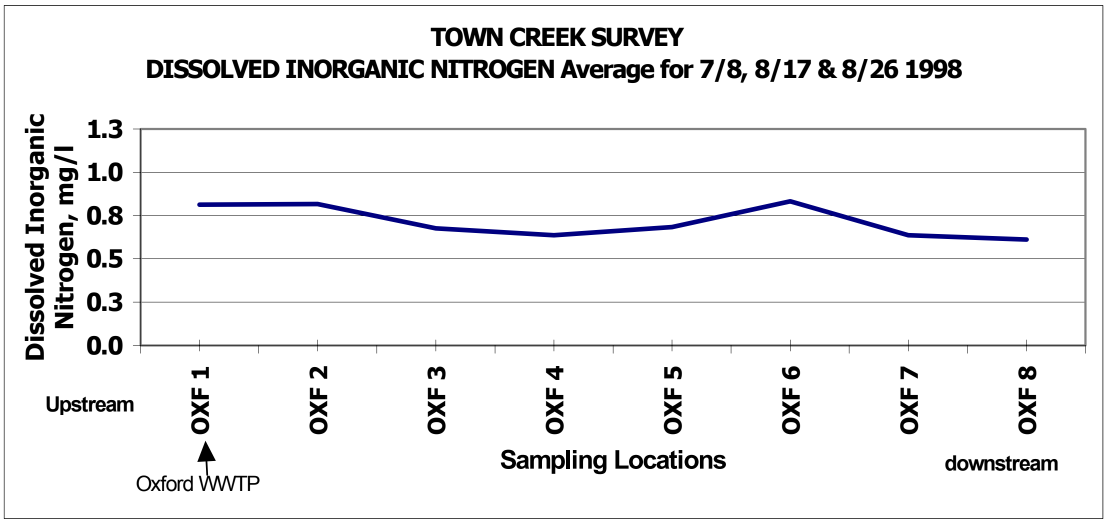

Figure 6: Longitudinal Profile of Dissolved Inorganic Nitrogen Data (Low Flow)

Figure 6 presents a longitudinal profile of DIN measured in the samples collected in 1998 during low flow conditions. The levels are generally below 1.0 mg/l throughout the stream system with several observations around 0.8 mg/l.

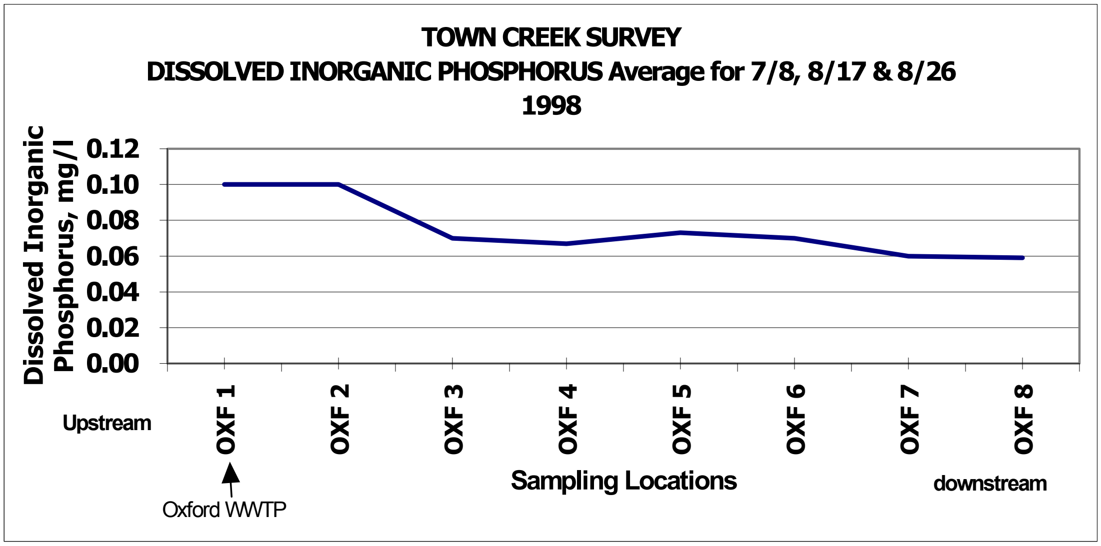

Figure 7: Longitudinal Profile of Dissolved Inorganic Phosphorus Data (Low Flow)

Figure 7 shows a longitudinal profile of DIP as represented by ortho-phosphate levels measured in samples collected in 1998, during low flow conditions. All values fall in the range between 0.06 to 0.10 mg/l. It should be noted that the highest observed values are upstream, near the Town of Oxford WWTP.

2.3 Water Quality Impairment

Town Creek is a small tributary of the Tred Avon River with a relatively small drainage area of about 0.93 square miles. The Tred Avon River is a tributary of the Choptank River. The Maryland Surface Water Use Designation [Code of Maryland Regulations (COMAR) 26.08.02.07] for Town Creek is Use II – Shellfish harvesting waters. According to the numeric criteria for DO for Use II waters, concentrations may not be less than 5.0 mg/l at any time (COMAR 26.08.02.03-3C(2)) unless resulting from natural conditions (COMAR 26.08.02.03.A(2)). The water quality data collected during the 1986, 1988 and 1998 intensive surveys indicated a violation of the numeric water quality standard for DO of 5.0 mg/l minimum at any time, as shown in Table 1 and Figure 4. In addition to the low DO problems, the Department's analysis revealed that when the Town of Oxford WWTP discharges at its full permitted limits, the ambient chlorophyll *a* concentrations increase to levels that exceed the 50 µg/l mark just below the WWTP. Generally, low in-stream DO may be caused by several sources including, but not limited to, the decay of oxygen demanding waste from both point and nonpoint sources, SOD, and algal respiration. The water quality impairments for which the TMDLs for Town Creek address, consists of violations of the numeric DO criterion and potential high concentrations of chlorophyll *a* (a surrogate for algal blooms).

The primary substances of concern to be addressed in these TMDLs are the BOD and nutrients (nitrogen and phosphorus) entering Town Creek watershed. BOD is a composite term that describes the consumption of oxygen through the oxidation of carbon and nitrogen by bacteria in the water. The sources of BOD and nutrients include both point and nonpoint loads within the watershed. The Town of Oxford WWTP is the only point source in the Town Creek watershed. The nonpoint source loads of BOD and nutrients account for both human and natural sources, and enter the system at the boundaries in the main channel and three unnamed coves downstream of the Town of Oxford WWTP.

In addition to accounting for sources of BOD and nutrients, the processes that deplete dissolved oxygen were also considered. These processes include those that consume oxygen (sinks) as well as those that generate oxygen (sources). These processes and some additional factors are presented in Figure 8. BOD reflects the amount of oxygen consumed through two processes: Carbonaceous Biochemical Oxygen Demand (CBOD) and Nitrogenous Biochemical Oxygen Demand (NBOD). CBOD is the reduction of organic carbon material to its lowest energy state, carbon dioxide (CO_2), through the metabolic action of microorganisms (principally bacteria). NBOD is the term for the oxygen required for nitrification, which is the biological oxidation of ammonia to nitrate. The BOD values seen throughout this document represent the amount of oxygen consumed by the oxidation of carbonaceous and nitrogenous waste materials over a 5-day period at 20°C. This is referred to as a 5-day, 20°C BOD and is the standard reference value utilized internationally by design engineers and regulatory agencies. The 5-day BOD represents primarily the consumption of carbonaceous material and minimal nitrogenous material. The ultimate BOD represents the total oxygen consumed by carbonaceous and nitrogenous material over an unlimited length of time.

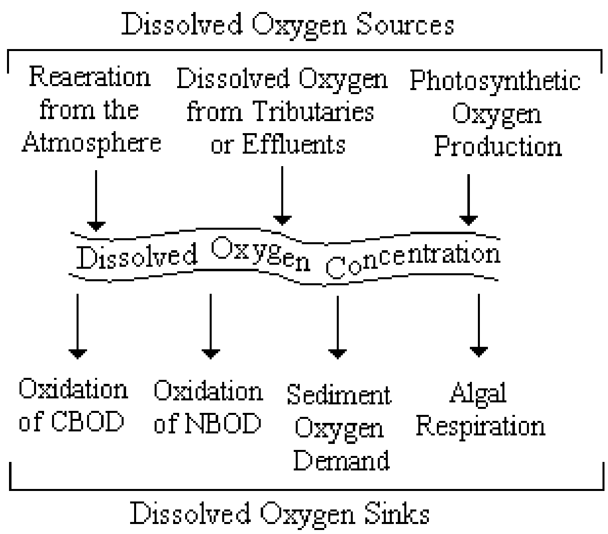

Figure 8: Sources and Sinks for Dissolved Oxygen in a River

Another factor influencing dissolved oxygen concentrations is sediment oxygen demand (SOD). As with BOD, SOD is a combination of several processes. Primarily, it is the aerobic decay of organic materials that settle to the bottom of the stream. All of these DO sources and sinks make up a DO balance as shown in Figure 8.

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. Based on MDE's analysis, the chlorophyll *a* concentrations in the upper reaches of Town Creek near the WWTP should range between 50 and 69 µg/l when the facility discharges at its full permitted limits. These levels are believed to be associated with excessive eutrophication in Town Creek, near the WWTP. Violations of the DO water quality standards and high chlorophyll *a* levels in Town Creek are the result of over-enrichment by BOD, nitrogen and phosphorus.

3.0 TARGETED WATER QUALITY GOAL

The objective of the BOD, nitrogen and phosphorus TMDLs established in this document are to assure that the DO levels support the Use II designation for Town Creek and to control nuisance algal blooms. Specifically, the TMDLs for BOD, nitrogen and phosphorus for Town Creek are intended to assure that a minimum DO level of 5.0 mg/l is maintained throughout the Town Creek system and to reduce peak chlorophyll *a* levels (a surrogate for algal blooms) to below 50 µg/l. The DO level is based on specific numeric criteria for Use II waters set forth in the COMAR 26.08.02.03-3C(2). The chlorophyll *a* water quality level is based on the designated use for the Town Creek and guidelines set forth by Thomann and Mueller (1987) and by the EPA *Technical Guidance Manual for Developing Total Maximum Daily Loads, Book 2, Part* (1997).

4.0 TOTAL MAXIMUM DAILY LOADS AND ALLOCATION

4.1 Overview

This section describes how the BOD, nutrient TMDLs, and load allocations were developed for Town Creek. The first section describes the modeling framework for simulating BOD and 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 flows, BOD 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 seasonal low flow conditions and for average annual loads.

4.2 Analysis Framework

The computational framework chosen for the Town Creek TMDLs was the Water Quality Analysis Simulation Program version 5.1 (WASP5.1). This water quality simulation program provides a generalized framework for modeling contaminant fate and transport in surface waters and is based on the finite-segment approach (Di Toro *et al.*, 1983). WASP5.1 is supported and distributed by U.S. EPA's Center for Exposure Assessment Modeling (CEAM) in Athens, GA

(Ambrose *et al.*, 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 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 waterbody, which in this case, considered low flow and average annual flow conditions, described in more detail below.

The spatial domain of the Town Creek Eutrophication Model (TCEM) extends from the Town of Oxford WWTP discharge point for about 1.2 miles to the confluence of Town Creek with Tred Avon River. Fourteen WASP5.1 model segments represent this modeling domain. Concentrations of relevant water quality parameters, observed in 1998 serve as the model's upstream and downstream boundaries. A diagram of the WASP5.1 model segmentation is presented in Figure 9.

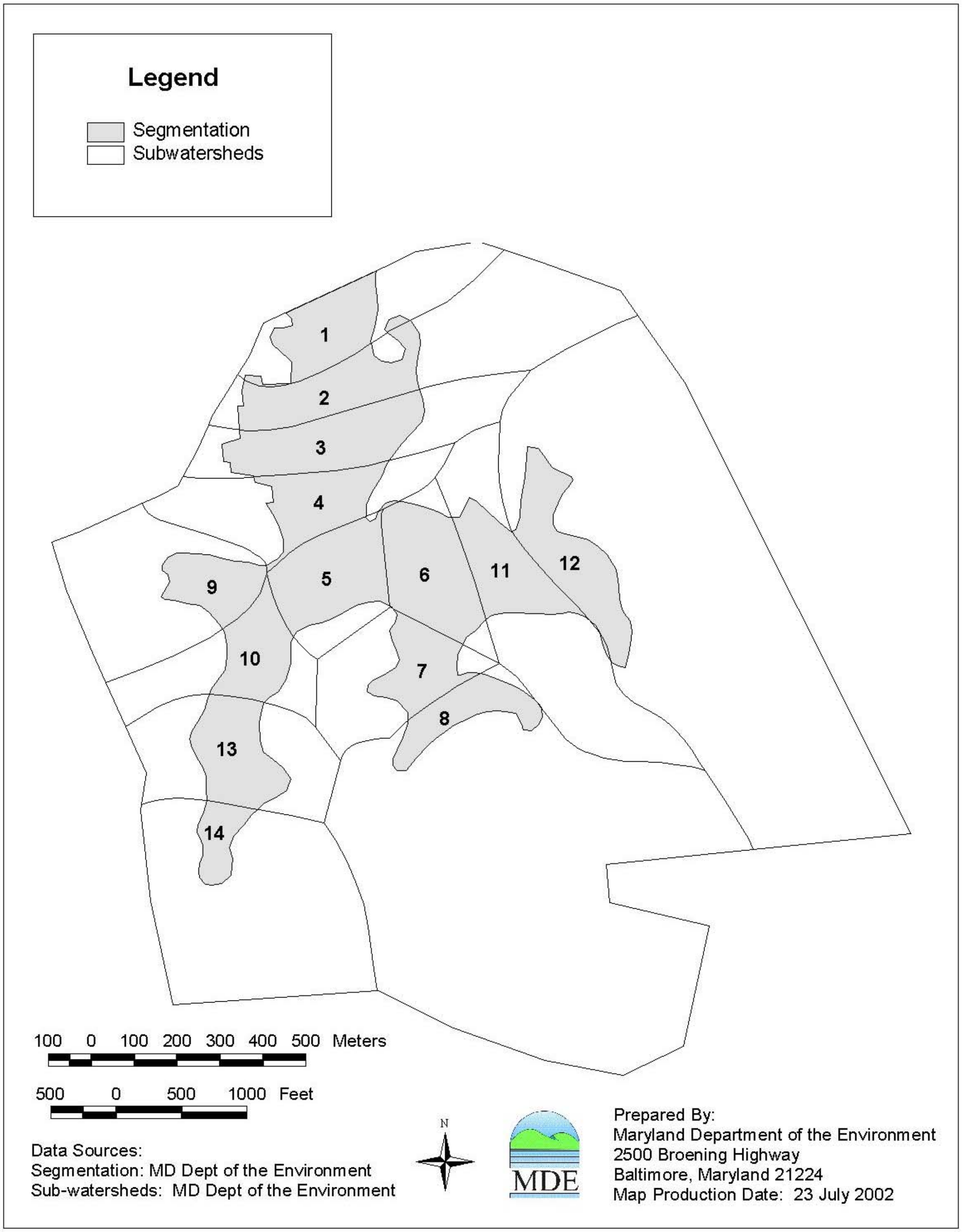

Figure 9: Town Creek Model Segmentation

Town Creek BOD, nitrogen and phosphorus TMDLs analyses consist of two specific elements, namely an investigation of low flow loading conditions and an investigation of the average annual loading. The low flow TMDLs analyses assess the critical conditions under which symptoms of in-stream low DO and 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, verified and used to reproduce observed water quality characteristics for the observed low flow conditions. Calibration of the model for the low flow regime establishes an analysis tool that may be used to assess a range of scenarios of differing flow, BOD and nutrient loading conditions. Observed water quality data collected during 1998 was used to support the calibration process, as explained further in Appendix A.

The stream flow used in the critical low flow analysis was based on data from two U.S. Geological Survey (USGS) gages (1489000-Faulkner Branch, Federalsburg and 1490000-Chicamacomico River, Salem) near the Town Creek basin. Averaging 7Q10 summer low flow data from these two gages and computing a run-off rate that was then multiplied by the area of each subwatershed estimated flow. The average stream flow was estimated using a similar methodology based on the same two USGS gages by averaging the computed summer and winter data, to get average annual flow. The methods used to estimate stream flows are described further in Appendix A.

The baseline point source (PS) loads for low flow and average conditions were based on the current Town of Oxford WWTP maximum permitted flow of 0.208 million gallons per day (mgd) with the effluent treatment quality of 30 mg/l BOD, 18 mg/l assumed TN for a lagoon such as this, 2.0 mg/l TP and 5.0 mg/l DO minimum.

Nonpoint source (NPS) loads for low flow conditions were derived from the concentrations observed during low flow sampling in 1998 multiplied by the estimated sub-watershed critical low flows, thus accounting for all human and natural sources. Similarly, the average annual NPS loads were derived from the concentrations observed during low flow sampling in 1998 multiplied by the estimated sub-watershed average annual flows, accounting for all human and natural sources. These methods are elaborated upon in Appendix A.

The concentrations of the nutrients (nitrogen and phosphorus) are modeled in their speciated forms. Nitrogen is simulated as ammonia (NH_3), nitrate plus nitrite (NO_{23}), and organic nitrogen (ON). Phosphorus is simulated as ortho-phosphate (PO_4) and organic phosphorus (OP). Ammonia, nitrate and nitrite, and ortho-phosphate represent the dissolved forms of nitrogen and phosphorus. The dissolved forms of nutrients are more readily available for biological processes such as algal growth, which affect chlorophyll *a* levels and DO concentrations.

4.3 Scenario Descriptions

The WASP5.1 model was applied to investigate different BOD and nutrient loading scenarios under two stream conditions, low and average annual flows. These analyses allow a comparison of conditions under which water quality problems exist, with future conditions that project the water quality response to various simulated load reductions of the impairing substances. By modeling both low flow and average annual loadings, the analysis accounts for seasonality, a necessary element of the TMDL development process.

The analyses are grouped according to *baseline conditions* and *future conditions* associated with the TMDLs. Both groups include low and average annual flow loading scenarios, for a total of six scenarios. The baseline conditions are intended to provide a point of reference by which to compare the future scenarios that simulate conditions of the TMDLs. 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 TMDL projects and does not vary in time. The alternative of using a "current condition" has the drawback that is changing over time creating confusion. Since the development and review of a TMDL often takes years; by the time it is completed, the "current" condition is no longer current. To avoid this confusion we use the "*baseline condition*". The baseline conditions correspond roughly to the system at the present permitted point source (PS) and nonpoint source (NPS) background loadings.

<u>Scenario 1</u>: 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 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 low DO and excessive nutrient enrichment.

The low flow point source loads for this scenario were computed under the assumption that the Town of Oxford WWTP will be discharging at its maximum National Pollutant Discharge Elimination System (NPDES) monthly permit limits of 0.208 million gallons per day (mgd) plant flow, 30 mg/l BOD_5, 18 mg/l assumed TN, 2.0 mg/l TP, and 5.0 mg/l DO. The low flow NPS loads were computed as the product of the average observed data collected during the low flow conditions of July and August of 1998 and estimated critical low flow. These low flow NPS loads integrate all natural and human induced sources, including direct atmospheric deposition, and loads stemming from septic tanks, urban development, and agriculture, that generate base flow during low flow conditions.

<u>Scenario 2</u>: The second scenario provides an estimate of water quality conditions for the average annual loads and flows, which serve as the baseline from which the average annual TMDL (Fifth Scenario) is computed. The second scenario assumes the same point source (PS) loads as in Scenario 1, and the NPS loads were computed as the product of the average observed data collected during the low flow conditions of July and August of 1998 and estimated average annual flow. The average annual stream flow was estimated using proportional drainage area and the average data from two USGS stream gages 1489000 and 1490000 for the period 1950 to 1992.

At the upper boundary of Town Creek, an average annual stream flow of 0.168 cfs was used. This scenario also simulates a condition when the sunlight and warm water temperatures are most conducive to algal growth, which can lead to water quality problems associated with low DO and excessive nutrient enrichment.

Scenario 3: The third scenario represents the natural conditions of the creek at a simulated critical low flow without the WWTP discharge. This scenario investigates the sensitivity of the WWTP discharge during the critical low flow summer months. All model parameters were computed under the same assumption as Scenario 1, except for point source loads, which were removed. The stream flow is the same as that used in Scenario 1. The scenario simulates a potential effect of NPS when there is no WWTP discharge, the creek system is poorly flushed due to low flows and when sunlight and warm water temperatures are most conducive to algal growth.

Scenario 4: The fourth scenario represents the future condition of maximum allowable loads during the critical low stream flow. The stream flow is the same as that used in Scenario 1. The WWTP effluent DO input was raised from 5.0 to 6.0 mg/l. The scenario simulates a condition when the creek system is poorly flushed due to low flows and when sunlight and warm water temperatures are most conducive to algal growth. This scenario simulates an estimated 50% reduction in controllable PS loads from the Town of Oxford WWTP, and 35% reduction in NPS loads from sub-watershed of the Town Creek basin. This scenario accounts for point source margin of safety computed as 25% of the difference between monthly and weekly WWTP permitted limits, and 5% of the NPS load allocation. In this future condition scenario, reduction in SOD was estimated based on the percentage reduction of organic matter available to settle to the bottom, which was computed as a function of the nutrient reductions. Further discussion is provided in Appendix A.

Scenario 5: The fifth scenario provides an estimate of future conditions of maximum allowable average annual loads. The scenario uses an average annual stream flow as in Scenario 2. The scenario also simulates a condition when sunlight and warm water temperatures are most conducive to algal growth, which can lead to water quality problems associated with low DO and excessive nutrient enrichment. Since higher stream flows, like the average annual flow, typically occur during cooler seasons, the assumptions of high water temperature and solar radiation used in the analysis are conservative with respect to environmental protection.

This scenario simulates an estimated 50% reduction in PS loads from the WWTP and 35% in NPS loads from the sub-watershed of Town Creek basin. A point source margin of safety computed as 25% of the difference between monthly and weekly WWTP permitted limits, and 5% of the NPS load allocation were also included. Reduction in SOD is the same as in Scenario 4, and was estimated based on the percentage reduction of organic matter settling to the bottom, computed as a function of the nutrient reduction.

Scenario 6: The sixth scenario represents the future conditions of Town Creek at the average annual flow without WWTP discharge during the average annual flow for comparison purposes. All model parameters remained the same as in Scenario 3, except the loadings are based on the average annual flow.

4.4 Scenario Results

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

Scenario 1 results (solid lines in Figure 10) represent the baseline condition for summer low flow. Under these conditions, dissolved oxygen dropped to 4.0 mg/l, and the chlorophyll *a* level rose beyond the desired goal of 50 µg/l in two downstream segments below the WWTP discharge point, reaching a peak value of about 67 µg/l.

Scenario 2 results (solid lines in Figure 11) represent the baseline condition for the average stream flow. Under these conditions, dissolved oxygen values in the two segments near the WWTP remain below the 5.0 mg/l minimum standard, and chlorophyll *a* concentrations are also above the desired goal of 50 µg/l, reaching a peak value of 68 µg/l.

Scenario 3 results (connected dots lines in Figure 10) represent the creek's condition during low flow, without the WWTP discharge. Under these conditions, the chlorophyll *a* concentrations dropped sharply below the desired goal of 50 µg/l and DO concentrations in the two segments near the WWTP improved and were close to the 5.0 mg/l minimum standards.

Scenario 4 results (dotted lines in Figure 10) represent the maximum allowable loads for summer critical low flow. Under these conditions, the BOD and nutrient loads were reduced as described above for this scenario. The results show that the minimum DO in all stream segments are above the water quality criterion of 5.0 mg/l and the chlorophyll *a* concentrations remain below 50 µg/l along the entire length of Town Creek.

Scenario 5 results (dotted lines in Figure 11) represent the maximum allowable loads for average annual flow. Under these conditions, the PS and NPS loads were reduced as described above for this scenario. The results show that the chlorophyll *a* concentrations remain below 50 µg/l marks along the entire length of Town Creek. For the DO levels, the results show the values above the minimum water quality criterion of 5.0 mg/l along the entire stretch of the creek.

Scenario 6 results (connected dots lines in Figure 11) represent the creek's natural conditions during average annual flow without PS loads. Under these conditions, the PS was removed, and the NPS loads are the same as described above for this scenario. The results show that chlorophyll *a* concentrations remain below 50 µg/l and DO levels remains above the minimum water quality criterion of 5.0 mg/l. The scenarios loads comparison is shown below in Table 2.

Table 2: Scenarios Loads Comparison

Parameters	Low Stream Flow			Annual Average Stream Flow		
	Scenario 1 Baseline	**Scenario 3** No WWTP	**Scenario 4** 50% PS 35% NPS Reduction	**Scenario 2** Baseline	**Scenario 5** 50% PS 35% NPS Reduction	**Scenario 6** No WWTP
Point Source			(MOS)		(MOS)	
BOD (lbs/month)	1,561.2	0.0	780.6 (130.1)	1,561.2	780.6 (130.1)	0.0
TN (lbs/month)	936.7	0.0	468.4 (58.3)	936.7	468.4 (58.3)	0.0
TP (lbs/month)	104.1	0.0	52.0 (6.8)	104.1	52.0 (6.8)	0.0
WWTP Flows (mgd)	0.208	0.0	0.208	0.208	0.208	0.0
Nonpoint Source			(MOS)		(MOS)	
BOD (lbs/month)	15.22	15.22	9.85 (0.49)	43.54	27.88 (1.40)	43.54
TN (lbs/month)	6.55	6.55	4.24 (0.21)	18.74	12.01 (0.60)	18.74
TP (lbs/month)	0.73	0.73	0.48 (0.02)	2.10	1.36 (0.07)	2.10
Total Background Flows (mgd)	0.038	0.038	0.038	0.1084	0.1084	0.1084

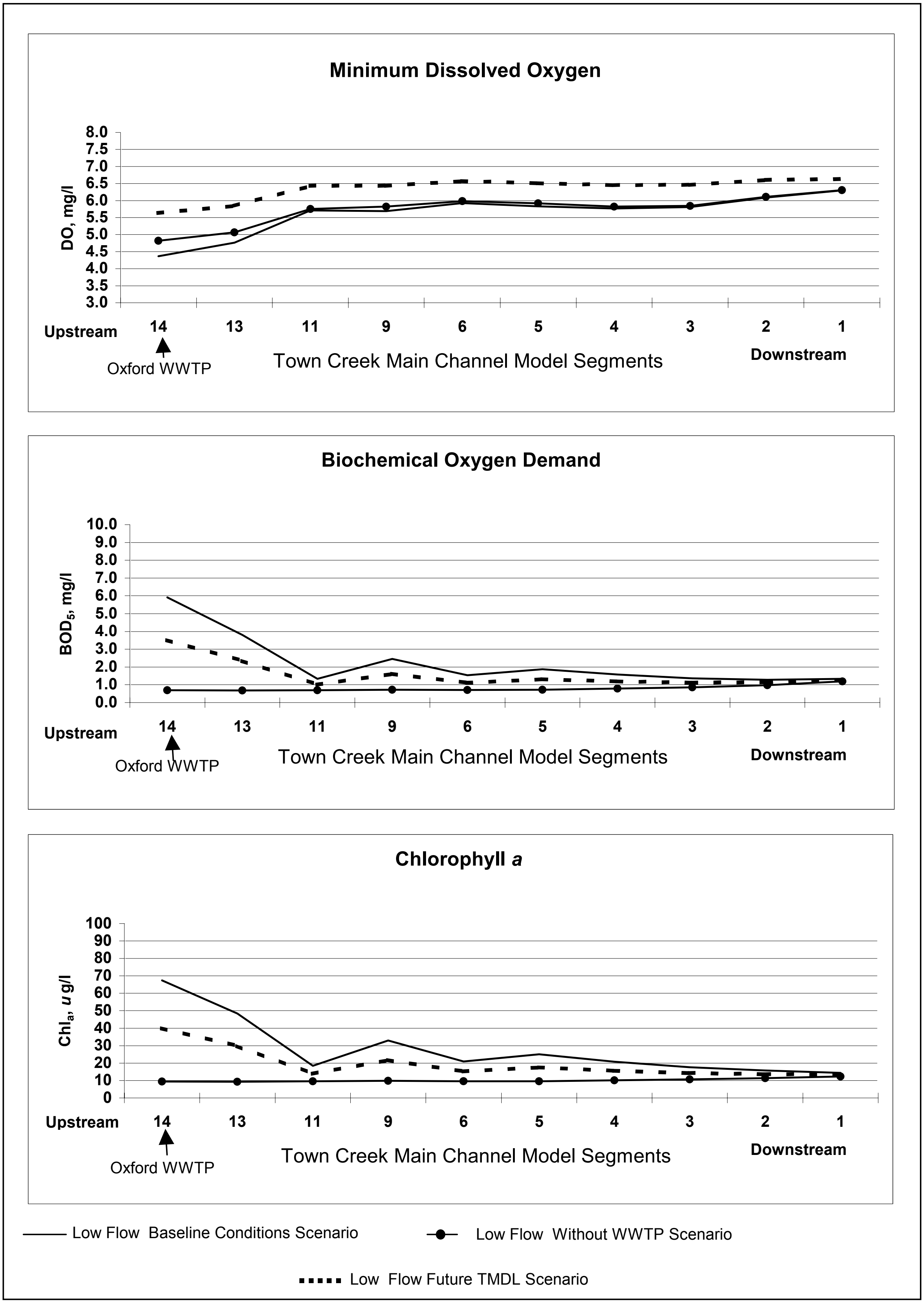

Figure 10: Model Results for the Low Flow Scenarios 1, 3 and 4.

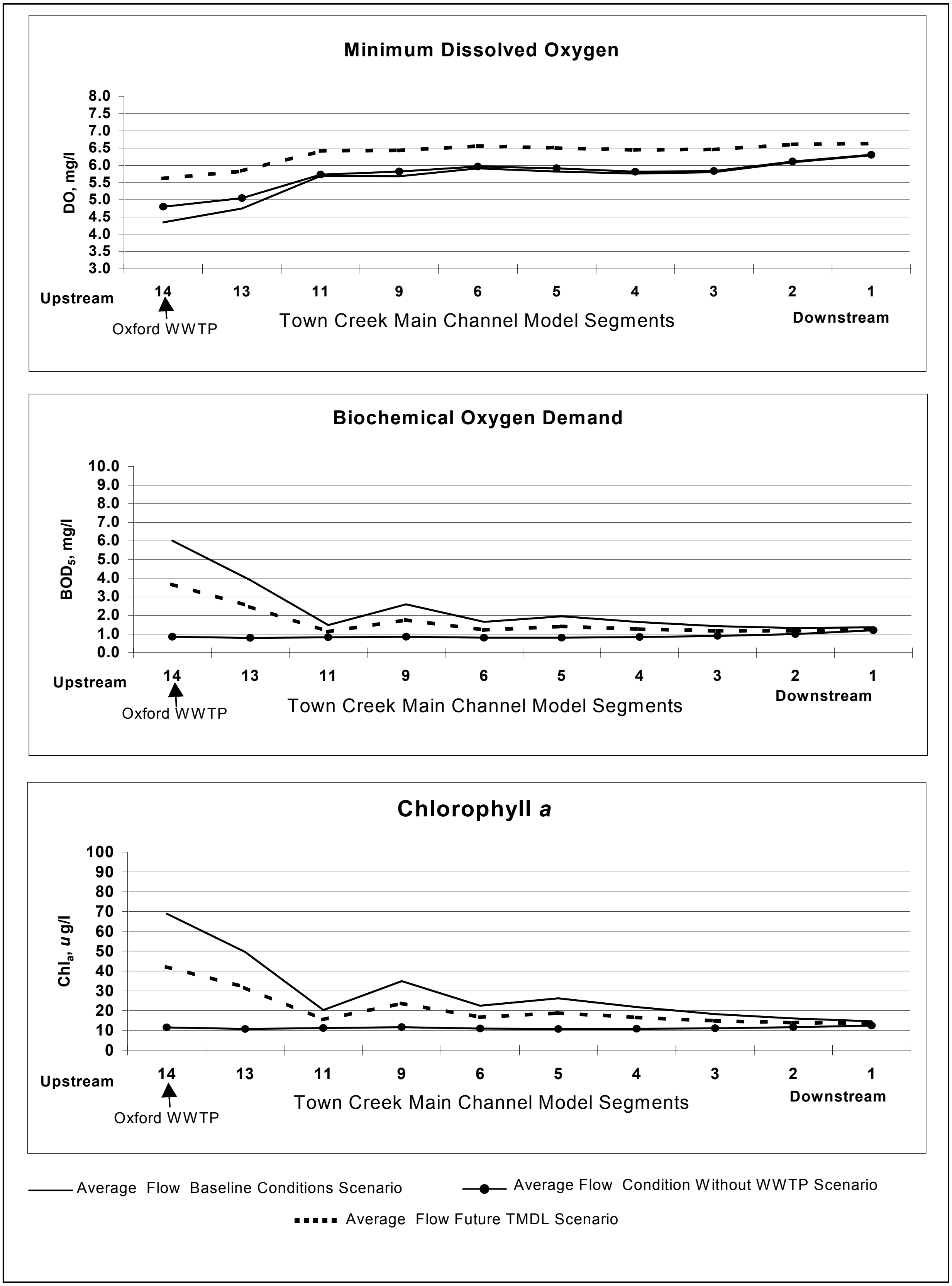

Figure 11: Model Results for the Average Annual Flow Scenarios 2, 5 and 6.

This section presents the TMDLs for BOD, nitrogen and phosphorus. The outcomes are presented in terms of the low flow TMDLs and average annual TMDLs. The critical season for excessive algal growth in Town Creek is during the summer months, when the creek is poorly flushed. During this critical time, sunlight and warm water temperatures are most conducive to creating the water quality problems associated with excessive nutrient enrichment. The low flow TMDLs are stated in monthly terms because this critical condition occurs for a limited period of time. The low flow and average annual flow TMDLs loading cap are presented schematically in Figure 12 and Figure13.

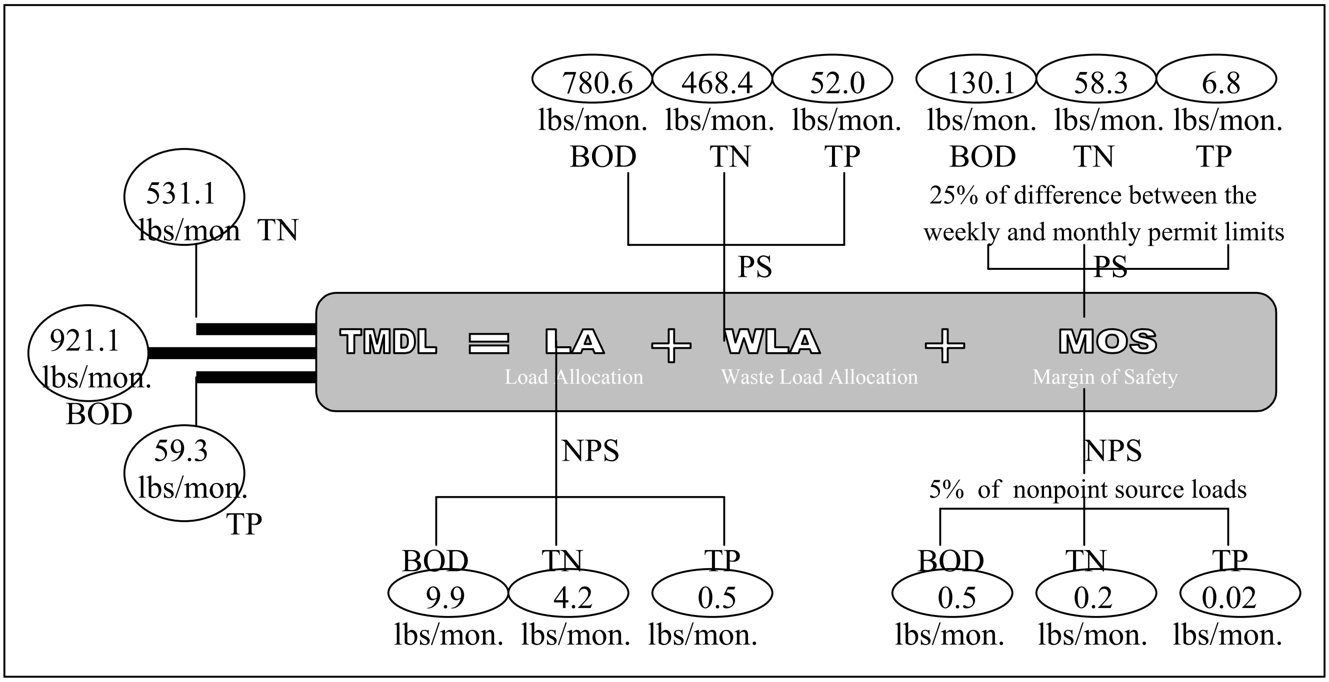

Figure 12: Low Flow TMDL Loading Cap Schematic

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

Low Flow TMDLs:

BOD TMDL **921.1** ***lbs/month***

NITROGEN TMDL **531.1** ***lbs/month***

PHOSPHORUS TMDL **59.3** ***lbs/month***

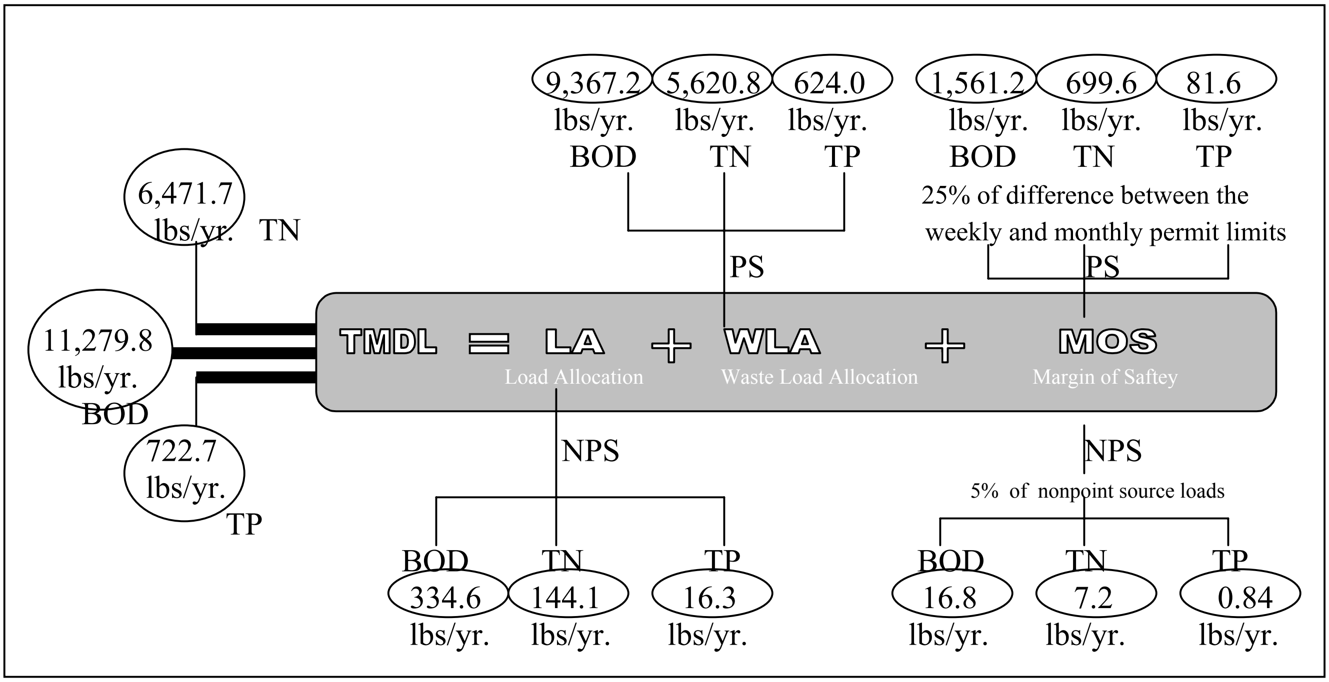

Figure 13: Average Annual Flow TMDL Loading Cap Schematic

For the winter months, November 1 through April 30, the following TMDLs apply:

Average Annual TMDLs:

BOD TMDL **11,279.8** ***lbs/year***

NITROGEN TMDL **6,471.7** ***lbs/year***

PHOSPHORUS TMDL **722.7** ***lbs/year***

Because the TMDLs set limits on nitrogen, and because of the way the TCEM model simulates nitrogen, it is not necessary to include an explicit TMDL for NBOD.

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 Town Creek. Specifically, these allocations show that the sum of BOD, nitrogen and phosphorus loadings to Town 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.

Low Flow Allocations:

The point and nonpoint source loads of BOD, nitrogen and phosphorus simulated in Scenario 4 represent 50% PS and 35% NPS reductions from the baseline scenario. Recall that the baseline scenario loads were based on current WWTP maximum permitted limits and the NPS background concentrations observed in summer 1998. These NPS loads account for both "natural" and human-induced components and cannot be separated into specific source categories. The BOD, nitrogen and phosphorus allocations for summer low flow conditions are presented in Table 3. Point source allocations are described further in the technical memorandum entitled "*Significant Biochemical Oxygen Demand, Total Nitrogen and Total Phosphorus Point and Nonpoint Sources in the Town Creek Watershed"* and Appendix A.

Table 3: Summer Low Flow Allocations

	Point Source	Nonpoint Source	Total
BOD *(lbs/month)*	780.6	9.9	790.5
Total Nitrogen *(lbs/month)*	468.4	4.2	472.6
Total Phosphorus *(lbs/month)*	52.0	0.5	52.5

Average Annual Allocations:

The point and nonpoint source loads of BOD, nitrogen and phosphorus simulated in Scenario 5 represent 50%(PS) and 35%(NPS) reductions from the average annual baseline scenario. Recall that the average annual baseline scenario loads were based on current WWTP maximum permitted limits and the assumed nonpoint source background concentrations based on observed summer 1998 data and computed average annual flow. The nonpoint source loads that were assumed in the model account for both "natural" and human-induced components. The BOD, nitrogen and phosphorus allocations for the average annual TMDLs are shown in Table 4. Point source allocations are described further in the technical memorandum entitled "*Significant Biochemical Oxygen Demand, Total Nitrogen and Total Phosphorus Point and Nonpoint Sources in the Town Creek Watershed"* and Appendix A.

Table 4: Average Annual Allocations

	Point Source	Nonpoint Source	Total
BOD *(lbs/year)*	9,367.2	334.6	9,701.8
Total Nitrogen *(lbs/year)*	5,620.8	144.1	5,764.9
Total Phosphorus *(lbs/year)*	624.0	16.3	640.3

4.7 Margins of Safety

A margin of safety (MOS) is required as part of a TMDL in recognition of many uncertainties in the understanding and simulation of water quality in natural systems. For example, knowledge is incomplete regarding the exact nature and magnitude of pollutant loads from various sources and the specific impacts of those pollutants on the chemical and biological quality of complex, natural waterbodies. The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental protection.

Based on EPA guidance, the MOS can be achieved through two approaches (EPA, April 1991). One approach is to reserve a portion of the loading capacity as a separate term in the TMDL (i.e., TMDL = WLA + LA + MOS). The second approach is to incorporate the MOS as conservative assumptions used in the TMDL analysis.

Maryland has adopted margins of safety that combine these two approaches. Following the first approach, the MOS at the Oxford WWTP was calculated as 25% of the difference between the weekly and monthly effluent permit limits for BOD, nitrogen and phosphorus for the low flow TMDLs. Similarly, a 25% MOS was included in computing the average annual TMDLs. The nonpoint source MOS was computed as 5% of the nonpoint source loads for BOD, nitrogen and phosphorus for the low and average annual flow TMDLs. These explicit BOD, nitrogen and phosphorus margins of safety are summarized in Table 5 and Table 6.

Table 5: Low Flow Margins of Safety (MOS)

	Point Source	Nonpoint Source	Total
BOD *(lbs/month)*	130.1	0.5	130.6
Total Nitrogen *(lbs/month)*	58.3	0.2	58.5
Total Phosphorus *(lbs/month)*	6.8	0.02	6.8

Table 6: Average Annual Flow Margins of Safety (MOS)

	Point Source	Nonpoint Source	Total
BOD *(lbs/year)*	1,561.2	16.8	1,578.0
Total Nitrogen *(lbs/year)*	699.6	7.2	706.8
Total Phosphorus *(lbs/year)*	81.6	0.8	82.4

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 around 40 µg/l. For the present TMDLs, MDE has elected to use the more conservative peak concentrations of 50 µg/l.

Another MOS is that Scenario 5, for average annual flow, was run under the assumption of summer temperature and summer solar radiation. When the water is warmer and more sunlight is present, there will be a higher potential for low DO concentrations and more algal growth. The model was also run under steady-state conditions, for 120 days, assuming continuous average annual flows and loads. It is unlikely that these flows and loads will actually be seen for such an extended period of time during the summer. The higher temperatures and solar radiation are conservative assumptions representing a significant margin of safety.

4.8 Summary of Total Maximum Daily Loads

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

For BOD (*lbs/month*):

TMDL	=	LA	+	WLA	+	MOS
921.1	=	**9.9**	+	**780.6**	+	**130.6**

For Nitrogen (*lbs/month*):

TMDL	=	LA	+	WLA	+	MOS
531.1	=	**4.2**	+	**468.4**	+	**58.5**

For Phosphorus (*lbs/month*):

TMDL	=	LA	+	WLA	+	MOS
59.3	=	**0.5**	+	**52.0**	+	**6.8**

The average annual TMDLs for Town Creek, applicable from November 1 – April 30, follows:

For BOD (*lbs/yr*):

TMDL	=	LA	+	WLA	+	MOS
11,279.8	=	**334.6**	+	**9367.2**	+	**1,578.0**

For Nitrogen (*lbs/yr*):

TMDL	=	LA	+	WLA	+	MOS
6,471.7	=	**144.1**	+	**5,620.8**	+	**706.8**

For Phosphorus (*lbs/yr*):

TMDL	=	LA	+	WLA	+	MOS
722.7	=	**16.3**	+	**624.0**	+	**82.4**

Where:

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

5.0 ASSURANCE OF IMPLEMENTATION

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

Enforceable NPDES permit limits will include raising the WWTP effluent minimum DO from 5.0 to 6.0 mg/l any time, in addition to the mass loadings which will also provide confidence in assuring the implementation of these TMDLs. The implementation of point source BOD, TN and TP controls will be executed through the NPDES permit for the Town of Oxford WWTP.

Maryland's WQIA requires that comprehensive and enforceable nutrient management plans be developed, approved, and implemented for all agricultural lands throughout Maryland. This act specifically requires that these nutrient management plans be developed and implemented by 2004. Maryland's CWAP has been developed in a coordinated manner with the State's 303(d) process. All Category I waters identified in Maryland's Unified Watershed Assessment process are totally coincident with the impaired waters list for 1996 and 1998 approved by EPA. The State has given a higher priority for funding assessment and restoration activities to these watersheds.

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

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

Finally, Maryland has recently adopted a five-year watershed cycling strategy to manage its waters. Pursuant to this strategy, the State is divided into five regions and management activities will cycle through those regions over a five-year period. The cycle begins with intensive monitoring, followed by computer modeling, TMDL development, implementation activities, and follow-up evaluation. The choice of a five-year cycle is motivated by the five-year federal NPDES permit cycle. This continuing cycle ensures that, within five years of establishing a TMDL, intensive follow-up monitoring will be performed. Thus, the watershed cycling strategy establishes a TMDL evaluation process that assures accountability.

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APPENDIX A