Total Maximum Daily Loads of Nitrogen and Phosphorus for Swan Creek Harford County, Maryland

FINAL

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List of Abbreviations

7Q10	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
DE	Delaware
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphorus
DNR	Maryland Department of Natural Resources
DO	Dissolved Oxygen
EPA	U.S. Environmental Protection Agency
EUTRO5.1	Eutrophication Module of WASP5.1
FA	Future Allocation
LA	Load Allocation
lbs/month	pounds per month
lbs/year	pounds per year
MDA	Maryland Department of Agriculture
MDE	Maryland Department of the Environment
MD	Maryland
MGD	Million Gallons per Day
mg/L	milligrams per liter
MOS	Margin of Safety
NH_3	Ammonia
NPS	Nonpoint Source
NO_{23}	Nitrate + Nitrite
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
ON	Organic Nitrogen
OP	Organic Phosphorus
PO_4	Ortho-Phosphate
SCEM	Swan Creek Eutrophication Model
SOD	Sediment Oxygen Demand
The Act	Clean Water Act
TMDL	Total Maximum Daily Load
µg/L	micrograms per liter
USGS	United States Geological Survey
WASP5.1	Water Quality Analysis Simulation Program Version 5.1
WQIA	Water Quality Improvement Act of 1998
WQLSs	Water Quality Limited Segment
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

Swan Creek (02-13-07-06) is a tributary of the Chesapeake Bay, and is part of the Upper Western Shore Tributary Strategy Basin. Swan Creek was identified on the State's 1996 list of Water Quality Limited Segments (WQLSs) as impaired by excess nutrients and suspended sediments. This document proposes to establish Total Maximum Daily Loads (TMDLs) for the nutrients nitrogen and phosphorus in Swan Creek. The suspended sediment impairment will be addressed at later date.

Excess nutrients in an aquatic system act as a fertilizer - algal growth is promoted, which ultimately dies and decomposes, leading to bacterial consumption of dissolved oxygen. The water quality goals of these nutrient TMDLs are to reduce high chlorophyll *a* concentrations (a surrogate for algal blooms) and to maintain the dissolved oxygen criterion at a level where the designated uses for Swan Creek will be met. The TMDLs for the nutrients nitrogen and phosphorus were determined using the WASP5.1 water quality model. Loading caps for total nitrogen and total phosphorus entering Swan Creek are established for low flow and average annual flow conditions.

Loading Caps for Low-Flow Condition:

The low-flow TMDL for nitrogen is 11,136 lbs/month. This TMDL is applied during the period May 1 through October 31. The allowable loads have been allocated between nonpoint and point sources. The nonpoint sources are allocated as 757 lbs/month of nitrogen. The point sources are allocated as 10,341 lbs/month of nitrogen.

The low-flow TMDL for phosphorus is 759 lbs/month. This TMDL is applied during the period May 1 through October 31. The allowable loads have been allocated between nonpoint and point sources. The allowable loads have been allocated between nonpoint and point sources. The nonpoint sources are allocated as 30 lbs/month of total phosphorus. The point sources are allocated as 727 lbs/month of phosphorus.

Both the nitrogen and phosphorus low-flow TMDLs include a margin of safety (MOS) in the point source allocation through conservative modeling iterations. The explicit margins of safety make up the remainder of the nitrogen and phosphorus allocations.

Loading Caps for Average Annual Flow Condition:

The average annual TMDL for nitrogen is 252,094 lbs/year. This TMDL is applied to the annual average flow condition. The allowable loads have been allocated between point and nonpoint sources. The nonpoint sources are allocated as 121,907 lbs/year of total nitrogen. The point sources are allocated as 124,092 lbs/year of nitrogen.

The average annual flow TMDL for phosphorus is 18,987 lbs/year. This TMDL is applied to the annual average flow condition. The allowable loads have been allocated between nonpoint and

point sources. The nonpoint sources are allocated as 9,774 lbs/year of total phosphorus. The point sources are allocated as 8,724 lbs/year of phosphorus.

Both the nitrogen and phosphorus average annual flow TMDLs include a margin of safety (MOS) in the point source allocation through conservative modeling iterations. The explicit margins of safety make up the remainder of the nitrogen and phosphorus allocations.

Four factors provide assurance that these TMDLs will be implemented. First, NPDES permits will play a role in assuring implementation. Second, Maryland has several well-established programs to draw upon, including Maryland's Tributary Strategies for Nutrient Reductions developed in accordance with the Chesapeake Bay Agreement. Third, Maryland's Water Quality Improvement Act of 1998 (WQIA) requires that nutrient management plans be implemented for all agricultural lands throughout Maryland. Finally, Maryland adopted a watershed cycling strategy, to assure that routine monitoring and TMDL evaluations are conducted.

1.0 INTRODUCTION

Section 303(d)(1)(C) of the federal Clean Water Act and the applicable federal regulations direct each State to develop a Total Maximum Daily Load (TMDL) for each impaired water quality limited segment (WQLS) on the Section 303(d) list, taking into account seasonal variations and a protective margin of safety (MOS) to account for uncertainty. A TMDL reflects the total pollutant loading of the impairing substance a 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. Criteria may differ among waters with different designated uses.

Swan Creek was first identified on the 1996 303(d) list submitted to the U.S. Environmental Protection Agency (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 and for suspended sediments. The suspended sediment impairment will be addressed at a later date. Eutrophication is the over-enrichment of aquatic systems by excessive inputs of nutrients (nitrogen or phosphorus). The nutrients act as a fertilizer leading to excessive growth of aquatic plants, which eventually die and decompose, leading to bacterial consumption of dissolved oxygen. For these reasons, this document proposes to establish TMDLs for the nutrients, nitrogen and phosphorus, in Swan Creek.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

Swan Creek is in Harford County, Maryland, approximately 4 miles south of the mouth of Susquehanna River (Figure 1). The lower portion of Swan Creek is a small shallow tidal embayment. Average tidal range is 1 foot and the tidal water extends inland 4.5 river miles. The estimated volume of Swan Creek at mean low water is 93.7×10^{6} ft^{3} and at mean high water is 187.5×10^{6} ft^{3} [Maryland Department of Natural Resources (DNR), 1973]. The Swan Creek watershed has an area of approximately 16,127 acres or 25.2 square miles. Land uses in the watershed consist of forest and other herbaceous cover (5,645 acres or 35 %), mixed agriculture (5,483 acres or 34%), urban (4,848 acres or 30 %) and water (151 acres or 1%) based on 1997 Maryland Office of Planning land cover data with crop acres refined using 1997 Farm Service Agency data. Figure 2 shows the geographic distribution of the different land uses. Figure 3 shows the relative amounts of the different land uses.

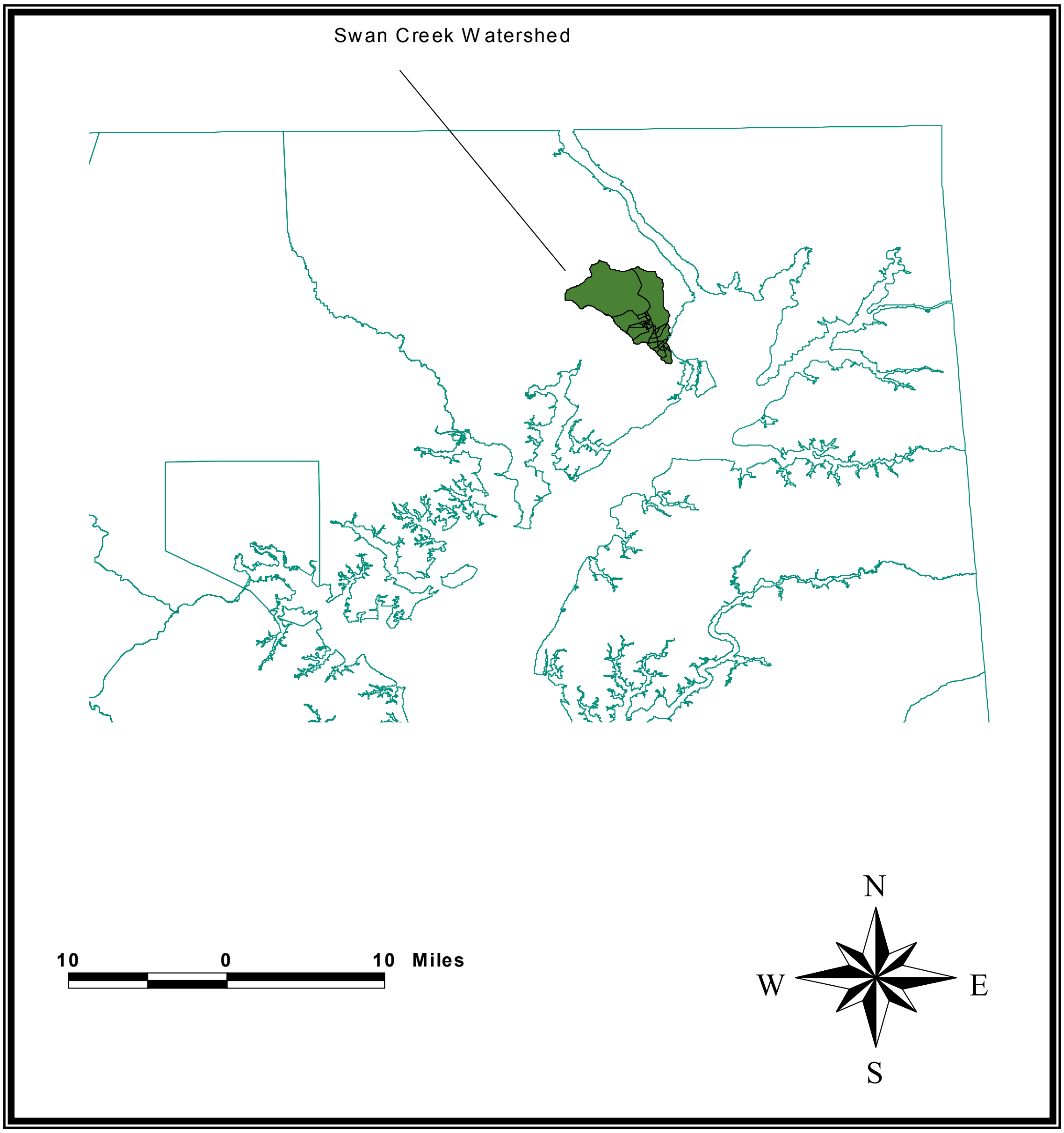


Figure 1: Location of the Swan Creek Drainage Basin within Upper Chesapeake Bay Area

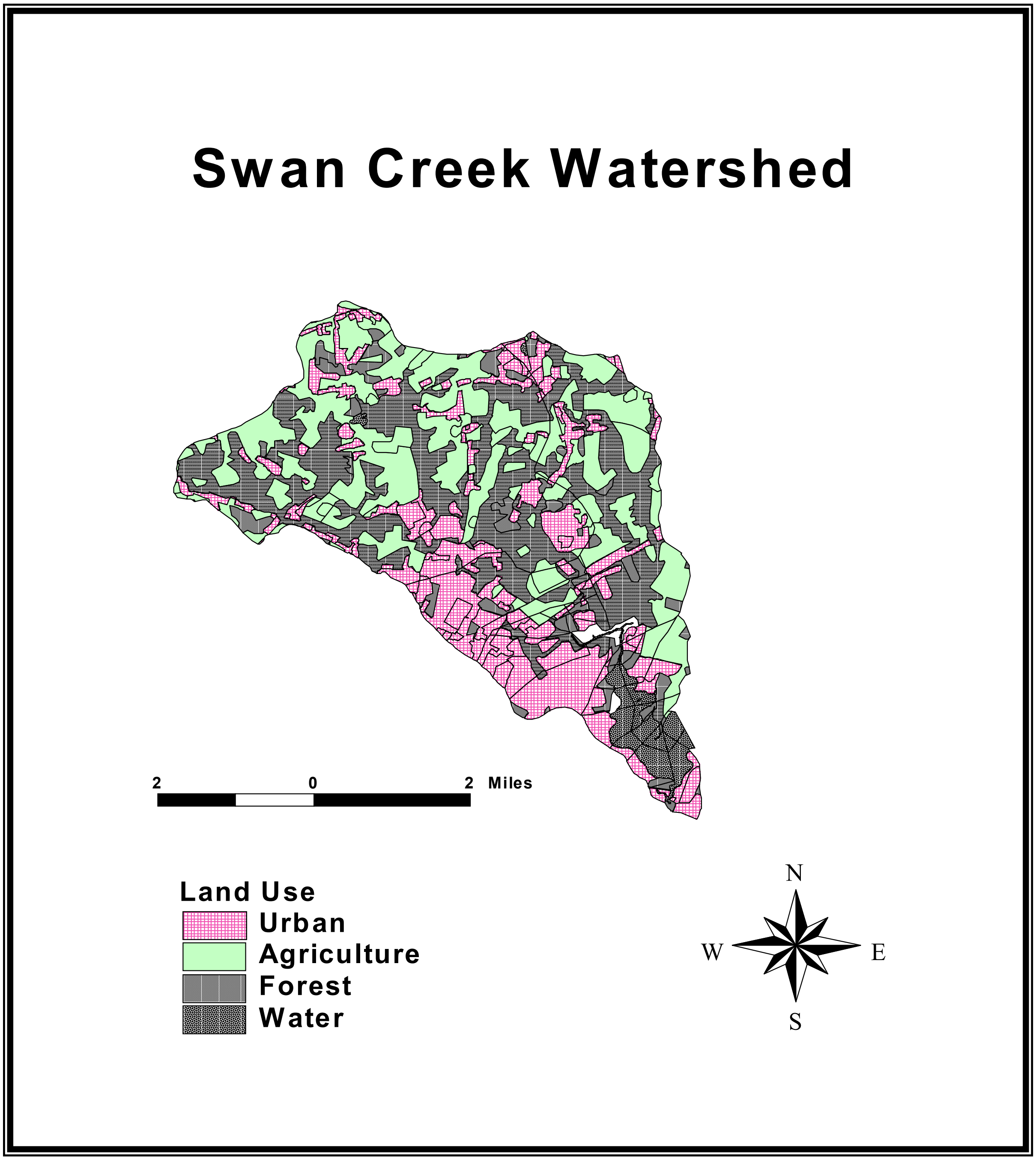


Figure 2: Predominant Land Use in the Swan Creek Drainage Basin

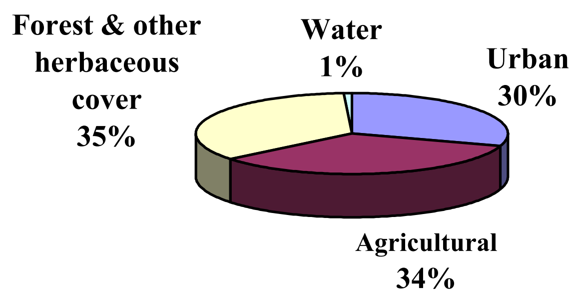


Figure 3: Proportions of Land Use in the Swan Creek Drainage Basin

There are two point sources on the Swan Creek watershed. The City of Aberdeen WWTP, is located about 3.1 river miles from the mouth with a design capacity of 4 MGD. The Swan Harbour Dell WWTP, the second treatment plant serving a mobile home park with much smaller capacity (0.05 MGD), is located 4.7 river miles from the mouth.

2.2 Water Quality Characterization

Four water quality parameters associated with the observed impairment of Swan Creek - chlorophyll *a*, dissolved oxygen, dissolved inorganic nitrogen, and dissolved inorganic phosphorus - are presented below. These data were collected by MDE during six water quality surveys conducted in Swan Creek during 1999. Three sets of samples were collected during seasonal low flow periods in summer (12-Aug-99, 26-Aug-99, 23-Sep-99). Data from the 23-Sep-99 collection was not used in the model calibration due to possible impact of Hurricane Floyd on the low flow condition. The reader is referred to Figure A10 (Appendix A) for the locations of the water quality sampling stations. Table 1 presents the distance of each station from the mouth.

Table 1: Location of Water Quality Stations

Water Quality Station	Distance from the Mouth (mile)	Description
SWA0022	1.9	Off the boat landing at the end of Old Landing Road
SWA0033	3	0.1 mile below the unnamed tributary carrying discharge from Aberdeen WWTP
SWA0035	3.2	0.1 mile above the unnamed tributary carrying discharge from Aberdeen WWTP
SWA0046	4.2	Old Post Road bridge Crossing
SWA0050	4.4	Robinhood Road under railroad crossing.
SWA0052	4.8	Oak Street bridge crossing
UEW0003		0.15 mile downstream from Aberdeen WWTP outfall
UEW0006	-	0.15 mile upstream from Aberdeen WWTP outfall
GAS0001	-	Gasheys Creek. Oakington Road bridge crossing.

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 the decay of dead plant matter. Because problems associated with eutrophication are usually most acute during this season, temperature, flow, sunlight and other parameters associated with this period represent critical conditions for the TMDL analysis. The following graphs present data from the low-flow period. Additional data, including that for the average annual flow periods, are presented in Appendix A.

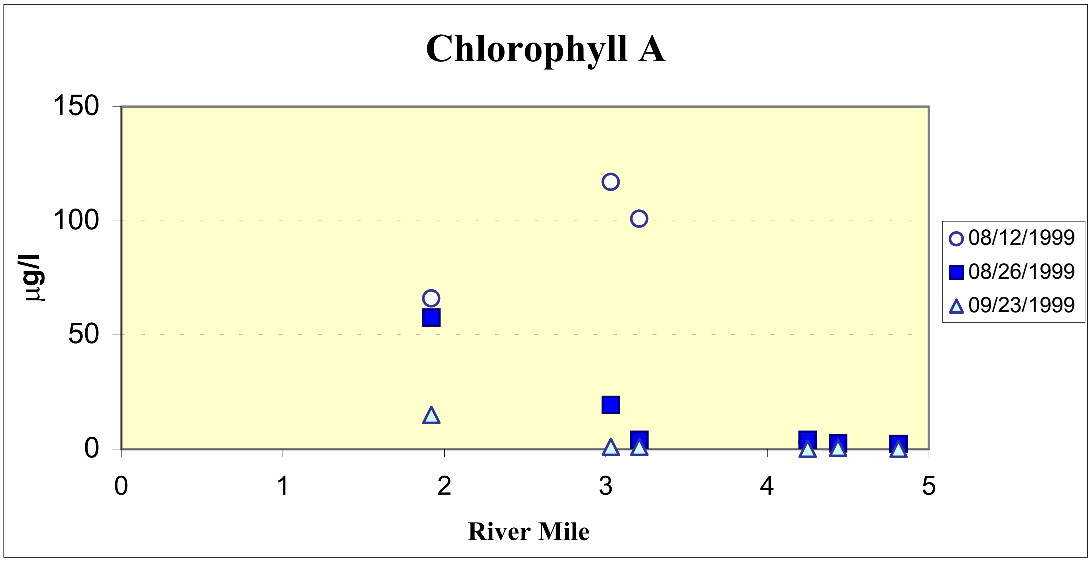


Figure 4: Longitudinal Profile of Chlorophyll *a* Data (Low flow)

Figure 4 presents a longitudinal profile of chlorophyll *a* data sampled during summer 1999, the low-flow period. High chlorophyll *a* concentrations were observed on August 12, 1999 at water quality stations SWA0022 (68 µg/L), SWA0033 (117 µg/L) and SWA0035 (101 µg/L). Another high chlorophyll *a* concentration was also reported from the August 26, 1999 data at station SWA0022 (58 µg/L). These results suggest the stream segments near these areas are likely to have eutrophication problems under critical flow conditions.

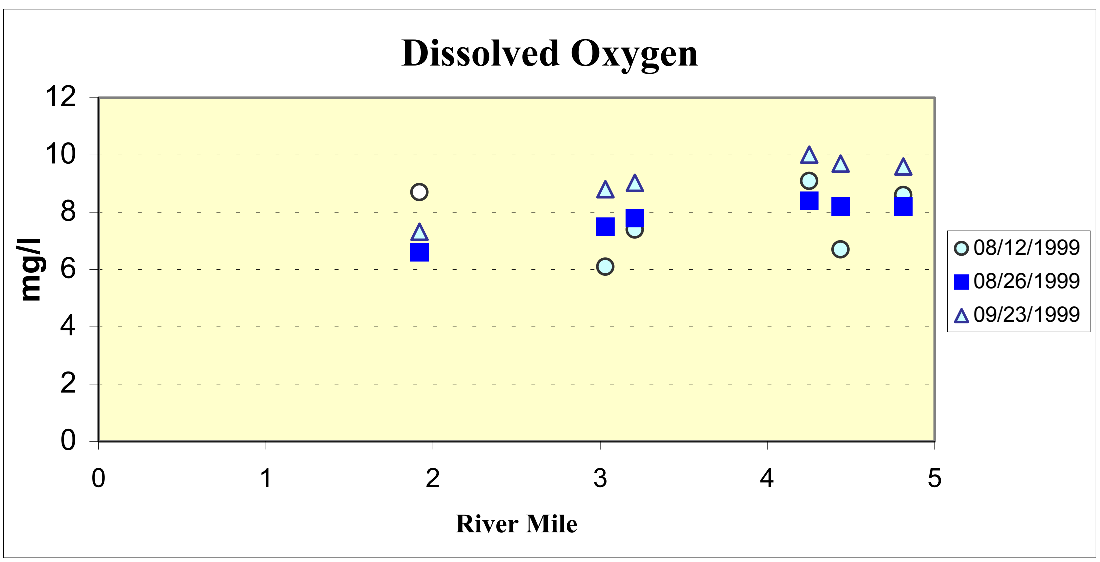


Figure 5: Longitudinal Profile of Dissolved Oxygen Data (Low flow)

A similar longitudinal profile for dissolved oxygen (DO) concentrations is depicted in Figure 5. The observed DO levels along the whole stretch of the river do not fall below the standard of 5.0 mg/L. The average DO along the river length is above 6.0 mg/L.

2.3 Water Quality Impairment

The Maryland water quality standards Surface Water Use Designation [Code of Maryland Regulations (COMAR) 26.08.02.07] for Swan Creek is Use I - *water contact recreation, fishing, and protection of aquatic life and wildlife*. The water quality impairment of the Swan 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 26.08.02.03.A(2). The achievement of 5.0 mg/L is expected in the well-mixed surface waters of the Swan 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 26.08.02.03B2). Additionally, COMAR 26.08.03.01.B3 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 levels of algae and interfere with designated uses such as fishing and swimming. The baseline scenario of the 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 the meantime, dissolved oxygen could also fall below 5 mg/L (Figures A13 and A14).

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 Swan Creek. Specifically, the TMDLs for nitrogen and phosphorus for Swan Creek are intended to assure that a minimum dissolved oxygen level of 5.0 mg/L is maintained throughout the Swan Creek system and to reduce peak chlorophyll *a* levels (a surrogate for algal blooms) to below 50 µg/L. The dissolved oxygen level is based on specific numeric criteria for Use I waters set forth in the COMAR 28.08.02. The chlorophyll *a* level is based on the designated uses of Swan 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 target threshold 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 Swan Creek. The first section describes the modeling framework for simulating nutrient loads, hydrology, and water quality responses. The second and third sections summarize the scenarios that were explored using the model. The assessment investigates water quality responses assuming different stream flow and nutrient loading conditions. The fourth and fifth sections present the modeling results in terms of TMDLs and load allocations. The sixth section explains the rationale for the margin of safety. Finally, the pieces of the equation are combined in a summary accounting of the TMDLs.

4.2 Analysis Framework

The computational framework chosen for the Swan 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 WASP model was implemented in a steady-state mode. This mode of using of WASP simulates constant flow and average waterbody volume over the tidal cycle. Tidal mixing is accounted for using dispersion coefficients, quantifying the exchange of conservative substances between model segments. The model simulates an equilibrium state of the waterbody, which in this case, considered low-flow and average flow conditions. These conditions are described in more detail below.

The spatial domain of the Swan Creek Eutrophication Model (SCEM) extends from the mouth of Swan Creek for about 5 miles (8 km) along the main stem of Swan Creek. There are 17 model segments represented in the modeling domain. A diagram of the WASP model segmentation is illustrated in Figure A10 in Appendix A.

The nutrient TMDL analyses presented here consist of assessments of both low-flow and average annual flow conditions. The low-flow TMDL analysis investigates the critical conditions under which symptoms of eutrophication are typically most acute (in late summer when flows are low, poor flushing of the system and when sunlight and temperatures are most conducive to excessive algal production). An annual average flow TMDL is also developed to set nutrient loading cap for the watershed based on the average flow condition in the stream to protect its water quality on a year round basis.

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

The estimation of stream flow used in the low-flow calibration was based on the flows of three nearby U.S. Geological Survey (USGS) stations. An average flow for each individual USGS gage was calculated by obtaining an average value over three low flow months (July, August, September) for the entire range of the flow data available. A ratio of flow to drainage area was calculated for each of the USGS gages; then an average of all three 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 seven day consecutive lowest flow expected to occur once every 10 years (7Q10) flows for the subwatersheds were also derived using the same method as described for the low-flow calibration using 7Q10 flows from the four USGS stations. The estimation of stream flow used for the annual flow condition is similar to what is described in the low-flow condition except the flow was calculated by obtaining an average annual flow value over 30 years from the three selected reference gaging stations. The methods used to estimate stream flows are described further in Appendix A.

There are two point sources in the Swan Creek basin, the City of Aberdeen WWTP (design flow capacity 4.0 MGD) and Swan Harbour Dell WWTP (design capacity 0.05 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 the 1999 low-flow sampling in 1999 multiplied by the estimated critical low flows. On the other hand, the average annual flow NPS loading estimation is calculated based on the 10-year average loading data from EPA's Chesapeake Bay Program (2000). The point source loads were based on the maximum permitted flow loads.

The concentrations of the nutrients (nitrogen and phosphorus) are modeled in their speciated forms. Nitrogen is simulated as ammonia (NH_3), nitrate and 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. Dissolved forms of the nutrients are more readily available for biological processes such as algal growth, affecting chlorophyll *a* levels and dissolved oxygen 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 Swan Creek.

4.3 Scenario Descriptions

The WASP model was applied to investigate different nutrient loading scenarios under both low and average annual 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 result of average annual flow scenario is also being utilized to develop nutrient loading cap for the average flow condition in the stream to protect its water quality on a year round basis.

The analyses are grouped according to *baseline conditions* and *future TMDL* associated with TMDLs. The baseline conditions are intended to provide a point of reference to compare the future scenario that simulates the 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*".

Baseline Condition (Low Flow): The first scenario represents the baseline conditions of the stream at simulated critical low flow in the river. The method of estimating the critical low flow is described in Appendix A. The scenario simulates a critical condition when the river system is poorly flushed, where sunlight and warm water temperatures are most conducive to creating the water quality problems associated with excessive nutrient enrichment.

The nutrient concentrations for the first scenario were calculated using observed data collected during low-flow conditions of August and September of 1999. The low-flow NPS loads were computed as the product of the observed concentrations and estimated critical low flow. These low-flow NPS loads integrate all natural and human induced sources - including direct atmospheric deposition, loads from septic tanks, which are associated with river base flow during low-flow conditions. For point source loads, these baseline conditions assume maximum allowable effluent flow (based on plant design flow approved by water and sewer plan) with their current NPDES permitted concentrations as the nutrient parameters.

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% reduction in overall nonpoint source nitrogen and phosphorus input from the watershed. In this future condition scenario, reductions in nutrient fluxes and sediment oxygen demand (SOD) were estimated based on the percent reduction of organic matter settling on the bottom. Since the point sources are operating at 40% of their design capacity with the effluent quality from Aberdeen WWTP (4MGD) at or beyond current best management practice (average total nitrogen: 6.4 mg/L, phosphorus: 0.13 mg/L, based on the discharge monitoring report from July, 2000 to June, 2001). The point source loads assume the maximum allowable flow (based on the plant design flow approved by water and sewer plan) and current NPDES permit limits. Details of this modeling activity are described further in the technical memorandum entitled "*Significant Nutrient Point Sources in the Swan Creek Watershed*" and Appendix A.

Baseline Condition (Average Annual Flow): This scenario represents the baseline conditions of the stream at a simulated average annual condition in the river. The model predicts the stream's response for nutrient inputs during year round condition. The method of estimating the average annual flow is described in Appendix A.

The average annual flow NPS loads were computed based on the 10 year average regional nutrient loading data from EPA's Chesapeake Bay Program (2000). These NPS loads integrate all major natural and human induced sources. For point source loads, these baseline conditions assume maximum allowable effluent flow (based on plant designed flow approved by water and sewer plan) with their current NPDES permitted concentrations as the nutrient parameters.

TMDL (Average Annual Flow): This scenario represents the baseline conditions of the stream at a simulated average annual condition in the river. The model predicts the stream's response for nutrient inputs during year round conditions. The method of estimating the average annual flow is described in Appendix A.

The average annual flow NPS loads were computed based on 60 % the 10 year average regional nutrient loading data from EPA's Chesapeake Bay Program (2000) (i.e. 40% reduction of nonpoint source input). These NPS loads integrate all major natural and human induced sources. For point source loads, as in the low flow condition, these baseline conditions assume the maximum allowable effluent flow (based on plant designed flow approved by water and sewer plan) with their current NPDES permitted concentrations as the nutrient parameters.

4.4 Scenario Results

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

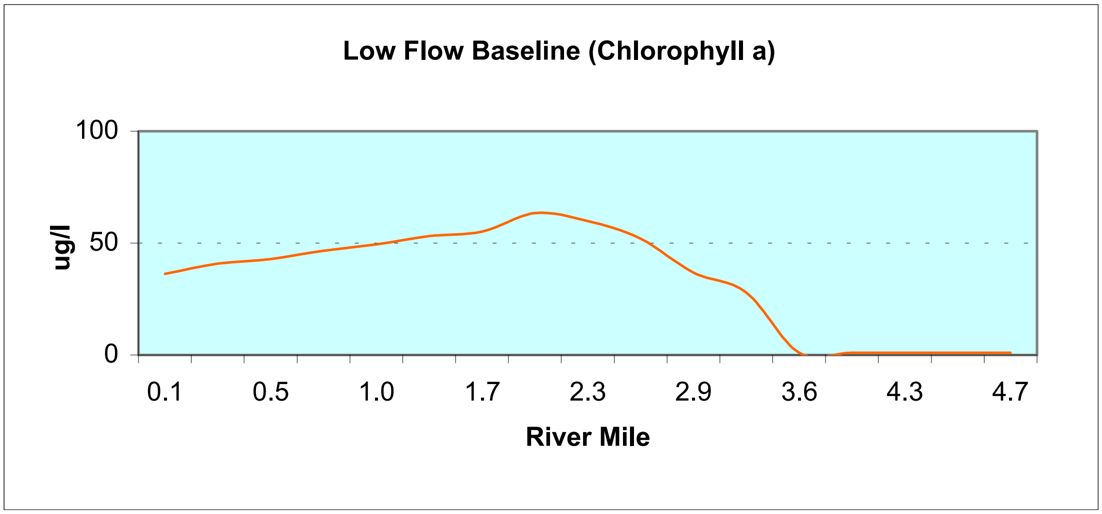
Baseline Condition (Low Flow Condition) :

This scenario simulates 7Q10 conditions during the summer season. Water quality parameters (e.g., nutrient concentrations) are based on 1999 observed data. Point source loads assume maximum approved water and sewer plan flow and NPDES permit limits expected in the effluent (4.0 MGD at **Aberdeen WWTP**, 0.05 MGD at **Swan Harbour Dell** WWTP). Results for this scenario, representing the baseline condition for summer low flow, are summarized in Figure 6. Figure 6A shows the peak chlorophyll *a* levels above 50 µg/L under the critical condition of temperature and flows among the lower segments of the river. The dissolved oxygen level in the middle segment of the stream also indicates a potential to be below the water quality standard (5.0 mg/L). The TMDL scenario presented below, establishes maximum allowable loads to address these problems.

TMDL (Low Flow Condition):

The TMDL simulates the future condition of maximum allowable loads for 7Q10 conditions during summer season to meet the water quality criteria in Swan Creek. Results for the TMDLs are illustrated in comparison to the appropriate baseline condition (solid line) in Figure 7. Under the nutrient load reduction conditions described above for this scenario, the results show chlorophyll *a* concentrations are below the levels of 50 µg/L along the entire length of Swan Creek. Results from Figure 7B also 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.

(A)



(B)

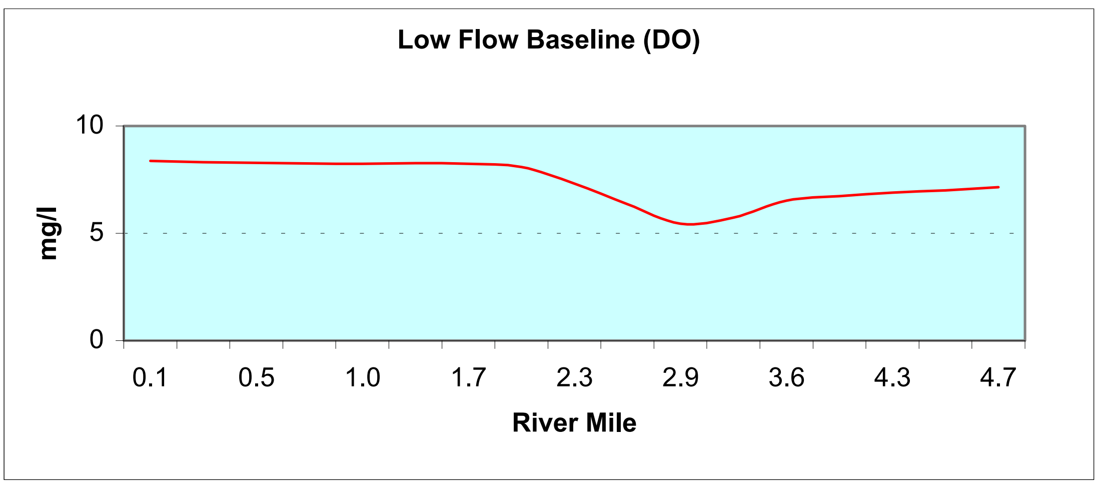
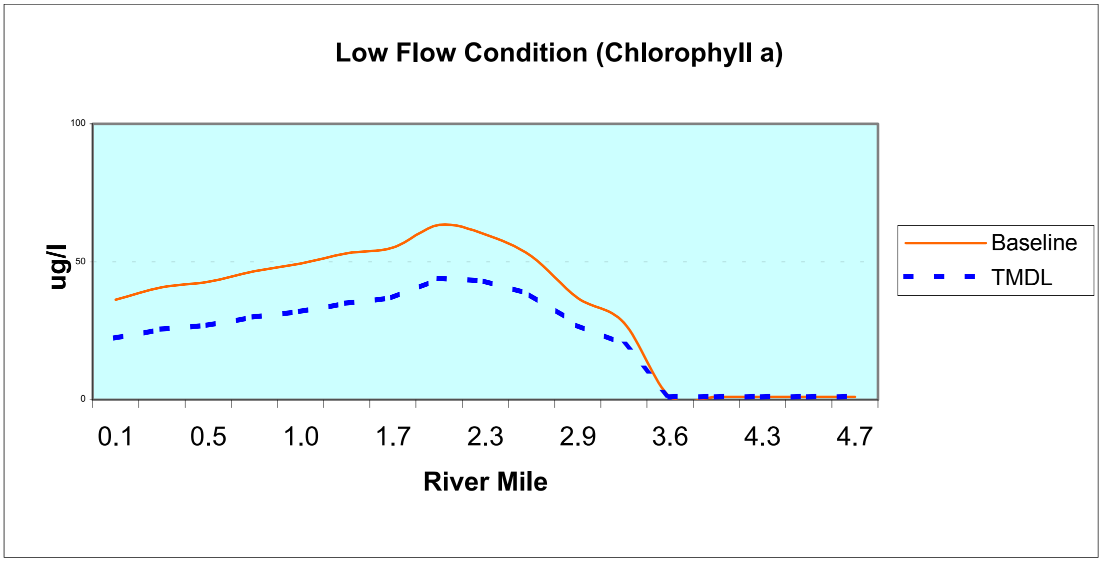


Figure 6: Model Results for the Baseline Low Flow Scenario for (A) Chlorophyll *a* and (B) Dissolved Oxygen

(A)



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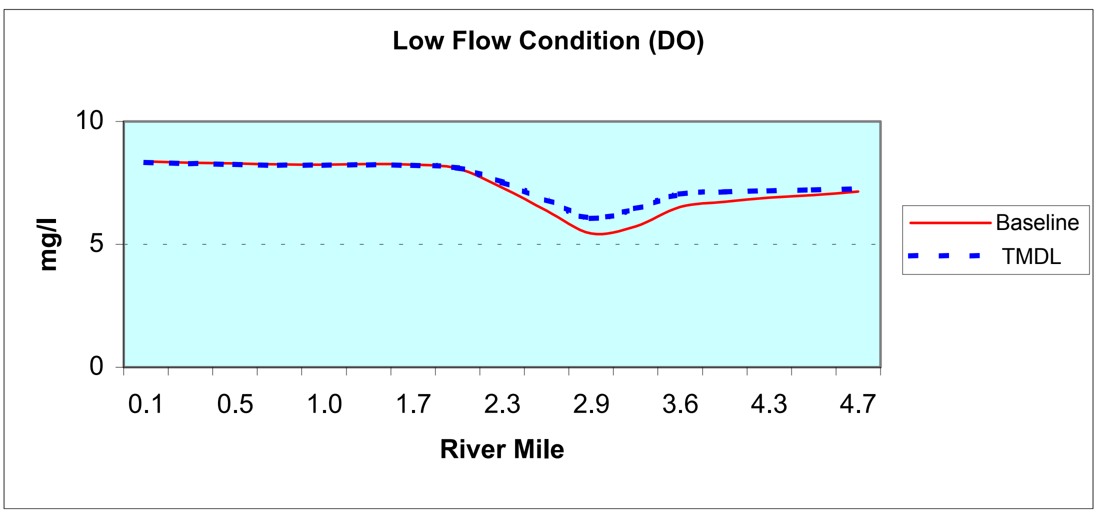


Figure 7: Model Results for the TMDL for (A) Chlorophyll *a* and (B) Dissolved Oxygen

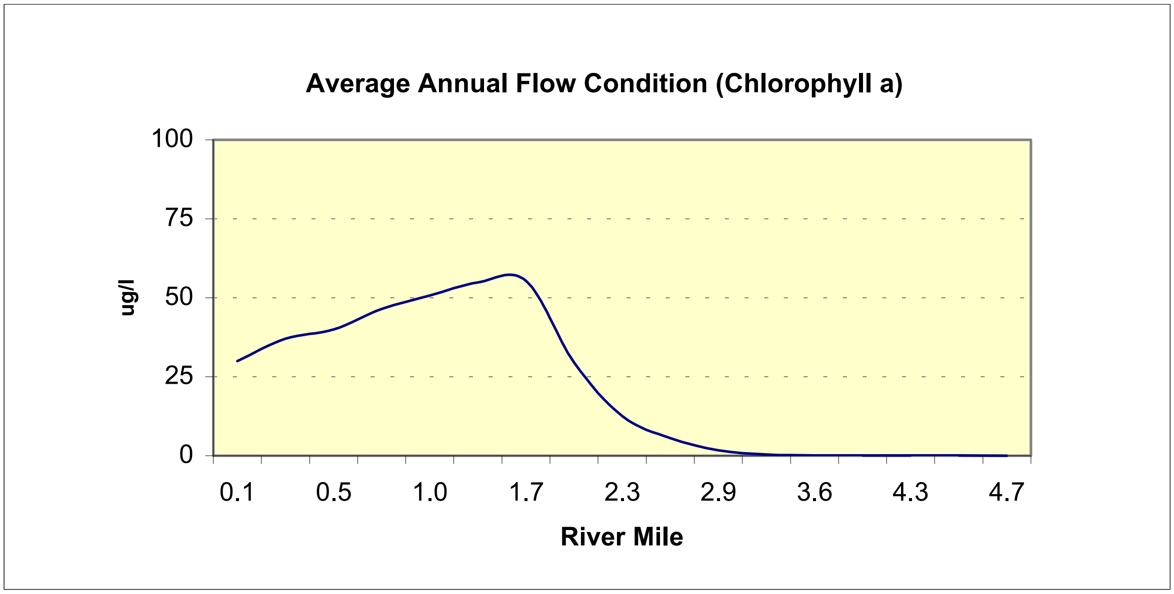
Baseline Condition (Average Annual Flow Condition):

This scenario simulates average stream flow conditions under average annual conditions. Water quality parameters (e.g., nutrient concentrations) are based on the 10 years average regional nutrient loading data from EPA's Chesapeake Bay Program (2000). Point source loads assume maximum approved water and sewer plan flow and NPDES permit limits expected in the effluent (4.0 MGD at **Aberdeen WWTP**, 0.05 MGD at **Swan Harbour Dell WWTP**). Results for this scenario, representing the baseline condition for average annual flow, are illustrated in Figure 8. The potential for algal blooms was predicted by the model results showing the peak chlorophyll *a* level as 56 µg/L (Figure 8). On the other hand, the dissolved oxygen level in the middle segment of the stream is also above the 5.0 mg/L (Figure 8). The TMDL scenario, presented below, establishes maximum allowable loads to address these problems.

TMDL (Average Annual Flow Condition):

This scenario simulates average stream flow conditions under average annual conditions. Since NPS is generally considered as the major contributor of nutrient during higher stream flow period, it was decided that a 40 % reduction of water quality parameters will be calculated based on the 10 years average regional nutrient loading data from EPA's Chesapeake Bay Program (2000). Point source loads assume maximum approved water and sewer plan flow and NPDES permit limits expected in the effluent (4.0 MGD at **Aberdeen WWTP**, 0.05 MGD at **Swan Harbour Dell WWTP**). Results for this scenario, representing the TMDL for average annual flow seasons, are illustrated in Figure 9. No potential algal blooms or low dissolved oxygen levels were predicted by the model results. The peak chlorophyll *a* level is 45 µg/L while the dissolved oxygen level in the middle segment of the stream is well above the 5.0 mg/L (Figure 9). These results suggest that the nutrient loadings set for this scenario will be adequate for average annual flow TMDL.

(A)



(B)

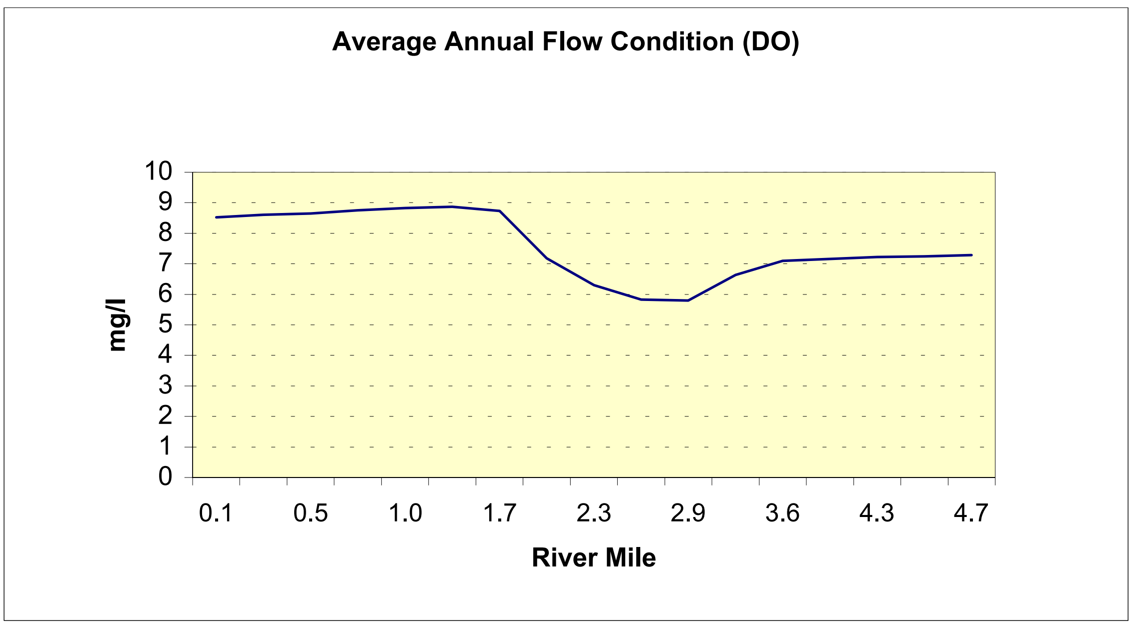


Figure 8: Model Results of Annual Flow Baseline for (A) Chlorophyll *a* and (B) Dissolved Oxygen

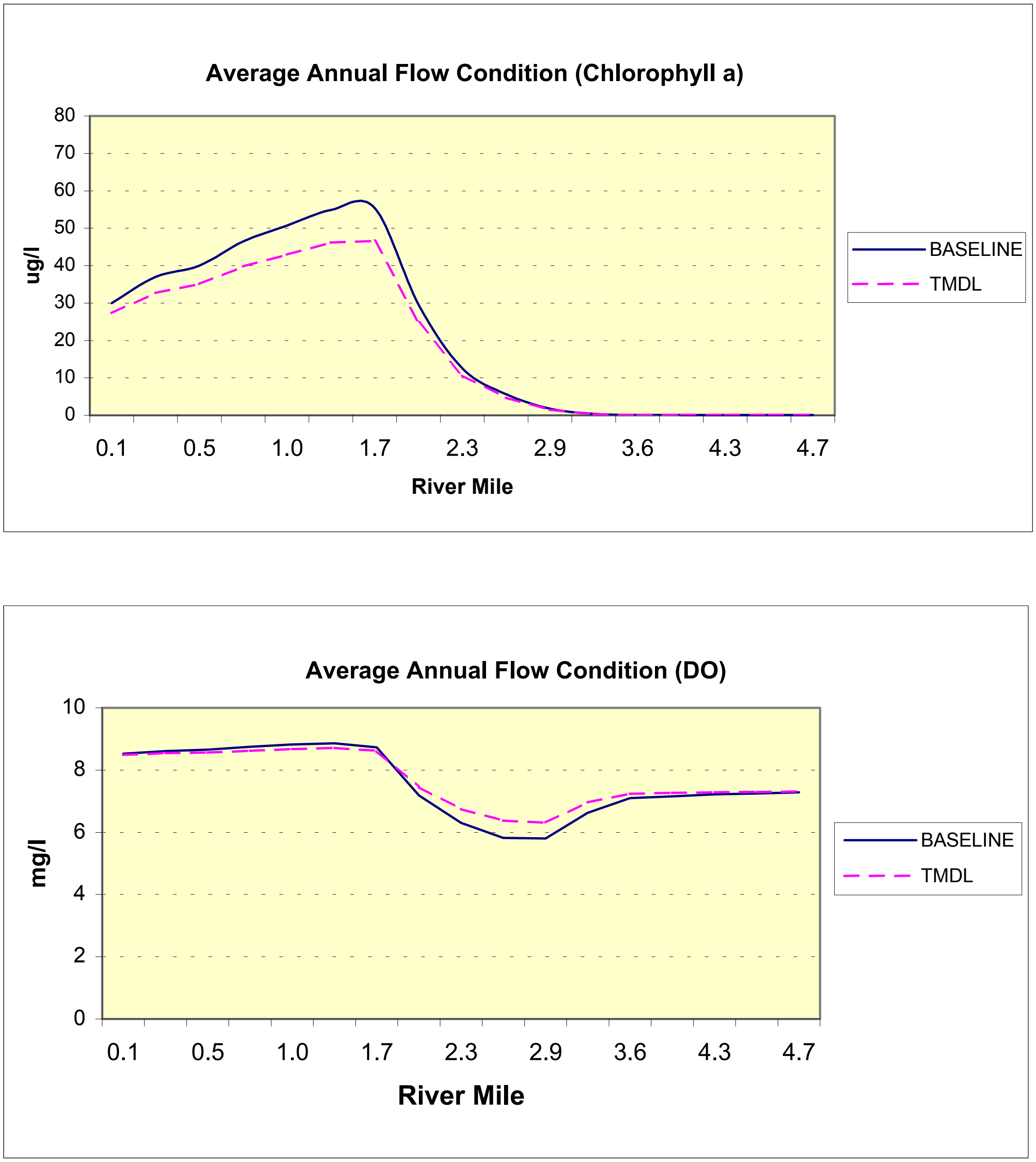


Figure 9: Model Results of Annual Flow TMDL for (A) Chlorophyll *a* and (B) Dissolved Oxygen

4.5 TMDL Loading Caps

This section presents total maximum daily loads (TMDLs) for nitrogen and phosphorus applicable during critical low-flow conditions. The critical season for excessive algal growth in Swan 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-flow 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:

Low Flow TMDL:

NITROGEN **11,136** *lbs/month*

PHOSPHORUS **759** *lbs/month*

For the average annual flow, the following TMDLs apply:

Average Annual Flow TMDL:

NITROGEN **252,094** *lbs/year*

PHOSPHORUS **18,987** *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 Swan Creek. Specifically, these allocations show that the sum of nitrogen and phosphorus nutrient loadings to Swan 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 nonpoint source 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 Swan Creek water quality survey conducted in summer 1999. These nonpoint source loads, based on observed concentrations, account for both "natural" and human-induced components and cannot be separated into specific source categories. There are two point sources, **Aberdeen WWTP** and

Swan Harbour Dell WWTP, discharging nutrients in the watershed. Allocations have been made to the point sources based on their maximum permitted discharge flows. Point source allocations are described further in the technical memorandum entitled "*Significant Nutrient Point Sources in the Swan Creek Watershed"* and Appendix A. The nitrogen and phosphorus allocations for the low-flow conditions are presented in Table 2.

Average Annual Flow Allocations:

The nonpoint source load calculated based on 60% of the 10 years average regional nutrient loading data from EPA's Chesapeake Bay Program (2000) was adapted in the average annual flow condition. These nonpoint source loads account for both "natural" and human-induced components. Nonpoint source allocations based on the land usage are described further in the technical memorandum entitled *"Significant Nutrient Nonpoint Sources in the Swan Creek Watershed"* and Appendix A. There are two point sources, **Aberdeen WWTP** and **Swan Harbour Dell WWTP**, discharging nutrients in the watershed. Allocation has been made to these point sources based on their maximum permitted discharge flows. Point Source allocations are described further in the technical memorandum entitled "*Significant Nutrient Point Sources in the Swan Creek Watershed"* and Appendix A. The nitrogen and phosphorus allocations for average annual flow conditions are presented in Table 3.

	Total Nitrogen ***(lbs/month)***	**Total Phosphorus** ***(lbs/month)***
Nonpoint Source	757	30
Point Source	4,137	291

Table 2: Summer Low Flow Allocations

	Total Nitrogen ***(lbs/year)***	**Total Phosphorus** ***(lbs/year)***
Nonpoint Source	121,907	9,774
Point Source	49,637	3,492

Table 3: Average Annual Flow Allocations

4.7 Margins of Safety

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

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

Maryland has adopted margins of safety that combines these two approaches. Following the first approach, the load allocated to the MOS was computed as 5% of the nonpoint source loads for nitrogen and phosphorus. In addition to these explicit set-aside MOSs, additional safety factors are built into the TMDL development process. For instance, the average monthly flows from Aberdeen WWTP and Swan Harbour Dell WWTP from May 2000 to June 2001 are 1.6 MGD and 0.015 MGD (source: Discharge Monitoring Report). These flows only account for 40 % or less of their design flows (4 MGD and 0.05 MGD) that were used for the baseline and scenario simulations in SCEM. 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 use the more conservative peak concentrations of 50 μg/L. With this approach, MDE also added an additional margin of safety in the average annual TMDL given the projected maximum chlorophyll *a* at a value of 45 μg/L.

4.8 Summary of Total Maximum Daily Loads

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

For Nitrogen (*lbs/month*):

TMDL	=	LA	+	WLA[1]	+	MOS
11,136	=	757	+	10,341	+	38

For Phosphorus (*lbs/month*):

TMDL	=	LA	+	WLA[1]	+	MOS
759	=	30	+	727	+	2

Where: TMDL = Total Maximum Daily Load
LA = Load Allocation (Nonpoint Source)
WLA = Waste Load Allocation (Point Source)
MOS = Margins Of Safety

1.Representing the current average loading from Aberdeen WWTP and Swan Harbour Dell WWTP (40% of their NPDES approved maximum loading). The future allocation is incorporated in the point source allocation because both Aberdeen WWTP and Swan Harbour Dell WWTP are currently operating near 40% of their NPDES approved capacity.

The Average Annual TMDLs, applicable for the average annual flow condition for Swan Creek:

For Nitrogen (*lbs/year*):

TMDL	=	LA	+	WLA[1]	+	MOS
252,094	=	**121,907**	+	**124,092**	+	**6,095**

For Phosphorus (*lbs/year*):

TMDL	=	LA	+	WLA[1]	+	MOS
18,987	=	**9,774**	+	**8,724**	+	**489**

Where: TMDL = Total Maximum Daily Load
LA = Load Allocation (Nonpoint Source)
WLA = Waste Load Allocation (Point Source)
MOS = Margins Of Safety

1.Representing the current average loading from Aberdeen WWTP and Swan Harbour Dell WWTP (40% of their NPDES approved maximum loading). The future allocation is incorporated in the point source allocation because both Aberdeen WWTP and Swan Harbour Dell WWTP are currently operating near 40% of their NPDES approved capacity.

Average Daily Loads:

On average, the low flow TMDLs will result in loads of approximately 371 lbs/day of nitrogen and 25 lbs/day of phosphorus. The average annual flow TMDLs will result in loads of approximately 691 lbs/day of nitrogen and 52 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 to draw 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.

Maryland's WQIA requires that comprehensive and enforceable nutrient management plans be developed, approved and implemented for all agricultural lands throughout Maryland. This act specifically requires that nutrient management plans for nitrogen be developed and implemented by 2002, and plans for phosphorus to be done by 2005. Maryland's CWAP has been developed in a coordinated manner with the State's 303(d) process. All Category I watersheds identified in Maryland's Unified Watershed Assessment process are totally coincident with the impaired waters list for 1996 and 1998 approved by EPA. The State is giving a high-priority for funding assessment and restoration activities to these watersheds.

In 1983, the states of Maryland, Pennsylvania, and Virginia, the District of Columbia, the Chesapeake Bay Commission, and the U.S. EPA joined in a partnership to restore the Chesapeake Bay. In 1987, through the Chesapeake Bay Agreement, Maryland made a commitment to reduce nutrient loads to the Chesapeake Bay. In 1992, the Bay Agreement was amended to include the development and implementation of plans to achieve these nutrient reduction goals. Maryland's resultant Tributary Strategies for Nutrient Reduction provide a framework that will support the implementation of nonpoint source controls in the Upper Western Shore Tributary Strategy Basin, including the Swan 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 non-point source reductions of the magnitude identified by this TMDL allocation. Urban stormwater runoff in Harford County is regulated under an NPDES Phase I Stormwater Permit; in addition, a Phase II Stormwater Permit will be issued to the City of Aberdeen. Under these permits, they are required to implement best management practices (BMPs) to control new development runoff. Maryland has just issued a new design manual - "2000 Maryland Stormwater Design Manual - Volumes I and III [MDE, 2000], which details BMPs needed to reduce suspended solids runoff by at least 80% and total phosphorus runoff by at least 40%. These new programs, which are to be implemented over the next few years, should significantly reduce the nonpoint source loading during the moderate storm events which still occur during low-flow periods, plus limit the deposit of nutrients and organic material to the streambed during higher flow events.

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

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

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