UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

DEC 1 0 1999

The Honorable Jane T. Nishida
Secretary
Maryland Department of the Environment
2500 Broening Highway
Baltimore, Maryland 21224

Dear Secretary Nishida:

The Environmental Protection Agency (EPA), Region III has reviewed the report "Total Maximum Daily Loads (TMDLs) of Phosophorus and Sediments to Tony Tank Lake. Wicomico County. Maryland" which was submitted by the Maryland Department of Environment on October 4, 1999. Pursuant to 40 CFR Section 130.7(d), EPA is approving the Tony Tank TMDLs.

The definition of Load Allocation (LA) at 40 CFR Section 130.2(g) states in part that "Load allocations are best estimates of the loading, which may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading." Further, a wasteload allocation (WLA), according to 40 CFR Section 130.2(h), is "The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation." In addition, a TMDL is defined at 40 CFR Section 130.2(I) as "The sum of the individual WLAs for point sources and LAs for nonpoint sources and natural background."

EPA has determined that the TMDLs and technical report are consistent with the regulations and requirements of 40 CFR Section 130 (see enclosed Decision Rationale). Pursuant to 40 CFR Sections 130.6 and 130.7(d)(2), the TMDLs and the supporting documentation should be incorporated into Maryland's current water quality management plan.

If you have any questions or concerns, please contact Thomas Henry at 215-814-5752.

Sincerely,

Jon M. Capacasa
Acting Division Director

Enclosure

Decision Rationale

Total Maximum Daily Load of Phosphorus and Sediments to Tony Tank Lake, Wicomico County, MD

I. Introduction

This document will set forth the Environmental Protection Agency's (EPA) rationale for approving the Total Maximum Daily Loads (TMDLs) of Phosphorus and Sediments to Tony Tank Lake in Wicomico County, Maryland submitted for final Agency review on October 4, 1999. Our rationale is based on the TMDL, Technical Memorandum, and other information provided in the submittal document to determine if the TMDL meets the following 8 regulatory conditions pursuant to 40 CFR §130.

1) The TMDLs are designed to implement applicable water quality standards.
2) The TMDLs include a total allowable load as well as individual waste load allocations and load allocations.
3) The TMDLs consider the impacts of background pollutant contributions.
4) The TMDLs consider critical environmental conditions.
5) The TMDLs consider seasonal environmental variations.
6) The TMDLs include a margin of safety.
7) The TMDLs have been subject to public participation.
8) There is reasonable assurance that the TMDLs can be met.

The Technical Memorandum, *Significant Phosphorus and Sediment Nonpoint Sources in the Tony Tank Lake Watershed* submitted by the Maryland Department of the Environment (MDE), specifically allocates phosphorus and sediments to each of three land use categories. Each land use is allocated some percentage of the total load originating from nonpoint sources. Current nonpoint source load estimates were based on the Chesapeake Bay Model Phase IV loading coefficients which consider natural background, loads from septic tanks, as well as baseflow contributions. Likewise, the load allocations to each land use also consider natural background, septic tanks and baseflow. Each land use load allocation represents yearly allowable loads of phosphorus and sediments.

II. Summary

Tony Tank Lake[1], a small elongated impoundment in Wicomico County, was created in

[1] Tony Tank Lake is located near the cities of Fruitland and Salisbury and is owned by Wicomico County.

1948 by the construction of the Shad Point Dam[2]. The impoundment, which is used for recreational purposes, lies on the Tony Tank Creek which is a tributary of the Wicomico River in the Lower Eastern Shore Tributary Strategy Basin. Tony Tank Pond, which is fed by the discharges from Morris Mill and Coulbourne Ponds, is directly upstream of Tony Tank Lake and serves as the primary flow into the lake. The dominant land use in the watershed is forested or other herbaceous cover (54%), with urban (26%) and agriculture (20%) comprising the remaining significant portions.

As a result of the Lake Water Quality Assessment Project (LWQAP) (MDE, 1993) and Maryland's 1996 305(b) report, the Lower Wicomico River[3] watershed was included on the 1996 Clean Water Act (CWA) Section 303(d) list of water quality impaired waterbodies. The primary reason for listing this watershed was the water quality impairments associated with Tony Tank Lake. The lake was classified as eutrophic due to its high total phosphorus concentrations, algal blooms, low secchi depth, and possible diurnal dissolved oxygen variations below the water quality criterion which caused violations of the designated uses[4] of the lake. Nutrients and suspended sediments resulting from natural and nonpoint sources were listed as the causes and sources of the water quality impairment, respectively. The 1998 303(d) list further clarified the scope of the water quality impairment by listing the Lower Wicomico Creek and specifically Tony Tank Lake due to nutrients and sedimentation from nonpoint sources. On both the 1996 and 1998 303(d) lists, the waterbody was given low priority. Section 303(d) of the CWA and its implementing regulations require a TMDL to be developed for those waterbodies identified as impaired by the State where technology-based and other controls did not provide for attainment of water quality standards.

MDE developed TMDLs to address the excessive sedimentation and nutrient enrichment that Tony Tank Lake is currently experiencing. These TMDLs are designed to satisfy the water quality standards and designated uses of Tony Tank Lake only. Impairments in the remainder of the Lower Wicomico River watershed and Lower Eastern Shore are not addressed by these TMDLs.

Maryland has interpreted its narrative water quality standards in order to determine an appropriate endpoint for the TMDL. The sediment TMDL is designed to restore the designated uses of Tony Tank Lake through the control of sediment delivered to the lake and will result in the preservation of 64% to 85% of the lake volume over the next 40 years. In order to control nutrient enrichment in Tony Tank Lake to restore designated uses, a phosphorus TMDL was developed by MDE predicated on the identification of phosphorus as the limiting nutrient. MDE estimated that phosphorus is the limiting nutrient by dividing the nitrogen load by the

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[2] The dam is the dividing line between tidal and non-tidal waters in Tony Tank Creek.

[3] The Lower Wicomico River is listed as basin segment 02130301.

[4] The Code of Maryland Regulations (COMAR) at Section 26.08.02.07 list the designated uses of Tony Tank Lake as Use I-Water Contact Recreation, and Protection of Aquatic Life.

phosphorus load delivered to the lake, both of which are estimated using EPA/Chesapeake Bay Model Phase IV loading coefficients[5]. The phosphorus TMDL is designed to control nuisance algae blooms, excessive plant growth and foul odors. In addition, MDE links the control of phosphorus loading to the attainment of the dissolved oxygen water quality standard in the surface waters[6] of the lake. EPA believes that these endpoints are acceptable for deriving the phosphorus and sediment TMDLs. Table 1 below summarizes the phosphorus and sediment TMDLs.

Table 1, Phosphorus and Sediment TMDL summary

Parameter	Rate	TMDL	WLA	LA	MOS
Phosphorus	lbs/yr	735.7	0	662.1	73.6
	lbs/day	2.01	0	1.81	0.20
Sediment	tons/yr	188.3	0	188.3	Implicit
	tons/day	0.51	0	0.51	Implicit

III. Discussion of Regulatory Conditions

EPA finds that Maryland has provided sufficient information to meet all of the 8 basic requirements for establishing phosphorus and sediment TMDLs for Tony Tank Lake. EPA therefore approves the TMDLs, Technical Memorandum, and supporting documentation for phosphorus and sediments in Tony Tank Lake. Our approval is outlined according to the regulatory requirements listed below.

1) The TMDL is designed to implement the applicable water quality standards.

Maryland does not currently have numeric water quality standards for nutrients (phosphorus or nitrogen) or sediments. Therefore, Maryland utilized its General Water Quality Criteria[7] and the Vollenweider Approach[8] to establish an endpoint for phosphorus such that the

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[5] MDE estimated a nitrogen to phosphorus ratio of 14:1.

[6] Maryland has provided an interpretation regarding how the dissolved oxygen water quality standard applies to lakes in a June 17, 1999 letter to Tom Henry, EPA from Robert Summers, MDE. The dissolved oxygen water quality criterion only applies to the well-mixed surface layers of the lake.

[7] The Code of Maryland Regulations at Section 26.08.02.03B(5)(a).

[8] The Vollenweider Approach (1968, 1975) is a simple empirical model which uses a linear relationship between phosphorus loading and the ratio of the lake's mean depth to hydraulic residence time to establish the lake's eutrophication status.

designated uses of Tony Tank Lake are restored. Utilizing land use data provided by the Maryland Office of Planning's 1990 Landuse database and landuse specific phosphorus loading coefficients from the Chesapeake Bay Program model Phase IV, the current areal annual phosphorus load to Tony Tank Lake was calculated as 4.9 g/m^2 yr (1812 lbs/yr total). This current phosphorus load and the ratio of the mean depth to hydraulic residence time of Tony Tank Lake were used to classify the lake as eutrophic according to the Vollenweider Plots. The endpoint of the phosphorus TMDL was identified as the areal phosphorus loading which is consistent with achieving a mesotrophic status according to the loading plots. MDE believes that achieving a mesotrophic status will support the designated uses and general water quality criteria of Tony Tank Lake. The areal phosphorus loading must be reduced from the current loading of 4.9 g/m^2 yr to the TMDL value of 2.0 g/m^2 yr which represents the upper level of the mesotrophic zone based on the lake's current characteristics. This areal load was then converted to 737.5 lbs/yr for consistency with the TMDL process. Implementation of the TMDL will result in 63.5% reduction to current phosphorus loading into Tony Tank Lake.

The Tony Tank Lake watershed is unique in that it is comprised of three sub-watersheds. The Coulbourne and Morris Mill watersheds flow into their respective impoundments which both discharge to Tony Tank Pond. In addition to the discharges of these ponds, Tony Tank Pond also receives nutrient and sediment inputs from its surrounding watershed. The discharge from Tony Tank Pond then flows into Tony Tank Lake, which also receives input from its own watershed. Determining the phosphorus load into Tony Tank Lake is a complicated process which relies on an understanding of phosphorus fate and transport within this system. In order to effectively account for this, MDE utilizes the Brune Method[9] to determine the phosphorus load from each subwatershed impoundment that ends up in Tony Tank Lake. In a 1986 study, the Illinois EPA estimated that 70%-90% of phosphorus is bound to sediments. Based on this study, MDE estimated that 85% of the phosphorus in this watershed was bound to sediments. The Brune Method was then used to determine the amount of phosphorus loading from the subwatershed which would settle in that particular subwatershed impoundment. For example, MDE estimates that 968 pounds per year of phosphorus is loaded into Coulbourne Pond from the surrounding watershed. The Brune Method estimates that the trap efficiency of Coulbourne Pond is 23%. Since 85% of the phosphorus load is bound to sediments (968 lbs/yr x 0.85=822.8lbs/yr), and only particulate phosphorus is susceptible to settling, then 189.2 pounds per year of phosphorus will settle out in Coulbourne Pond (822.8 lbs/yr x 0.23=189.2 lbs/yr). Therefore, 778.8 pounds per year of phosphorus is discharged from Coulbourne Pond (968 lbs/yr - 189.2=778.8 lbs/yr), of which 145.2 lbs/yr is in the dissolved form (968 lbs/yr - 822.8 lbs/yr = 145.2 lbs/yr). Maryland conservatively assumes that dissolved phosphorus will flow unfettered through the system and ultimately to Tony Tank Lake. This process is repeated for Morris Mill pond to determine the amount of phosphorus which is loaded into Tony Tank Pond. This same process is also applied to Tony Tank Pond to determine the ultimate loading of 1812.1 pounds per year of dissolved and particulate phosphorus to Tony Tank Lake from the entire watershed. (See Figure 1). Please refer to tables 1, 2, and 3 of the TMDL document to see the initial

[9] This method is used to estimate the sediment trapping efficiency of impoundments.

sediment and phosphorus loadings originating from major land uses within each sub-watershed.

Although nutrients, both nitrogen and phosphorus, are listed as the cause of impairment in Tony Tank Lake, a TMDL of phosphorus was developed to control algae blooms, excessive plant growth, foul odors, and possible dissolved oxygen criteria violations because phosphorus is often the major nutrient in shortest supply and is frequently a prime determinant of the total biomass[10]. Phosphorus is also the most effectively controlled using existing engineering technology and land use management[11]. MDE estimates based on phosphorus loading indicate that phosphorus is the limiting nutrient in Tony Tank Lake.

Lake eutrophication is both a natural and culturally-based phenomenon. Natural eutrophication is a slow, largely irreversible process associated with the gradual accumulation of organic matter and sediments in lake basins. Cultural eutrophication is an often rapid, possibly reversible process of nutrient enrichment and high biomass production stimulated by cultural activities causing nutrient transport to lakes[12]. Lakes are considered to undergo a process of "aging" which can be characterized by the trophic status as oligotrophic, mesotrophic, or eutrophic. Oligotrophic lakes are normally associated with deep lakes which have relatively high levels of dissolved oxygen throughout the year, bottom sediments typically contain small amounts of organic matter, chemical water quality is good, and aquatic populations are both productive and diverse. Mesotrophic lakes are characterized by intermediate levels of biological productivity and diversity, slightly reduced dissolved oxygen levels, and generally have adequate water quality to support designated uses. However, there is a recognition that these lakes are naturally or culturally moving towards a eutrophic state. Lakes which are classified as eutrophic typically exhibit high levels of organic matter, both suspended in the water column and in the upper portions of sediments. Biological productivity is high , often indicated by seasonal algae blooms and excessive plant growth. Dissolved oxygen concentrations are low, and may reach extreme levels during critical periods. In addition, water quality is often poor resulting in violations of the designated uses[13]. The following table illustrates typical water quality variables of these three trophic designations.

Table 2, Trophic-state classifications and typical variables

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[10] Modeling Phosphorus Loading and Lake Response under Uncertainty: A manual and compilation of Export Coefficients, 1980, EPA 440/5-80-011.

[11] Id.

[12] Id.

[13] Technical Guidance Manual for Performing Water Load Allocations, Book IV, Lakes and Impoundments, Chapter 2, Nutrient/Eutrophication Impacts, EPA 440/14-84-019.

	Trophic-state		
Variable	Oligotrophic	Mesotrophic	Eutrophic
Total Phosphorus (ug/l P L^{-1})	<10	10-20	>20
Chlorophyll-a (ug/l Chl-a L^{-1})	<4	4-10	>10
Secchi-disk depth (m)	>4	2-4	<2
Hypolimnion oxygen (% saturation)	>80	10-80	<10

In a conceptual sense, the Vollenweider Approach attempts to provide a standard means of expressing nutrient input so that the supply to different lakes could be compared on a common basis in the hopes that this would lead to relationships between this standard measure of nutrient supply and the degree of eutrophication of the lakes[14]. In that regard, Vollenweider first attempted to plot the areal total phosphorus loading against mean depth on a log-log scale, in essence the volumetric loading. This simple empirical model worked well for lakes with phosphorus loading data available at that time. However, it was soon recognized that this model was an approximation at best and required further development. Vollenweider refined his model to incorporate the flushing rate of lakes by plotting the phosphorus loading against the mean depth divided the mean residence time of water, which is equivalent to the height of water load that is supplied to the lake in one year. This refinement added significant accuracy for the prediction of trophic states of lakes. Dillion[15] comments that a plot of phosphorus loading against mean depth divided by mean residence time would have the same corrective result as a plot which included both the flushing rate and the phosphorus retention rate. The difference being that the latter plot would account for one more source of variation.

MDE has chosen to control phosphorus loading to achieve a mesotrophic status and support the designated uses in Tony Tank Lake. These levels result in a 63.5% reduction to current phosphorus loading rates and will restore the designated uses and general water quality of the lake. EPA provides the following calculations to confirm the in-lake phosphorus and chlorophyll-a concentrations which would result from the phosphorus TMDL.

[14] The Application of the Phosphorus Loading Concept to Eutrophication Research, Vollenweider, R.A. and P.J Dillion, Canada Centre for Inland Waters, NRCC 13690, Environmental Secretariat, 1975.

[15] Id.

1) Relationship of areal phosphorus loading to in-lake phosphorus concentration

$p=L/q_s+v_s$ (pg. 209, eq. 8.18)[16]

p=in-lake P conc (mg/l)
L=areal P loading rate ($g/m^2/yr$)
q_s= areal water loading (m/yr)
v_s=apparent settling velocity(m/yr)

$q_s= z/t_w$ (pg. 209, eq. 8.18)[17]

t_w=residence time (yrs)
z=depth (m)

$v_s= 16\ m/yr$

$q_s= 0.71m / 0.008\ yrs = 88.75\ m/yr$

$p=2.0g/m^2/yr / 88.75\ m/yr + 16\ m/yr = 0.019\ mg/l$ or $19\ ug/l$

According to these calculations, the TMDL for phosphorus will result in an in-lake phosphorus concentration of 19 ug/l, which is within the mesotrophic state range. EPA chose a value of 16 m/yr for the apparent settling velocity (v_s) because this value seemed appropriate based on separate studies of Canadian Shield Lakes and northeast and northcentral U.S. lakes[18].

2) Relationship of in-lake phosphorus concentration to chlorophyll-a concentration

$\log_{10}(chl\text{-}a) = 0.807(\log_{10}(p)) - 0.194$ (pg. 412, eq. 7.18a)[19]

(p)=in-lake phosphorus concentration

$chl\text{-}a = 6.89\ ug/l$

An in-lake phosphorus concentration of 19 ug/l from the phosphorus TMDL results in an estimated chlorophyll-a concentration of 6.89 ug/l. Again, this chlorophyll-a value is within the mesotrophic state range.

Calculations of the secchi depth and percent saturation of oxygen in the hypolimnion are not possible due to the shallow depth of the lake and lack of data. These variables are not

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16 Engineering Approaches for Lake Management, Volume 1: Data Analysis and Empirical Modeling, 1983, Reckhow, Kenneth H., Steven C. Chapra.

17 Id.

18 Id., pages 224 and 225.

19 Principles of Surface Water Quality Modeling and Control, 1987, Thomann, R.V., and Mueller, J.A.

critical, as both the in-lake phosphorus concentration and chlorophyll-a concentration are well within the range of oligotrophic conditions.

Maryland also identified violations of the numeric dissolved oxygen water quality criterion in the waters of Tony Tank Lake which contributed to the non-attainment of designated uses and possible fish kills. The State has developed a link in order to demonstrate that achieving this level of phosphorus loading will result in attainment of the dissolved oxygen water quality standard throughout the well-mixed surface waters. This link is based on determining the lakewide dissolved oxygen concentration resulting from the phosphorus TMDL. This calculation is based on factors[20] specific to Tony Tank Lake which were observed during the 1993 Lake Water Quality Assessment Project. In addition, the diurnal dissolved oxygen fluctuation based on the average photosynthetic dissolved oxygen production and the light attenuation factor is calculated to ensure that the dissolved oxygen water quality criterion of 5 mg/l is met at all times in the lake.

1) <u>Calculation of lakewide dissolved oxygen concentration</u>

$$c = (Q/(Q + k_l A))c_{in} + (k_l A/(Q + k_l A))c_s - (V*K_d/(Q + k_l A))L - (S_b A/(Q + k_l A))$$

Q=lake discharge=39,916 m^3/d $\qquad$ $(Q + k_l A)$ = 185,380 m^3/day
k_l=D.O. transfer rate=0.87 m/d
k_d=effective deoxygenation rate 0.3/d
L=ambient lakewide CBOD=2mg/l
A=area=167,200 m^2
V=volume=118,712 m^3
S_b=SOD rate=0.92 g/m^2/d
c_{in}=flow-weighted average ambient levels of DO of 3 tributaries flowing into lake= 5 mg/l[21]
c_s=D.O saturation at 30°C and zero(0) chlorinity=7.559 mg/l (Thomann and Mueller, 1987)

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[20] These factors include lake discharge, volume and area, lake Carbonaceous Biochemical Oxygen Demand and Sediment Oxygen Demand as well as contributing tributary effects.

[21] No current data regarding incoming dissolved oxygen concentration from Tony Tank Pond into Tony Tank Lake is available. Data from the 1993 LWQAP indicates a surface water dissolved oxygen concentration of at least 8 mg/l. Therefore, Maryland conservatively assumes an incoming dissolved oxygen concentration of 5mg/l in these calculations. Further analysis indicates that any incoming dissolved oxygen concentration above 2.5 mg/l from Tony Tank Pond will attain the water quality standard of 5 mg/l is met at all times. Based on the proposed nutrient and sediment reductions of the TMDL, it is unlikely that the incoming dissolved oxygen concentration will fall below 2.5 mg/l.

A) *Temperature adjustment for deoxygenation rate at 30°C*

$(k_d)_T = (k_d)_{20} * 1.047^{T-20}$
$(k_d)_{30} = (0.2/d) * 1.047^{30 - 20}$
$(k_d)_{30} = 0.3/d$

B) *Temperature adjustment for sediment oxygen demand rate at 30°C*

$(S_B)_T = (S_B)_{20}(\theta)^{T-20}$
$(S_B)_T = 0.5 \text{ g } O_2/m^2/\text{day} * 1.065^{10}$
$(S_B)_T = 0.92 \text{ g } O^2/m^2/\text{day}$

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c= [(39,916 m^3/d / 185,380 m^3/d)5 mg/l]+ [(145,464 m^3/d / 185,380 m^3/d)7.559 mg/l]- [(35,614 m^3/d / 185,380 m^3/d)2mg/l] - (153,824 g/d / 185,380 m^3/d)

c= 1.08 mg O_2 / l-day + 5.93 mg O_2 / l-day - 0.38 mg O_2 / l-day - 0.83 mg O_2 / l-day

c= 5.8 mg O_2 / l-day

The TMDL for phosphorus will result in a lakewide dissolved oxygen concentration of 5.8 mg/l, which exceeds the water criterion of 5 mg/l.

In addition to determining the lakewide dissolved oxygen concentration, Maryland also provided calculations to ensure that the diurnal dissolved oxygen concentration does not fall below the water quality criterion of 5 mg/l at any time. MDE has indicated that decreased levels of dissolved oxygen concentrations below the water quality criterion, including diurnal fluctuations, could contribute to fish kill events and disruptions in the lake's ecosystem balance.

1) Determine the average gross photosynthetic production of dissolved oxygen (p_a)

$p_a = p_s(G(I_a))$ — p_s =light saturated D.O. production rate; $G(I_a)$ = light attenuation factor

$p_s = 0.25P$ — P=chl-a in ug/l

$$G(I_a) = \frac{2.718f}{K_e H}\left[e^{-(\propto 1)} - e^{-(\propto 0)} \right]$$

$$-(\propto 1) = (I_a / I_s\, e^{(-K(e)Z)})$$

$$-(\propto 0) = (I_a / I_s)$$

f=photoperiod (0.6 day)
K_e = light extinction(1.04 m)
H=max depth (1.83 m)
I_a=solar radiation (500 langley/day)
I_s=saturation light intensity(350 langley/day)
Z=photosynthetic activity depth (0.71m)
K(e)=K_e

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p_s= 0.25 * 10 ug/l chl-a[22]
p_s= 2.5 mg O_2/l-day

$-(\propto 1) = (500 \text{ langley/day} / 350 \text{ langley/day})*(e^{(-1.04\text{ m})(0.71\text{ m})})$
$-(\propto 1) = (1.42)*(0.47)$
$-(\propto 1) = 0.68$

$-(\propto 0) = (500 \text{ langley/day} / 350 \text{ langley/day})$
$-(\propto 0) = 1.42$

$$G(I_a) = \frac{2.718\ (0.6\text{ day})}{1.04\text{m}\ (1.83\text{m})}\left[e^{-0.68} - e^{-1.42}\right]$$

$$G(I_a) = \frac{1.63}{1.90}\left[0.51 - 0.24\right]$$

$G(I_a) = (0.86)*(0.27)$
$G(I_a) = 0.23$

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p_a = (2.5 mg O_2/l-day)*(0.23)
p_a = 0.57 mg O_2/l-day

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2) Estimate the diurnal dissolved oxygen range

[22] MDE conservatively assumes a chlorophyll-a concentration of 10 ug/l, which is greater than the expected concentration of 6.89 ug/l resulting from the TMDL of phosphorus.

$$\triangle c/p_a = \frac{(1 - e^{-k(a)*f*T})(1 - e^{-k(a)*T(1-f)})}{f*k_a(1 - e^{-k(a)*T})}$$

$k(a)=k_a$=reaeration coefficient=0.5 day
T= t =period =1 day

$$\triangle c/p_a = \frac{(1 - e^{-(0.5\ day)(0.6\ day)(1day)})(1 - e^{-(0.5\ day)(1\ day)(1-0.6\ day)})}{0.6\ day(0.5\ day)(1 - e^{-(0.5\ day)(1\ day)})}$$

$\triangle c/ p_a = 0.39$
$\triangle c = 0.39*(p_a)$
$\triangle c = (0.39)*(0.57)$
$\triangle c = 0.23$ mg O_2/l-day

Diurnal variations in dissolved oxygen concentrations are mainly due to photosynthesis and respiration of aquatic plants such as phytoplankton, aquatic weeds, or algae. Photosynthesis is the process by which plants utilize solar energy to convert simple inorganic nutrients into more complex organic molecules[23]. Due to the need for solar energy, photosynthesis only occurs during daylight hours and is represented by the following simplified equation:

$6CO_2$ +	$6H_2O$	<--------->	$C_6H_{12}O_6$ +	$6O_2$
(Carbon Dioxide)	(Water)		(Sugar)	(Oxygen)

In this reaction, photosynthesis is the conversion of carbon dioxide and water into sugar and oxygen such that there is a net gain of dissolved oxygen in the waterbody. Conversely, respiration and decomposition operate the process in reverse and convert sugar and oxygen into carbon dioxide and water resulting in a net loss of dissolved oxygen to the waterbody. Respiration and decomposition occur at all times and are not dependent on solar energy. Waterbodies exhibiting the typical diurnal variation of dissolved oxygen experience the daily maximum in mid-afternoon during which photosynthesis is the dominant mechanism and the daily minimum in the predawn hours during which respiration and decomposition have the greatest effect on dissolved oxygen and photosynthesis is not occurring.

The calculations above show that the expected diurnal dissolved oxygen range is 0.23 mg/l. Taking in to consideration the expected lakewide dissolved oxygen concentration of 5.8 mg/l, the TMDL of phosphorus will result in an expected daily minimum of 5.57 mg/l and a daily maximum of 6.03 mg/l. Based on the calculations provided by MDE, the TMDL of phosphorus will assure that the dissolved oxygen water quality criterion of 5 mg/l is maintained.

[23] Surface Water-Quality Modeling / Steven C. Chapra, 1997, page 347

The sediment TMDL endpoint was determined based on identifying an acceptable reservoir volume preservation rate such that the designated uses of Tony Tank Lake are achieved and maintained. MDE determined that preserving 64% to 85% of the reservoir volume over a period of 40 years supported this water quality objective. The preservation rate varies due to the use of a range of environmentally conservative volume-weight ratios to estimate the amount of volume loss associated with the sediment loading. The current sediment loading rate of 275.7 tons of sediment per year will be reduced 31.8% to 188.5 tons per year of sediment. The current estimated sediment loading was determined using land use data and the Chesapeake Bay Program model Phase IV sediment loading coefficients.

The rationale for a 31.8% decrease in sediment loading is based on sediment/phosphorus control relationships from the Chesapeake Bay Program watershed modeling assumptions. When considering agricultural Best Management Practices (BMPs), a 1 to 1 control ratio can be expected. However, due to variation in the type of BMPs to be used in the Tony Tank Lake watershed, Maryland uses a 0.5 to 1 ratio, which means that for each unit of phosphorus controlled, only ½ of the sediment unit will be controlled. Thus, BMPs which result in an 63.5% reduction in phosphorus loading will result in a 31.8% reduction in sediment loading.

MDE used the sedimentation rates based on loading coefficients to determine a range of probable volume losses due to sedimentation. Using empirical information on volume-weight measurements from impoundments (USDA/SCS 1978, see MD TMDL document), it was determined that Tony Tank Lake will experience anywhere from 0.35 acre-feet to 0.86 acre-feet of volume loss per year. These estimates are based on a lower range of volume-weight measurements (10 to 25 lbs/ft3) for Tony Tank Lake sediments due to settling of larger particulates in the upstream impoundments and the lack of depth and turbulence in a smaller impoundment such as Tony Tank Lake.

2) The TMDLs include a total allowable load as well as individual waste load allocations and load allocations.

Table 3, summary of total allowable loads of phosphorus and sediments

	Phosphorus		Sediment	
	lbs/year	lbs/day	tons/year	tons/day
TMDL	735.7	2.01	188.3	0.51

A) Waste load Allocations

Maryland states that there are three National Pollutant Discharge Elimination System (NPDES) industrial dischargers in the watershed. However, one discharge has been inactive since 1997 and the other two discharges are not expected to contribute nutrients or sediment to the lake after a review of the permits. Therefore, the WLA is set at zero.

B) Load Allocations

While Maryland did have adequate land use and loading coefficient data, they did not distribute the total load allocation to the specific land uses within the Tony Tank Lake watershed. The total load allocation for phosphorus and sediments can be found in table 1 of this document.

According to federal regulations at 40 CFR 130.2(g), load allocations are best estimates of the loading, which may range form reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished. MDE uses the Chesapeake Bay Program model Phase IV loading coefficients which are land use specific and include natural background contributions, atmospheric deposition, and baseflow contributions.

As noted above, Maryland did not provide a breakdown of the load allocation in the TMDL report, however, such a breakdown was provided in the Technical Memorandum. The TMDL is based on the phosphorus and sediment loading from the three generalized land uses within the watershed. According to the Technical Memorandum, the specific load allocations fro the TMDL are as follows:

Table 4, Summary of Technical Memorandum Load Allocations

Land Use Category	Percent Land Use	Watershed area (acres)	Percent of Nonpoint Source Load		Nonpoint source load	
			Phosphorus	Sediment	Phosphorus (lbs/yr)	Sediment (Tons/yr)
Agriculture	20%	1768.6	55%	66%	364.1	124.3
Forest and other herbaceous	54%	4775.2	2%	6%	13.2	11.3
Urban	26%	2299.2	43%	28%	284.8	52.7
Total	100%	8843	100%	100%	662.1	188.3

<u>Allocation Scenario</u>

EPA realizes that the above breakout of the load allocations for phosphorus and sediments to specific land uses is one allocation scenario. As implementation of the established TMDLs proceed or more detailed information becomes available, Maryland may find other combinations of land use allocations that are more feasible and/or cost effective.

3) The TMDL considers the impacts of background pollutant contributions.

As previously stated, MDE relies on the EPA Chesapeake Bay Program model Phase IV loading coefficients to determine the amount of phosphorus and sediment originating from land uses in Tony Tank Lake watershed. Natural background contributions as well as contributions from base flow are included within those loading coefficients.

4) The TMDLs consider critical environmental conditions.

EPA regulations at 40 CFR 130.7(c)(1) require TMDLs to take into account critical conditions for streamflow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of Tony Tank Lake is protected during times when it is most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken to meet water quality standards.[24] In specifying critical conditions in the waterbody, an attempt is made to use a reasonable "worst-case" scenario condition. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence. For example, stream analysis often uses a low-flow (7Q10) design condition as critical because the ability of the waterbody to assimilate pollutants without exhibiting adverse impacts is at a minimum.

In terms of sediment and phosphorus, one critical condition occurs during precipitation events which cause and increase in loading of sediment and phosphorus to the lake. A separate critical period specific to phosphorus occurs during times when the lake experiences warmer temperatures which encourage algae growth. Negative water quality impacts from sedimentation occur on a continuing basis and can not be defined by a single, critical period.

Critical environmental conditions such as those described above are implicitly considered by the Vollenweider Approach. Sediment and phosphorus loads are given on a yearly basis and would effectively include precipitation events. The TMDLs also consider the increased water temperatures which may be experienced by this lake during the summer months through the use of temperature values in the dissolved oxygen calculations well in excess of those experienced by the lake.

5) The TMDLs consider seasonal environmental variations.

Seasonal variations involve changes in streamflow as a result of hydrologic and climatological patterns. In the continental United States, seasonally high flow normally occurs during the colder period of winter and in early spring from snowmelt and spring rain, while seasonally low flow typically occurs during the warmer summer and early fall drought periods[25]. Consistent with our discussion regarding critical conditions, determining load allocations on a

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[24] EPA Memorandum regarding EPA Actions to Support High Quality TMDLs from Robert H. Wayland III, Director, Office of Wetlands, Oceans, and Watersheds to the Regional Water Management Division Directors, August 9, 1999.

[25] Technical Guidance Manual for Developing Total Maximum Daily Loads, Book 2, Part 1, Section 2.3.3, (EPA 823-B-97-002, 1997).

yearly basis will effectively consider seasonal environmental variations. The assumptions regarding increased temperature will also effectively capture seasonal variations.

6) The TMDLs include a margin of safety.

This requirement is intended to add a level of safety to the modeling process to account for any uncertainty. Margins of safety may be implicit, built into the modeling process, or explicit, taken as a percentage of the wasteload allocation, load allocation, or TMDL.

MDE utilizes an explicit process for determining the margin of safety for the phosphorus TMDL by allocating 10% of the total allowable load to the margin of safety. In addition, certain implicit margins of safety, such as assuming a higher temperature than expected for use in the minimum dissolved oxygen calculations, are included in the phosphorus TMDL margin of safety.

The following discussion is needed in order to fully explain the margins of safety used in the sediment TMDL. In determining the sediment TMDL, MDE considered 2 scenarios. The first involved utilizing the overall phosphorus TMDL value of 735.7 lbs/yr as the basis of the sediment TMDL. In order to achieve a phosphorus loading of 735.7 pounds per year, the current phosphorus loading rate of 1812 pounds per year would need to be reduced 59.4%

(1812 lbs/yr - 735.7 lbs/yr) / 1812 lbs/yr = 0.294 = 59.4%

Considering the BMPs most likely to be used in the Tony Tank Lake watershed, a conservative sediment to phosphorus control ratio of 0.5 to 1 was determined based on Chesapeake Bay Program information. Applying this ratio to the 59.4% reduction to achieve a loading rate of 735.7 pounds per year, sediment loading would be reduced 29.7%. When applied to the current sediment loading rate of 275.7 tons per year, the sediment TMDL would be 193.8 tons per year.

275.7 tons/yr x 0.297 = 81.9 tons/yr
275.7 tons/yr - 81.9 tons/yr = 193.8 tons/yr

Scenario 2 involves utilizing the phosphorus load allocation of 662.1 pounds per year as the basis of the sediment TMDL. This allows for consideration of the explicit 10% phosphorus MOS and provides for an explicit/implicit relationship between the phosphorus and sediment TMDLs. In order to achieve a phosphorus loading rate of 662.1 pounds per year, the current loading rate of 1812 pounds per year would need to be reduced 63.5%.

(1812 lbs/yr - 662.1lbs/yr) / 1812 lbs/yr = 0.635 = 63.5%

Considering the BMPs most likely to be used in the Tony Tank Lake watershed, a sediment to phosphorus control ratio of 0.5 to 1 was determined based on Chesapeake Bay Program information. Applying this ratio to the 63.5% reduction needed to achieve a phosphorus loading rate of 662.1 pounds per year, the sediment loading rate to Tony Tank Lake would be reduced 31.8%. When applied to the current sediment loading rate of 275.7 tons per year, the sediment TMDL would be 188.3 tons per year.

275.7 tons/yr x 0.3175 = 87.4 tons/yr
275.7 tons/yr - 87.4 tons/yr = 188.3 tons/yr

Maryland determined that scenario 2 would ensure that the water quality objective/endpoint of preserving 64% to 85% of the lake volume over the 40 years would be met, which would also provide for the attainment of the designated uses of Tony Tank Lake.

As previously mentioned, scenario 2 also provides for an explicit/implicit relationship between the phosphorus and sediment TMDL. Scenario 1 resulted in a sediment TMDL of 193.8 tons per year while scenario 2 results in a sediment TMDL of 188.2 tons per year. The difference between these scenarios is 5.6 tons per year. Therefore, the explicit 10 % phosphorus MOS results in an approximate 2.9% sediment MOS. Due to the manner in which the sediment TMDL was determined and the complicated relationship of explicit and implicit margins of safety within the context of these TMDLs, the 2.9% (5.6 tons/yr) MOS can not be expressed or characterized as explicit. However, scenario 2 does impart some implicit conservatism to the sediment TMDL.

193.8 tons/yr - 188.2 tons/yr = 5.6 tons/yr
5.6 tons/yr / 188.2 tons/yr = 0.029 = 2.9%

EPA believes that this combined explicit/implicit approach to account for margins of safety is acceptable in this situation.

7) There is a reasonable assurance that the TMDL can be met.

EPA requires that there be a reasonable assurance that the TMDL can be implemented. MDE states that reasonable assurance can be provided through implementation of the phosphorus reduction plan by three specific programs: 1) the Water Quality Improvement Act of 1998 (WQIA); 2) the Clean Water Action Plan of 1998 (CWAP); 3) and the State's Chesapeake Bay Agreement's Tributary Strategies for Nutrient Reduction. EPA believes that these programs will be able to provide the necessary tools for implementing the TMDLs and achieving water quality standards.

8) The TMDL has been subject to public participation.

The TMDLs of phosphorus and sediments to Tony Tank Lake were open for public comment from November 20, 1998 through December 22, 1998. Only one set of written comments were received by MDE, which was provided along with their response document with the TMDL report.