APPENDIX E

BMP NUTRIENT REDUCTION CALCULATIONS
May 2008

Calculating the Required Total Maximum Daily Load Reductions Based on Land-use

The Total Maximum Daily Load (TMDL) for receiving waters in the Inland Bays calls for a 40% reduction in total nitrogen (TN) and total phosphorus (TP) in the Low Reduction Area, and an 85% reduction in TN and 65% reduction in TP in the High Reduction Area (DNREC, 1998) (Figure 1). The baseline period for this TMDL was established from data collected from 1988 thru 1990; therefore land use data for the Inland Bays from 1992 was used to determine the acreages of each of the following land uses in the High and Low Reduction Areas: Urban, Agricultural, Forest, Wetland, and Other, which includes land uses like rangeland and barren land. Using GIS software, the 1992 land use data was clipped to the high and low reduction areas of the Inland Bays Watershed. The results are tabulated below (Table 1).

Figure 1. High and Low Reduction Areas in the Inland Bays Watershed.

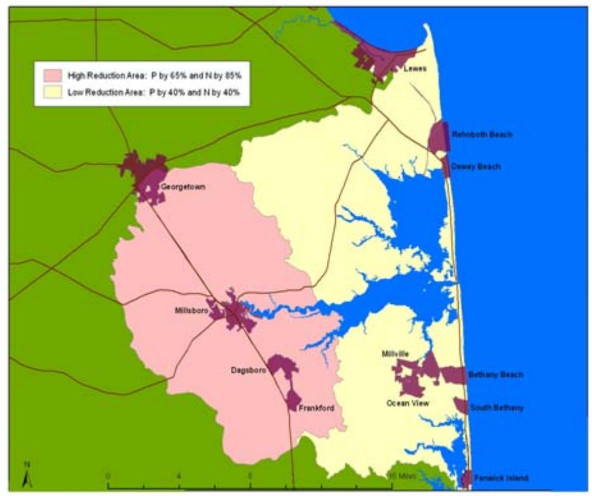

Table 1. 1992 Inland Bays Watershed Land-use Acreages						
Land-use	**Urban**	**Agricultural**	**Forest**	**Wetland**	**Other**	**Total acreage**
Low Reduction Area	17,433.50	32,610.34	20,554.90	16,090.68	4,039.94	91,908.96
High Reduction Area	7,634.55	36,675.73	22,047.62	14,818.75	1,024.21	82,588.06

In order to calculate nutrient loads from non-point pollution sources, the land use acreages from Table 1 were combined with the land use loading rates in Table 2, which were determined based on results of research conducted by experts in the Inland Bays Watershed to produce daily nutrient loads according to land use, as displayed in Table 3.

Table 2. Land-use Loading Rates			
	TN (lbs/acre/yr)	**TP (lbs/acre/yr)**	**Source**
Developed	20.0	0.7	Ward (2001)
Agriculture	21.0	0.8	Average of Ritter (1986) and Ward (2001)
Grasslands	12.5	0.6	Average of Ritter's (1986) agriculture and forest
Forests	5.0	0.4	Ritter (1986)
Wetlands	0.0	0.0	Ritter (1986)
Other	12.5	0.6	Average of Ritter's (1986) agriculture and forest

Table 3. 1992 Inland Bays Watershed Land-use Based Loads During the Baseline Period as Specified by 1998 TMDL						
Land-use Type	**Urban**	**Agricultural**	**Forest**	**Wetland**	**Other**	**Total**
	Loads for Low Reduction Area					
Nutrient	**lbs/day**					
TN	955.26	1,876.21	281.57	0.00	138.35	**3,291.80**
TP	33.43	71.47	22.53	0.00	6.67	**136.05**
	Loads for High Reduction Area					
Nutrient	**lbs/day**					
TN	418.33	2,110.00	302.02	0.00	35.08	**2,878.80**
TP	14.64	80.39	24.16	0.00	1.69	**121.52**

I. Baseline load calculation for land-use type by reduction area:

Using the land use loading rates listed in Table 2, the nutrient loads coming from non-point sources during the baseline period (1988-1990) as listed in Table 3 are determined using the equation below. It should be noted that the grassland loading rate was used to determine the loads from the "Other" land use category.

Nutrient load (lbs/yr) (Table 3)	=	Acreage of specific land-use (Table 1)	x	Loading rate for specific land-use (lbs/acre/yr) (Table 2)

EX: TN load for urban land use in low reduction area:

TN load (lbs/yr)	=	17,434 acres	x	20 lbs TN/acre/yr	=	**348,680 lbs TN/yr or 955.3 lbs TN/day**

II. Required TMDL reduction on a land-use basis:

The annual and daily nutrient load reductions needed from non-point sources to achieve the reductions outlined in the Inland Bays TMDL are calculated using the following equation. For the overall Inland Bays Watershed, the TN load needs to be reduced by 3,763.70 lbs/day and the TP load by 133.41 lbs/day. In order to achieve these reductions, the best management practices (BMPs) discussed in the Pollution Control Strategy must be implemented.

Required TMDL reduction (lb/day)	=	Baseline load (lb/day)	x	Percent reduction

EX: TN TMDL required load reduction in high reduction area:

Required TMDL reduction (high reduction area) (lb/day)	=	2,878.80 lbs TN/day	x	85%	=	**2,446.98 lbs TN/day Area**

Onsite Wastewater Disposal System (OWTDS) BMP Calculations

In order to determine the nutrient loading by OWTDS to groundwater, local watershed data and knowledge has been utilized.

Twelve OWTDS existing near Red Mill Pond in Lewes, Delaware were monitored in 1993 (DNREC, 1994). The average total phosphorus concentration of the effluent from these systems was 15.7 mg/L, while the total kjeldahl nitrogen (TKN) concentration was 58.5 mg/L and the nitrate/nitrite concentration was 0.8 mg/L. The total nitrogen concentration of the average effluent from this study was summed to equal 59.3 mg/L. Recent conversations with professionals in this industry have suggested that 50.0 mg/L is a more appropriate value of TN concentrations in on-site effluent and this value has been used in subsequent calculations.

Large systems serving commercial and communities exist within the watershed. The flow rates for large systems have been grouped into two categories for use with performance standards. The first category applies to systems with flows greater than 20,000 gallons per day (gpd). Within the Inland Bays Watershed, systems of this size have an average flow rate of 23,908 gpd. The second category is for systems with flows less than 20,000 gpd but greater than 2,500 gpd. Systems in this category have an average flow of 6,671 gpd in the Inland Bays Watershed. Small systems, which are typical individual household systems, have flows less than 2,500 gpd. The average design flow for individual residential OWTDS in the Inland Bays Watershed is 221 gpd. Since the population of the Inland Bays Watershed varies seasonally, with an influx of tourists during summer months, a seasonal occupancy rate was estimated (65%) and the individual OWTDS flow rates, and loadings, were reduced by 35%.

The nutrient load to the watershed from drain fields can be established by determining the product of the above concentrations and respective flow rates.

Robertson and Hartman (1999) found that 85% of the total phosphorous in the effluent will be retained in the vadose zone or the unsaturated soil above the water table, most of which is within 12 inches of the drain field (Gold and Sims, 2000). Initial calculations presented by the Department, also based on the Red Mill Pond study, assumed that 87% of TP and 52% of TN is assimilated in the soils once the effluent leaves the septic tank.

The final loading rates from OWTDS to groundwater can be determined using the following equations:

Large systems (>20,000 gpd):
[Conc. (mg/l) x (lb/453,592 mg)] x [(23,908 gal/system/day) x (3.7854 l/gal)] x (1-soil assimilative capacity)

Large systems (2,500 – 20,000 gpd):
[Conc. (mg/l) x (lb/453,592 mg)] x [(6,671 gal/system/day) x (3.7854 l/gal)] x (1-soil assimilative capacity)

Small systems (<2,500 gpd):
[Conc. (mg/l) x (lb/453,592 mg)] x [(221 gal/system/day) x (1-0.35) x (3.7854 l/gal)] x (1-soil assimilative capacity)

Thus, the OWTDS nutrient loading rates to groundwater in the Inland Bays Watershed are:

- 4.78 lbs TN/system/day and 0.41 lbs TP/system/day for large systems greater than 20,000 gpd,
- 1.33 lbs TN/system/day and 0.11 lbs TP/system/day for large systems greater than 2,500 but less than 20,000 gpd, and
- 0.029 lbs TN/system/day and 0.002 lbs TP/system/day for individual small systems less than 2,500 gpd

I. <u>Connecting OWTDS to Sewer Districts</u>

Between 1990 and 2005, 13,494 OWTDS (septic) systems have been removed from the Inland Bays watershed by connecting homes and businesses to sewer districts (Sussex County Engineering Department, written communication, 2006). Many of these systems have been connected to sewer districts that dispose of their waste at the Wolf Neck spray irrigation facility. Other systems have been connected to sewer districts that ultimately discharge their waste through the South Coastal facility, which discharges to the Atlantic Ocean. By 2010, an additional 2,359 systems will be connected to South Coastal (Sussex County Engineering Department, written communication, 2006). The number of equivalent dwelling units (EDUs) removed by hookup to a sewer district is summarized in Table 4 below.

Facilities that discharge to the ocean are assumed to remove 100% of the nutrients from the ecosystem. Reductions for systems that are connected to plants that use spray irrigation receive a 90% efficiency since nutrients remain in the ecosystem (DNREC Groundwater Discharges Section, personal communication, 2003). The nutrient load reduction are calculated using the following equation.

Nutrient load reduction (lbs/day) = OWTDS loading rate (lbs/system/day) x # of eliminated OWTDS x Reduction efficiency

EX: TN reduction due to OWTDS connection to Wolf Neck spray irrigation facility:

TN load reduction (lbs/day) = 0.029 lbs TN/system/day x 10,869 eliminated OWTDS x 90% = **281 lbs TN/day**

Table 4. OWTDS Connected to Sewer Districts		
District	**Hookup period**	**EDUs Eliminated**
Ultimate connection to spray irrigation		
Long Neck Sanitary Sewer	1993	4,365
West Rehoboth Expansion (I & II)	1996	5,104
West Rehoboth Expansion (III)	2001	1,400
Sub-total		*10,869*
Ultimate connection to ocean discharge		
Dagsboro-Frankford Sanitary Sewer	1994	622
Bethany Beach Sanitary Sewer (Ocean Way Estates I & II)	1997	59
Dagsboro-Frankford Sanitary Sewer (Prince Georges Acres)	2000	7
Holts Landing Sanitary Sewer (Bay Colony & Fairway Villas)	2000	202
Ocean View Expansion	2002	678
Cedar Neck Expansion (Yacht Basin Road)	2002	34
Cedar Neck Expansion	2005	1,023
Sub-total		*2,625*
Post 2005 Connections		
Millville Expansion (Rt. 26/Woodcrest)	To 1/30/06	90
Miller Creek Sanitary Sewer	To 6/5/06	50
South Ocean View Sanitary Sewer	-	309
Miller Creek Sanitary Sewer (remaining as of 6/5/06)	-	433
Millville Expansion (remaining as of 7/21/06)	-	1,477
Sub-total		***2,359***

II. Holding Tank Inspection and Compliance Program

A holding tank compliance program was established in the Inland Bays Watershed in 2001. On average, holding tanks have a 2,800 gallon capacity. Metcalf and Eddy (1991) reported that holding tanks typically hold 2,596 gallons of effluent and 204 gallons of septage (solids). Recent observations from the compliance program indicate volumes of 2,464 gallons of effluent and 336 gallons of septage volume. The average effluent concentrations previously discussed (50.0 mg TN/L and 15.7 mg TP/L) have been used to determine the effluent loads from holding tanks. The nutrient load contribution from septage in holding tanks will be determined using the nutrient concentrations in septage from holding tanks (600 mg TN/L and 250 mg TP/L), as reported in Wastewater Engineering, Third Edition (Metcalf and Eddy, 1991). The nutrients removed per holding tank pump-out are shown in Table 5, calculated using the above concentrations.

Table 5. Nutrient Reductions from a Holding Tank Pump-Out

	Total N (lbs/tank/pump-out)	Total P (lbs/tank/pump-out)
Holding Tank Effluent	1.03	0.32
Holding Tank Septage	1.68	0.70
Total	2.71	1.02

Effluent:
Nutrients Removed (lbs/tank/pump-out) =
Conc. (mglL) x (lb/453,592 mg) x (2,464 gal/tank) x (3.7854 l/gal)
***Septage**:*
Nutrients Removed (lbs/tank/pump-out) =
Conc. (mglL) x (lb/453,592 mg) x (336 gal/tank) x (3.7854 l/gal)

There are 252 holding tanks currently in use in the Inland Bays Watershed. Each time a holding tank is pumped, 2.71 lbs TN and 1.02 lbs of TP do not enter the Inland Bays estuary (Table 5).

Initially, the Department assumed that tanks are pumped-out 16 times per year. The Small Systems Branch, Groundwater Discharges Section of the Division of Water Resources determined this number to be high. Records from the Holding Tank Compliance program indicate that on average, holding tanks are pumped-out about 12 times per year, or once a month (DNREC Groundwater Discharges Section, personal communication, 2001). Thus, this latter figure was used for subsequent calculations to determine the annual load reduction using the equation below.

Nutrient load reduction (lbs/yr)	=	Reduction rate (lbs/tank/pump-out)	x	12 pump-outs / year	x	# of tanks

EX: TN reduction due to Holding Tank Compliance Program:

TN load reduction (lbs/yr)	=	2.71 lbs TN/tank/pump-out	x	12 pump-outs / year	x	252 tanks	=	**8,195 lbs TN/yr or 22.5 lbs TN/day**

III. OWTDS Pump-outs

Using a GIS, an analysis was conducted that determined as of December 31, 2005, there were 18,212 OWTDS in the Inland Bays Watershed. Plans are in place to convert 2,359 systems to sewer by 2010 (Sussex County Engineering Department, written communication, 2006). Once this projection is taken into account, the total number of OWTDS in the Inland Bays Watershed will be 15,853. If all individual/small system owners complied with the maintenance requirement to pump their systems once every three years, approximately 5,284 small systems should be pumped out each year.

Waste haulers usually deliver waste to the nearest wastewater treatment plant. The two wastewater treatment facilities in the watershed (South Coastal and Wolf Neck) keep records on the amount of waste they accept from OWTDS pump-outs. These records indicate that close to five million gallons of effluent and septage were pumped out in 2002 and earlier years (Sussex County Engineering Department, South Coastal Wastewater Treatment Plant, personal communication, 2000 & 2002). Since OWTDS tanks in Delaware have a 1,000 gallon capacity on average, then it can be assumed that approximately 4,698 septic tanks were pumped out for compliance purposes in 2002, which is a compliance rate of 77%. Then it will be assumed that the 2002 compliance rate continues into the future, which indicates that there will likely be 4,089 systems pumped-out per year in the future, on average.

By assuming that after three years, a septic tank will contain 750 gallons of effluent and 250 gallons of septage (volumes based on local inspector-hauler observations), and using the concentrations of effluent and septage given above, the effluent load reductions per system achieved by the pump-out program are shown below in Table 6.

Table 6. Nutrient Reductions from an OWTDS Pump-Out

	Total N (lbs/system/pump-out)	**Total P (lbs/system/pump-out)**
OWTDS Effluent	0.31	0.10
OWTDS Septage	1.25	0.52
Total	1.56	0.62

Effluent:
Nutrients Removed (lbs/system/pump-out) =
Conc. (mg/l) x (lb/453,592 mg) x (750 gal/system) x (3.7854 l/gal)
Septage:
Nutrients Removed (lbs/system/pump-out) =
Conc. (mg/l) x (lb/453,592 mg) x (250 gal/system) x (3.7854 l/gal)

The load reduction in the water column achieved by this practice can be calculated using the following equation.

$$\text{Nutrient load reduction (lbs/yr)} = \text{Reduction rate (lbs/system/pump-out)} \times \left[\left(\text{\# of existing OWTDS} \times \frac{\text{1 pump-out}}{\text{3 years}} \right) - \text{\# of compliant OWTDS} \right]$$

EX: TN reduction due to OWTDS pump-out program:

$$\text{TN load reduction (lbs/yr)} = \text{1.56 lbs TN/system/pump-out} \times \left[\left(\text{15,853 existing OWTDS} \times \frac{\text{1 pump-out}}{\text{3 years}} \right) - \text{4,089 compliant OWTDS} \right]$$

$$= \textbf{1,865 lbs TN/year or 5.11 lbs TN/day}$$

IV. OWTDS Performance Standards

Wastewater pretreatment technologies exist to remove nitrogen, phosphorus, or both from wastewater prior to soil dispersal of the effluent. A consultant hired by the Department evaluated the performance efficiencies of these technologies then recommended performance standards for OWTDS in Delaware and several levels of performance efficiencies for nitrogen and phosphorus (The On-Site Wastewater Corporation, draft written communication, 2003).

A. Systems greater than 20,000 gallons per day (gpd)

A recommendation in the Inland Bays Pollution Control Strategy requires large systems greater than 20,000 gpd to meet “Performance Standard Nitrogen 2” (PSN2) when replacement is required and/or when the operation and maintenance permit expires. If a system with an expired O&M permit is located in an area identified as having a high potential for phosphorus mobility, the system must be upgraded to comply with “Performance Standard Phosphorus 1” (PSP1). Technologies that can achieve PSN2 will produce an 80% reduction of effluent TN concentration when compared to the TN influent concentration. The nutrient load reduction can be determined using the following equation.

$$\text{Nutrient load reduction (lbs/day)} = \text{OWTDS loading rate (lbs/system/day)} \times \text{\# of existing OWTDS} \times \text{Reduction efficiency}$$

EX: TN reduction due to upgrading to large systems (>20,000 gpd):

$$\text{TN load reduction (lbs/day)} = \text{4.78 lbs TN/system/day} \times \text{4 existing OWTDS} \times 80\% = \textbf{15.3 lbs TN/day}$$

B. Systems greater than 2,500 gpd and less than 20,000 gpd

A recommendation in the Inland Bays Pollution Control Strategy requires large systems greater than 2,500 gpd and less than 20,000 gpd to meet "Performance Standard Nitrogen 3" (PSN3) when the system requires replacement and/or when the operation and maintenance permit expires. If a system with an expired O&M permit is located in an area identified as having a high potential for phosphorus mobility, the system must be upgraded to comply with "Performance Standard Phosphorus 2" (PSP2). Technologies that can achieve PSN3 will produce a 50% reduction of effluent TN concentration when compared to the TN influent concentration. The nutrient load reduction can be determined using the following equation.

Nutrient load reduction (lbs/day)	=	OWTDS loading rate (lbs/system/day)	x	# of existing OWTDS	x	Reduction efficiency

EX: TN reduction due to upgrading to large systems (2,500 - 20,000 gpd):

TN load reduction (lbs/day)	=	1.33 lbs TN/system/ day	x	20 existing OWTDS	x	50%	=	**13.3 lbs TN/day**

C. Systems less than 2,500 gpd

A recommendation in the Inland Bays Pollution Control Strategy requires all existing small systems less than 2,500 gpd to meet "Performance Standard Nitrogen 3" (PSN3) within 20 years of promulgating the PCS regulations. Technologies that can achieve PSN3 will produce a 50% reduction of effluent TN concentration when compared to the TN influent concentration. The nutrient load reduction can be determined using the following equation.

Nutrient load reduction (lbs/day)	=	OWTDS loading rate (lbs/system/day)	x	# of existing OWTDS	x	Reduction efficiency

EX: TN reduction due to upgrading to alternative systems:

TN load reduction (lbs/day)	=	0.029 lbs TN/system/ day	x	15,853 OWTDS	x	50%	=	**230 lbs TN/day**

Stormwater BMP Calculations

I. Stormwater BMPs

Several types of structures that treat stormwater runoff are used throughout the Inland Bays Watershed. The efficiencies associated with common stormwater BMPs are listed in Table 7. In order to calculate the load reduction to the receiving water body, the calculation outlined below is used. The nitrogen urban loading rate is 20 lbs/acre/yr, while the phosphorus loading rate is 0.7 lb/acre/yr (Ward, 2001).

Table 7. Stormwater BMP Reduction Efficiencies (ASCE, 2001)

BMP	TN (%)	TP (%)
Wet ponds	12	55
Dry pond (extended detention)	15	25
Infiltration (swale, infiltration basin/trench)	65	70
Biofiltration*	25	29
Sandfilter	47	41

*Must be at least 200ft long for TN reduction and 100ft swales are more effective in reducing TP (45%) as compared to 200ft swales (29%).

Nutrient load reduction (lbs/day)	=	# of structures	x	Mean drainage area treated by structure (acres)	x	Urban loading rate (lbs/acre/yr)	x	Reduction efficiency

EX: TN reduction due to wet ponds:

TN load reduction (lbs/day)	=	93 structures	x	7.96 acres treated on average	x	20 lbs TN/acre/yr	x	12%	=	**1,777 lbs TN/yr or 4.86 lbs TN/day**

II. Potential Future Stormwater Retrofit Projects:

It is anticipated that an additional 4,500 acres of urban area in the Inland Bays watershed will be retrofitted in the future. It is difficult to project, however, the exact number and type of treatment structures that will be used. The majority of stormwater practices (75 percent) currently in use in the watershed are wet and dry ponds, while infiltration, biofiltration, and sandfilter structures together account for 25 percent of the current practices in use. It is unlikely that these same proportions will be used in future retrofit projects since the construction of ponds will require a considerable amount of space and it may be unfeasible to create these structures in areas that are already developed. Because of this, it has been assumed that future retrofits will focus mainly on the various filtration practices listed above, now termed “Other,” (80 percent), while the assumption is that ponds will be used 20 percent of the time.

The load reductions achieved from the stormwater BMPs currently on the ground have been summed into two categories, “Ponds” and “Other.” These values were divided by the total area treated in each category to calculate nutrient reduction rates. For “Ponds,” the reduction rates are 2.53 lbs TN/acre/yr and 0.34 lbs TP acre/yr, while the reduction rates for “Other” are 12.6 lbs TN/acre/yr and 0.470 lbs TP acre/yr. However, these reductions are based the number of structural practices on the ground through 2001, it is known that there are other types of non-structural practices that may not have been accounted for as well as structural and non-structural practices put in place between 2001 and 2005.

The load reduction that will be achieved if the retrofit goal of 4,500 acres is reached can be estimated. The potential future loading reduction to the stream as a result of retrofitting 4,500 acres of urban lands can thus be determined using the equation below.

Nutrient load reduction (lbs/day)	=	Reduction rate (lbs/acre/yr)	x	Acres of retrofit	x	Future percent use of practice

EX: TN reduction from future stormwater ponds:

TN load reduction (lbs/day)	=	2.53 lbs TN/acre/yr	x	4,500 acres	x	20%	=	**2,277 lbs TN/yr or 6.24 lbs TN/day**

Agriculture BMP Calculations

The following calculations are provided as a result of the Agricultural Pollution Control Strategy Workgroup's efforts in gathering the best available science for nonpoint source pollution prevention from agricultural sources. The workgroup began meeting in April 2002 to gather the best available data on nutrient efficiencies for various agricultural best management practices. These recommendations and calculations are based on averages over several years from different studies and are dependent on weather conditions, soil type, crop production intensity, excess manure generation, topography and other site specific conditions. In addition, a lag time likely exists between practice implementation and benefit observation, which can not currently be estimated since all nutrient fate and transport processes are not well understood at this time.

I. Commercial Fertilizer

The Workgroup decided not to attempt a fertilizer mass balance in the Inland Bays because there are no clear trends in the amount of TN or TP sold in Sussex County and there is a fertilizer sales data by watershed does not exist as of 2001.

II. Cover Crops

Nitrogen reduction efficiencies for cover crops were calculated using a weighted average method for each year. The data used in this calculation came from ranges of cover crop TN efficiencies for several plant species presented by J.T Sims and J.L. Campagnini (written communication, 2002). The Workgroup chose a single efficiency, often an average of the range, for the commonly used species in lower Delaware (Table 8). The Coastal Zone Management Program and the Nonpoint Source Program in the Department's Division of Soil and Water Conservation provided the acreages within the high and low reduction areas of the Inland Bays watershed of each cover crop planted in 2005 (shown in bold). These acreages and efficiencies were used to calculate a weighted average efficiency, determined to be 59.41% in 2005. It should be noted that with this approach, the efficiency will change from year to year, depending on the acreage of each cover crop species planted. For TP, the Workgroup referred to the best professional judgment presented by Sims and Campagnini, which was "less than 5%," and will be considered for these purposes as 4.9%. The nutrient load reduction to is calculated with the equation shown below.

Table 8. Cover Crop Efficiencies for TN

Cover Crop Species	Work Group BMP Efficiency (%)
Barley	**70**
Hairy Vetch	6
Annual Rye	65
Cereal Rye	**54.5**
Oats	55
Wheat	**55**

Nutrient load reduction (lbs/yr) = Agricultural loading rate (lbs/acre/yr) x Acres of cover crops x Reduction efficiency (%)

EX: TN reduction due to 3,056 acres of cover crops:

TN Load Reduction (lbs/day) = 21 lbs TN/acre/yr x 3,056 acres x 59.41% = **38,127 lbs TN/yr or 104 lbs TN/day**

In addition, the Workgroup recommended that cost-share monies for cover crops vary with the species used, such that a higher rate will be offered for the species that offer the greatest nutrient savings. From this recommendation, a letter was sent to the Sussex Conservation District Board of Supervisors. The Board of Supervisors approved $17 per acre cost share for all cover crops under their program, which in recent years has been increased to $30-$40/acre. This method will promote the use of the higher reduction efficiency crops since those crops are usually less expensive to plant. The Board decided to allow the cover crop to be fertilized after March 15, for harvesting for on-farm uses, which include use as feed or bedding (SCD, 2003).

III. <u>Ponds, Grassed Waterways, Grassed Filter Strips, Wildlife Habitat</u>

The Conservation Reserve Program (CRP) practices are treated as a land use change from agricultural cropland to grassed waterways or grassed filter strips, or wildlife habitat. Thus, the acres that undergo change will receive a lower loading rate. Since the Conservation Reserve Enhancement Program (CREP) was implemented, any new grass filter strips created will be treated as a CREP practice and will receive a reduction calculated by the method described later. The loading reduction is calculated as follows.

Nutrient load reduction (lb/yr) = [Agricultural loading rate (lbs/acre/yr) - Grass loading rate (lbs/acre/yr)] x Acres of CRP practices

EX: TN reduction due to 134 acres of wildlife habitat:

TN load reduction (lb/yr) = [21 lbs TN/acre/yr - 12.5 lbs TN/acre/yr] x 134 acres = **1,139 lbs TN/yr or 3.1 lbs TN/day**

IV. Grass Buffers, Filter Strips, Forest Buffers, Riparian Buffers, Wetlands

The Conservation Reserve Enhancement Program (CREP) practices (CP21-grass filter strips) are assumed to act as grassed buffers. CREP practices (CP22-riparian buffer, CP23-wetland restoration and CP3A-hardwood trees) are all assumed to act as forested buffers. The Workgroup assumed that for every one acre of land where these practices are employed, that two upland acres are treated. This approach is similar to the practice employed by the Chesapeake Bay Program (CBP, 1998). The efficiencies for nutrient load reductions are an average of the range presented by J.T. Sims and J.L. Campagnini (written communication, 2002). Thus, the agreed efficiencies are as follows:

Grassed buffers: TN-- 46% and TP-- 54%
Forested buffers: TN-- 62% and TP-- 62%

For these BMPs, the actual acre of the practice will be treated as a land use conversion and the reduction efficiencies will be applied to two acres of affected upland for each acre of practice.

$$\text{Nutrient load reduction (lb/yr)} = \left[\left(\text{Agricultural loading rate (lbs/acre/yr)} - \text{Grass/Forest loading rate (lbs/acre/yr)}\right) \times \text{Acres of CREP practices}\right] + \left[\text{2 x Acres of CREP practices} \times \text{Agricultural loading rate (lbs/acre/yr)} \times \text{Reduction efficiency (\%)}\right]$$

EX: TN reduction due to 26 acres of grass buffers:

$$\text{TN load reduction (lb/yr)} = \left[\left(\text{21lbs TN/acre/yr} - \text{12.5 lbs TN/acre/yr}\right) \times \text{26 Acres}\right] + \left[\text{2 x 26 Acres} \times \text{21 lbs TN/acre/yr} \times 46\%\right]$$

$$= \textbf{723 lbs TN/yr or 1.98 lbs TN/day}$$

V. Water Control Structures

Controlled drainage through the installation of water control structures can lower nitrates in discharge waters by about one-third the amount found in uncontrolled drainage systems. Approximately 50% of the drainage water and slightly more than half of the nutrients leave the field during winter months. Water control structures also hold the water table high in the soils, which promotes denitrification and lowers nitrate concentrations in drainage waters (Evans et al., 1989; Evans et al., 1996; Osmond et al., 2002). The Workgroup assigned a nitrogen reduction efficiency of 33 percent to water control structures. This reduction can be applied to the 51 water control structures, each draining an average of 30 acres, in the Inland Bays watershed. There is currently no research to support the assignment of a TP reduction as a result of installation of water control structures. The reduction is determined with the calculation below.

TN load reduction (lbs/yr)	=	Agricultural loading rate (21 lbs TN/acre/yr)	x	1,530 acres drained by WCS (51*30acres)	x	Reduction efficiency (33%)	=	**10,603 lbs TN/yr or 29.0 lbs TN/day**

VI. Poultry Compost Sheds

This practice prevents pathogens from poultry mortality from entering groundwater and utilizes small amounts of manure during compost operations. Due to lack of research findings, no significant nutrient reductions can be considered to be associated with poultry compost sheds.

VII. Poultry Manure Storage Sheds

Literature was reviewed in an attempt to associate numeric nutrient reductions with poultry manure storage sheds. The literature search, however, did not produce any results that would substantiate the application of nutrient reductions specifically to these facilities. However, poultry manure sheds are an integral component of manure management systems. For these purposes, benefits are accounted for under nutrient management plans.

VIII. Manure Relocation and Alternative Use

According to the policy of the Nutrient Management Commission, relocated manure and/or manure sent to alternative use facilities comes from farms with insufficient acreage to apply the litter and/or have high phosphorus soils (Nutrient Management Commission, " Delaware Nutrient Management Notes, December 2000). The procedure used to calculate nutrient reductions from these practices is based on the fact that nutrient application rates change when manure is relocated. The percent reduction in application rates can further be used to determine the reduction associated with manure relocation. This approach assumes that inputs equal outputs, and there is no consideration of a lag time or the effects of processes like uptake or denitrification on loading rates. Thus, it is assumed that the load will be reduced by the same proportion as the reduction in application to land. As more research on the fate, transport, and storage of nutrients in soils becomes available, the model will be adjusted to more accurately depict natural processes.

Current and historic manure application rates and nutrient contents were obtained from several sources. Table 9 summarizes these values.

Table 9. Past and Present Nutrient Contents and Application Rates

	Manure Application Rate (tons/acre/yr)	Total Nitrogen Content (lb TN/ton)	TN Application Rate (lb TN/acre/yr)	Total Phosphorus Content (lb TP/ton)	TP Application Rate (lb TP/acre/yr)
Baseline	2.5	60.0	150.0	30.6	76.5
N Management	1.5	60.0	90.0	30.6	45.9
				19.7	29.6
High P Soils	1.0	60.0	60.0	19.7	19.7

The manure application rate for the baseline period was 5 tons per acre every other year (McGowan and Milliken, 1992), for an average of 2.5 tons/acre/yr. This value was reduced first to 3 tons every other year (1.5 tons/acre/yr) (McGowan and Milliken, 1992) and more recently to 1 ton/acre/yr on high phosphorus soils (University of Delaware Research and Education Center, personal communication, 2004).

The Total Nitrogen (TN) content of manure has not significantly changed over time, therefore, the average value from Sussex County in 2005 (60.0 lb TN/ton (Hansen et al., 2005)) has been used for the other periods as well and used to calculate the nitrogen application rates. The final TN manure application rate of 60.0 lb TN/acre/yr, corresponding to a manure application rate of 1.0 ton/acre/yr, is considered low for sustaining crop yield. Commercial inorganic fertilizer is likely applied to these areas as a supplement and thus, the true TN application rate in areas of high P soils is probably more similar to 90.0 lb TN/acre/yr. This value will be considered the current TN application rate, which results in a 40.0% reduction in TN application rates due to manure relocation practices.

The phosphorus manure content, often reported as P_2O_5, was historically reported as 70.0 lb P_2O_5/ton, or 30.6 lb TP/ton (Hansen et al., 2005). Recent measurements show that this value has reduced to 19.7 lb TP/ton (Hansen et al., 2005), due to the addition of phytase to poultry feed. If this manure was not relocated, it would have been applied at a rate of 1 ton/acre/yr. The combination of manure application rates and TP content, suggest that TP application rates have reduced 74.2% from the baseline period. The annual and daily nutrient reductions can be calculated with the following equation.

$$\text{Tons manure removed} \times \left(\frac{\text{Nutrient Content (lb/ton)}}{\text{Current Application Rate (lb/acre/yr)}} \right) \times \text{Agriculture loading rate (lb/acre/yr)} \times \text{Reduction efficiency (\%)} = \text{Nutrient load reduction (lb/yr)}$$

EX: TN reduction due to relocation/alternative use of 20,347 tons of manure:

$$\text{20,347 tons} \times \left(\frac{\text{53.8 lbs TN/ton}}{\text{80.7 lbs TN/acre/yr}} \right) \times \text{21 lbs TN/acre/yr} \times 40\% = \textbf{113,943 lbs TN/yr or 312 lbs TN/day}$$

The annual tonnage of manure relocated and/or put towards alternative uses has been obtained from the Delaware Nutrient Management Commission (written communication, 2006) and Perdue's "Agri- Recycle," center (written communication, 2006).

The accuracy of this approach is dependent on the accuracy of the utilized application and loading rates, as well as the assumption that no additional commercial inorganic fertilizer is added to compensate for reduced manure applications. It is also important to note that a lag time likely exists between reduced nutrient applications to land and reduced nutrient loadings in streams. This has implications for both nutrients but especially for phosphorus since the farms utilizing manure relocation practices have high P soils. Both dissolved and particulate phosphorus could be supplied in high rates to receiving waters for some time and the calculated reductions may not be seen in the water column immediately.

IX. Phytase

Sussex County is home to a large poultry industry and the approximately 72 million broiler chickens produced each year in the Inland Bays Watershed produce many thousand tons of poultry litter, most of which is applied to local cropland, serving as a source of nutrients. Poultry litter contains similar amounts of N and P, however, many crops, like corn, require much less P than N, resulting in a buildup of P in soils. Several approaches exist to address this problem including restricting litter applications on high P soils and relocating excesses to areas deficient in P. Another approach is to modify broiler diets in order to reduce the amount of P in the litter.

Most of the P in the grain fed to poultry exists as phytic acid, which is poorly digested by the birds so that most of the P passes through unutilized to the litter. Poultry operators must supplement the diets with other forms of phosphorus that the birds can utilize. Recent research has shown that an enzyme, called Phytase, can be added to poultry diets to help birds utilize the phytic acid in grain, allowing supplemental P additions to be reduced, and substantially reducing the P in litter (Hansen et al., 2005).

Since 2000, effectively all poultry feed on the Delmarva Peninsula is required to include Phytase as a result of the Maryland Water Quality Improvement Act of 1998.

Hansen et al. (2005) reports that litter P contents are 30-40% lower now than in the past as a result of modifying poultry diets with Phytase, with P contents reducing from about 20 lb TP/ton to 31 lb TP/ton. For the purposes of calculating nutrient reductions to streams as a result of the use of Phytase and other feed additives, an efficiency of 35% will be used.

The reduction in P loading due to Phytase in the Inland Bays Watershed for 2005 can be calculated using the following equation.

Reduction due to Phytase	=	Acres of manure application	x	Loading rate (lb/acre/yr)	x	Reduction efficiency (%)

The area of manure application was estimated using data from 2005. First, the amount of poultry manure produced in the Inland Bays in one year was determined based on estimated number of birds per year and using a litter production rate of 1.1 tons per 1000 birds for broiler poultry (Malone, 2000). This value was found to be 36,402 tons/yr. For 2005 though, 20,347 tons of manure were relocated, leaving 16,055 tons requiring application to cropland. Assuming that the average manure application rate across the watershed is 1.5 tons per acre, it was determined that manure was applied to approximately 10,703 acres in 2005.

TP load reduction (lb/yr)	=	10,703 acres	x	0.8 lbs TP/acre/yr	x	35%	=	**2,997 lbs TP/yr or 8.24 lbs TP/day**

This process assumes that farmers do not apply more litter to cropland to compensate for the lower P content of the manure. The reduction will be large for the size of the efficiency, but this is due to the large amount of manure used in the calculation, especially in comparison to the amount of relocated manure in the watershed.

X. Nutrient Management Plans

For TN, the percent load reduction achieved due to the implementation of nutrient management plans (NMPs) was calculated using data presented in McGowan and Milliken (1992). This report lists the reductions associated with various management practices observed over a three year period, with a total of 103,736 lbs TN reduced by 2,328 acres under nutrient management planning. To determine a general NMP TN reduction, it was decided that the reductions and acreage associated with manure allowance and cover crops should be removed from further calculations since reductions for both of these items are determined separately and all NMPs will not include manure relocation. This subtraction gives a total of 1,224 acres of nutrient management planning and a load reduction of 70,136 lbs of TN, resulting in a reduction rate of 57.3 lbs/acre per 3-year planning cycle.

McGowan and Milliken (1992) reported that the TN application rate prior to the introduction of NMPs was 280 lbs/acre per 3-year planning cycle, so NMPs produced a 20.5% reduction in TN. This estimate falls in the lower range reported by the state of Maryland (MDNR, 1996), which was 20-39% for nitrogen. The corresponding phosphorus range reported by the Maryland Department of Natural Resources was 9-30%. However, due to the absence of a report similar to the McGowan and Milliken study in Delaware for P, there is not enough information available to determine an appropriate reduction efficiency to apply to NMPs for phosphorus. This value will be determined and utilized as more data from the Inland Bays region becomes available.

There were 23,543 acres of nutrient management planning in the Inland Bays Watershed in 2005 (Delaware Nutrient Management Commission, personal communication, 2006). Using the TN efficiency and the loading rate reported earlier, the annual and daily load reductions due to these acres can be calculated as follows. It is assumed that fewer nutrients will be applied to this land as a result of better planning, and thus, the TN load will reduce by 20.5% as well.

TN load reduction (lb/yr)	=	23,543 acres under NMPs	x	Agriculture loading rate (21 lbs TN/acre/yr)	x	Reduction efficiency (20.5%)	=	**101,353 lbs TN/yr or 278 lbs TN/day**

Estimation of Nutrient Load Reductions by Implementing Future Agricultural BMPs

The total nutrient reductions achieved by practices currently on the ground in the wastewater, stormwater, and agricultural sectors have been determined. In addition, the nutrient reductions possible from several potential future wastewater management policies and stormwater projects have been estimated. These values are shown in Table 10 along with the nutrient reductions required to meet the TMDL goals. Current practices have contributed 31 percent of the required TN reduction and 62 percent of the required TP reduction. Potential reductions from the wastewater and stormwater sectors increase the progress for TN to 44 percent and 72 percent for TP. Although significant progress has been made in reaching the goal for both nutrients, additional reductions are still needed. The proposed policies and projects for the wastewater and stormwater sectors are considered to be the extent of what can feasibly be done with respect to infrastructure and financial constraints. Therefore, the only sector which could potentially make up the difference in loading reductions is the agricultural sector. The Department does not regulate the agriculture industry; however, it is important to propose voluntary goals for the implementation of future BMPs on agricultural lands. The concept of setting voluntary goals was supported by the Nutrient Management Commission.

Table 10. Nutrient Reductions Achieved from Current and Potential Future BMPs

	TN Reduced (lbs/day)	TP Reduced (lbs/day)
OWTDS	378.67	38.74
Stormwater	17.53	1.29
Agriculture	758.71	42.94
Sub-total	1,154.91	82.97
Future OWTDS	377.22	7.79
Future Stormwater	130.50	5.48
Total	1,662.63	96.24
Required Reduction	**3,763.70**	**133.41**

Additional acres are proposed for grass and forest buffers, wetlands, cover crops, water control structures, and manure relocation. In order to determine the number of acres of each practice needed to reach the reduction goals, the “Solver” tool in Microsoft Excel was utilized. Solver is a what-if analysis tool, which allows one to find an optimal value for a formula located in a target cell. Solver adjusts the values in a specified group of cells to produce the result defined by the target cell formula. In addition, constraints can be applied to restrict the values in the adjustable cells (Microsoft, 2003).

Although the phosphorus goal reduction was in closer reach than the nitrogen goal, it was decided to base the solver on achieving phosphorus goals since many agricultural practices are more efficient at reducing nitrogen. With this approach, the phosphorus target can be met, ancillary and adequate nitrogen reductions will be produced, and the amount of agriculture taken out of production will be minimized since fewer acres of buffers and restored wetlands will be required.

The formula specified in the Solver program summed the products of each BMPs TP reduction rate and additional acres required by that BMP as outlined below.

$$\text{Target TP reduction (lb/day)} = \sum \text{BMP reduction rate (lb/acre/day)} \times \text{Additional acres of that BMP required}$$

Solver was programmed to have the formula in the target cell equal 37.17 lbs TP/day, which is the difference in loading needed to meet the TMDL reduction goal. The tool then attempts to reach this target by adjusting the cells that contain the additional acreage needed. In order to produce useful results, the adjustable cells were each constrained so that the value produced by solver would not be greater than the number of acres that could actually be available for that BMP. The assumption used to estimate the number of acres available for each BMP to be used as a constraint are described below.

The total number of agricultural acres in the Inland Bays watershed in 2002 was 65,191. Since considerable development is occurring throughout the watershed, where agricultural lands are often converted to residential and commercial areas, a GIS analysis was done to estimate land use changes since the 2002 land use coverage was produced. Sussex County maintains a polygon shapefile of “communities,” or the larger subdivisions, which was last updated in November 2005. This file was clipped to the Inland Bays Watershed and the 2002 land use coverage was then clipped to it. Any 2002 agricultural lands falling within this layer are assumed to have been developed between 2002 and 2005. This analysis reveals that approximately 2,465 agricultural acres have been developed, reducing the number of agricultural acres for future BMPs to 62,728. It is very likely that even fewer agricultural acres exist within the Inland Bays Watershed since the “communities” shapefile only covered subdivisions, excluding smaller scale land use changes, and other development projects are likely planned but have not yet gone through the approval process that gets them placed within the GIS shapefile.

The CREP practices of grass buffers and grass filter strips, which each receive the same nutrient reduction rate, and have been combined. The Urban Riparian Buffer fact sheet produced for the Inland Bays Tributary Action Team reports that a 100 ft buffer will take up 8% of the land (DNREC, 2001), which in the case of the Inland Bays Watershed, is 5,018 agricultural acres. In 2005, there were 54.5 acres of grass buffers and filter strips (DNREC 319 Program, personal communication, 2006).

The CREP practices of forest buffers and riparian buffers also receive the same nutrient reduction rate and have also been combined. Like grass buffers, 100 ft forest buffers could take up 5,018 acres of the cropland in the Inland Bays Watershed. In 2005, there were 209.2 acres of forest and riparian buffers (DNREC 319 Program, personal communication, 2006). However, only 8% of the agricultural area in the watershed is available to buffers, so that both grass and forest buffer BMPs can only total 5,018 acres (5,018 - 54.5 grass - 209.2 forest = 4,755 acres). Solver optimizes the number of acres devoted to each buffer type based on their reduction rates.

In 2002, there were 29 acres of restored wetlands. A recent GIS analysis revealed that there are 4,718 acres of farmed and prior converted wetlands in the Inland Bays watersheds and they are considered to be available for restoration.

Through a personal communication with a Sussex County farmer who shall remain anonymous, in a given year, about 40% of the cropland would not be available for cover cropping since it would be grown for small grains in the fall and fertilizer would be applied. By subtracting out this fraction, there are 37,637 acres available for cover crops. In 2005, there were 3,056 acres of cover crops and it is assumed that those farmers will plant the same acreage in future years.

There were 51 water control structures existing in the Inland Bays watershed as of 2002 (DNREC 319 Program, personal communication, 2006). Each drains approximately 30 acres, so that 1,530 acres are likely being treated by this BMP. It is estimated that an additional 30 smaller structures can be added. These structures, would drain 15 acres each, for a total of 450 additional acres.

A University of Delaware Soil Test Laboratory study, reported in a memorandum from Dr. Tom Sims to Mr. William Vanderwende, Chairman of the Delaware Nutrient Management Commission, indicates that one third of the soils in Sussex County are high in P (written communication, 2002) and it is assumed that these soils (20,909 acres) participate in manure relocation/alternative use programs. In 2005, 20,347 tons were relocated (Delaware Nutrient Management Commission, written communication, 2003; Perdue's "Agri- Recycle," written communication, 2006), which if applied at a 1 ton/acre/yr rate would have gone on 20,347 acres. This suggests that another 562 acres could and should participate in these programs. It is assumed that farmers currently involved in these programs will relocate equal amounts in future years.

Once these constraints were entered into the program, Solver was allowed to run. The resulting acreages required to meet the needed TN reductions are shown below (Table 11).

Table 11. Additional Agricultural BMP Acres and Associated TP Reduction

	Additional Acres	TP Reduced (lbs/day)
Grass buffers/Grass filter strips	1,717.70	5.03
Forest buffers/Riparian buffers	3,036.85	11.63
Wetlands	4,146.56	15.87
Cover crops	34,581.31	3.73
Water Control Structures	450.00	0.00
Manure Relocation	562.40	0.92
Total Reduction		37.17
Target Reduction		**37.17**

This analysis reveals that the TP reduction target can be achieved (100% of the target reached) while only removing 14% of the cropland from production for the creation of buffers and wetlands.

This phosphorus scenario subsequently produces a nitrogen reduction of 2,156 lb TN/day. Additionally, by January 1, 2007, every farm must have a nutrient management plan and a TN reduction rate exists for NMPs. Since buffers and wetland restoration remove cropland from production, those acres have been removed from the ensuing calculation. In addition, 23,543.00 acres of agricultural lands in the Inland Bays Watershed were managed under NMPs in 2005 (DNMC, personal communication, 2006), so these acres have also been subtracted from the total acreage receiving the reduction. By taking NMPs into account, an additional 356.97 lbs TN/day will be removed from the load reaching receiving waters. When added to the reductions from the other sectors, the total TN reduction is 4,176 lbs/day, which is 111% of the target.

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