Appendix A: Possible Nutrient Management Strategies

In this appendix, we examine various nutrient management strategies. We present various methods of estimating the amount of nutrient reduction of landscape loading inputs that are needed to meet the CBPO goals for the Potomac River Basin.

The Chesapeake Bay Program Base Loads and Nutrient Goals

The Chesapeake Bay Program agreed in March 2003 to nitrogen and phosphorus reduction goals needed to restore the Bay (1). The 1985 base load; the measured load in 2000, 2003, and 2004; and the goals and reductions for nitrogen and phosphorus for the Potomac Basin developed by the CBPO are presented below.

Nitrogen	**1985 million lbs/yr**	**2000 million lbs/yr**	**2003 million lbs/yr**	**2004 million lbs/yr**	**Allocation Goal million lbs/yr**
VA	24.20	24.30	20.26	19.51	12.84
MD	23.90	18.70	18.61	18.10	11.81
WVA	7.50	7.50	6.80	6.59	4.71
PA	6.80	6.40	6.18	6.16	4.02
DC	8.30	5.00	4.12	3.55	2.40
Total	70.80	61.90	55.95	53.90	35.78

Phosphorus	**1985 million lbs/yr**	**2000 million lbs/yr**	**2003 million lbs/yr**	**2004 million lbs/yr**	**Allocation Goal million lbs/yr**
VA	2.31	1.96	1.94	1.80	1.40
MD	1.79	1.20	1.22	1.22	1.04
WVA	0.55	0.54	0.61	0.64	0.36
PA	0.49	0.45	0.47	0.48	0.33
DC	0.16	0.14	0.14	0.13	0.34
Total	5.30	4.28	4.38	4.27	3.47

These reductions were based on water quality computer model calculation requirements to meet water quality criteria for dissolved oxygen, water clarity, and chlorophyll. The base loads were estimated using a watershed model. The allocation of the total nitrogen and phosphorus load to the Potomac Estuary, to four of the states, and to the District of Columbia were also estimated using the watershed model. For each of the four states and the District of Columbia, the allocation was further delineated according to eight sources: forest/wooded, crop, other agriculture, urban, mixed open, point source, septic, and atmosphere.

One of the difficulties in the process of setting these goals, of which there are many, is how to establish a base load. The CBPO used 1985 as an "average" base year (70.8 million lbs/yr of TN) for the watershed model estimates.

The actual TN loadings for 1985, using the measured loading data, are presented in Chapter Five. The four five-year periods demonstrate this difficulty, as presented below for TN.

Years	Atmosphere lbs/yr	POTWs lbs/yr	River lbs/yr	Total lbs/yr
1980-84	1,464,502	20,784,008	72,622,123	94,870,633
1985-89	1,137,612	21,902,087	61,805,707	84,845,405
1990-94	1,130,058	25,700,490	70,950,343	97,780,892
1995-99	1,186,288	21,075,015	80,044,826	102,306,130
2000-04	986,518	15,129,609	62,967,872	79,083,999

If 1996, which was a very wet year, is not included in the 1995 through 1999 five-year period, the TN load drops from102.3 to a new base year of 77.6 million pounds per year. If one uses the 10-year period, 1980 through1989, the base nitrogen load would be 89.8 million pounds per year instead of 70.8 million pounds per year, as determined by the CBPO.

TP loadings are presented below.

Years	Atmosphere lbs/yr	POTWs lbs/yr	River lbs/yr	Total lbs/yr
1980-84	8,393	1,421,338	5,951,537	7,381,268
1985-89	8,393	183,794	4,998,622	5,190,808
1990-94	8,393	192,983	3,594,327	3,795,703
1995-99	8,393	191,452	6,937,887	7,137,731
2000-04	8,393	121,204	5,028,082	5,517,678

The average TP loading for the 1985-89 time frame was 5,190,000 lbs/yr, which is very similar to the CBPO base year loading of 5,300,000 lbs/yr, as shown above.

Another difficulty in the current watershed model nutrient load estimates is that it does not address "lag times" and, therefore, can significantly underestimate the 2003 loads, as presented above. The year 2003 was an unusually wet year and the computed TN load was over 160,000,000 pounds/yr (in Chapter Five), as compared to 55,950,000 pounds/yr estimated by the model, as presented on the previous page. For 2004, also a high-flow year, the computed load was 95,000,000 pounds/yr, as compared to the model estimate of 54,000,000 pounds/yr.

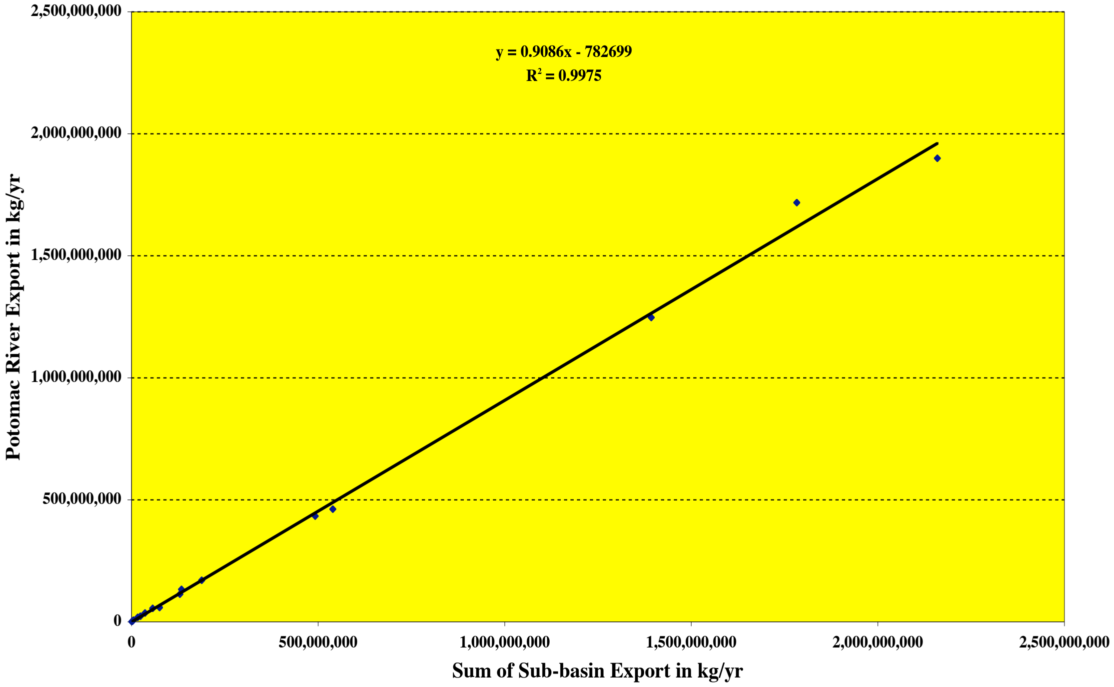
Allocation of Potomac Nutrient Goals to Sub-basins Based on Sub-basin Mass Balances

To expand the CBPO allocation process, we divided the Upper Basin into nine sub-basins and the Lower Basin into the lower watershed and tidal POTW discharges. This delineation makes it possible to use the landscape versus riverine export relationships developed in Chapter Four.

Of the 29,681 km^2 drainage area of the Upper Basin, the eight largest sub-basins contain 69% of the area, or 20,430 km^2. These sub-basins have both flow and water quality monitoring stations. About 31% of the Upper Basin has minimal to no water quality monitoring efforts.

To conduct a sub-basin mass balance (see Chapter Four), we examined two methods of estimating the fluxes from the unmonitored area: (1) area adjustment, and (2) flux estimates for unmonitored area. The results of method 1 for the 16 water quality parameters are presented below.

Potomac River at Fall Line
Riverine Export Versus Sum of Eight Sub-basin Export



The very strong correlation between the sum of the sub-basin and Upper Basin river export suggests that the mass balance approach can be used in the allocation process. Similar results were obtained using method 2 (see Chapter Four).

For the base period 1985 through 1989, we calculated the riverine export fluxes for the eight sub-basins and extrapolated these fluxes to estimate the export fluxes for the unmonitored areas of the Upper and Lower Basins (see below). The tidal POTWs were discharging about 21,000,000 lbs/yr during the base period.

We calculated that the total base load was about 82,600,000 lbs/yr. This is higher than the CBPO estimate but within the range of the measured loads, as presented earlier in this appendix. The CBPO nutrient goals for the entire Potomac River Basin are presented below.

Nitrogen	**35,780,000** lbs/yr or 50% of the base year
Phosphorus	**3,470,000** lbs/yr or 35% of the base year

Our sub-basin allocation for TN is as follows:

Upper Basin Sub-basins	**Area km^2**	**Base Year River TN Flux kg/km^2/yr**	**Base Year River TN Load lbs/yr**	**Allocated Goal TN Load lbs/yr**	**Allocated Goal TN River kg/km^2/yr**
North Branch	2,266	629	3,136,037	1,568,018	314
South Branch	3,756	518	4,279,768	2,139,884	259
Cacapon	1,753	504	1,944,203	972,102	252
Conococheague	1,215	2,056	5,494,726	2,747,363	1,028
Antietam	733	1,874	3,021,889	1,510,944	937
Opequon	800	720	1,263,691	633,846	360
Shenandoah	7,801	594	10,194,450	5,097,276	297
Monocacy	2,106	1,467	6,795,839	3,397,920	733
Unmonitored Area	9,251	770	15,672,007	7,836,004	385
Sum Total	29,681		54,097,968	27,048,984	414
Loss in Transport			-4,210,144	-2,105,072	
Total Upper Basin	29,681	764	49,887,825	**24,943,912**	382
Lower Basin					
POTWs	NA	NA	21,000,000	4,560,000*	
Watersheds	8,314	645	11,797,566	5,898,783	322
Total Basin	37,995		82,685,391	**35,402,695**	

*Technical Goal is 3.0 mg/l of TN in POTW effluents or 4,560,000 lbs/yr

Our allocated TN load for the entire Potomac River watershed is about 35,400,000 lbs/yr, which is very similar to the CBPO recommendation.

Using the process we used for TN and the CBPO 35% reduction of the base year, our allocation for TP is presented below.

Upper Basin Sub-basins	**Area km^2**	**Base Year River TP Flux kg/km^2/yr**	**Base Year River TP Load lbs/yr**	**Allocated Goal TP Load lbs/yr**	**Allocated Goal TP River kg/km^2/yr**
North Branch	2,266	38	190,456	123,796	25
South Branch	3,756	15	123,932	80,555	10
Cacapon	1,753	15	57,863	37,611	10
Conococheague	1,215	92	245,857	159,807	60
Antietam	733	140	225,456	146,546	91
Opequon	800	53	93,316	60,655	34
Shenandoah	7,801	25	429,059	278,889	16
Monocacy	2,106	115	532,735	346,277	75
Unmonitored Area	9,251	80	1,628,260	1,058,369	52
Sum Total	29,681	60	3,917,892	2,546,662	39
Loss in Transport			-390,958	-254,123	
Total Upper Basin	29,681	60	3,526,934	**2,292,539**	35
Lower Basin					
POTWs*	NA		190,000	190,000	
Watersheds	8,314	60	1,097,448	713,341	35
Total Basin	37,995		5,205,340	**3,449,971**	

* Note: Assumed no further reduction of TP from POTWs

Our allocated TP load for the entire Potomac River watershed is about 3,400,000, lbs/yr, which is very similar to the CBPO recommendation. The Upper Basin of the Potomac River TN goal is 24,900,000 lbs/yr and the TP goal is 2,292,000 lbs/yr, as presented in the tables above.

Equal Percent Reduction of Landscape Loading Inputs to Meet CBPO Nutrient Goals

To meet water quality criteria established for the Potomac Estuary, the CBPO determined nutrient goals for the entire Potomac River Basin, as presented in the section above. The nutrient loadings for nitrogen and phosphorus respectively are 37,780,000 and 3,470,000 lbs/yr. Based on loading inputs, as presented in Chapters Three and Four, the base year average annual total landscape input loadings for nitrogen and phosphorus were 357,860,000 and 76,650,000 lbs/yr respectively. The landscape inputs include the contributions from the POTWs in the Upper Basin but not from the tidal POTWs.

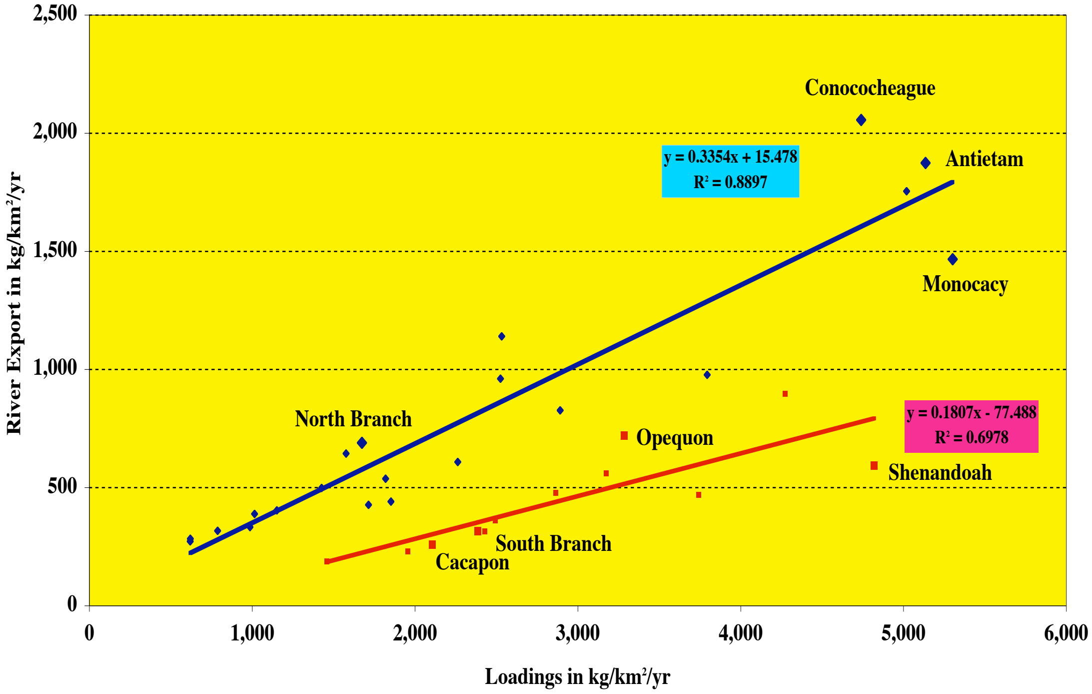
If we use 8.0 mg/l of nitrogen in the tidal POTW effluents, this would result in a nitrogen load of 12,180,000 lbs/yr, or about 34% of the 35,780,000 lbs/yr of the nitrogen goal. This results in a landscape export goal of 23,700,000 lbs/yr. Assuming about 19% of landscape loading inputs (357,860,000 lbs/yr) are exported by the rivers into the Potomac Estuary during an average year, the goal for the landscape inputs would be 23,700,000 (35,780,000-12,180,000) lbs/yr divided by 0.19 or 124,740,000 lbs/yr. **This would require a landscape loading input reduction of (357,860,000-124,740,000) divided by 357,860,000, or about 65%.**

If we use 3.0 mg/l of nitrogen in the tidal POTWs, this would result in a nitrogen load of 4,560,000 lbs/yr, or about 13% of the 35,780,000 lbs/yr of the nitrogen goal. This results in a landscape export goal of 31,200,000 lbs/yr. Assuming about 19% of landscape loading inputs (357,860,00 lbs/yr) are exported by the rivers into the Potomac Estuary, the goal for the landscape inputs is 31,200,000 divided by 0.19 or 162,210.000 lbs/yr. **This would require a landscape loading input reduction of (357,860,000-162,210,000) divided by 357,860,000, or about 54%.**

The current phosphorus load from the tidal POTWs is 190,000 lbs/yr, or about 5% of the phosphorus goal of 3,470,000 lbs/yr and is at its technical goal. Assuming about 6% of landscape loading inputs (70,650,000 lbs/yr) are exported by the rivers into the Potomac Estuary during an average year, the goal for the landscape inputs would be 3,280,000 lbs/yr (3,470,000-190,000) divided by 0.06 or 54,600,000 lbs/yr. **This would require a landscape loading input reduction of (70,650,000-54,600,000) divided by 70,650,000, or about 23%.**

Landscape Loading Input Reductions

In Chapter Four, we examined the relationships between landscape loading fluxes and riverine nutrient export fluxes for 25 major watersheds of the Middle Atlantic and Northeast USA, as well as for the eight major sub-basins of the Upper Basin (see chart below).



River TN Riverine Export Versus Landscape TN Loading Inputs from Wastewater, Air Deposition, Manure, and Fertilizer 25 Major Watersheds of the Middle Atlantic and NE USA Plus Eight Potomac Sub-basins

As explained in Chapter Four, there was some variability in the nitrogen landscape loading inputs (X term) and river export fluxes (Y term) relationship for the eight major sub-basins. Therefore, we used the two stratified stream flow relationships that we developed for the 25 watersheds and for the eight sub-basins, as presented above.

The upper equation is for the high water-yield sub-basins (North Branch, Antietam, Conococheague, and Monocacy), as presented below.

$$Y = 0.3354X + 15.478$$

The lower equation is for the low water-yield sub-basins (South Branch, Cacapon, Opequon, and Shenandoah), Upper Basin unmonitored area, Lower Basin unmonitored area, and the entire Upper Basin at the Fall Line, as presented below.

$$Y = 0.1807X - 77.488$$

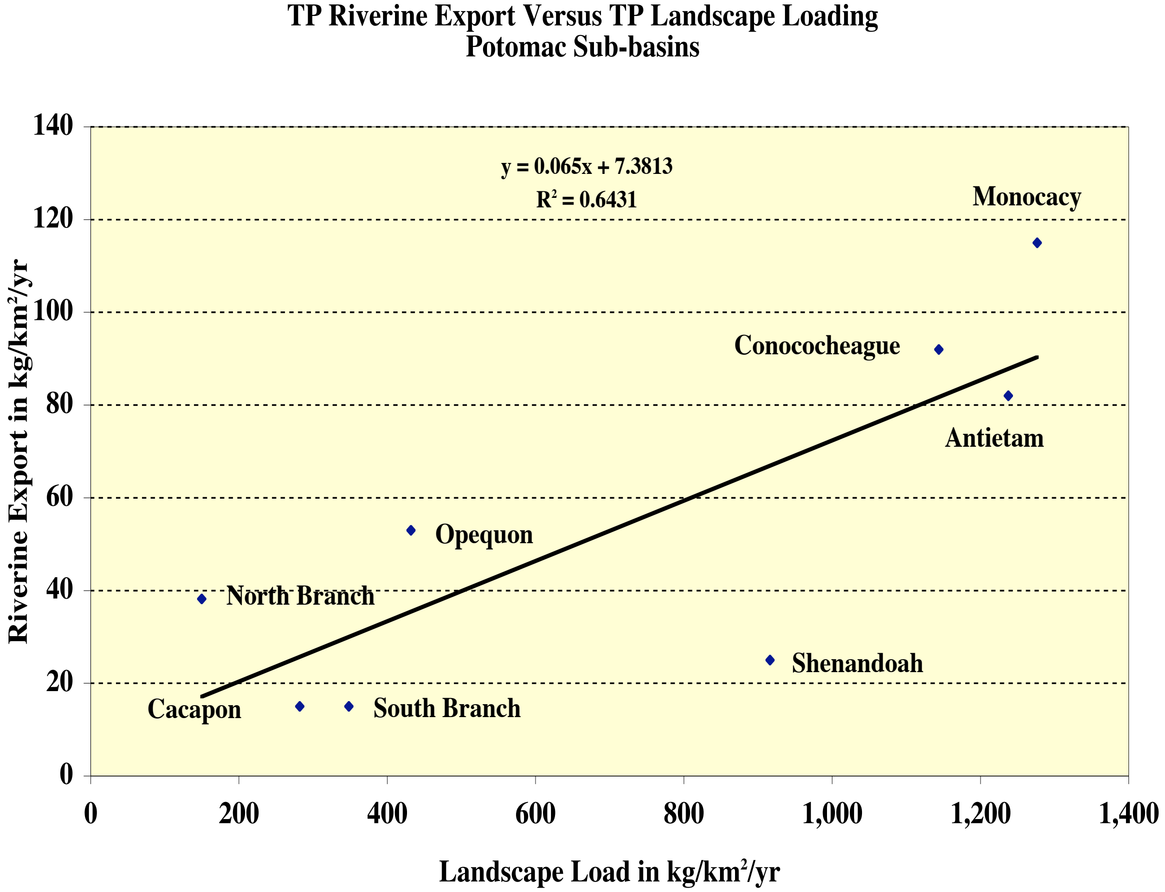
We use the two equations to estimate how much of the total landscape loading TN inputs had to be reduced to meet the Upper and Lower Basin TN river goals, as developed in the previous section of this chapter.

For the two reduction equations, the landscape loading inputs and percent reductions are presented below.

	Landscape TN Load kg/km^2/yr	**TN Goal River Flux kg/km^2/yr**	**Landscape Goal kg/km^2/yr**	**Amount of Reduction in kg/km^2/yr**	**Percent Reduction %**
Upper Basin					
North Branch	1,800	315	891	909	50.5%
South Branch	2,958	259	1,862	1,096	37.0%
Cacapon	2,518	252	1,823	695	27.6%
Conococheague	5,938	1,028	3,019	2,919	49.2%
Antietam	6,144	937	2,747	3,397	55.3%
Opequon	3,842	360	2,421	1,421	37.0%
Shenandoah	6,464	297	2,072	4,392	67.9%
Monocacy	6,276	734	2,141	4,135	65.9%
Unmonitored Area	4,128	385	2,559	1,569	38.0%
Upper Potomac	4,500	382	2,543	1,957	43.5%
Lower Basin					
POTWs	NA	NA	NA	NA	NA
Unmonitored Area	3,500	322	2,136	1,354	38.6 %

Using the same procedure for TP as for TN, we estimated the TP landscape loading input reductions for the Upper Basin and Lower Basin. For the TP relationship, a single linear equation appears to be sufficient to describe the loading versus export relationship.

The linear relationship is presented in the chart below.



We did not have enough information for TP to stratify the sub-basins into two water-yield watersheds as we did for TN. We used the equation as presented below for all areas.

$$Y = 0.065X + 7.38$$

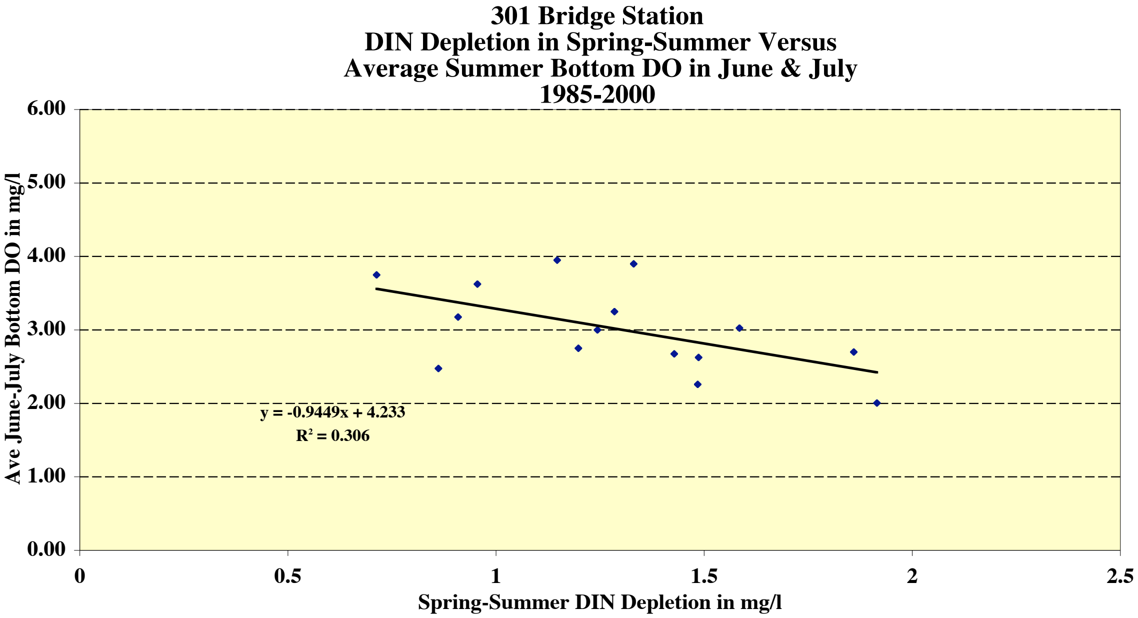
For an Upper Basin riverine export goal of 39 kg/km^2/yr, the landscape load input goal for the entire Upper Basin is 486 kg/km^2/yr, based on the equation above. The base year TP landscape loading input was 900 kg/km^2/yr, resulting in a landscape loading input reduction requirement for all areas of about 46%.

The landscape loading goal for a 46% TP reduction is presented below.

	Landscape TP Load kg/km²/yr	**TP Goal River kg/km²/yr**	**Landscape Loading Goal 46% kg/km²/yr**	**Reduction In kg/km²/yr**
Upper Basin				
North Branch	150	25	81	69
South Branch	348	15	188	160
Cacapon	282	7	152	130
Conococheague	1,144	60	618	526
Antietam	1,238	91	668	569
Opequon	432	46	233	199
Shenandoah	916	39	495	421
Monocacy	1,276	75	689	587
Unmonitored Area	648	52	350	298
Upper Potomac	900	39	486	414
Lower Basin				
POTWs	NA	NA	NA	NA
Unmonitored Area	650	39	351	299

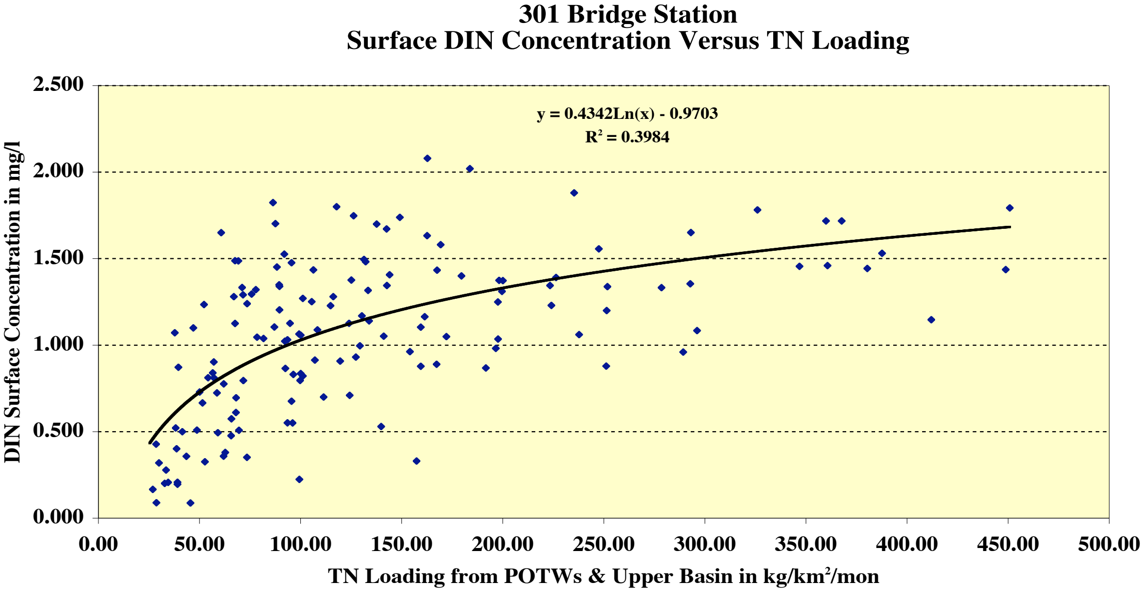
Making the Case for Nitrogen Reduction Based on Improving Bottom DO Levels at 301 Bridge Station

As shown below, the average DO of the bottom waters at the 301 Bridge Station for the June-July period is linearly related to the February-to-June depletion period of the surface DIN pool.



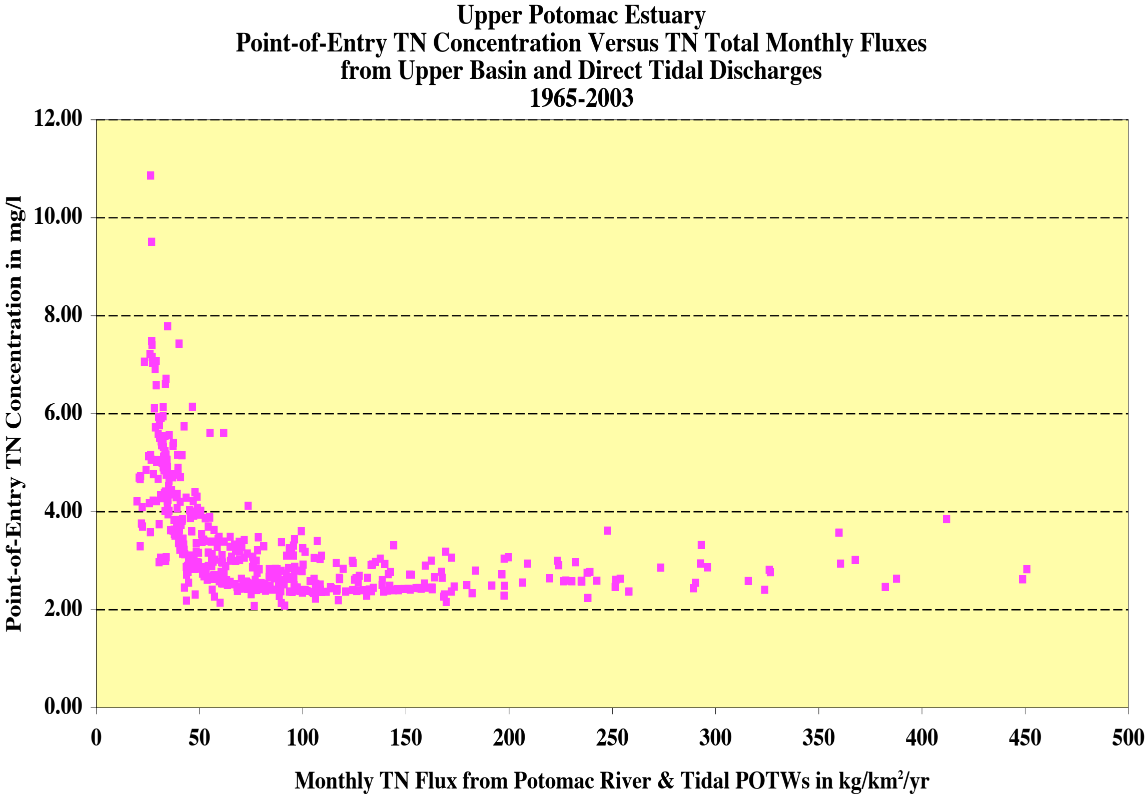
The chart above suggests that there is a linear inverse relationship between the summer bottom water DO and the amount of spring-to-summer DIN depletion at the 301 Bridge Station. The less DIN depletion the higher the bottom water DO. However, for a given sampling cruise, the DO in the bottom waters often can be much lower than the summer average. These short transitional periods of low DO are caused by temporary thermal and/or salinity stratification. Thus, the correlation of DIN depletion and bottom water DO was not very strong, as shown above.

The surface DIN concentrations at the 301 Bridge Station correlates to the TN monthly loading from the Upper Basin and direct POTW discharges, as shown below.



There is some scatter in the TN loading versus surface DIN pool, as presented above. The scatter is, in part, due to the inability to quantify the amount of DIN that is recycled in the Lower Estuary. We estimate about 50% of the summer DIN surface pool can be from recycled nitrogen. However, the recycled source is not included in the TN load and may explain, in part, why the correlation was not strong.

The TN point-of-entry concentration versus TN monthly total loading flux relationship has a very interesting association, as shown below.



When the monthly fluxes were 50 kg/km^2/month or less, the point-of-entry TN concentrations were dominated by the tidal POTW discharges. When the monthly fluxes were 100 kg/km^2/month and larger and dominated by the land runoff, the point-of-entry TN concentrations remain level at about +3.0 mg/l of TN (see above).

The strongest case for nitrogen control is the observation that over the past 50 years the TN point-of-entry concentration has increased from 2.27 mg/l to 2.91 mg/l (Chapter Five). During the past 50 years, the bottom DO at the 301 Bridge Station in the summer months has decreased from about 4.0 to 2.0 mg/l, responding to the increase in the point-of-entry TN concentrations (see Chapter Six). The above observations suggest that if the TN point-of-entry concentration was decreased, the bottom DO should increase.

There were only four summer samples taken at the 301 Bridge Station prior to the 1965 cruises. The 1962 summer cruise had bottom waters of 0.0 mg/l DO. The downward trend of the bottom waters at 301 Bridge Station suggests that nitrogen reduction will improve bottom water DO at the 301 Bridge and Point Lookout stations, where the bottom DO has been hypoxic for the past 50 years.

In the 1910s and 1920s, the point-of-entry TN concentration was about 1.0 mg/l and the bottom water DO was about 2.0 mg/l at the Ragged Point Station. Therefore, there may not be any major improvement in bottom water DO at Ragged Point. For the past 25 years, the point-of-entry TN concentrations have hovered around 3.0 mg/l and the bottom water DO has been less than1.0 mg/l.

Reducing to 1950 TN Inputs

In the 1950s, the total TN load to the Estuary from direct air deposition, landscape runoff, and direct POTW discharges was about 35,000,000 lbs/yr, as compared to 90,000,000 lbs/yr in the late 1980s. To reduce the inputs to the 1950s level would require a reduction of 55,000,000 lbs/yr. This reduction of 55,000,000 is more than the input from the direct POTW discharges, which is about 22,200,000 lbs/yr.

If the tidal POTWs reduce the effluent TN to 3.0 mg/l, the POTW input would be 4,500,000 lbs/yr, or a reduction of 17,700,000 lbs/yr. This would result in a current landscape runoff reduction requirement of 37,300,000 lbs/yr (55,000,000-17,700,000). **The current landscape riverine runoff and direct air deposition reductions required would be (90,000,000-37,300,000) divided by 90,000,000, or about 58%.**

TN Point-of-Entry Concentrations When Tidal POTW Effluents Are at 8.0 and 3.0 mg/l

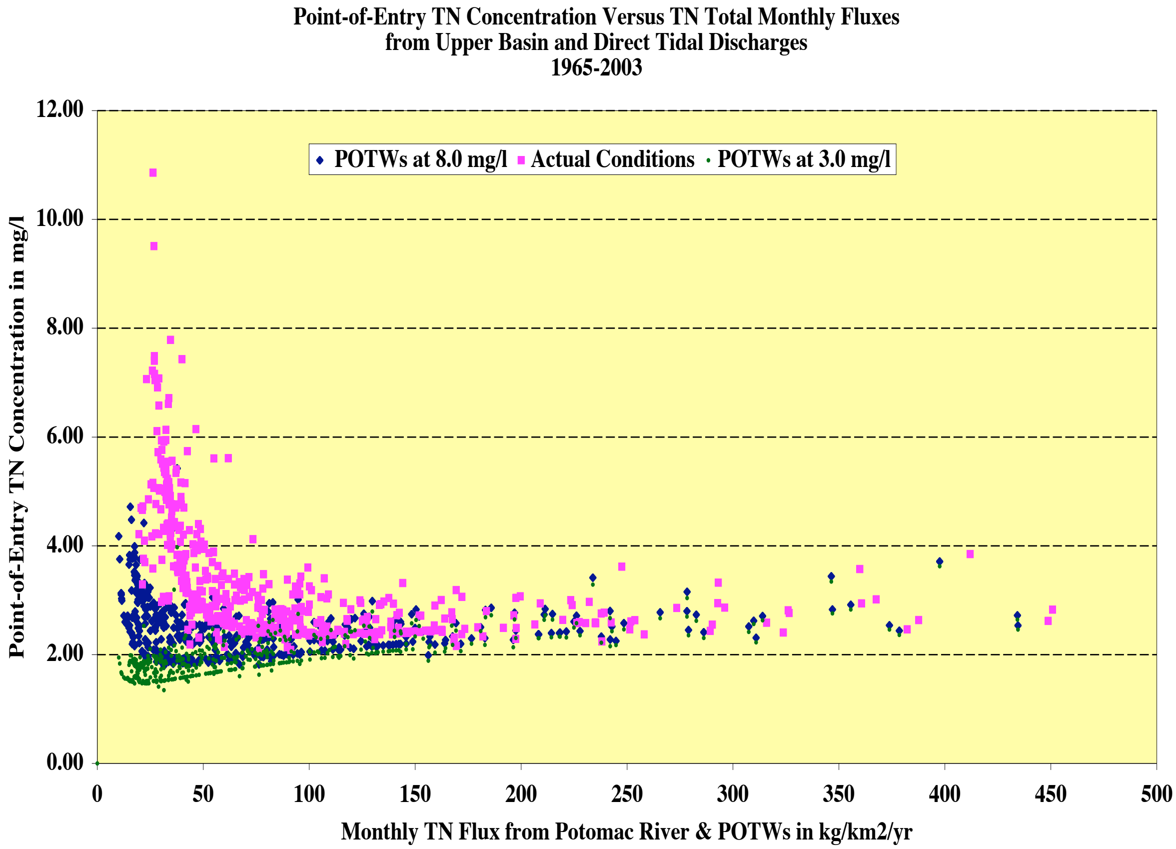
One means of demonstrating the effect of increasing nitrogen removal at the tidal POTWs is to determine how many months would have lower TN point-of-entry concentrations than the actual conditions from the 1965-2003 time frame. To reduce the point-of-entry TN concentration from 2.91 (1990s) to 2.27 mg/l (1950s) levels would require reducing the 1990s point-of-entry by 0.64 mg/l. In 2003, the average POTW TN effluent concentration was about 8.5 mg/l.

The 2003 average annual TN effluent concentrations for the major tidal POTWs are presented below.

Blue Plains	6.3 mg/l	Piscataway	2.7 mg/l
Mattawoman	18.0 mg/l	Dale City #8	3.2 mg/l
Occoquan	14.8 mg/l	Dale City #1	5.2 mg/l
Mooney	4.9 mg/l	Arlington	8.0 mg/l
Alexandria	6.3 mg/l	N. Cole	6.1 mg/l

While two of the POTWs above have not initiated nitrogen removal, the other treatment plants have effluent TN concentrations ranging from 2.7 to 8.0 mg/l. With two POTWs having effluents about 3.0 mg/l, it suggests that a technical TN effluent goal of 3.0 mg/l is feasible.

For the tidal POTWs having TN effluents of 8.0 and 3.0 mg/l and for the actual effluent conditions, the monthly TN point-of-entry concentrations versus total monthly input fluxes are shown below.



The **pink squares** represent monthly TN fluxes versus monthly average point-of-entry TN concentrations and actual effluent TN concentrations for all 468 months in the 1965-2003 time frame. See Chapter Five for details.

For monthly TN fluxes of 50 kg/km^2/month or less and POTW effluents at 8.0 mg/l, there will be a dramatic lowering of the TN point-of-entry concentrations (**blue diamonds** in chart above). The number of months in which the point-of-entry TN concentrations were over 4.0 mg/l would be reduced from 93 months for actual conditions to four months when the effluents are 8.0 mg/l.

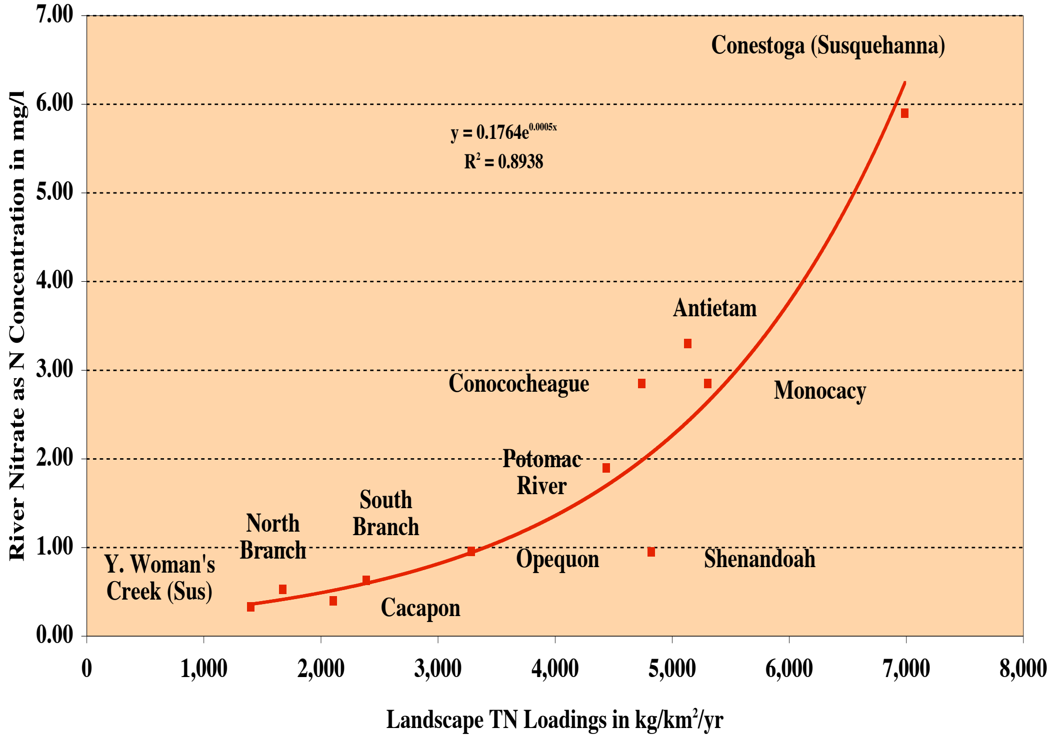
If the POTW effluents were further reduced to 3.0 mg/l (the **green circles**), all of the months would have TN point-of-entry concentrations less than 4.0 mg/l at all loading fluxes. Moreover, all 468 months would have point-of-entry TN ranging from less than 2.0 to 3.0 mg/l. **This would be a dramatic improvement in reducing the TN concentration in the Upper Estuary.**

However, at monthly fluxes over 150 kg/km^2/month, the nitrogen reduction at the POTWs will have little impact on the TN point-of-entry concentrations. These high loadings occur during periods of high river discharge conditions, resulting in large nitrogen pulses, which replenish the surface DIN pool of the Lower Estuary. **This replenishment process would result in anoxic conditions at the Ragged Point and Point Lookout stations**.

Exponential NO$_3$ River Concentration/Landscape Loading Relationship Used to Obtain Maximum Nitrogen Reduction for the Least Amount of Landscape Loading Reduction

To estimate the river nitrate concentration in response to landscape loading reductions, one can use the relationship developed in Chapter Four, as shown in the figure below.

Nitrate River Concentrations Versus Landscape TN Loading Inputs
from Wastewater, Air Deposition, Manure, and Fertilizer
Upper Potomac River and its Eight Major Sub-basins
Plus Conestoga and Young Woman's Creek (Susquehanna)
1990-1994



To obtain a reduction of 1.0 mg/l river export concentration, the 4,500 kg/km^2/yr landscape loading input fluxes for the entire Upper Basin would need to be reduced to 3,000 kg/km^2/yr from the 1990s loading, as shown above. This 1,500 kg/km^2/yr reduction would result in lowering the Upper Basin nitrate level from 1.9 to 0.9 mg/l.

For the North Branch, Cacapon, and South Branch sub-basins, the slope of the exponential relationship is flat and, therefore, there would be very little nitrate reduction for a given reduction in landscape loading. In that the exponential relationship is the steepest for the Conococheague, Antietam, and Monocacy sub-basins, the landscape loading reductions should be focused on these three watersheds. The Opequon sub-basin has an annual nitrate concentration approaching 2.0 mg/l, but has a low watershed runoff rate in inches-per-year. We attribute the Shenandoah low riverine nitrate export concentrations to agricultural practices, which we discuss later in this chapter.

Targeting Sub-basins with High Nitrate River Export Concentrations and High Watershed Runoff Rates

As can be seen in the figure above, the sub-basins that have high nitrate levels were the Antietam, Monocacy, Conococheague, Shenandoah, and Opequon. The sub-basins with the lowest concentrations were the North Branch, South Branch, and Cacapon. When one includes watershed runoff rates, the eight sub-basins fall into four target groups, as shown below.

Group One. The sub-basins with **high** nitrate river export concentrations and **high** watershed runoff rates were the:

Antietam,
Conococheague, and
Monocacy.

Group Two. The sub-basins with **high** nitrate river export concentrations and **low** watershed runoff rates were the:

Opequon and
Shenandoah.

Group Three. The sub-basin with **low** nitrate river export concentrations and **high** watershed runoff rates was the:

North Branch.

Group Four. The sub-basins with **low** nitrate river export concentrations and **low** watershed runoff rates were the:

South Branch and
Cacapon.

Targeting Group One first would be the most efficient and effective approach to reducing nitrogen export from the Upper Basin. Group Two would be the second targeted group.

Focusing first on Group One will present administrative challenges. The reduction levels could be based on a "least cost" solution. Administrative focus on the sub-basins that have the highest nitrate levels and the highest runoff rates makes sense. This targeting of sub-basins based on high nitrate export concentrations could also be the basis for nutrient trading.

Changes in Agriculture Practices

We looked at six counties in six separate watersheds to determine if the type of animals raised had an impact on the riverine export of nitrogen for the 1990-1994 period. Presented below is a summary for two of the six counties.

County	**Franklin**	**Rockingham**
State	**Pennsylvania**	**Virginia**
Sub-basin	**Conococheague**	**Shenandoah**
Animals	**Animals/km^2**	**Animals/km^2**
Milk cows	21.4	11.1
Heifers	18.6	15.4
Beef	1.9	10.8
Hogs	36.2	5.0
Broilers	220.7	5,442
Turkeys	29.9	1,900

In Rockingham County, Virginia, more beef cows and poultry were raised than in Franklin County, Pennsylvania. In Franklin County, the focus was on dairy farming. The amount of nitrogen manure generated in the two counties is presented below in kgN/km^2/yr:

County	**Franklin**	**Rockingham**
State	**Pennsylvania**	**Virginia**
Sub-basin	**Conococheague**	**Shenandoah**
Animals	**kgN/km^2/yr**	**kgN/km^2/yr**
Milk cows	2,599	1,345
Heifers	680	562
Beef	114	631
Hogs	211	29
Broilers	15	380
Turkeys	11	741
Total	3,633	3,690
River Export	2,056	594

Dairy farming was the largest animal nitrogen production source in both counties. While the two counties had about the same total nitrogen manure production, about 3,600 kg/km^2/yr, the riverine export by the Conococheague was 2,056 kgN/km^2/yr, as compared to 594 kgN/km^2/yr for the Shenandoah. The nitrate concentration in the Shenandoah was 1.3 mg/l, while the nitrate level in the Conococheague was 2.85 mg/l.

This suggests that agricultural practices can impact how much and at what concentration nitrogen is exported out of the watershed. The beef production in the Shenandoah Valley is mainly in non-confined areas of pasture and forestlands. Dairy cattle production is usually in confined areas.

As part of the NAWQA program, the USGS (2) assessed the water quality of the Lower Susquehanna River Basin. One of their findings was *"**Manure-application rate may be the most important factor controlling nitrate concentrations in agriculture basins underlain by limestone**."*

Their data suggest that increasing the application rate from 100 to 200 lbs/acre/year would increase the riverine nitrate concentration from 5 to 10 mg/l. The Antietam, Conococheague, and Monocacy are very similar to those of the Lower Susquehanna River Basin.

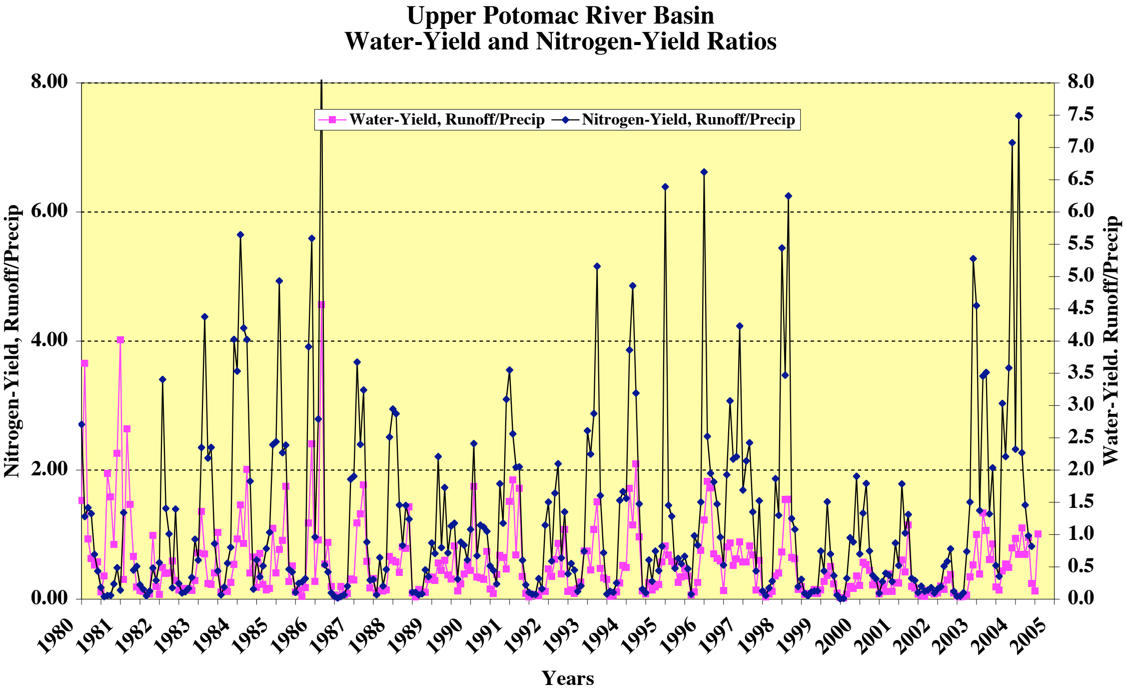
Cover Crops, Buffers, and Wetland Restoration

In a recent article in the *BAY JOURNAL* (3), the use of cover crops, buffers, and wetland restoration was presented as one approach to reducing nutrient export from the landscape loads.

It was estimated that if the potential 2.8 million acres of cropland in the Chesapeake Bay Watershed had cover crops, it would result in about a quarter of the 100 million pounds (25,000,000 lbs) of required annual nitrogen reductions.

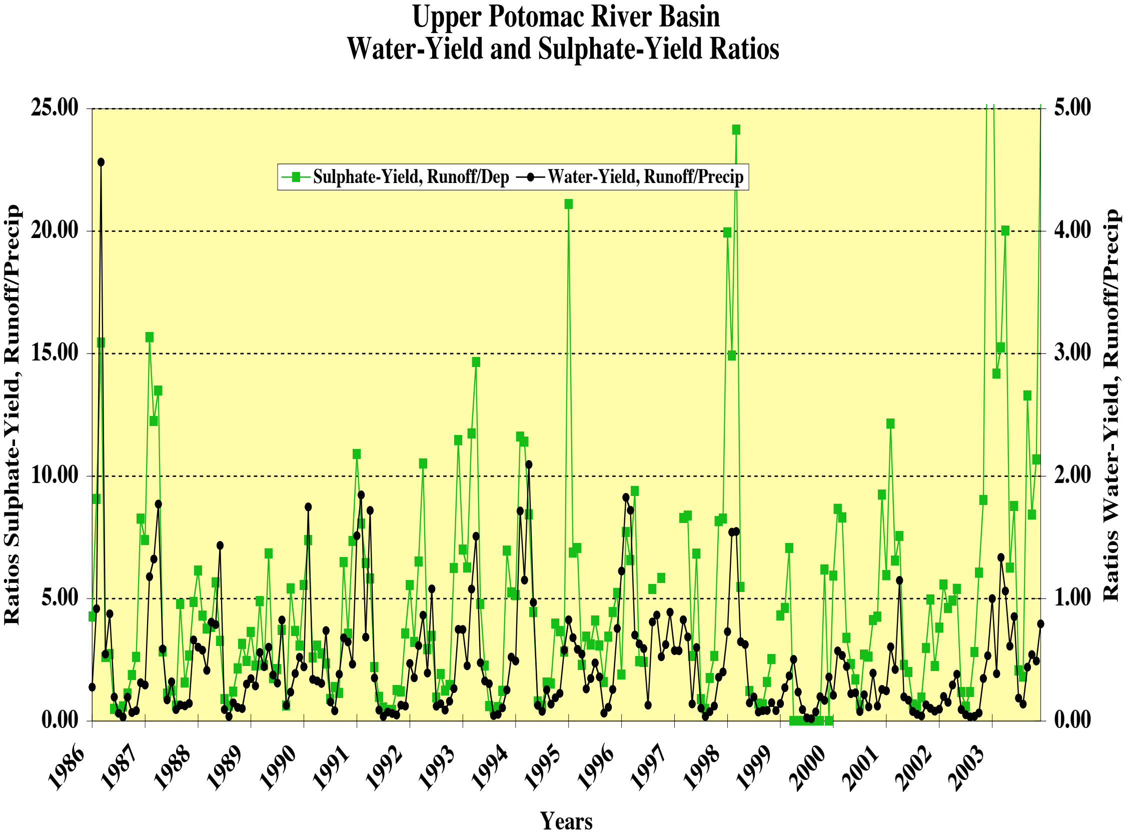
This is about a 400 kg/km^2/yr reduction for the 2.8 million acres. The landscape load from air deposition alone is about 900-1,000 kg/km^2/year (75,000,000 lbs/yr) for the entire Potomac River Basin watershed.

In Chapter Five, we showed that during the first five months of the year large pulses of nitrates enter the Upper Estuary from the Upper Basin. To examine how and when nitrates are exported out of the Upper Basin, we looked at the monthly water-yield ratios and the monthly nitrogen-yield ratios of the Upper Basin. The high nitrogen-yield ratios were associated with the high water-yield ratio, as presented below. These high water-yield ratios occur in the cold, nongrowing months. Even though summer precipitation is usually higher than other seasons, evaporation-transpiration is also the highest. The nitrogen-yield ratios over 1.0 are months where other landscape nitrogen sources are greater than air deposition.



For sulfur, the sulphate-yield ratios are even higher than the nitrogen-yield ratios, as presented below. This suggests that most of the sulphates are geological in origin. For the Upper Basin, about 21% of the SO_4 riverine export is from air deposition. Nevertheless, the amount and timing of nitrate and sulphate export is a function of water-yield dynamics. High water-yield periods during the nongrowing months facilitate the export of nutrients from the landscape to the river.

The cost, effectiveness, and high nitrogen-yield ratios during nongrowing months may not make cover crops the "**Silver Bullet,**" as indicated in the *BAY JOURNAL* article.

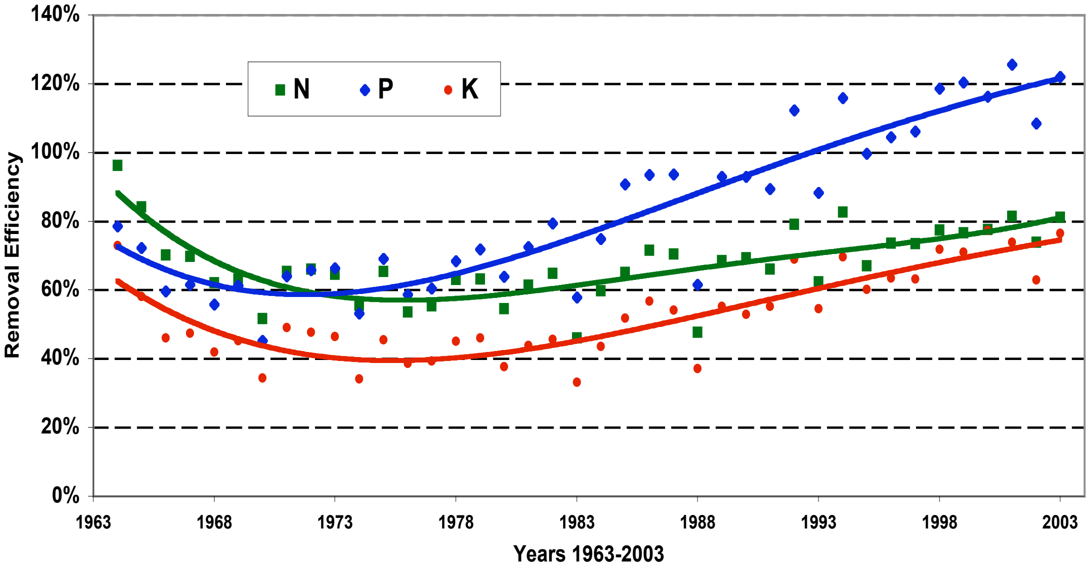


Efficient Use of Commercial and Animal Fertilizers

In the Upper Basin, there is an excess amount of nutrients, mainly from commercial fertilizers and animal waste used for plant production. With over half of animal nutrient requirements imported into the Upper Basin, animal fertilizer management along with efficient use of commercial fertilizer is a critical factor in reducing riverine TN export.

A recent summary in *BETTER CROPS* (4) suggests that nutrient efficiency is influenced by long-term dynamics of the soil's organic matter. It defined the recovery-efficiency ratio as the amount of nutrients in the crop divided by the amount applied or available. For corn, it found that the nitrogen in above ground plant biomass contains, on the average, only 37% of the fertilizer applied.

The summary also included recent data for producer-managed cornfields, as presented below.



Grain Nutrient Removal
as Percent of Fertilizer Applied on Corn

Source: PPI, *BETTER CROPS*

The upward removal efficiency trends, especially for nitrogen, are very encouraging, as shown above. In the early 1960s, the nitrogen removal efficiency was about 60%. In the 1990s, the nitrogen removal efficiency increased to over 100%. This suggests that the corn is also removing some of the nitrogen from the organic matter in the soil.

With the proper blend of commercial fertilizer and animal waste, which is high in organic matter, there is **HOPE** that the amount of nitrogen in riverine export from the use of fertilizers and animal waste can be reduced

References for Appendix A

1. Alliance for the Chesapeake Bay, (2005), Chesapeake Cleanup Update*, BAY JOURNAL*, Volume 15, Number 1, Baltimore, MD, pp 11-22.

2. Lindsey, B.D*., et al*, (1998), Water Quality in the Lower Susquehanna River Basin, Pennsylvania and Maryland, 1992-95, USGS Circular 1168, pp 38.

3. Blankenship, Karl, (2004), Off-season Crops Able to Soak Up Loads of Nutrients, Alliance for the Chesapeake Bay*, BAY JOURNAL,* Volume 14, Number 5, Baltimore, MD, pp 1-17.

4. Bruulsema, T.W., *et al*, (2004), Fertilizer Nutrient Recovery in Sustainable Cropping Systems*, BETTER CROPS,* Vol. LXXXVIII (88), No. 1, pp 15-17.

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