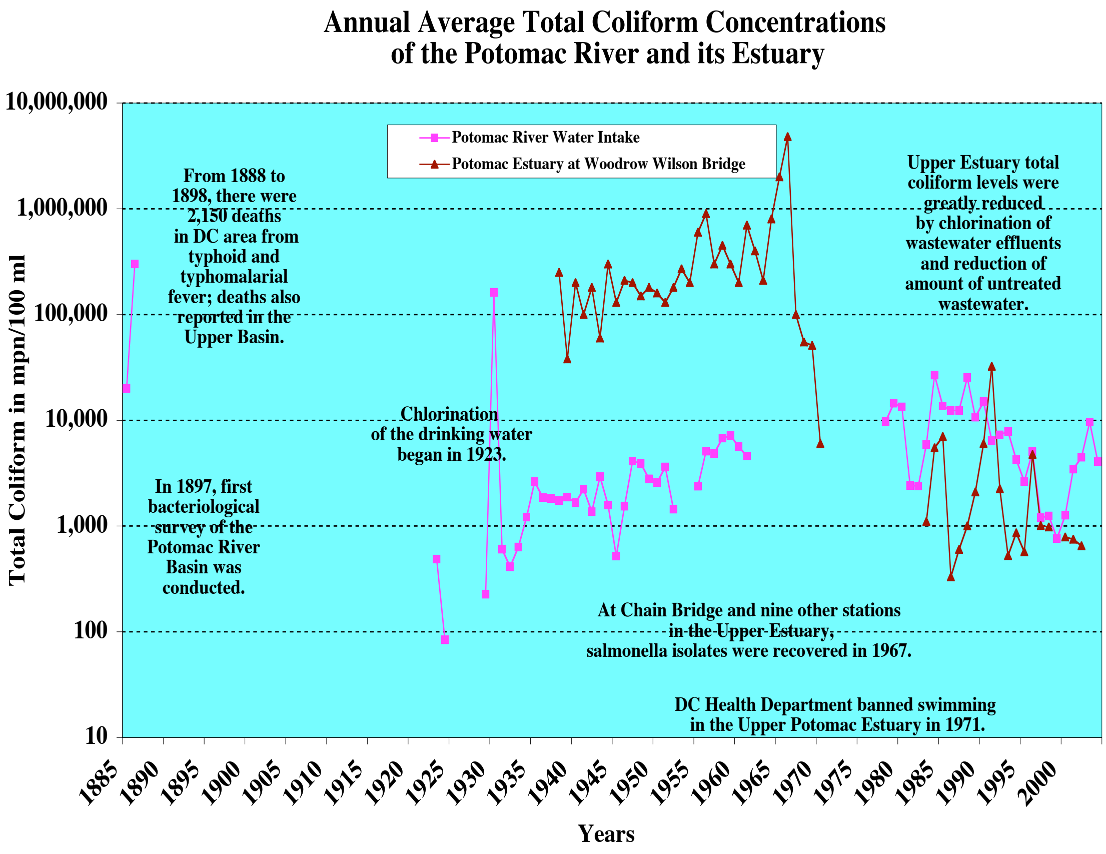
Chapter Nine: A Summary of How and Why the Water Quality of the Potomac River and its Estuary Has Changed During the Past 100 Years

Bacteriological Conditions in the Potomac River and Upper Estuary (in Chapters Two and Six)

In the late 1880s and1890s, the water supplies (mainly wells and springs) in the District of Columbia and many other communities of the Upper Basin were grossly contaminated (see below).



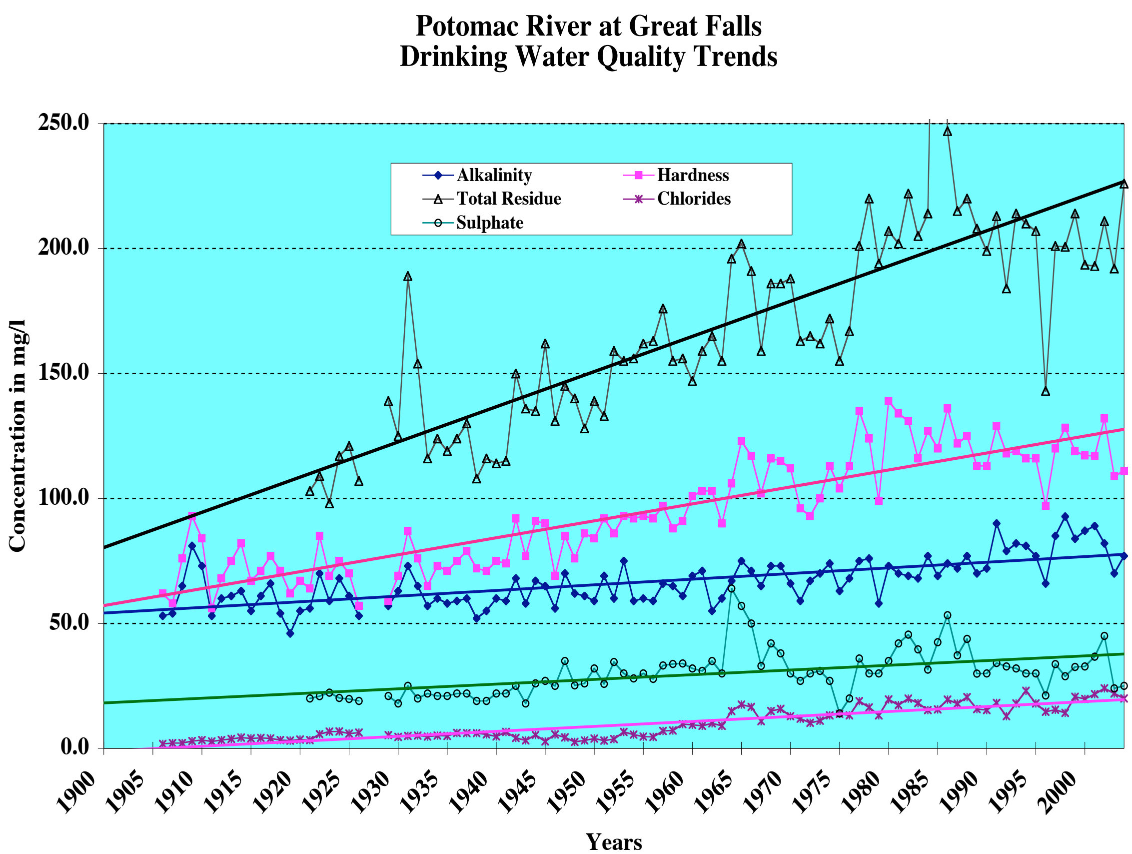
In the early 1900s, the contaminated wells and springs were closed and the Potomac River above the District of Columbia became the city's major source of drinking water. Initially, slow sand filtration was provided and later upgraded to rapid sand filtration. Chlorination of treated drinking water was added in 1923.

Routine bacteriological monitoring of the Upper Estuary began in the late 1930s. Beginning in the early 1970s, the bacteriological quality of the Upper Estuary improved dramatically as a result of chlorination of wastewater effluents and reduction in the amount of untreated wastewater discharge.

In the 1990s, the bacteriological quality of the Upper Estuary at the Woodrow Wilson Bridge Station was often better than at Great Falls. The bacteriological quality of the Potomac River at Great Falls improved in the 1990s, but coliform levels increased in the early 2000s.

Chemical Quality of the Drinking Water at Great Falls (in Chapter Two)

Using five general indicators of the chemical quality of the "untreated" drinking water, the increase in three of them—total residue, hardness, and chlorides—has been significant over the past 80 years (see below).

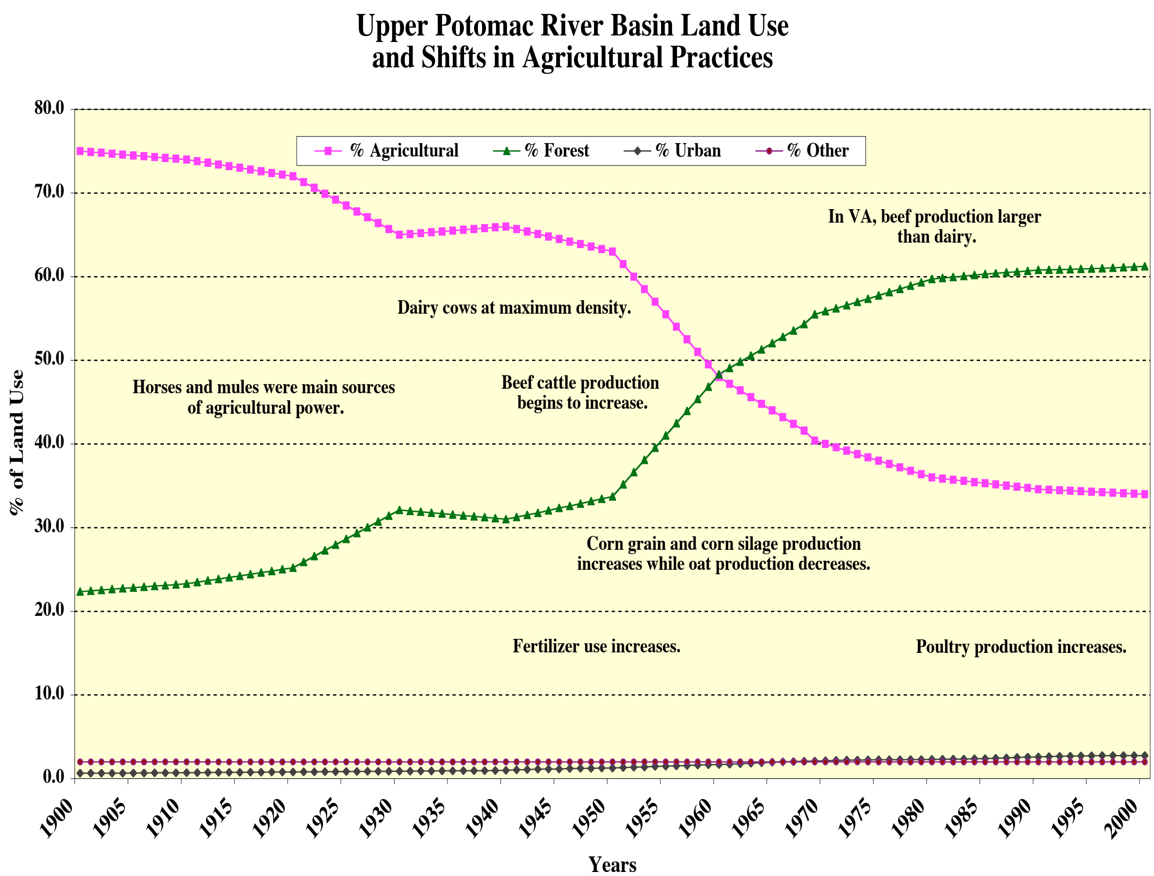


The total residue, hardness, alkalinity, and sulphate levels have about doubled in the past 80 years. Chloride concentration has increased by a factor of 10, from 2.0 to over 20.0

mg/l. These increases were caused mainly by the increasing use of fertilizer, liming of agricultural land, and deicing of roads.

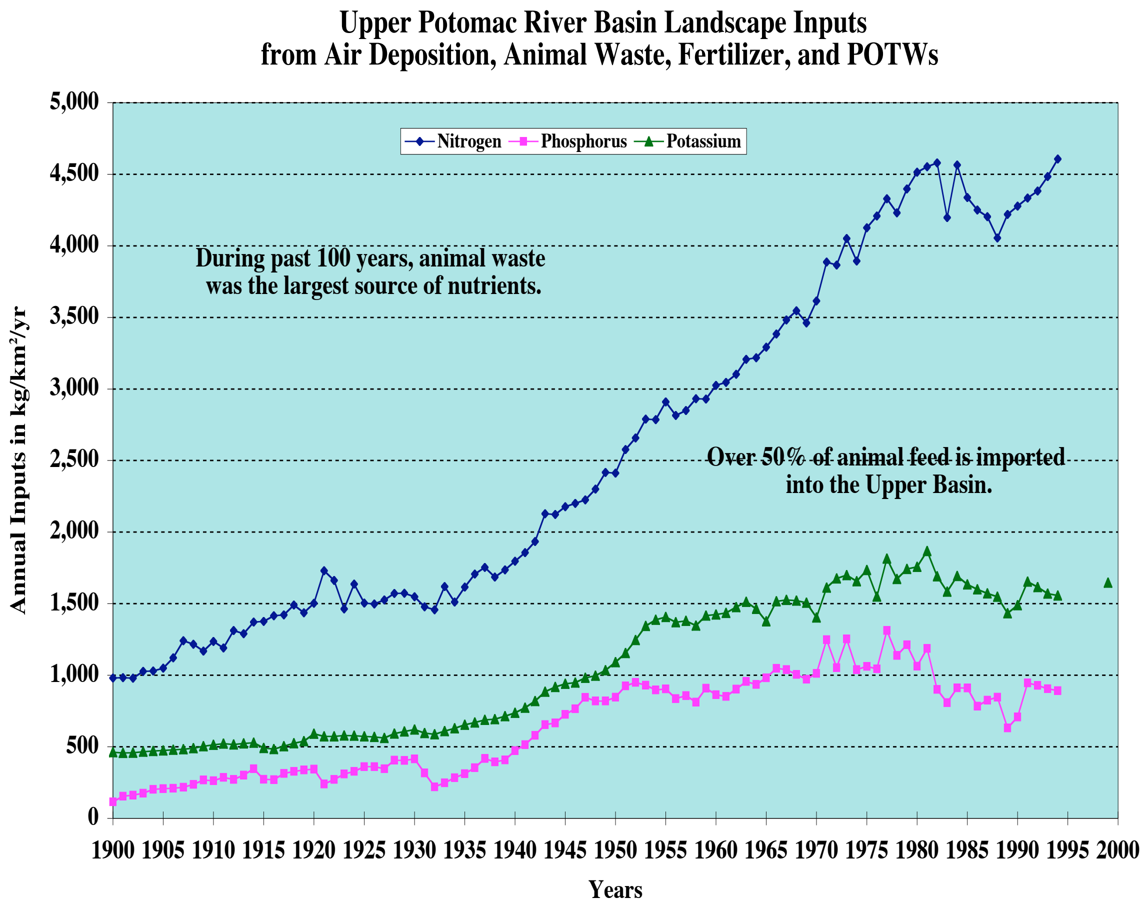
Land Use and Nutrient Loading Trends for the Upper Basin (in Chapters Three and Four)

In the early 1900s, agriculture was the major land use of the Upper Basin, comprising about 75% of total use (see below). In the 1990s, agriculture use had decreased to about 35% of total use with forestlands increasing to about 60%.



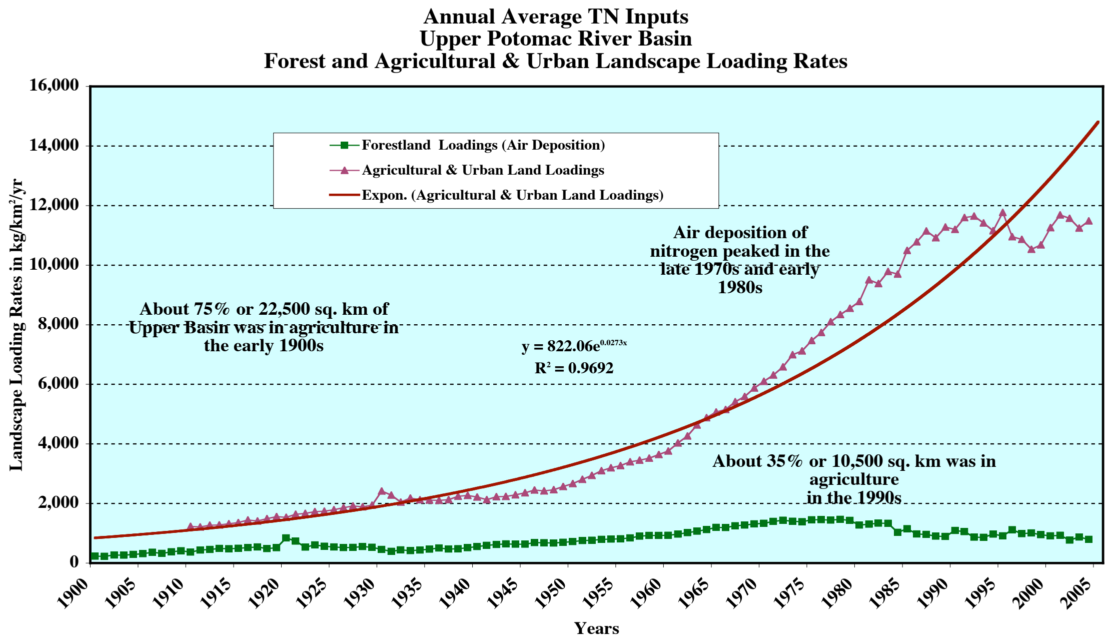
As can be seen above, there have been some major shifts in animal production practices, such as beef production increases in Virginia and large increases in poultry production in Virginia and West Virginia. In Pennsylvania and Maryland, the number of dairy cows reached maximum densities in the 1960s. Responding to these changes in animal production, crop production also changed, as shown in the notes in the chart above. See Chapter Three for details.

The landscape TN, TP, and K inputs from air deposition, POTWs, fertilizer, and animal waste have increased over the past 100 years, as shown below.



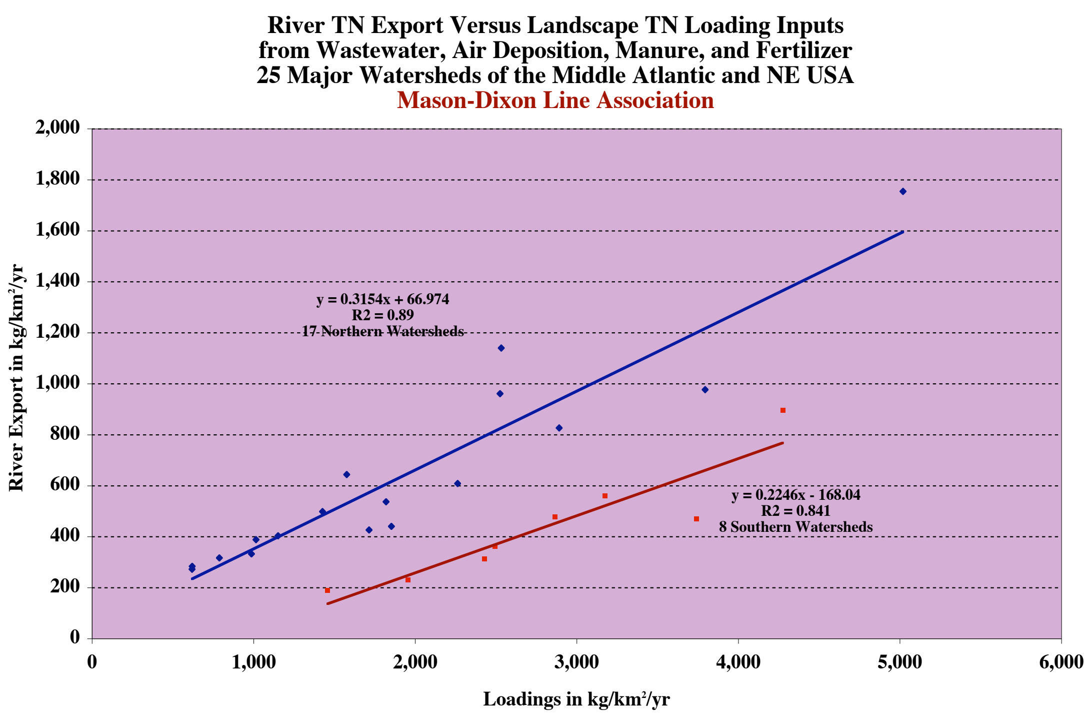
The major source of landscape nutrient inputs was from animal waste, with about 50% of the animal feed needs imported into the Upper Basin (see above). As stated in Chapter Four, about 19% of the 4,500 kg/km^2/yr of TN landscape inputs are exported out of the Upper Basin, or about 855 kg/km^2/yr. Currently, about 5% to 6% of the 900 kg/km^2/yr of TP landscape inputs are exported out of the Upper Basin, or about 45 kg/km^2/yr.

Agricultural land use has decreased and TN landscape inputs have increased over the past 100 years, as shown in the two charts above. The TN loading rate in kg/km^2/yr (over 1,000 in the early1900s) has grown **exponentially, by a factor of 10**, to over 10,000 kg/km^2/yr for agricultural and urban land uses in the late 1990s (see below).

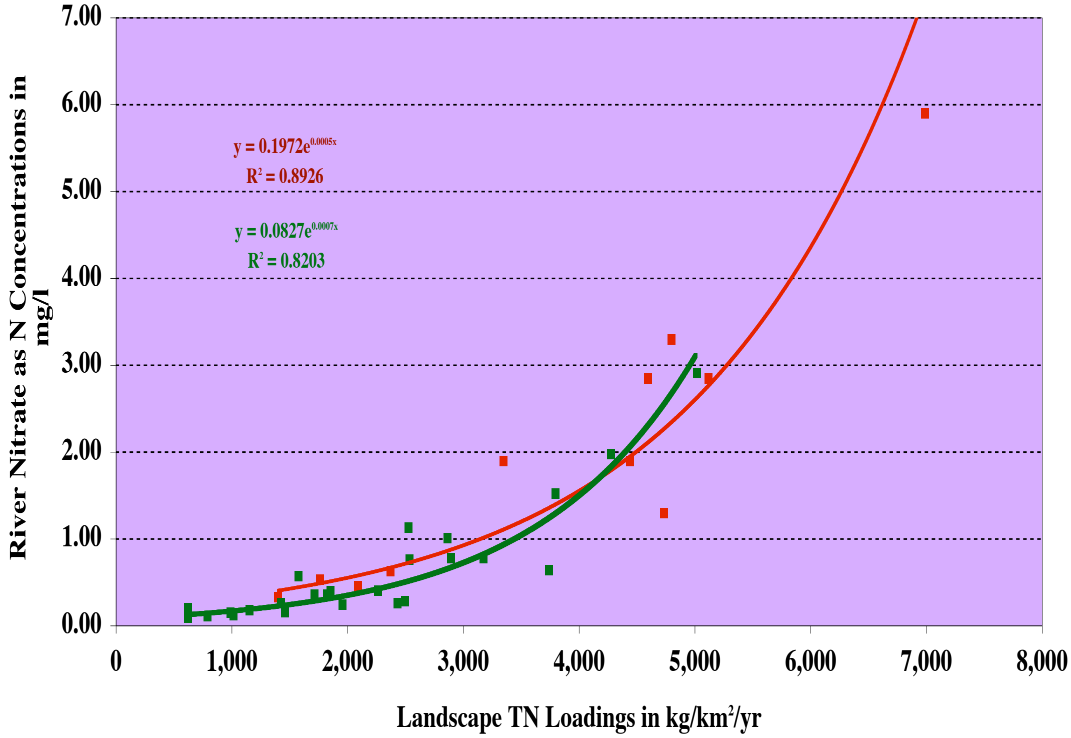


Relationships Between Nutrient Landscape Loading Inputs Versus Riverine Export Fluxes and Nutrient Landscape Loading Inputs Versus Riverine Nitrate Concentrations (in Chapter Four)

We developed and applied two models that relate (1) riverine export fluxes to landscape loading inputs, and (2) riverine nitrate concentrations to landscape loadings (see below for nitrogen)**.**



River Nitrate Concentrations Versus Landscape TN Loading Inputs
25 Major Watersheds of the Middle Atlantic and NE USA (GREEN)
Upper Potomac River Basin and its Eight Major Sub-basins
Plus Two Susquehanna Watersheds (RED)
1990-1994



The two TN landscape inputs/riverine export linear relations are very strongly correlated and had slopes of 0.31 for the northern and 0.22 for the southern watersheds (see above). Upon further examination, the Mason-Dixon Line separation or "stratification" was due to the amount of watershed runoff. See Chapter Six for details.

We also examined the possibility of whether the relationships were exponential. The nitrate riverine concentration versus landscape loading inputs relationship appears to be exponential (see above). The exponential relationship appears to be a better general model than a linear model and can also be used to estimate the riverine nitrate concentration response to landscape loading input changes. We also applied both models to the 42 sub-basins of the Mississippi River watershed.

Allocations of Landscape TN Loading Inputs to Riverine Export (in Chapter Four)

Expanding on the landscape loading inputs and riverine export analysis presented in Chapter Four, we estimated what the allocations of landscape TN loading inputs to riverine export were for the 1990s and early 2000s, as presented below.

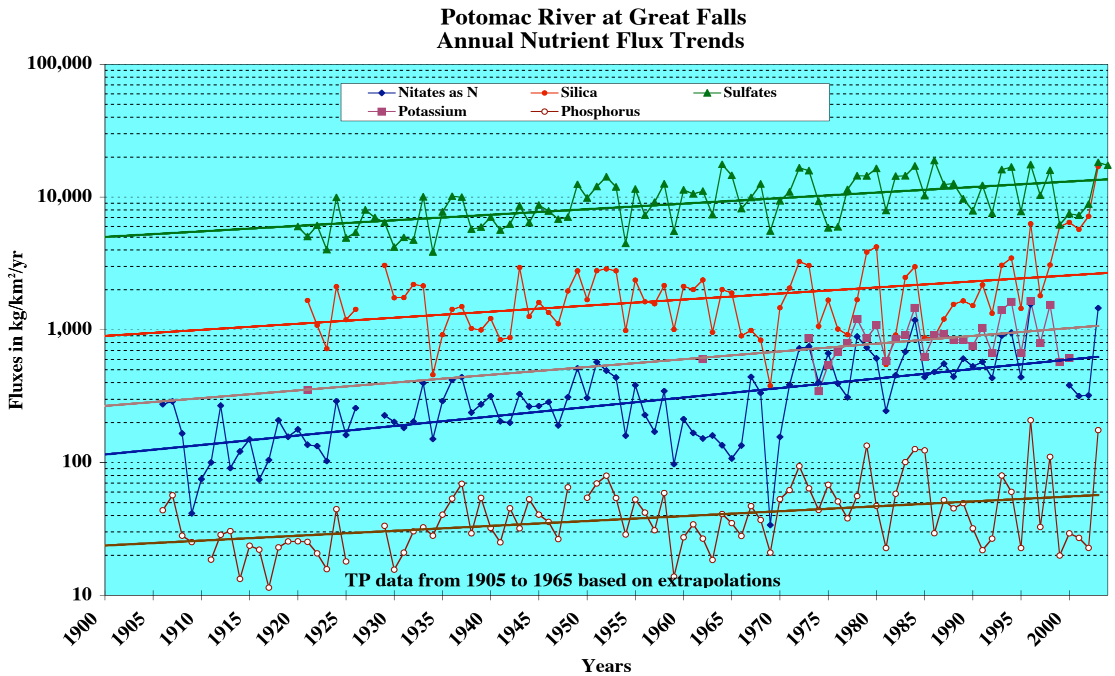
For the agricultural and urban source area of 10,000 km^2, we used a landscape load of 11,000 $kg/km^2/yr$ with a 19% export rate. For the air deposition source area of 29,940 km^2 (the entire area of the Upper Basin), we used a landscape load of 1,000 $kg/km^2/yr$ with a 19% export rate. Riverine export = loading rate **X** (times) area **X** % export, as presented below.

Source		Loading Rate		Area		% Export	Riverine Export
Agriculture & Urban	=	11,000 $kg/km^2/yr$	**X**	10,500 km^2	**X**	19%	= 21,845,000 kg/yr
Air Deposition	=	1,000 $kg/km^2/yr$	**X**	29,940 km^2	**X**	19%	= 5,686,000 kg/yr
Total Estimated Export							= **26,621,000 kg/yr**
Measured Export	=	855 $kg/km^2/yr$	**X**	29,940 km^2			= **25,600,000 kg/yr**

About 21%, or 5,686,000 kg/yr, of the total landscape allocation of inputs (26,621,000 kg/yr) was from air deposition on the entire Upper Basin, while 79%, or 21,845,000 kg/yr, was from agriculture and urban areas. The total estimated export (**26,621,000 kg/yr**) is just slightly higher than the average measured river export (**25,600,000 kg/yr**).

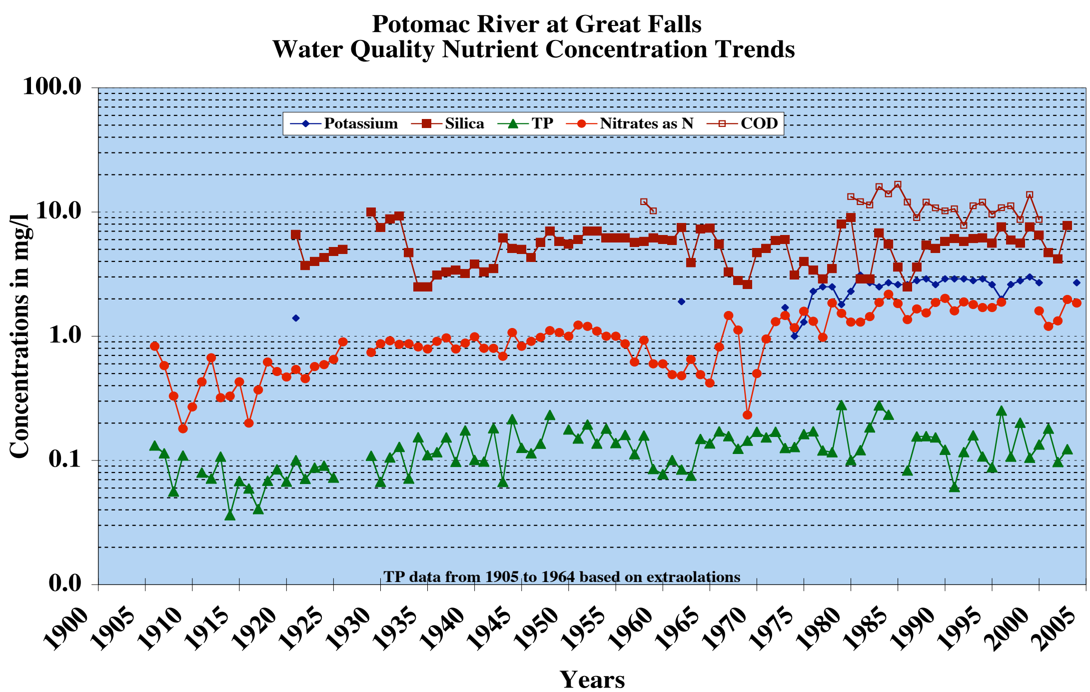
Upper Basin Riverine Nutrient Export and Water Quality Trends (in Chapters Two, Four, and Five)

The trends in nutrient riverine export fluxes for the Potomac River from 1905 to 1965 are based on drinking water data, except for TP (see note in chart) and are presented below.



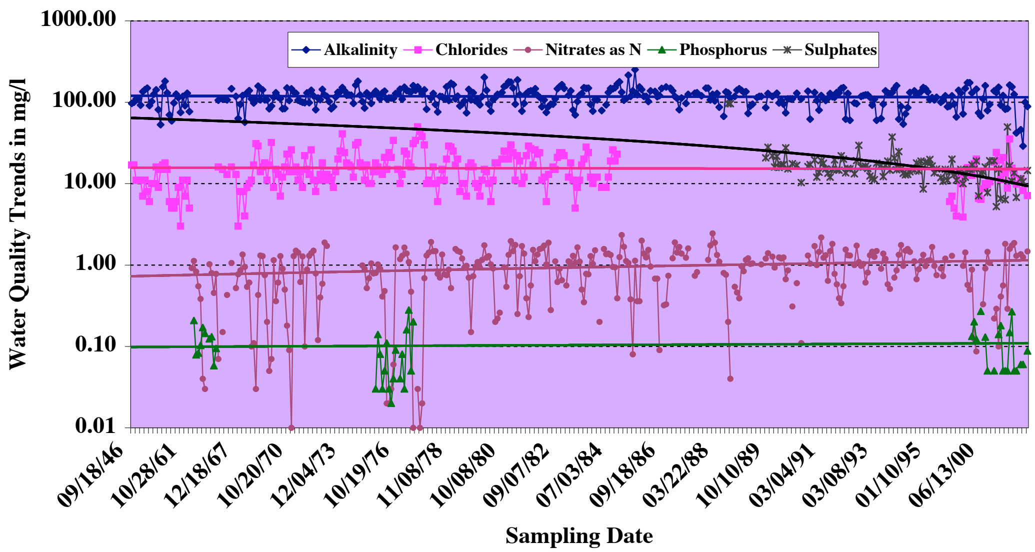
All the Upper Potomac River export fluxes for all five nutrients have increased **logarithmically**—about a factor of 2 to 3—over the past 80 to 95 years. These increases have been mainly due to agricultural practices and, to a lesser extent, to air deposition.

The nutrient concentration trends for the Upper Basin above Great Falls are presented below. The TP data from 1965 to 2005 are from the EPA and USGS monitoring programs, while the TP data from 1905 to 1964 are extrapolations, as presented in Chapter 2.

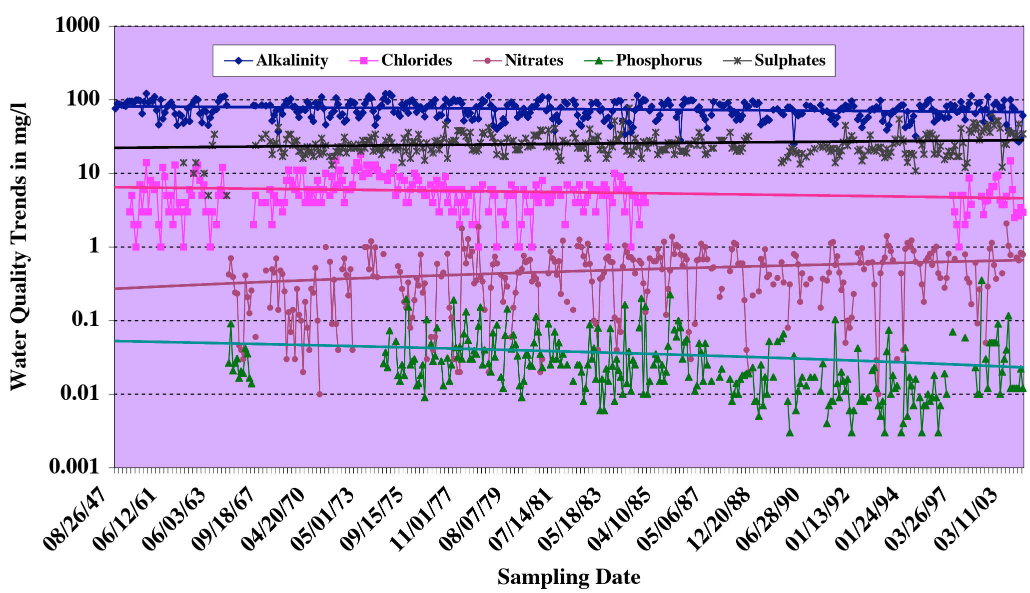


The phosphorus, nitrate, and potassium concentrations have increased l**ogarithmically**, while the silica and Chemical Oxygen Demand (COD) concentrations have not changed (see above). The water quality trends for the Shenandoah and South Branch sub-basins are presented below.

Water Quality Trends for Shenandoah River

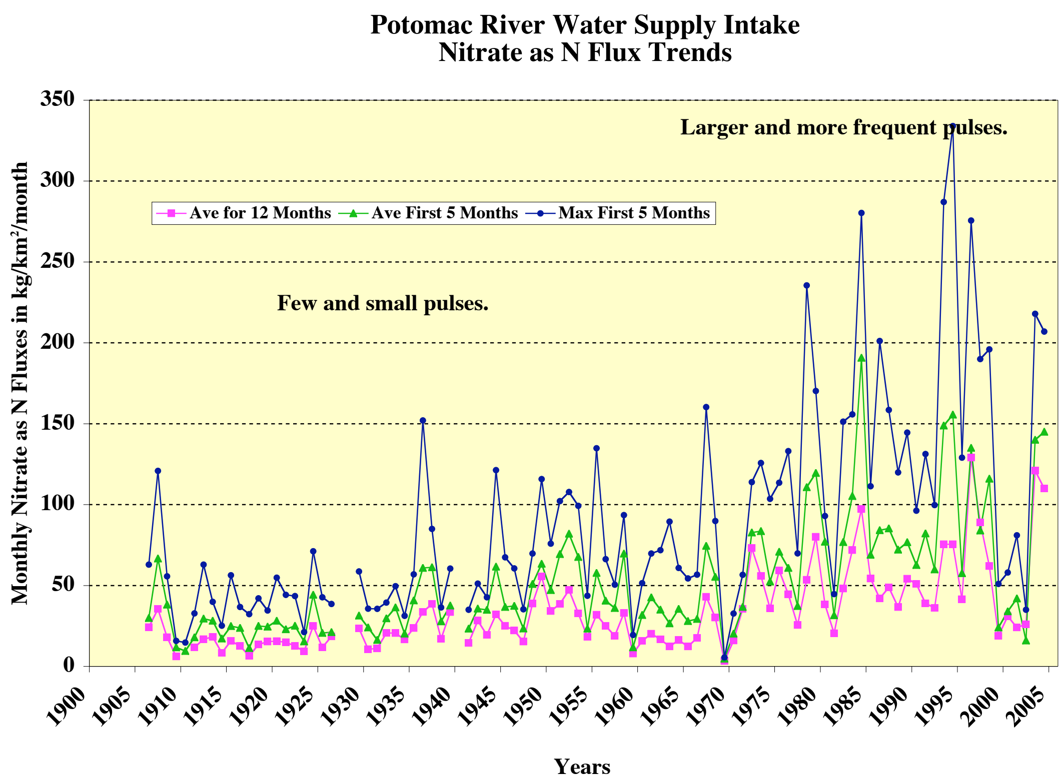


Water Quality Trends for South Branch Potomac



For both sub-basins, there were large increases in nitrates, as presented above. Other stations are presented in Chapter Four.

The average annual NO_3 exported from the Upper Basin has more than doubled for the period 1905 to 2004, increasing from a mean monthly load of about 20 kg/km^2/month to over 50 kg/km^2/month (see below).

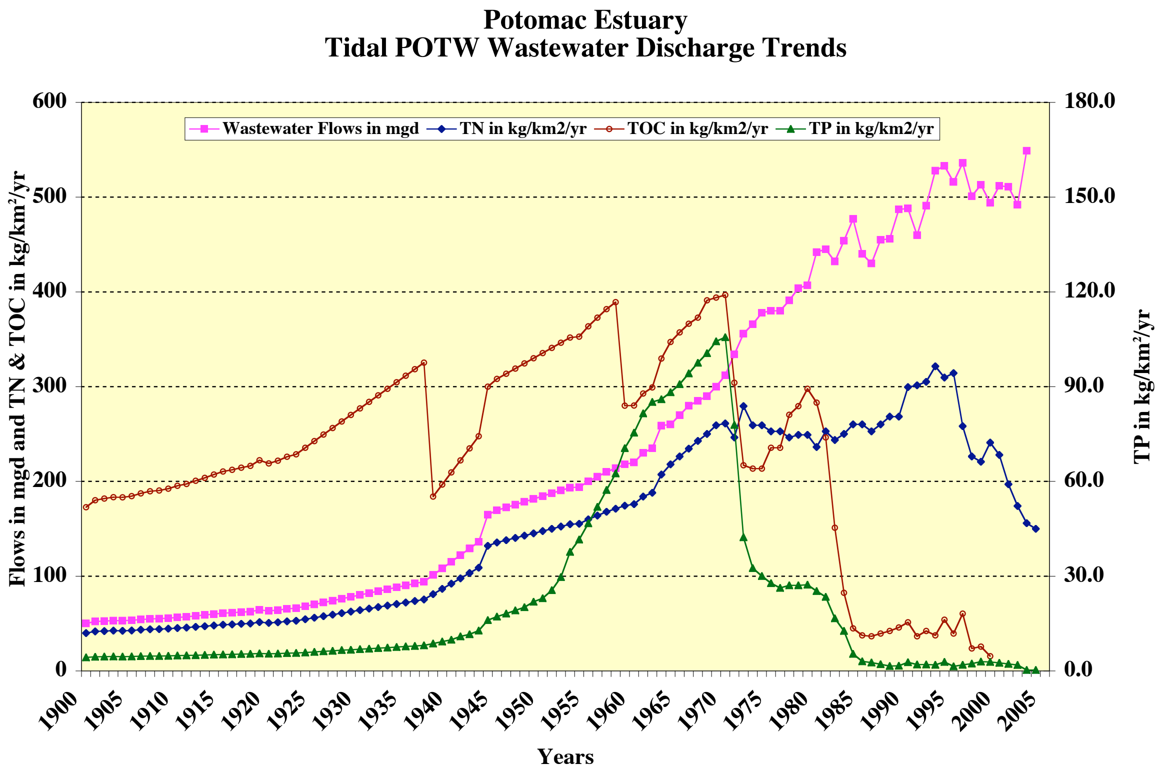


As a result of the greater number of high-flow months and increased loading of nitrogen to the landscape (see above), spring pulses for the first five months have increased in intensity and frequency. Prior to the 1950s, there were only five years in which the Upper Basin maximum monthly loading for the first five months of the calendar year was over 100 kg/km^2/month.

From 1950 to 2004, there were 28 years in which the Upper Basin maximum monthly loading for the first five months of the calendar year was over 100 kg/km^2/month. Twenty-six years had a maximum monthly load of less than 100 kg/km^2/month. **The spring pulses have increased in intensity and frequency during the past +50 years, responding to the exponential increase in agricultural landscape loadings and higher river flows.**

POTWs Discharging to Tidal Waters (in Chapter Five)

The flow of the tidal discharges has increased from 50 mgd in the 1900s to over 500 mgd in the early 2000s, as shown below.

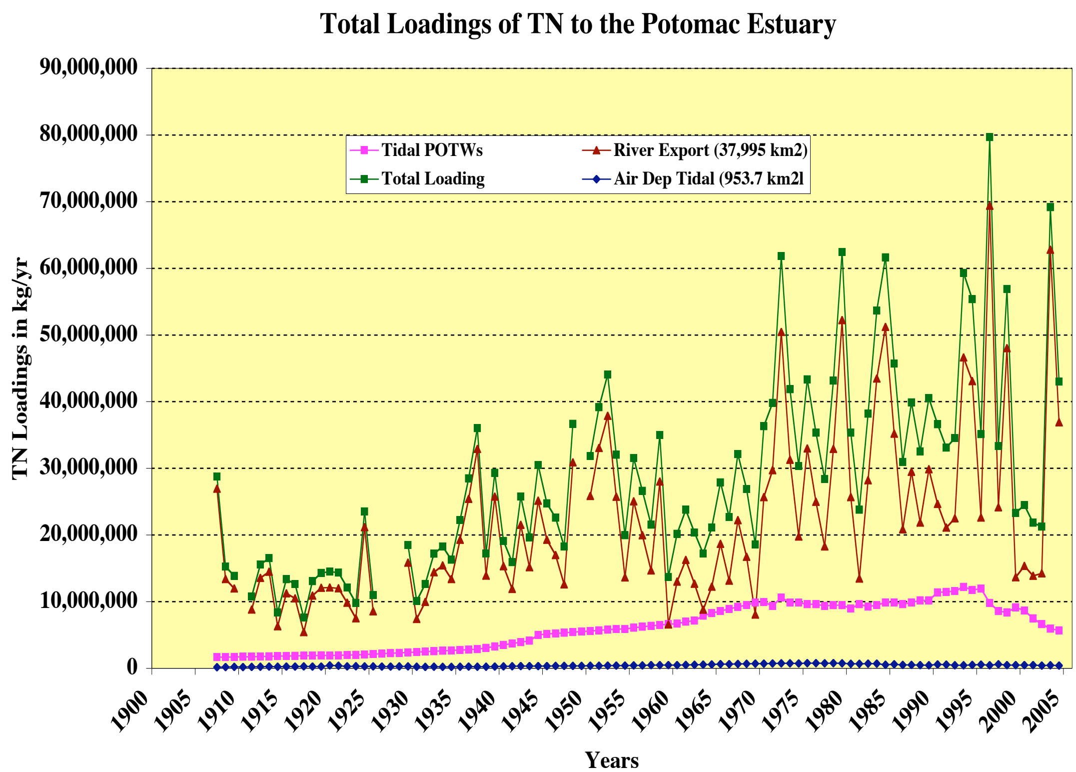


The large increase in TP fluxes, beginning in the late 1940s to over 100 kg/km^2/yr, was due to phosphorus being added to soaps and detergents (see above). The maximum TN fluxes were in the early 1990s (just over 300 kg/km^2/yr) and have since decreased to about 150 kg/km^2/yr, due primarily to nitrogen removal at the POTWs discharging into tidal waters.

Total Loadings of TN and TP to the Entire Potomac Estuary (in Chapter Five)

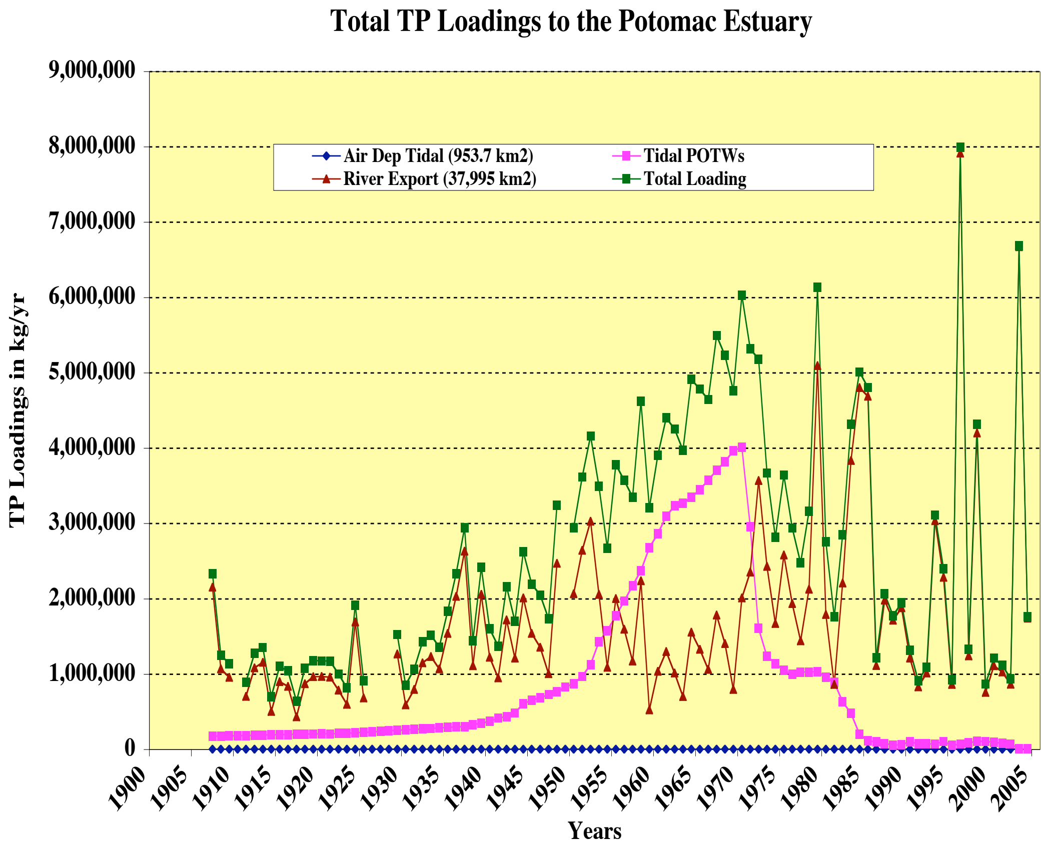
For the period from 1905 to 2000, estimates were made of TN, TOC, and TP loadings to the entire Potomac Estuary. Except for TOC, the estimates include inputs from direct air deposition on the tidal waters, from direct tidal POTWs, and from riverine export of the entire 37,995 km^2 drainage basin. No long-term estimates of inputs from the Chesapeake Bay to the Lower Estuary were available.

The total TN loadings to the entire Potomac Estuary have increased from about 13,674,000 kg/yr in the late 1900-1910, to a high of about 43,159,000 kg/yr in the 1980-2000s (see below).



Except during the four-year drought of late 1998 through 2002, the total TN loading to the Potomac Estuary increased by 215% over the past 100 years. The riverine exports from the Upper and Lower Basins were the major source of the total TN loading. The TN loadings from the tidal POTW discharges have decreased by about 50% since the mid-1990s to about 5,000,000 kg/yr, as seen above.

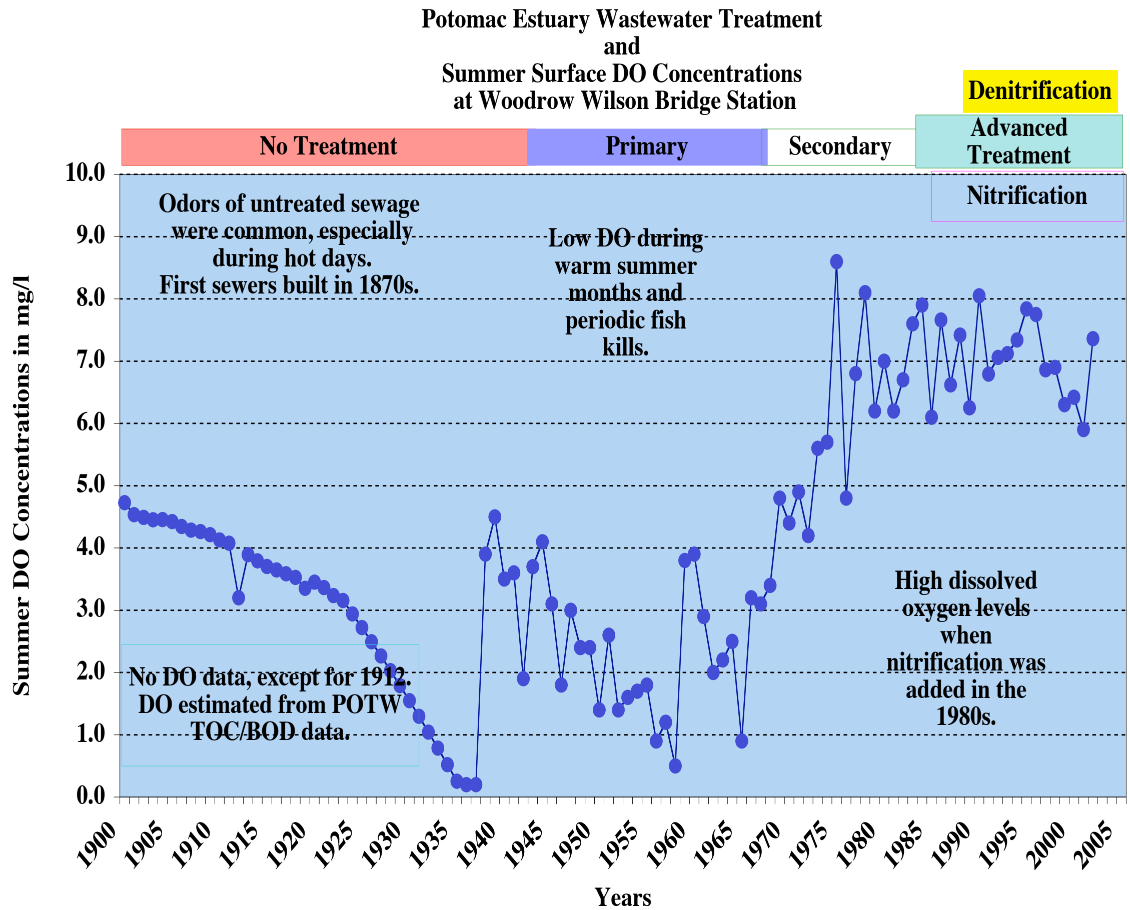
The total TP loadings to the entire Potomac Estuary have increased from about 1,111,000 kg/yr in the late 1900-1910s, to a high of 6,000,000 kg/yr in the 1970s, and then decreased to about 2,500,000 kg/yr in the 1980-2000s (see below).



Except during the four-year drought of late 1998 through 2002, the total TP loading increased by 142% over the past 100 years. However, the large increase after World War II was due to phosphorus in soaps and detergents. The large decrease, in the 1970s and 1980s, was due to phosphorus removal at the tidal POTWs and to the reduction in phosphorus in wastewater caused by phosphorus detergent bans. The TP loadings from the tidal POTW discharges have decreased by over 98% since the mid-1960s. The riverine exports from the Upper and Lower Basins have become the major source of total TP loadings in recent years (see above).

Upper Potomac Estuary Wastewater Treatment and Summer Surface DO Concentrations (in Chapters Five and Six)

Construction of the first sewers in the DC area began in the 1870s. Untreated municipal wastewater was discharged directly into the Upper Estuary and its tributaries until the late 1930s, when the first primary treatment plant was built (see below). By the late 1930s, the DO levels were below 1.0 mg/l.

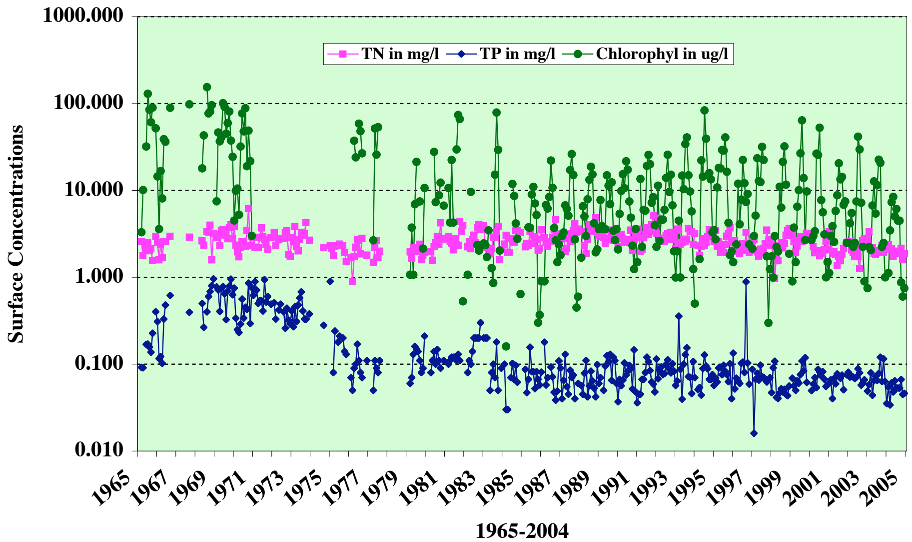


The rapid increase in wastewater flows and BOD after World War II continued into the late 1950s. During this time, the wastewater treatment capacity and the degree of BOD removal by the primary POTWs were exceeded. Secondary treatment, which was added in the late 1950s, was not adequate and DO levels dropped again below 1.0 mg/l (see above). It was not until advanced wastewater treatment, including nitrification, was added to the POTW treatment processes that DO levels approached 6.0 to 8.0 mg/l during the summer months.

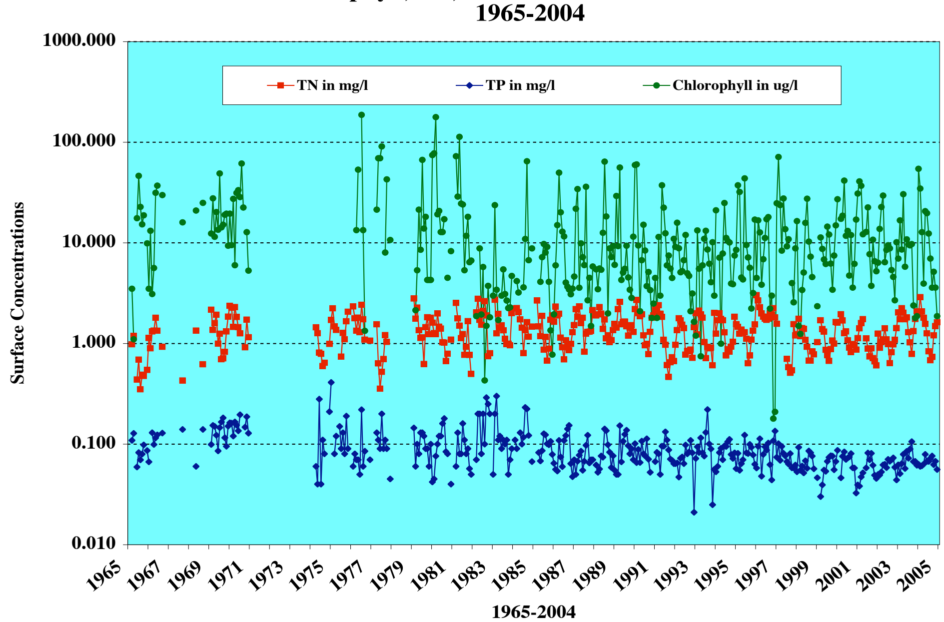
Nutrient and Chlorophyll Trends for the Potomac Estuary (in Chapters Six and Seven)

The TN, TP, and chlorophyll trends for the Upper Estuary at the Piscataway Station for the 1965-2005 time frame are presented below. The nutrient and chlorophyll trends for the Lower Estuary at the 301 Bridge Station are also presented below.

Potomac Estuary at Piscataway
Chlorophyll, TN, & TP Surface Concentrations
1965-2004



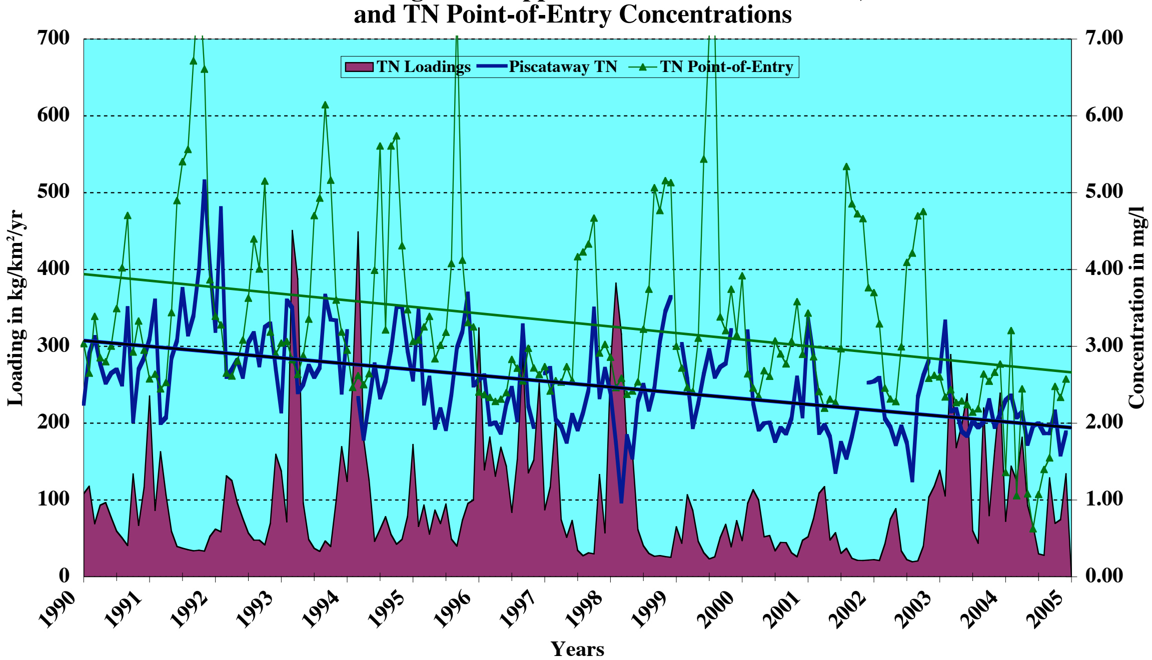
Potomac Estuary at 301 Bridge Station
Chlorophyll, TN, & TP Surface Concentrations
1965-2004



At both stations, there were significant reductions in TP and resulting reductions in chlorophyll levels. The TN concentrations were unchanged from 1965 to 1995 for the Piscataway Station, while there was a downward trend during the late 1990s and early 2000s, as presented above. For the 301 Bridge Station, the TN concentrations were unchanged from 1965 to 2005. Other stations and trends are presented in Chapter Six.

The Piscataway Station TN surface concentrations, the fall line TN concentrations, point-of-entry TN concentrations, and the sum of TN loadings from the Upper Basin and from direct POTW discharges for the period 1990 to 2004 are presented below.

Upper Potomac Estuary
TN Surface Concentrations at Piscataway,
TN Loadings from Upper Basin and Tidal POTWs,
and TN Point-of-Entry Concentrations



For the 15-year period from 1990 to 2004, the TN surface concentrations decreased by about 1.0 mg/l, while the point-of-entry TN concentrations decreased by 1.3 mg/l. In 2003 and 2004, there were large pulses of TN from the Upper Basin. The annual average TN concentration in the Potomac River above Washington, DC was 2.0 mg/l. The decreases in both TN surface and point-of-entry concentrations were due primarily to the addition of denitrification processes at the POTWs.

Maryland Department of Natural Resources Trend Analyses: 1985-2005 Time Frame (in Chapter Six)

The Maryland Department of Natural Resources performs trend analyses on water quality data that are collected on a monthly or bimonthly basis from monitoring stations along the main stem of the Potomac River and its Estuary. The most recent trends available are for the 1985-2005 time frame (see Chapter Six).

Total nitrogen concentrations dramatically decreased between 1985 and 2005 at and above the Route 301 Bridge Station in Morgantown, Maryland. Changes ranged from –43% at Piscataway to –17% at Route 301 Bridge. No trends were detected in total phosphorus in the 1985-2005 time frame.

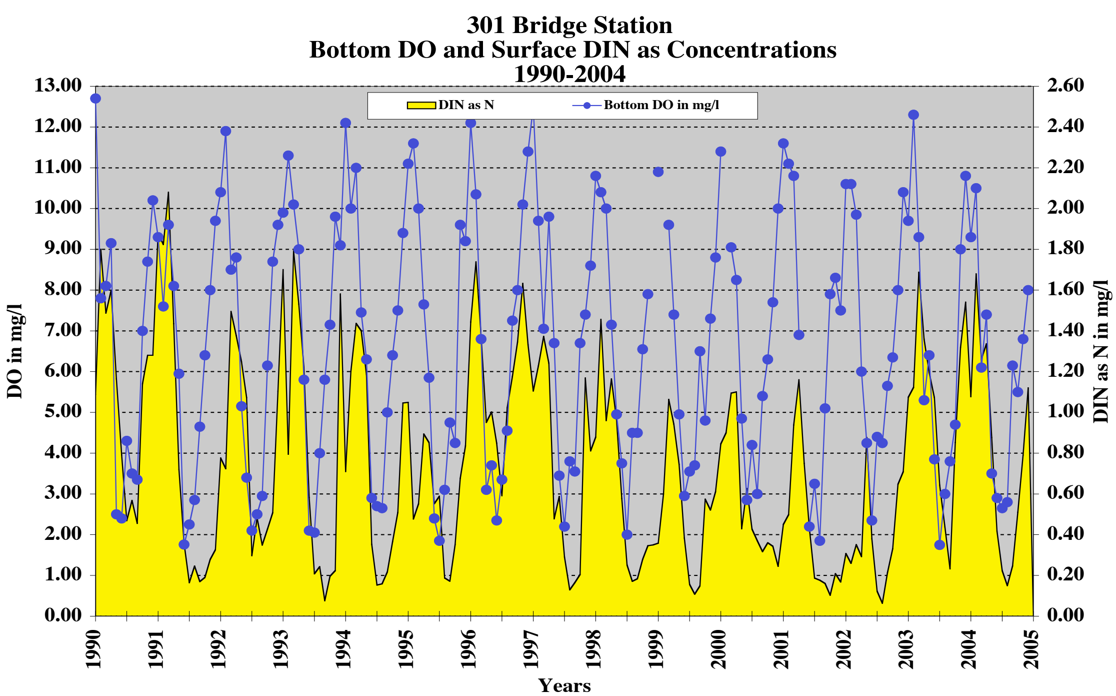
Only one significant trend was detected in chlorophyll-*a*—a 45% increase at the Route 301 Bridge Station. No trends in summer bottom layer dissolved oxygen were detected. Decreasing trends, which indicate degrading water quality, were detected in secchi depth readings at the Maryland Point (-21%), Route 301 Bridge (-22%), and Point Lookout (-26%) stations.

The recent Maryland DNR results are alarming, because they indicate continued degradation of water quality in the lower Potomac River despite efforts to make improvements through the implementation of best management practices. It appears that the only improvements in water quality in the 1985-2005 trend period were to total nitrogen in the Upper Estuary.

Nitrogen and Dissolved Oxygen Depletion and Replenishment (in Chapter Eight)

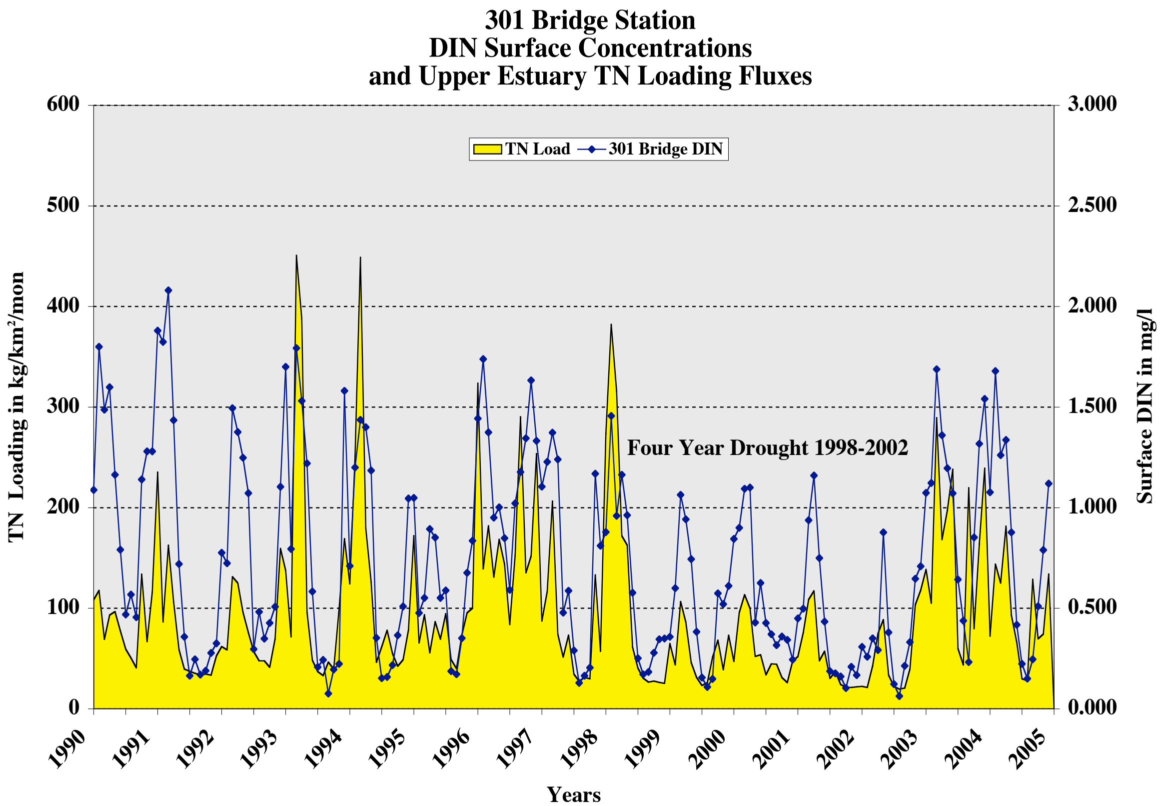
In Chapter Eight, we examined the nutrient and dissolved oxygen depletion and replenishment dynamics for the three stations of the Lower Estuary. In this section, we focus on nitrogen and the 301 Bridge Station.

The depletion of the surface DIN pool begins in February. The plankton assimilate the DIN pool from a concentration of over +1.0 mg/l downward to about 0.2 mg/l by June, as shown below.



At the 301 Bridge Station, the surface DIN pool was not completely depleted by mid-summer, while bottom water DO was usually about +2.0 mg/l. Even in a wet year, such as 1996, there was significant depletion of the surface DIN pool and bottom water DO, as presented above.

For a typical river flow year for the 301 Bridge Station, the depletion and replenishment of the DIN surface pool parallels the decrease and increase of TN loadings to the Upper Estuary, as also shown below.

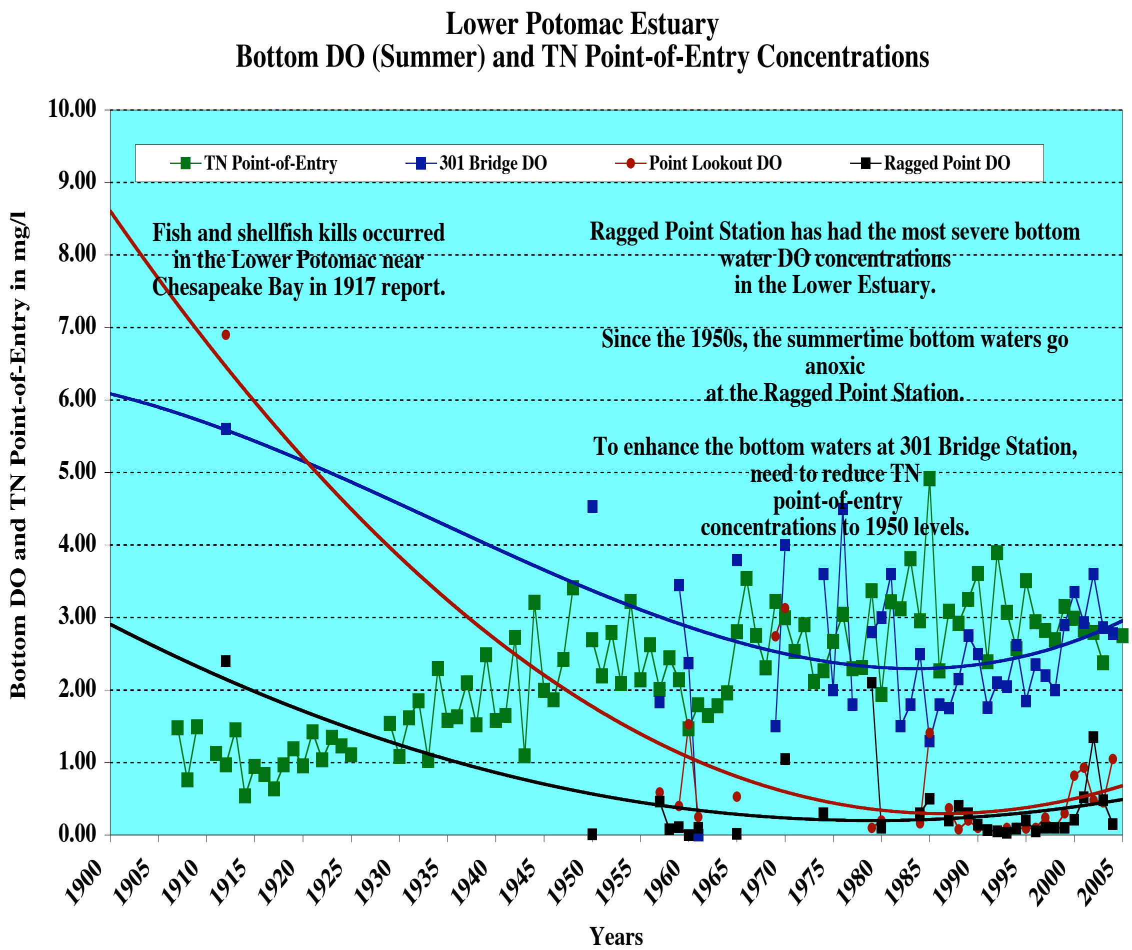


As the spring-early summer plankton blooms depleted the DIN pools, the TN loadings were also reduced (see above). Usually, the lowest Upper Estuary TN loading occurred in the summer months when the loadings from the Upper Basin were the lowest. While the depletion-replenishment of the DIN pool and the decrease-increase of the TN loading processes occurred at the same time, the two processes are independent.

The DIN surface pool usually has one annual peak, a spring peak replenished by Upper Basin spring runoff. The surface TP pool has two annual peaks: a spring peak replenished by Upper Basin spring runoff, and an even larger summer peak, replenished by the diffusion of phosphorus from the anoxic bottom waters and the sediments. In a typical year, the surface silica concentrations have two distinct annual peaks: the spring peak, replenished from riverine export, and the summer peak, replenished during the anoxic period. See Chapter Eight for more details.

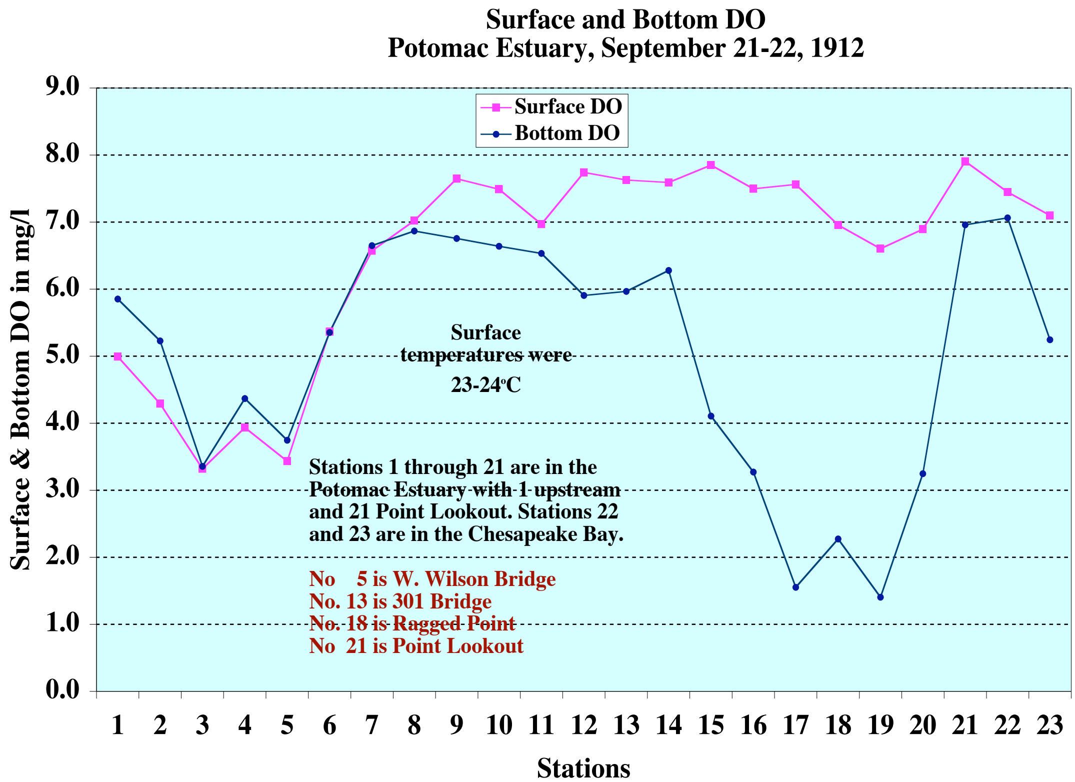
Low DO Concentrations in the Bottom Waters of the Lower Estuary (in Chapters Six and Seven)

The bottom water DO concentrations and TN point-of-entry concentrations for three sampling stations of the Lower Estuary are presented below.



Since the 1950s, the bottom waters at the Ragged Point and Point Lookout stations were anoxic, around 1.0 mg/l and less during the summer months (see above). At the 301 Bridge Station, the bottom waters were hypoxic, usually between 2.0 and 3.0 mg/l.

To get a better understanding as to why the bottom waters are so low in DO, one also needs to look at the 1912 survey, as presented in Chapter Six and also below.



As presented earlier in Chapter Four, the TP point-of-entry concentrations have been dramatically reduced from 0.606 mg/l in the 1960s to 0.150 mg/l (a 75% reduction) by the early 2000s. The surface TP concentrations were reduced from 30% to 60% at all stations. There was also a reduction in spring chlorophyll levels at all stations**. However, there was no major increase in bottom DO concentrations in the Lower Estuary as a result of the 75% decrease in TP point-of-entry concentrations.**

In 1912, the annual average point-of-entry concentration for TN was about 1.0 mg/l, while TP was about 0.1 mg/l. There were sufficient nutrients to cause the bottom water DO in the three stations in the Ragged Point area to be hypoxic—about 2.0 mg/l in mid-late September. In a May 9, 1912 survey, the bottom water DO at Ragged Point was at 78% saturation or 6.1 mg/l. The low DO in the bottom waters in the Ragged Point area in September 1912 appears to be a **natural occurrence**.

It is important to note that the 1912 DO survey was in response to reports of fish and shellfish mortality occurring at the mouth of the Potomac Estuary and other rivers flowing into the Chesapeake Bay, as well as in other tidal waters. It is also important to note that in the 1910s, there were no major power plants, pesticides, commercial fertilizers, chemical plants, etc. in the Potomac Basin.

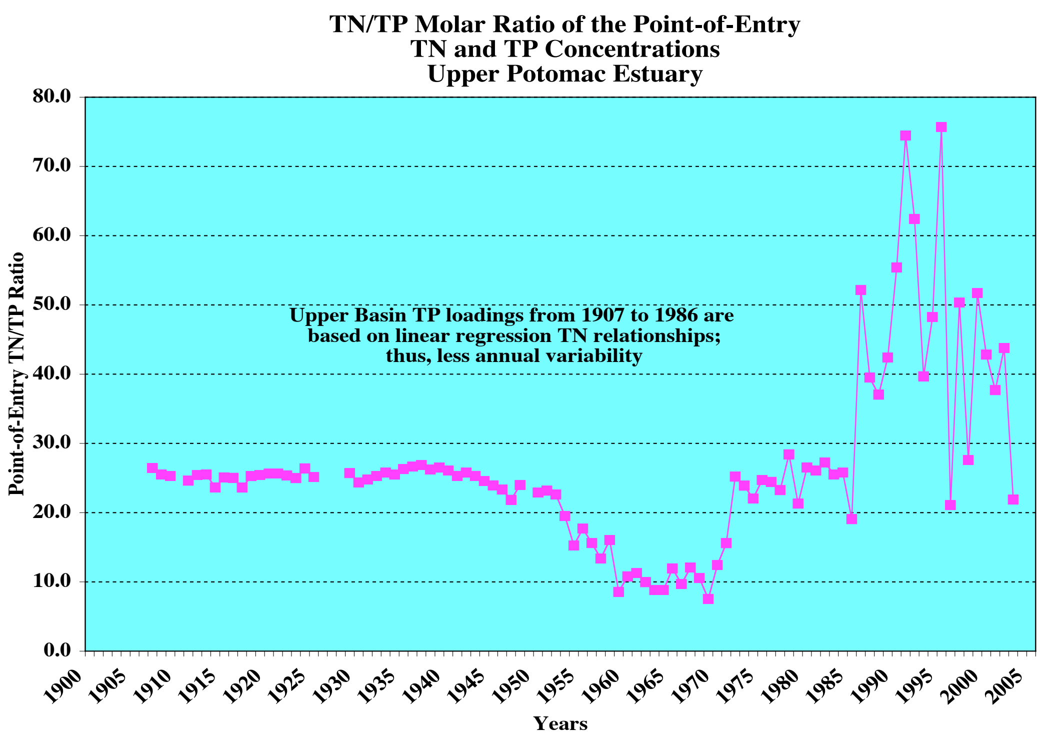
These reported mortalities, along with the low DO measured in September 1912 in the Ragged Point area, very strongly suggest that this area was anoxic in the early 1900s.

Plankton Production Limitations (in Chapters Seven and Eight)

As presented in the previous section, the bottom waters for the Ragged Point and Point Lookout stations have been anoxic, around 1.0 mg/l and less, during the summer months for the past 50 years. **There appears to be sufficient light penetration and nutrients in the spring surface pool to produce plankton blooms every year in the Lower Estuary. These blooms produce enough oxygen-consuming organic matter to drive the DO in the bottom waters anoxic every summer.**

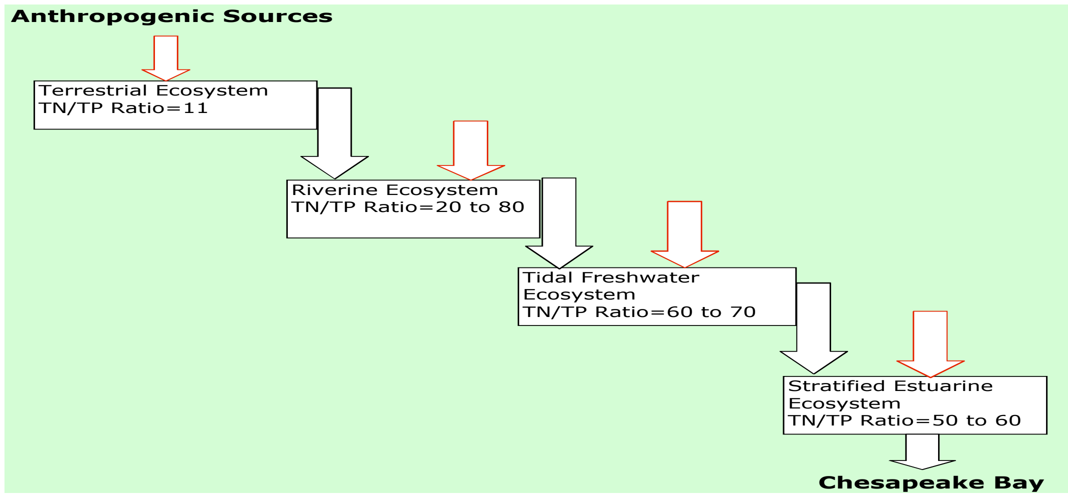
There also appears to be sufficient nutrients, which diffuse from the anoxic bottom waters during the summer months, to supply the nitrogen, phosphorus, and silica needs of the plankton in the surface pool. The ample nutrient supply allows the phytoplankton to produce enough oxygen-consuming organic matter to keep the DO in the bottom waters anoxic. As presented in Chapter Seven, the molar DIN/Inorganic P ratios in the surface waters were often less than 10, suggesting that the Lower Estuary is a nitrogen-limited system in the summer months.

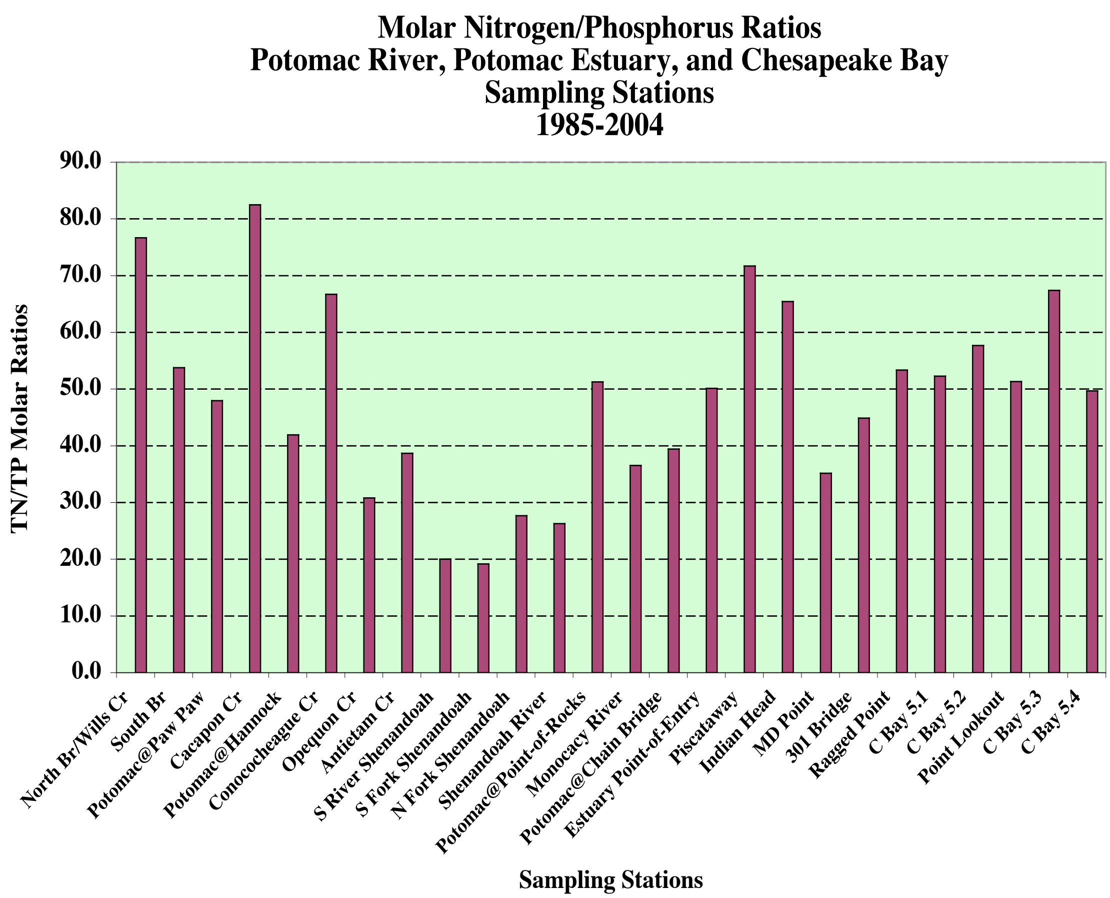
There have been major changes in the TN/TP molar ratios of the point-of-entry concentrations, as shown below.



From 1906 to 1950, the TN/TP molar ratio was about 25. In the 1960s and 1970s, the ratio was the lowest, about 10, suggesting a nitrogen-limited environment. This was also when the amount of phosphorus in detergents and soaps was the highest. In the 1980s and 1990s, the ratio was around 45. These high ratios suggest that the Upper Estuary, on an annual basis, has become a phosphorus-limited environment.

The movement of nutrients from their anthropogenic terrestrial sources through the four ecosystems and the molar TN/TP ratios for the four Potomac Waterways are shown below.



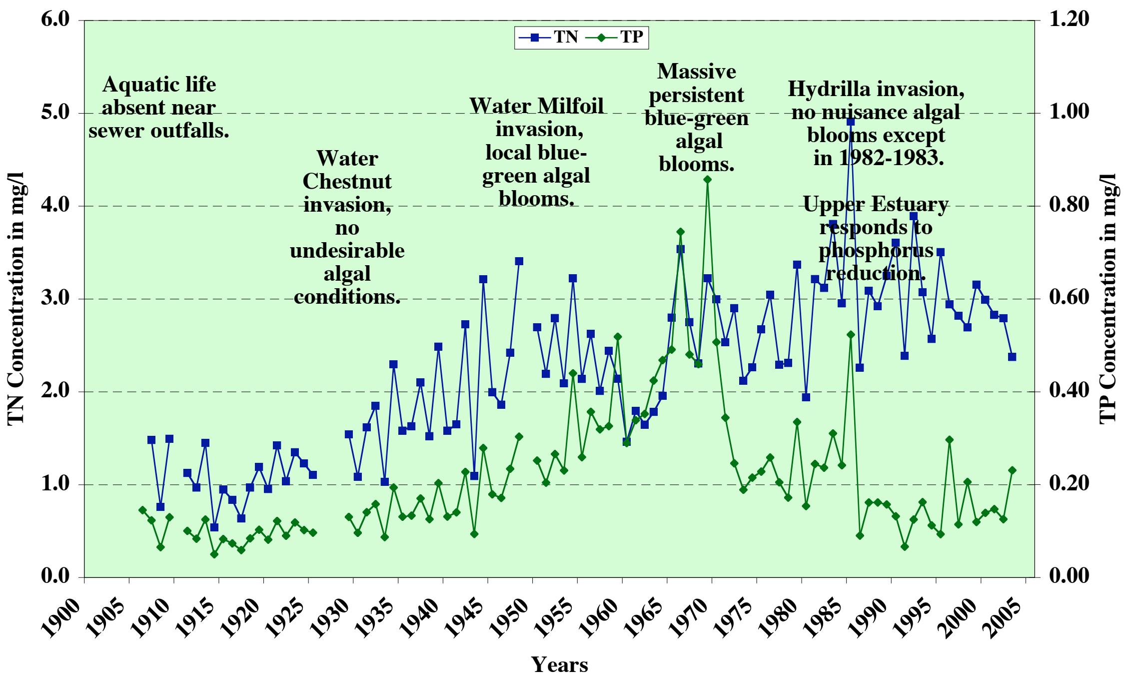


The average molar TP/TN ratio for anthropogenic sources of terrestrial nutrients in the Upper Potomac Basin was 11 for the 15-year period, as shown above. This suggests that the terrestrial ecosystem is phosphorus rich or nitrogen limited. The riverine molar TN/TP ratios increased to 20 to 80 for the 15 riverine stations. This suggests that the riverine ecosystem is phosphorus limited. The TN/TP ratios for the two freshwater tidal stations were 60 to 70. For the Lower Estuary and Chesapeake Bay stations, the average TN/TP ratios were about 50 to 60. This suggests that, on average, phosphorus was limiting primary production by phytoplankton in the Upper and Lower Estuary.

Ecological Successions of the Upper Estuary in Response to Changes in Point-of-Entry Concentrations of TN & TP (in all chapters)

The ecological responses to changes in point-of-entry concentrations of TN and TP have been very dramatic over the past 100 years, as shown below.

Ecological Successions and Point-of-Entry Concentrations of TN & TP from Upper Basin Export and Estuarine Wastewater POTWs for the Upper Potomac Estuary

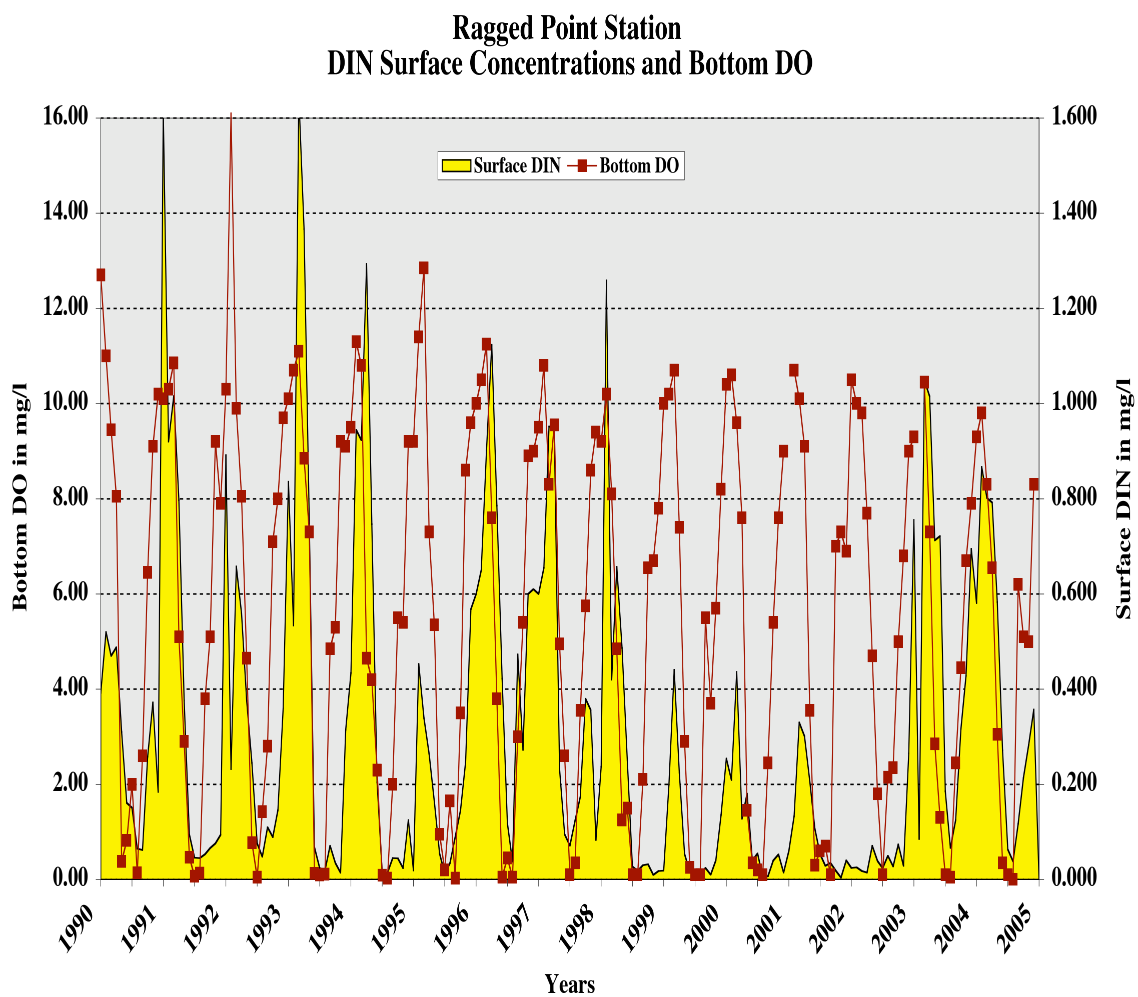


During the period from 1900 to 1940, the DO levels were low and the environment of the Upper Estuary was significantly degraded, as shown above. When the DO levels started to increase as a result of primary treatment, localized blue-green algae appeared. As the amount of phosphorus in wastewater increased due to phosphorus-rich detergents, massive, persistent blue-green algal blooms occurred, mainly in the Upper Estuary, which is tidal fresh water.

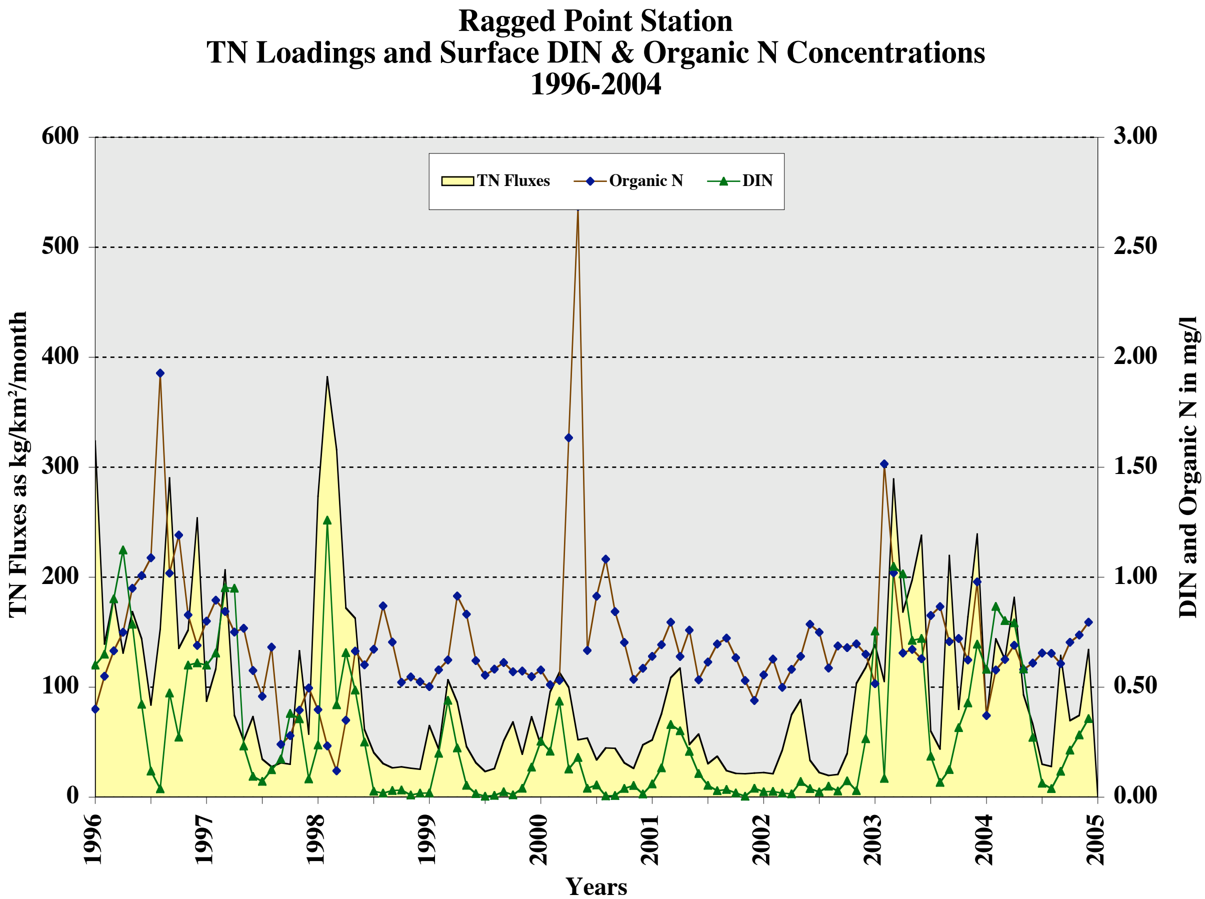
When the phosphorus levels in the POTW discharges were reduced to less than 1.0 mg/l, beginning in the early 1970s, Submerged Aquatic Vegetation (SAV) replaced the massive blue-green algal blooms. The SAV beds are dominated by a nonnative species, *Hydrillia*. The long-term consequences of nonnative species dominance on biological communities are unknown.

Will a Greater than 50% Reduction of TN Inputs into the Potomac Estuary Improve Conditions at Ragged Point? (in Chapter Eight)

In Chapter Eight, we presented the data for the Ragged Point Station, which indicated that the DO of the bottom waters goes anoxic each summer. During the drought years, from late 1998 to 2002, the spring DIN surface pools were dramatically reduced, as shown below.



When we look at the recent TN loading, DIN, and organic N data, we see that **Nature** has provided us with the answer to the question above, as shown below. From the summer of 1998 to the summer of 2002, the flow of the Potomac River was low for this four-year period.



From January 1996 through June 1998, the average TN loading was 147.7 kg/km^2/yr. The average TN load from July 1998 to July 2002 was 48.7 kg/km^2/yr—a reduction of 66%. In the winter-spring months of 1999 through 2002, there were only a few months when there was some replenishment of the surface DIN pool (see graphic above). In the winter-spring months of 2002, there was no replenishment of the DIN pool. The surface organic nitrogen remained fairly constant, ranging from about 0.5 to 1.0 mg/l.

For the four years of dramatically reduced inputs, the TN loadings were around 100 kg/km^2/yr. There appears to have been sufficient light penetration and nutrients in the spring surface pool to produce the plankton blooms. These blooms were able to produce enough oxygen-consuming organic matter to drive the DO in the bottom waters anoxic in June.

However, in July and August 2002, there appears to have not been sufficient nutrients, which diffused from the anoxic bottom waters, to supply the nitrogen, phosphorus, and silica needs of the plankton in the surface pool. The phytoplankton, therefore, were not able to produce enough oxygen-consuming organic matter to keep the DO in the bottom waters anoxic. Thus, the bottom water DO increased to over 2.0 mg/l in July and August 2002.

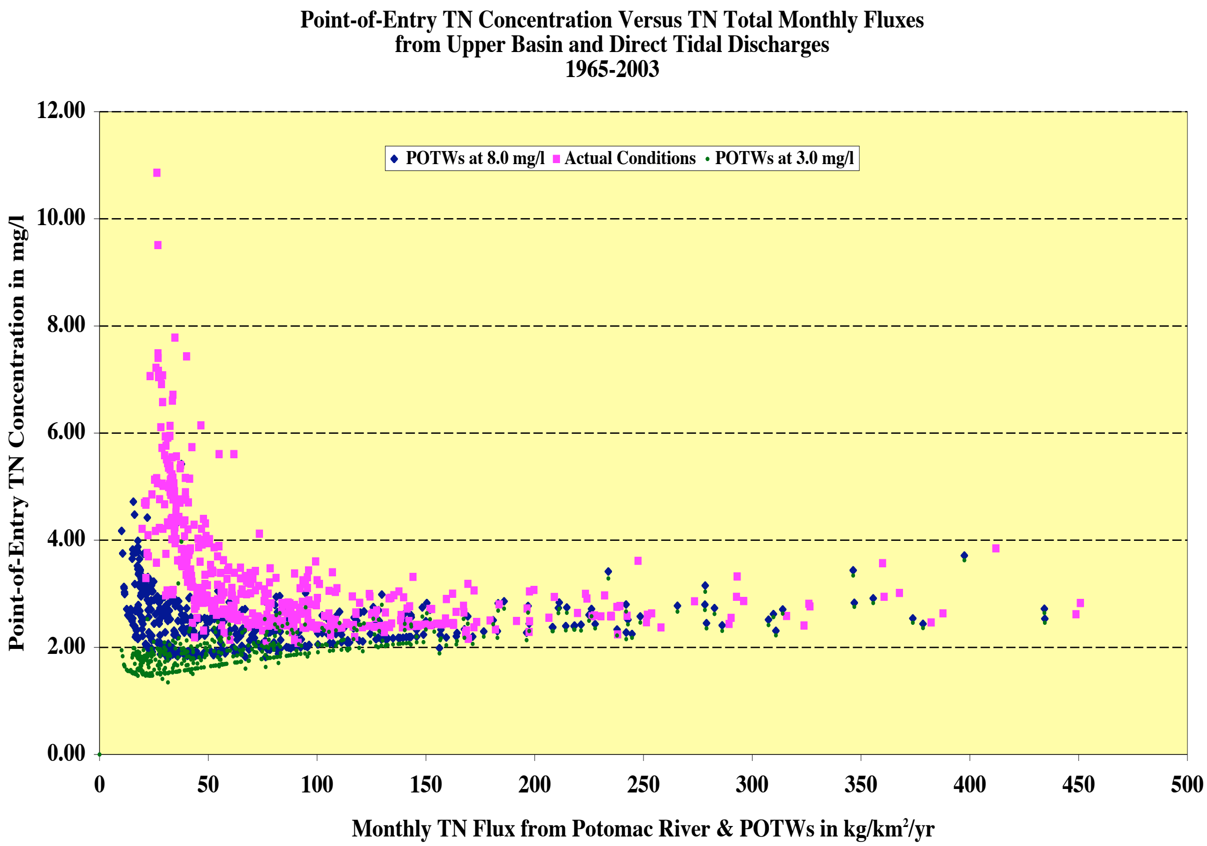
This suggests that if the spring pulses are less than 100 kg/km^2/month, there will not be sufficient replenishment of nutrients in the spring surface pool to allow the plankton to produce enough oxygen-consuming organic matter to drive and keep the DO in the bottom waters anoxic in the summer months.

Effect of Increasing Nitrogen Removal at the Tidal POTWs, Resulting in Effluents of 8.0 and 3.0 mg/l (in Chapter Five and Appendix A)

In the early 1900s, the effluents of the tidal POTWs had an average TN concentration of about 16.5 mg/l. By 2003, as nitrogen removal began to be implemented at the POTWs, the average TN in the effluents decreased to 8.5 mg/l (see Appendix A).

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 conditions existing from the 1965-2003 time frame. For the tidal POTWs having TN effluents of 8.0 and 3.0 mg/l, and for the actual effluent concentrations, the monthly TN point-of-entry concentrations versus total monthly input fluxes are shown below.

The **pink squares,** representing monthly TN fluxes versus monthly average point-of-entry TN concentrations, represent actual effluent TN concentrations for all 468 months in the 1965-2003 time frame (see below). See Chapter Five and Appendix A 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 to four months under actual conditions. If the POTW effluents were further reduced to 3.0 mg/l (the **green circles**), all of the 468 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 concentrations 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.

Meeting the Chesapeake Bay Program Goals for Nitrogen and Phosphorus (in Appendix A)

To meet water quality criteria established for the Potomac Estuary, the CBPO has determined nutrient goals for the entire Potomac River Basin, as presented below.

Nitrogen	**35,780,000**	lbs/yr or 50% of the 1985 base year
Phosphorus	**3,470,000**	lbs/yr or 35% of the 1985 base year

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.

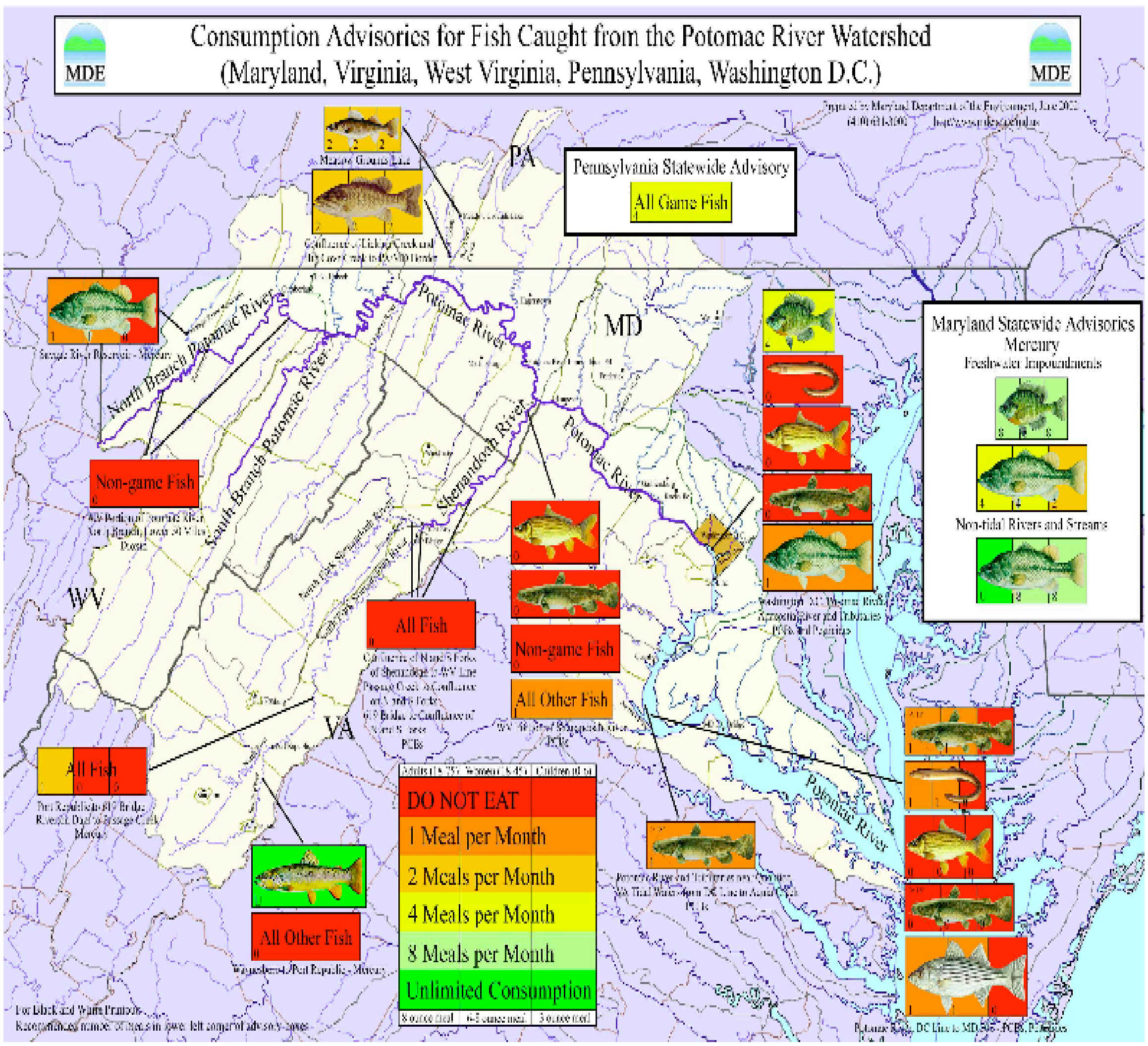
If we use 8.0 mg/l of nitrogen in the tidal POTW effluents, this would result in a nitrogen load of 12,180,000 lbs/yr, or about 34% of the **35,780,000** lbs/yr nitrogen goal. This results in a **landscape export goal of 23,700,000** (35,780,000-12,180,000) lbs/yr. Assuming about 19% of landscape loading 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 (375,860,000 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%.** See Appendix A for other nutrient management options.

Fish Advisories and Overall Heath of the Potomac River and its Estuary (in Recent Newsletters, Web Sites, Articles, and News Media)

In its *Year 2000* annual report, the Interstate Commission on the Potomac River Basin listed 15 reaches of water, including tidal water areas, where there were fish advisories. Pregnant women and children are generally advised to abstain from consuming fish from these areas. The Maryland Department of the Environment (MD DE) has recently posted a graphic on its web site on fish consumption advisories for the entire Potomac Basin, as shown below.



Source: MD DE

The "bottom line message," in terms of water quality for the protection of aquatic life and for human consumption, is that FISH in the POTOMAC ARE NOT SAFE TO EAT!

The Interstate Commission on the Potomac River Basin's Nov/Dec 2004 *REPORTER* feature article described how the Potomac River Basin's important resources fared during 2004. Some of the key observations were:

1. Decreases in SAVs, which began in 2003, did not recover in 2004.
2. Northern Snakehead Fish were discovered in the Tidal Potomac.
3. Smallmouth Bass fishing was poor in the Upper Basin.
4. Intersex Smallmouth Bass were collected in the South Branch and Antietam Creek.
5. Walleye and American Shad populations were growing.
6. Oyster harvest was among the "worst" on record.
7. Stripped Bass have been reproducing well.

In the June 2005 issue of *National Geographic*, Tom Horton asks the question, "***Why can't we save the [Chesapeake] bay?"*** He makes two other statements, which begin to explain the issues:

1. "The bay today has become the ecological equivalent of a morbidly obese person, force-fed nitrogen and phosphorus."

2. "Public support is like the estuary itself, impressively broad but deceptively shallow."

What applies to the entire Chesapeake Bay appears to apply as well to the Potomac River Basin and its Estuary.

A July 20, 2005 *Washington Post* article reported that a fish kill wiped out as much as 80% of the adult Smallmouth Bass population on the South Fork of the Shenandoah River. This is the third major environmental incidence affecting rivers in the region in the past four years.

The fish kill was reported to begin in April, while the fish were spawning and their immune systems were suppressed. Smallmouth Bass, as well as Redbreast Sunfish, began developing lesions. Before long, dead fish could be seen floating in the river. The same sequence occurred last spring on the North Fork of the Shenandoah, and two years before that on the South Branch of the Potomac River.

In June 2006, a large fish kill also occurred in the Lower Potomac Estuary, as reported in the ICPBR May/June 2006 *REPORTER*.