chapter ii

The Chesapeake Bay and Its Watershed

BACKGROUND

The Chesapeake Bay is the nation's largest estuary and one of its most valuable natural treasures. Even after centuries of intensive use, the Chesapeake Bay remains a highly productive natural resource. It supplies millions of pounds of seafood, functions as a major hub for shipping and commerce, provides habitat for an extensive array of wildlife and offers a variety of recreational opportunities for residents and visitors. The Chesapeake Bay supports 348 species of finfish, 173 species of shellfish and more than 2,700 plant species. It is home to 29 species of waterfowl and is a major resting ground along the Atlantic Migratory Bird Flyway. Every year, 1 million waterfowl winter in the Chesapeake Bay's basin.

The Chesapeake Bay proper is approximately 200 miles long, stretching from Havre de Grace, Maryland, to Norfolk, Virginia. It varies in width from about 3.4 miles near Aberdeen, Maryland, to 35 miles at its widest point, near the mouth of the Potomac River. Including its tidal tributaries, the Chesapeake Bay encompasses approximately 11,684 miles of shoreline.

On average, the Chesapeake Bay holds more than 15 trillion gallons of water. Although the Bay's length and width are dramatic, the average depth is only about 21 feet. The Bay is shaped like a shallow tray, except for a few deep troughs believed to be remnants of the ancient Susquehanna River. The troughs, which in some areas are maintained by dredging, form a deep channel along much of its length. This channel allows passage of large commercial vessels. Because it is so shallow, the Chesapeake Bay is far more sensitive to temperature fluctuations and wind than the open ocean.

The Chesapeake Bay is an estuary, where freshwater and saltwater mix. About half of the Bay's water volume consists of saltwater from the Atlantic Ocean. The other half drains into the Bay from an enormous 64,000-square-mile drainage basin or watershed. Ninety percent of this freshwater is delivered from five major rivers: the Susquehanna (which is responsible for about 50 percent), Potomac, James, Rappahannock and York rivers.

The distribution and stability of such an estuarine ecosystem depends on three important physical characteristics of the water: salinity, temperature and circulation. Salinity is a key factor influencing the Bay's morphology. Seawater from the Atlantic Ocean enters the mouth of the Chesapeake Bay; salinity is highest at that point and gradually decreases farther north. Saltwater is more dense than freshwater, thus salinity increases at greater depths while freshwater tends to remain at the surface. Salinity levels within the Chesapeake Bay vary widely, both seasonally and from year to year, depending on the volume of incoming freshwater.

Temperature dramatically changes the rate of chemical and biological reactions within the water. Because the Chesapeake Bay is so shallow, its capacity to store heat over time is relatively small. As a result, water temperature fluctuates throughout the year, ranging from 34° to 84° Fahrenheit (2° to 52° Celsius). These changes in water temperature influence the cycles in which plants and animals feed, reproduce, move locally or migrate. The temperature profile of the Chesapeake Bay is fairly predictable.

The circulation of water transports plankton, fish eggs, shellfish larvae, sediment, dissolved oxygen, minerals and nutrients throughout the Chesapeake Bay. Circulation is driven primarily by the movements of freshwater from the north and saltwater from the south. Circulation causes nutrients and sediments to be mixed and resuspended. This mixing creates a zone of maximum turbidity that, due to the amount of available nutrients, fish and other organisms often use as nursery areas.

Salinity, temperature and circulation dictate the physical characteristics of water. The warmer, lighter freshwater flows seaward over a layer of saltier and denser water flowing upstream. The opposing movement of these two flows forms saltwater fronts or gradients that move up and down the Chesapeake Bay in response to the input of freshwater. These fronts are characterized by intensive mixing. A layer separating water of different densities, known as a pycnocline, is formed. This stratification varies within seasons, depending on river flow.

In autumn, the fresher surface waters cool faster than deeper waters and sink. Vertical mixing of the two layers occurs rapidly. In the process nutrients are moved up from the bottom, making them available to phytoplankton and other surface organisms. This turnover also distributes much-needed dissolved oxygen to deeper waters. In winter, water temperature and salinity are relatively constant from the surface to the bottom. During spring and summer, surface and shallow waters are warmer than deeper waters with the coldest water found at the bottom. This layering of warmer waters over deeper waters is often broken down by turbulence.

The water's chemical composition also helps determine the distribution and abundance of plant and animal life in the Chesapeake Bay. The Bay's waters contain organic and inorganic materials, including dissolved gases, nutrients, inorganic salts, trace elements, heavy metals and other chemicals.

Dissolved oxygen is essential for most aquatic animals. The amount of available oxygen is affected by salinity and temperature. Cold water can hold more dissolved oxygen than warmer water, and freshwater holds more than saltwater. Thus, concentrations of dissolved oxygen vary, in part, with both location and time. Oxygen is transferred from the atmosphere into surface waters by diffusion and the aerating action of the wind. It also is released by aquatic plants in the process of photosynthesis. Since photosynthesis requires light, the production of oxygen by rooted aquatic plants is limited to waters that are usually no more than six feet deep. Surface water is nearly saturated with oxygen most of the year, while deep bottom waters range from saturated to anoxic (without oxygen).

In winter respiration levels of organisms are relatively low. Vertical mixing is good, and there is little salinity or temperature stratification. As a result, dissolved oxygen is plentiful throughout the water column. During the spring and summer, increased levels of animal and microbial respiration and greater stratification may reduce vertical mixing, resulting in low levels of dissolved oxygen in deep water. In fact, deep parts of some tributaries like the Patuxent, Potomac and Rappahannock rivers and the Chesapeake Bay's mainstem can become anoxic in summer. In the autumn when surface waters cool, vertical mixing occurs and the deeper waters are re-oxygenated.

CHESAPEAKE BAY WATERSHED

The Chesapeake Bay receives about half its water volume from the Atlantic Ocean. The rest drains into the Bay from its 64,000-square-mile drainage basin or watershed. Runoff from this enormous watershed flows into an estuary with a surface area of 4,500 square miles resulting in a land-to-water ratio of 14 to 1. This ratio is one of the key factors in explaining why the drainage area has such a significant influence on water quality. The watershed includes parts of six states—New York, Pennsylvania, West Virginia, Delaware, Maryland and Virginia—and the entire District of Columbia (Figure II-1). Threading through the Chesapeake Bay watershed are more than 100,000 streams and rivers that eventually flow into the Bay.

Although the Chesapeake Bay lies entirely within the Atlantic Coastal Plain, its watershed includes parts of the Piedmont and Appalachian provinces. The waters that flow into the Bay have different chemical identities, depending on the geology where they originate. In turn, the nature of the Bay itself depends on the characteristics and relative volumes of these contributing waters.

The Atlantic Coastal Plain is a flat, lowland area with a maximum elevation of about 300 feet. It is supported by a bed of crystalline rock, covered with southeasterly dipping wedge-shaped layers of relatively unconsolidated sand, clay and gravel. Water passing through this loosely compacted mixture dissolves many of the minerals. The most soluble elements are iron, calcium and magnesium. The coastal plain extends from the edge of the continental shelf, to the east, to a fall line that ranges from 15 to 90 miles west of the Chesapeake Bay. This fall line forms the boundary between the Piedmont Plateau and the coastal plain. Waterfalls and rapids clearly mark this line, which is close to Interstate Highway 95. Here, the elevation

Figure II-1. The Chesapeake Bay watershed crosses the boundaries of six states—Maryland, Virginia, Delaware, Pennsylvania, New York and West Virginia—and the District of Columbia.

Source: Chesapeake Bay Program website http://www.chesapeakebay.net.

rises to 1,100 feet. Cities such as Fredericksburg and Richmond in Virginia, Baltimore in Maryland, and Washington, D.C., developed along the fall line taking advantage of the potential water power generated by the falls. Since colonial ships could not sail past the fall line, cargo was transferred to canals or overland shipping. Cities along the fall line became important areas for commerce.

The Piedmont Plateau extends from the fall line in the east to the Appalachian Mountains in the west. This area is divided into two geologically distinct regions by Parrs Ridge, which traverses Carroll, Howard and Montgomery counties in Maryland and adjacent counties in Pennsylvania.

Several types of dense crystalline rock, including slates, schists, marble and granite, compose the eastern side. This variety results in a very diverse topography. Rocks of the Piedmont tend to be impermeable, and water from the eastern side is low in the calcium and magnesium salts.

The western side of the Piedmont consists of sandstones, shales and siltstones, layered over by limestone. This limestone bedrock contributes calcium and magnesium to its water, making it 'hard.' Waters from the western side of Parrs Ridge flow into the Potomac River, one of the Chesapeake Bay's largest tributaries.

The Appalachian Province covers the western and northern part of the watershed and is rich in coal and natural gas deposits. Sandstone, siltstone, shale and limestone form the bedrock. Water from this province flows to the Chesapeake Bay mainly via the Susquehanna River.

The hospitable climate, lush vegetation and natural beauty of the Chesapeake Bay watershed have attracted people for thousands of years. Hunters and gatherers first arrived about 10,000 years ago. Native Americans began cultivating crops and settling in villages throughout the area around a thousand years ago. Arriving less than 500 years ago, Europeans and later Africans (brought forcibly to the region beginning in 1619) struggled to transform forests into farmland during the colonial era between 1607 and 1775.

Since then, social, political, economic, and technological developments in metallurgy, steam power, internal combustion engines, chemical engineering and, most recently, electronics, have enabled people to transform regional environments in dramatic ways. Excessive forest clearing and poor land management have increased erosion, sending tons of sediment downstream. As a result, communities that once served as important ports are now landlocked, and elsewhere, the construction of sea walls and breakwaters has interfered with the natural flow of sand, causing beaches to erode too rapidly.

The changes brought about during hundreds of years of forest clearing and urban development have resulted in the following breakdown of current landuse in the watershed: 58 percent forest, 23 percent agriculture, 9 percent urban/suburban and 10 percent mixed open (herbaceous lands that are not agricultural such as golf courses or institutional grounds).

Today, nearly 16 million people live in the Chesapeake Bay watershed. Table II-1 provides a demographic summary of this population. Each resident lives just a few minutes from one of the more than 100,000 rivers, streams and creeks that drain into the Chesapeake Bay. Each tributary can be considered a pipeline from individual communities into the Chesapeake Bay and its rivers. Because materials on land are easily washed into streams and rivers, individual actions on the land ultimately affect the quality of Chesapeake Bay. These activities even include the use of automobiles, fertilizers, pesticides, toilets, water and electricity.

Table II-1. Chesapeake Bay watershed demographics

Race (%)	Educational Attainment (%)	Housing Location (%)	Means of Sewage Disposal (%)	Source of Water (%)	Transportation to Work (%)
White . . 78.1	No High School Diploma . . 23.1	Urban . . 71.7	Public 74.1	Public . . . 77.6	Drive Alone . . . 70.3
Black . . 18.5	High School Diploma 47.7	Rural . . . 27.4	Septic 24.6	Well 20.8	Car Pool 15
Asian . . . 2.3	Associate Degree 5.3	Farm 0.9	Other 1.3	Other 1.6	Public Trans. . . . 6.4
American Indian . . . 0.3	Bachelor Degree 14.4	Other 1			Bike/Walk 4.5
Other 1	Graduate Degree 9.5				Work Home 3.2

Source: 1990 U.S. Census.

CHESAPEAKE BAY TIDAL-WATER QUALITY PROBLEMS

Water quality problems in the Chesapeake Bay and its tidal tributaries are illustrated by the following environmental indicators which reveal the effects of excessive nutrients and sediments in the water column.

A significant proportion of living resource habitats are currently unsuitable due to low dissolved oxygen concentration during the summer months (Figure II-2). In 2001, half of the Chesapeake Bay's deeper waters had reduced dissolved oxygen

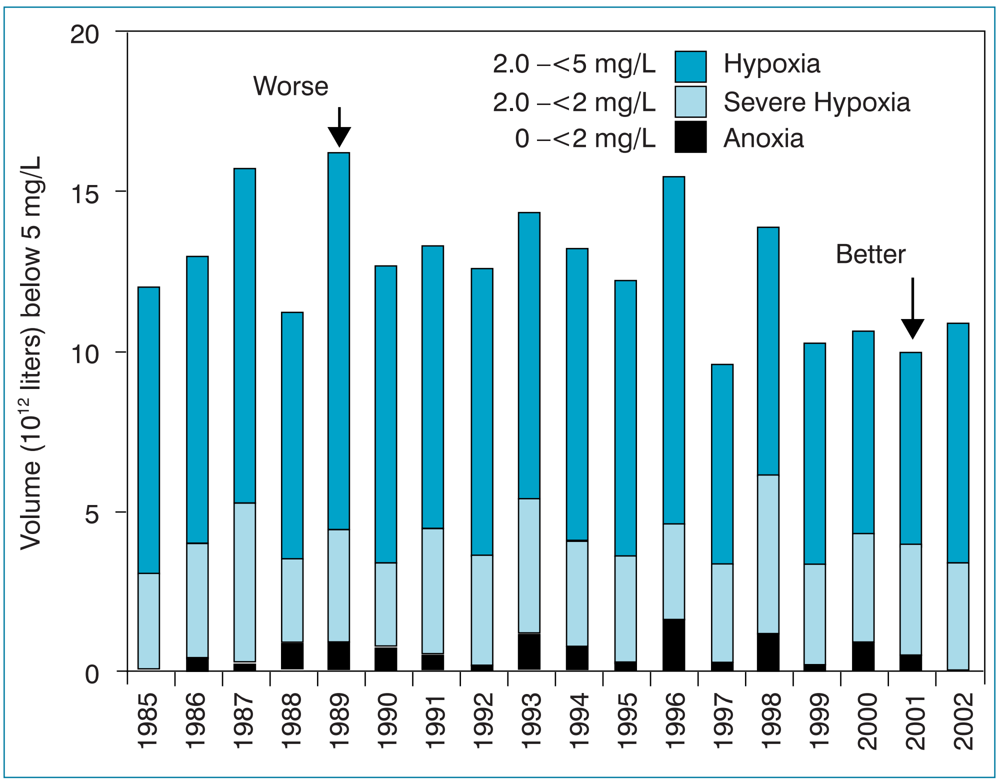

Figure II-2. Volume of the mainstem Chesapeake Bay lower layer waters with reduced dissolved oxygen concentrations–June through September average 1985-2002.

Source: Chesapeake Bay Program website http://www.chesapeakebay.net.

concentrations, a condition known as hypoxia. Hypoxic conditions stress aquatic life and severely hypoxic waters may be lethal to aquatic plants and animals. If bottom waters become completely without oxygen or anoxic, nutrients tied up in sediments are released into the overlying waters, further fueling algal growth. Recent indications show an improving trend in dissolved oxygen since 1985, the year the Chesapeake Bay Program's complete data collection efforts were initiated.

Chlorophyll *a* is an indicator of algal biomass. Algae serve as a crucial link in the food chain; they reduce water clarity, and, left uneaten, fuel the loss of dissolved oxygen from tidal waters. Measured as chlorophyll *a*, algae are the first to respond to changes in nutrient levels. Recent trends in the Middle, Wicomico and Manokin rivers show improvements in the level of algal biomass. Most areas show no significant change, although the Rappahannock River, Tangier Sound and the mouth of the James River show degrading trends in terms of chlorophyll *a* (Figure II-3).

Water clarity is degrading in many parts of the basin (Figure II-4). Water clarity criteria are not attained in many shallow-water designated use habitats. In portions of the upper Chesapeake Bay, in the Elk and Middle rivers, in upper regions of the Choptank River, in Piscataway and Mattawoman creeks, and in the South Branch Elizabeth River, water clarity is improving.

CAUSES OF CHESAPEAKE BAY WATER QUALITY PROBLEMS

The Chesapeake Bay is part of an extremely productive and complex ecosystem that consists not only of the Bay and its tributaries, but of the plant, animal and human life they support. Through a significant investment in scientific research and coordinated monitoring and modeling programs, the Chesapeake Bay Program partners have gained deep understanding of how human activities affect the Bay's ecology and have led to declines in water quality. Using modeling tools such as the Chesapeake Bay Watershed Model and the Water Quality Model, the partners have learned a great deal about this unique resource by allowing for, among other things, the calculation and projection of changes in loads and the resultant responses in water quality. These models provide an estimate of management actions (such as air controls and point source controls) which will reduce nutrient or sediment loads to the tidal waters and lead to attainment of the Chesapeake Bay dissolved oxygen, water clarity and chlorophyll *a* criteria.

HUMAN POPULATION INCREASE

The relentless encroachment of the human population threatens the ecological balance of the Chesapeake Bay. Population in the Chesapeake Bay watershed has doubled since the 1950s with population levels projected to reach almost 18 million people by 2020 (Figure II-5). Each individual directly affects the Chesapeake Bay by adding waste, consuming resources, and changing the character of the land, water and air that surround it.

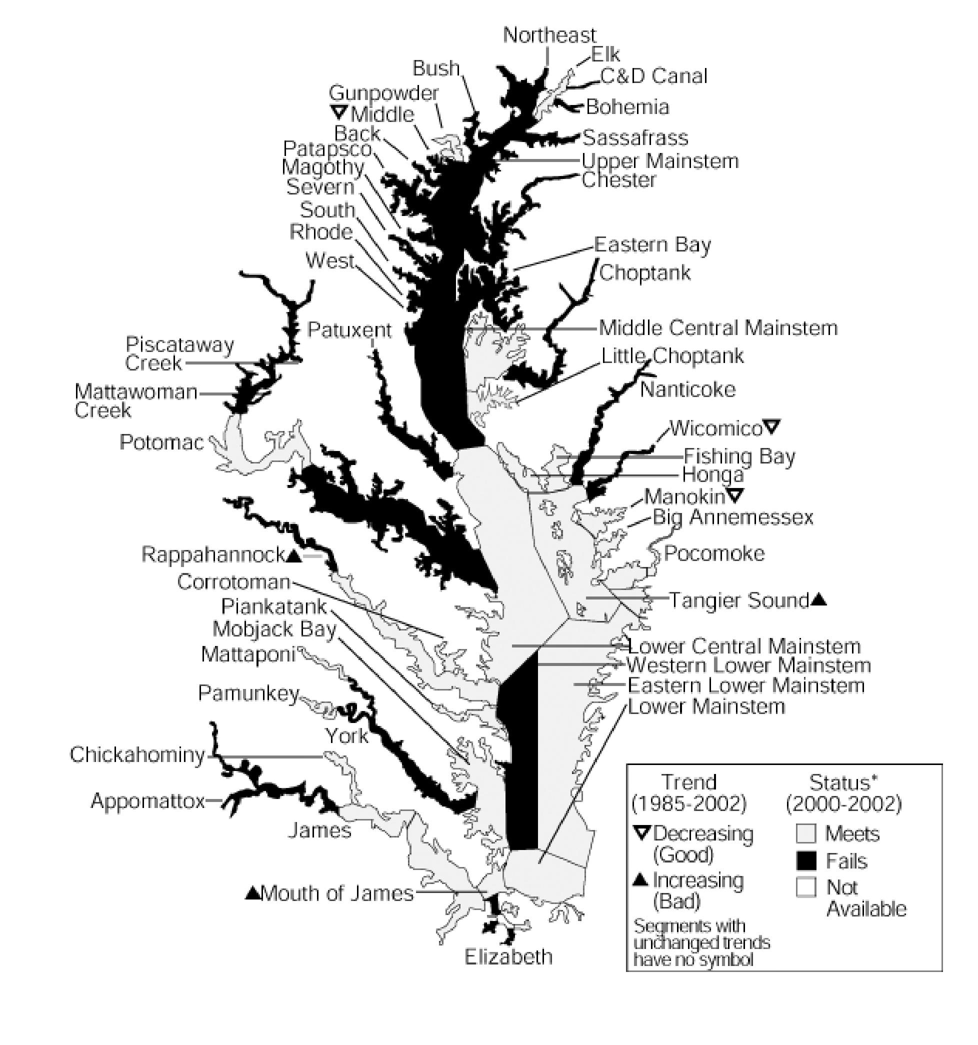

Figure II-3. Status and trends in summer Chesapeake Bay and tidal tributary chlorophyll *a* concentrations relative to concentrations characteristic of mesotrophic conditions.

* 'Meets' means equal to or less than and 'fails' means above the following chlorophyll *a* concentrations during the July through September timeframe:
25 ug/l tidal freshwaters
25 ug/l oligohaline waters
20 ug/l mesohaline waters
15 ug/l polyhaline waters.

Source: Chesapeake Bay Program website http://www.chesapeakebay.net.

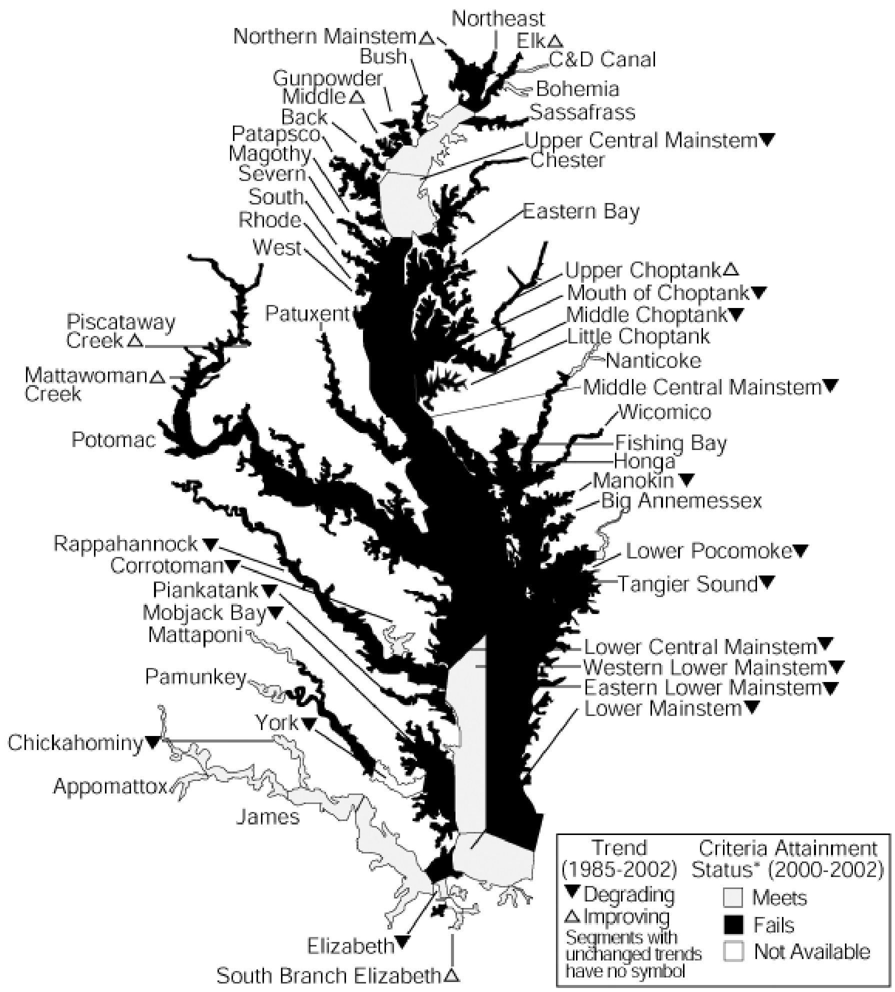

Figure II-4. Status and trends in underwater bay grass growing season water clarity in Chesapeake Bay and tidal tributaries.

* 'Meets' equals nonexceedance; 'fails' equals exceedance of the water clarity criteria during underwater bay grasses growing season applied in locations and depths where such grasses have occurred since the 1930s (however, if the single best year of underwater bay grasses, measured 2000–2002, achieves the acreage goal for a segment, there is no need to meet the clarity criteria). Application depths were based on: single best year percent of total potential habitat is >=20% or percent of total potential habitat is 10–19.9% and underwater bay grasses are persistent (1978–2000).

NOTE: The criteria attainment status covers the entire segment only for purposes of illustration. The water clarity criteria apply with the shallow-water designated use habitat which can extend as far out as the 2-meter depth contour depending on the segment.

Source: Chesapeake Bay Program website http://www.chesapeakebay.net.

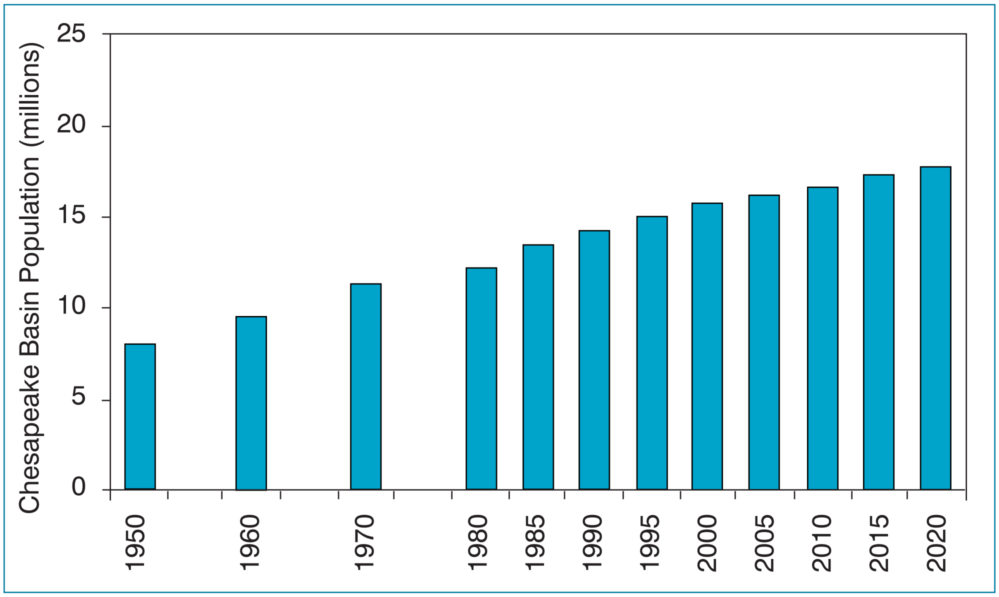

Figure II-5. Chesapeake Bay watershed human population trends since 1950 and projected through 2020.

Source: Chesapeake Bay Program website http://www.chesapeakebay.net.

LOSS OF HABITAT

Historically, habitat provided by oyster bars, underwater bay grasses, wetlands and forests enabled the Chesapeake Bay ecosystem to recycle nutrients and sediments efficiently, resulting in one of the most productive ecosystems in the world. Dramatic loss of these habitats has not only led to declines in the creatures that rely on them for food and shelter; their loss also has reduced the ecosystem's capacity to fully utilize nutrients and sediments leading to poor water quality in the Chesapeake Bay and its tidal tributaries. Restoration, conservation, and preservation of the habitat provided by oysters, underwater bay grasses, wetlands and forests are critical for restoring living resources and for improving Chesapeake Bay water quality.

In addition to the aquatic reef habitat they provide, oysters are voracious feeders, and each is capable of filtering up to 50 gallons of water per day. It is estimated that at their peak abundance, the total population of oysters in the Chesapeake Bay could filter an amount of water equal to all the water in the Chesapeake Bay in three days. Today, due to decreased abundance, it takes a year for these animals to filter the same volume of water. Oyster harvests in the Chesapeake Bay have declined due to over-harvesting, disease, pollution and loss of oyster reef habitat. Two diseases, discovered in the 1950s and caused by the parasites MSX and Dermo, have been a major cause of the oyster's decline during recent times (Figure II-6).

Underwater bay grasses are important because they produce oxygen, provide food for a variety of animals (especially waterfowl), serve as shelter and nursery areas for many fish and shellfish, reduce wave action and shoreline erosion, absorb nutrients such as phosphorus and nitrogen and trap sediments. Although underwater bay

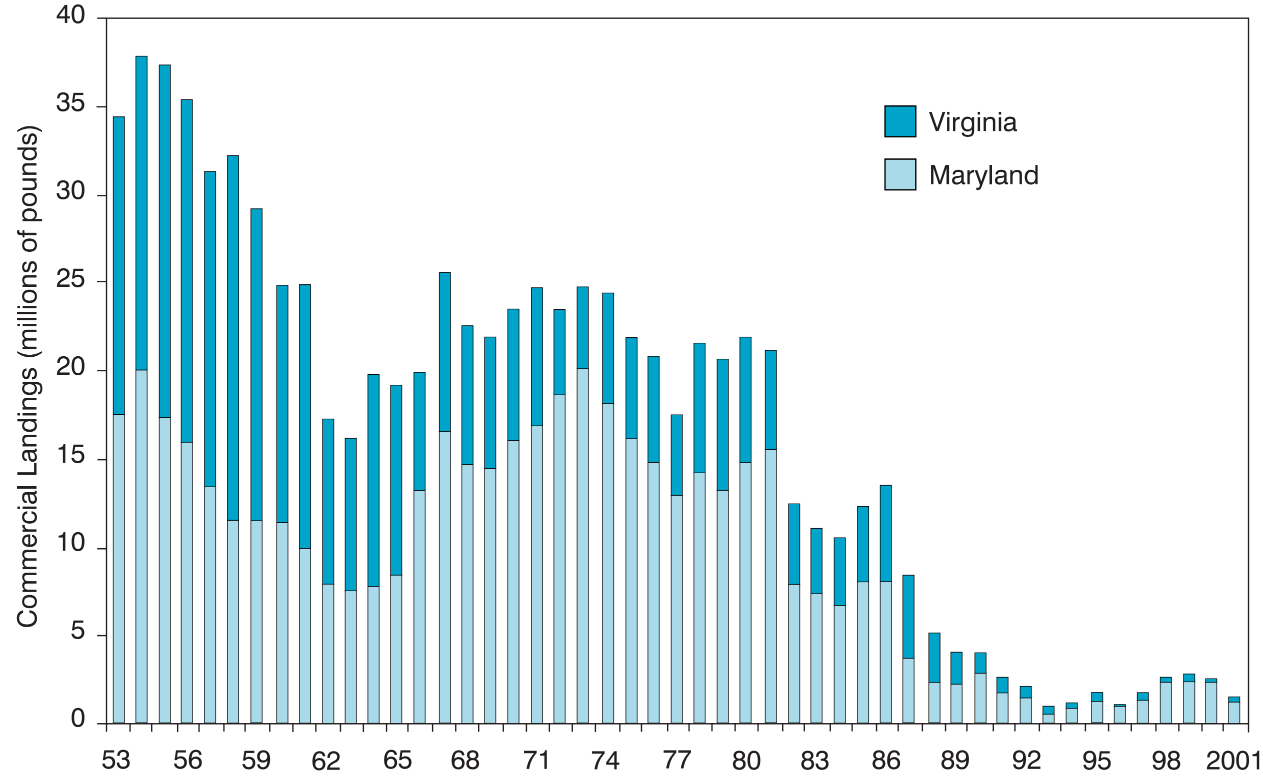

Figure II-6. Trends in Maryland and Virginia commercial harvest landings of oysters 1953–2001.
Source: Chesapeake Bay Program website http://www.chesapeakebay.net.

grasses increased from a low point of 37,000 acres in 1984 to 85,000 acres in 2001, the Chesapeake Bay Program watershed partners have adopted a new restoration goal of 185,000 acres (Figure II-7).

Wetlands and forests (especially those buffering streambanks and shorelines) provide critical habitat and also act as natural filters to minimize sediment loads and absorb nutrients. Approximately 1.5 million acres of wetlands remain in the Chesapeake Bay watershed, less than half of the wetlands that were here during colonial times. Forests that once covered 90 to 95 percent of the watershed now cover only 58 percent (Figure II-8).

EXCESS NUTRIENTS

Nutrients are essential; they provide crucial ingredients to help living things grow. However, there is a delicate balance between what is needed for organisms to thrive, and what is excessively harmful. The amount of nutrients that would naturally enter the Chesapeake Bay has been adversely multiplied by anthropogenic sources over the course of history. Runoff from fertilizers applied to agriculture and lawns, sewage and industrial discharges, automobile emissions and power generation, are all sources that create excessive amounts of nutrient pollution delivered to the Chesapeake Bay and

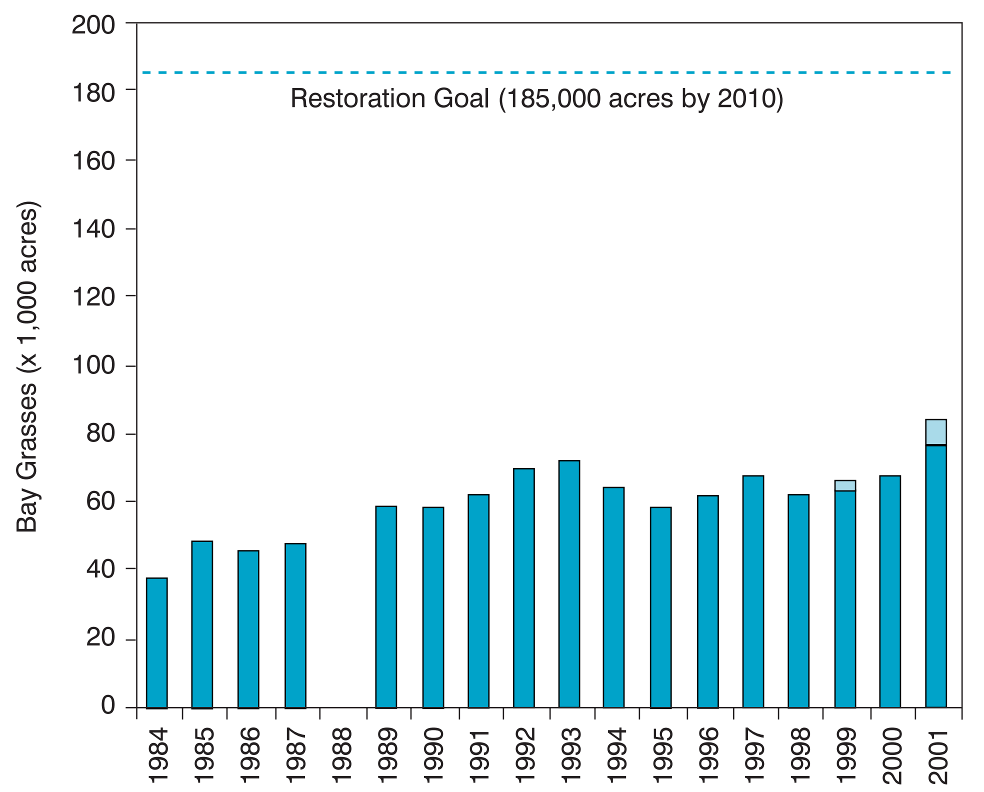

Figure II-7. Trends in the acreages of Chesapeake Bay and tidal tributary underwater bay grasses compared to the new 185,000 acre restoration goal. Light blue area of bar includes estimated additional acreage when flight restrictions or weather conditions prevented collection of a complete set of aerial photographs.

Source: Chesapeake Bay Program website http://www.chesapeakebay.net.

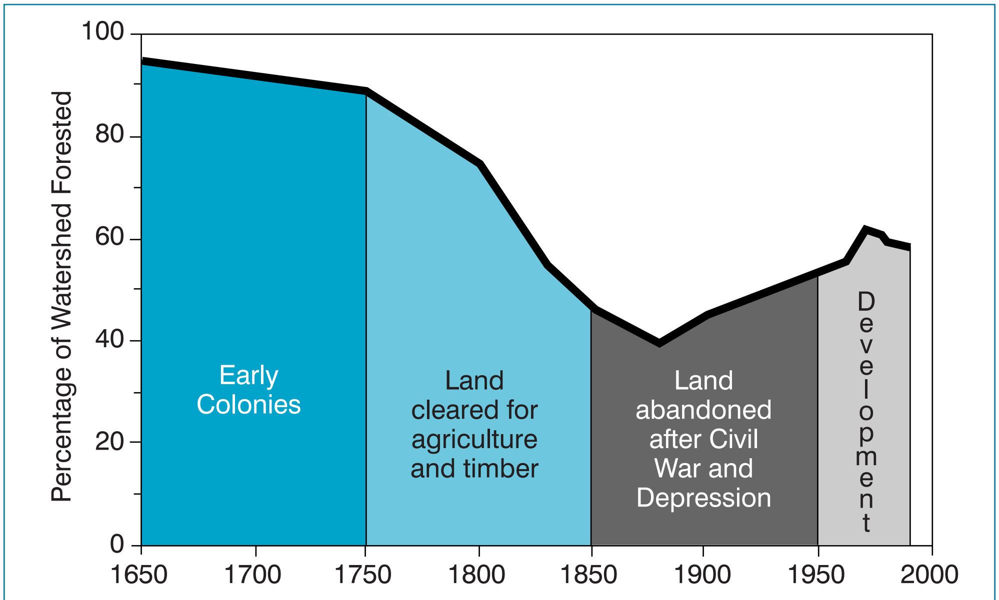

Figure II-8. Trends in Chesapeake Bay basin forests expressed as percentage of the watershed that was forested since 1650.

Source: Chesapeake Bay Program website http://www.chesapeakebay.net.

its tidal tributaries. These anthropogenic sources of nutrients, together with a decline in the Chesapeake Bay's own natural capacity to assimilate these pollutants due to loss of habitats and living resources, have created overwhelming stresses.

Excess amounts of nitrogen and phosphorus cause rapid growth of phytoplankton, creating dense algal populations or blooms. These blooms become so dense that they reduce the amount of sunlight available to underwater bay grasses. Without sufficient light, these underwater plants cannot photosynthesize and produce the food they need to survive. Algae also may grow directly on the surface of underwater bay grasses, further blocking light. Another hazard of nutrient-enriched algal blooms comes after the algae die. As the algal blooms decay, oxygen is consumed via bacterial decomposition which can lead to dangerously low oxygen levels available for aquatic organisms. Known as eutrophication, this nutrient over-enrichment, ultimately leading to low dissolved oxygen levels in ambient waters, is a widespread problem throughout the tidal waters.

EXCESS SEDIMENTS

The surrounding watershed and the tidal waters of the Chesapeake Bay and its tidal tributaries transport huge quantities of sediments. Although sediments are a natural part of the Chesapeake Bay ecosystem, accumulation of excessive amounts is undesirable. As sediments settle to the bottom of the Chesapeake Bay, they can smother bottom-dwelling plants and animals, such as oysters and clams. Sediments suspended in the water column cause the water to become cloudy, decreasing the light available for underwater bay grasses. Sediment-related water quality problems, however, tend to be more of a localized problem.

Individual sediment particles have a large surface area, and many molecules easily adsorb or attach to them. As a result, sediments can act as chemical sinks by adsorbing nutrients and other pollutants. Thus, areas of high sediment deposition sometimes have high concentrations of nutrients which may later be released. Reducing sediment loads to the Chesapeake Bay and its tidal tributaries is critical for restoring water quality.

SOURCES OF NUTRIENT LOADS TO THE CHESAPEAKE BAY TIDAL WATERS

When accounting for all the nutrients that enter the Chesapeake Bay from its watershed, the two largest anthropogenic contributors of both nitrogen and phosphorus are nonpoint source runoff from agriculture and point sources. Forests are a natural source of nutrients, but relative to anthropogenic sources, are a relatively small percentage of the total nutrient load entering the Chesapeake Bay. The largest source of sediments in the Bay is agriculture, followed by forest, urban runoff and mixed open lands. Figures II-9 through II-14 provide a breakdown of the nitrogen, phosphorus, and sediment loads delivered to the Chesapeake Bay and its tidal tributaries as well as estimated reductions achieved in these loads from 1985 to 2000 from each source. These loads do not include atmosphere deposition directly to tidal waters—see "Atmospheric Sources" below.

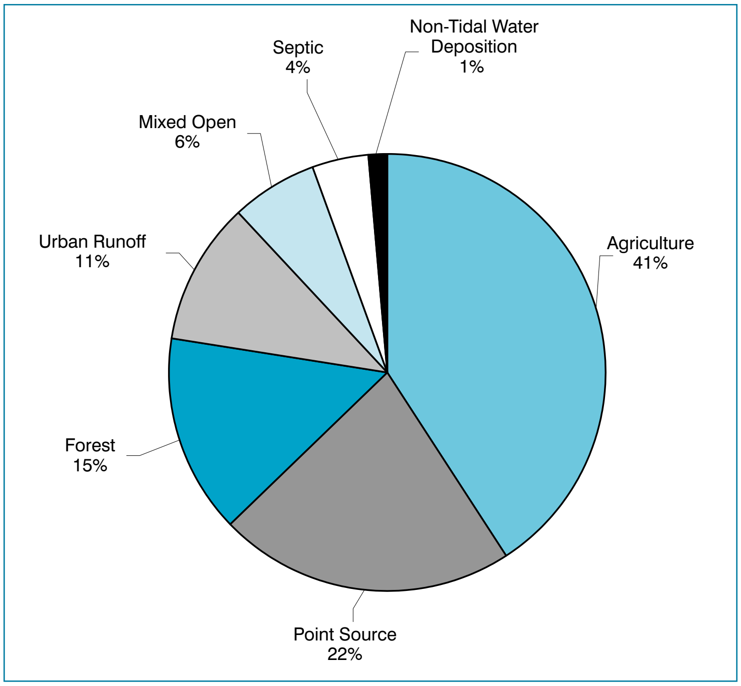

Figure II-9. Chesapeake Bay Watershed Model-estimated nitrogen loads by source delivered to the Chesapeake Bay and its tidal tributaries excluding direct atmospheric deposition to tidal waters and shoreline erosion. A total of 285 million pounds/year were delivered to the tidal waters based on the Watershed Model's 2000 Progress scenario.

Source: Chesapeake Bay Program website http://www.chesapeakebay.net.

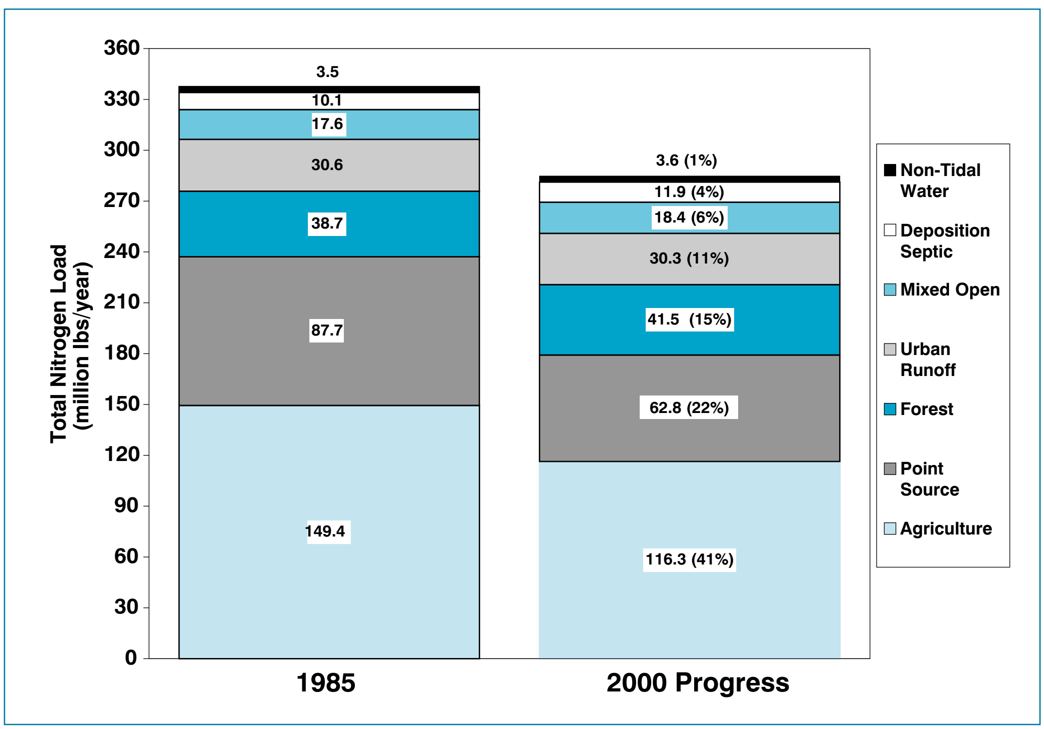

Figure II-10. 1985 and 2000 Chesapeake Bay Watershed Model-estimated nitrogen loads by source delivered to the Chesapeake Bay and its tidal tributaries excluding direct atmospheric deposition to tidal waters and shoreline erosion.

Source: Chesapeake Bay Program website http://www.chesapeakebay.net.

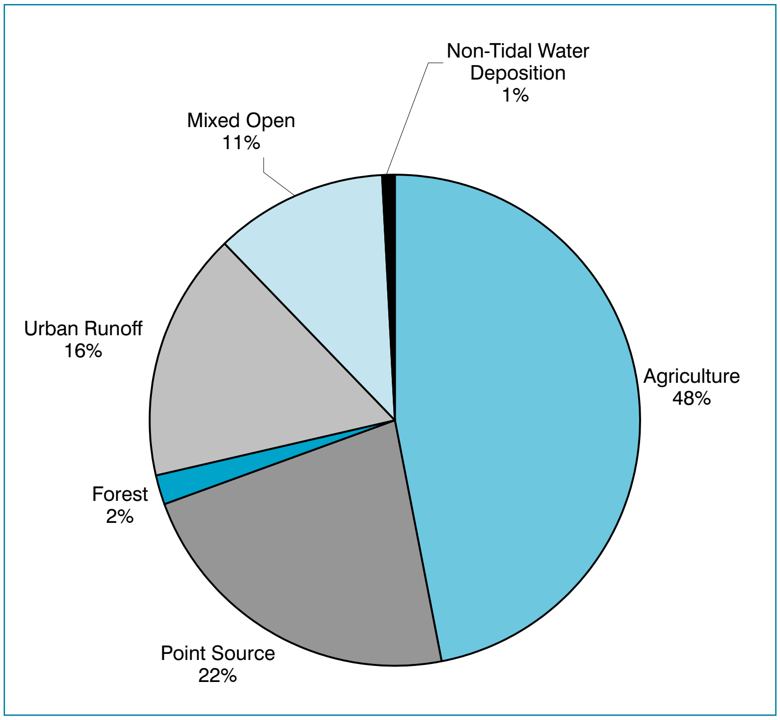

Figure II-11. Chesapeake Bay Watershed Model-estimated phosphorus loads by source delivered to the Chesapeake Bay and its tidal tributaries excluding direct atmospheric deposition to tidal waters and shoreline erosion. A total of 19.1 million pounds/year were delivered to the tidal waters based on the Watershed Model's 2000 Progress scenario.

Source: Chesapeake Bay Program website http://www.chesapeakebay.net.

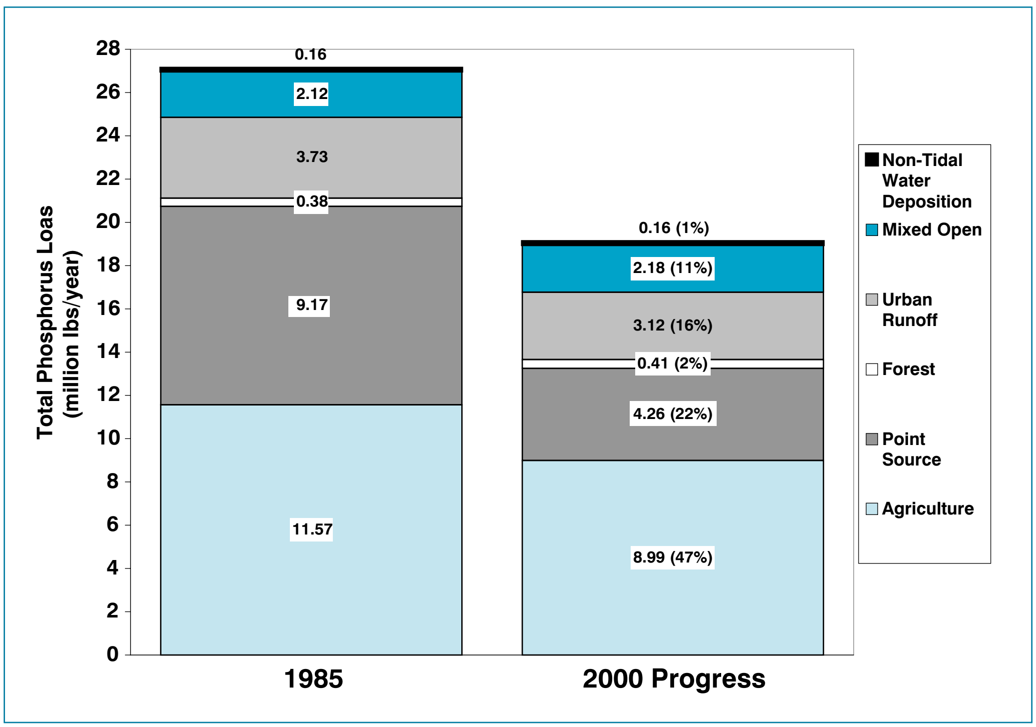

Figure II-12. 1985 and 2000 Chesapeake Bay Watershed Model-estimated phosphorus loads by source delivered to the Chesapeake Bay and its tidal tributaries excluding direct atmospheric deposition to tidal waters and shoreline erosion.

Source: Chesapeake Bay Program website http://www.chesapeakebay.net.

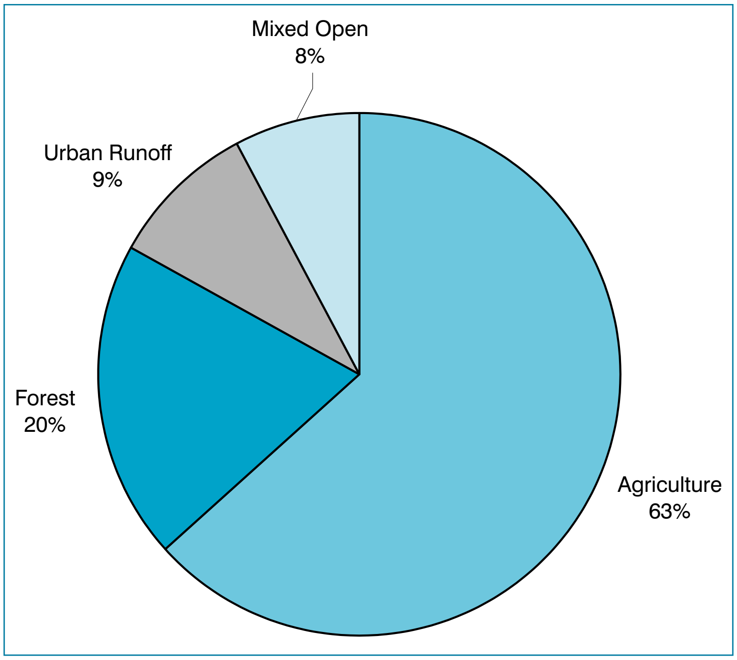

Figure II-13. Chesapeake Bay Watershed Model-estimated sediment loads by source delivered to the Chesapeake Bay and its tidal tributaries excluding direct atmospheric deposition to tidal waters and shoreline erosion. A total of 5.04 million pounds/year were delivered to the tidal waters based on the Watershed Model's 2000 Progress scenario.

Source: Chesapeake Bay Program website http://www.chesapeakebay.net.

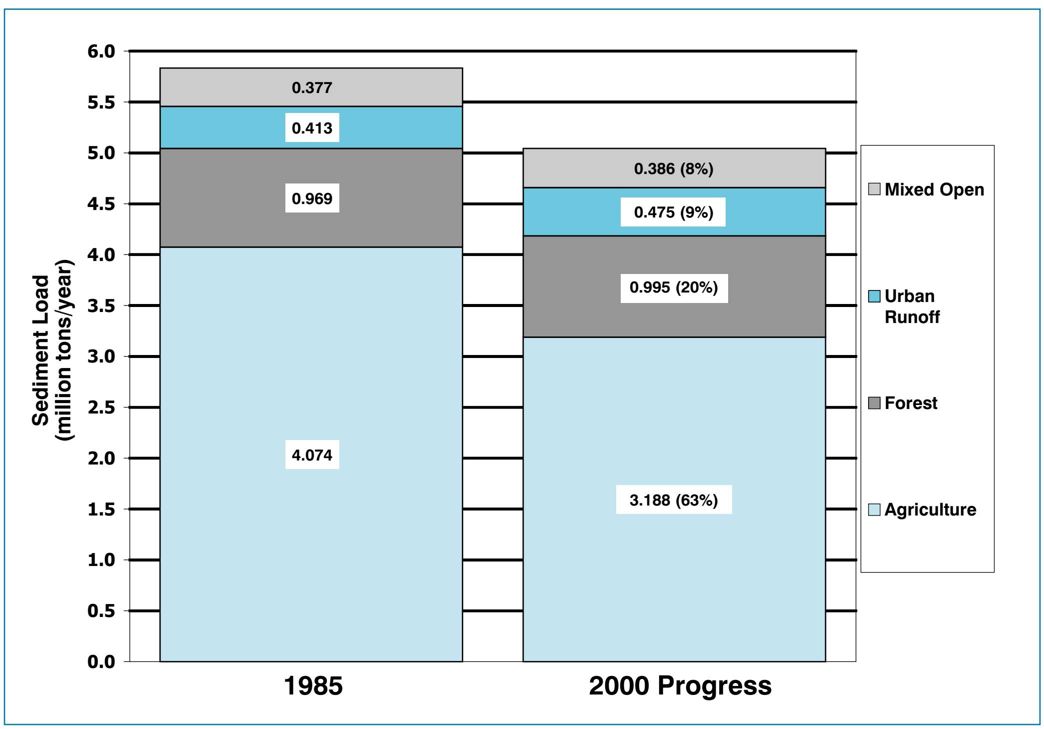

Figure II-14. 1985 and 2000 Chesapeake Bay Watershed Model-estimated sediment loads delivered to the Chesapeake Bay and its tidal tributaries excluding direct atmospheric deposition to tidal waters and shoreline erosion.

Source: Chesapeake Bay Program website http://www.chesapeakebay.net.

NONPOINT SOURCES

Nonpoint source pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. Rainfall or melted snow moving over and through the ground is one such source. As the runoff moves, it picks up and carries away natural and anthropogenic pollutants, some of which are deposited into the Chesapeake Bay and its tidal tributaries. Animal manure or chemical fertilizers applied to lawns, gardens and farm fields can wash off the land into streams and rivers or seep into the ground where they can be delivered to streams via groundwater.

Nonpoint source pollution in the Chesapeake Bay watershed emanates from six sources: agriculture, forest, urban, mixed open, septic and atmospheric deposition. As noted earlier, agriculture accounts for the largest percentage of nonpoint source nitrogen pollution.

Agricultural runoff includes nutrients from chemical fertilizers and animal manure applied to land, as well as eroded soil particles and organic matter. Improper storage of animal wastes and mortality can result in additional nutrients being leaked into the groundwater or carried off in rainwater. Animals pastured near streams and other water bodies also contribute to the nutrient load delivered to the tributaries of the Chesapeake Bay.

Septic systems leak nutrients into the groundwater since most systems currently do not incorporate technologies to remove nitrogen from the wastewater they treat then discharge. Such systems are a source of nitrogen to the watershed not only from the treated effluent, but from systems that are not functioning properly due to age, neglect in operation and maintenance, or improper siting and installation.

Increases in nutrient runoff from urban areas are expected to occur in the future due to increasing development of forested and agricultural lands. Nitrogen loads from septic systems are expected to increase as population increases, however, if people continue to move away from the urban and suburban areas that are currently serviced by public sewer facilities, projected loads may be even higher. Runoff from farms is generally declining as farmers adopt nutrient management and runoff control techniques, but also because the overall amount of farmland is declining.

POINT SOURCES

A point source is an outfall pipe associated with a point of entry, such as the end of a pipe, where nutrients enter waterways. Industrial sites and wastewater treatment plants are examples of point sources. As of 2000, point sources were estimated to account for 22 percent of the total load of nitrogen and phosphorus to the Chesapeake Bay and its tidal tributaries. The Chesapeake Bay Program, working with its partner states and jurisdictions, assimilated a database on all of the point sources with significant contributions of nutrients to the watershed. (Sediments are not currently counted as a component of point source effluents.) The point source database consists of facilities located in all the states and jurisdictions in the Chesapeake Bay watershed (Table II-2). These point sources are divided into four principal categories.

- Significant municipal facilities, which are generally municipal wastewater treatment plants that discharge flows of equal to or greater than 0.5 millions of gallons per day (MGD). More specifically, significant municipal facilities are defined slightly differently for each jurisdiction. For Virginia, these facilities are those that have a design flow of 0.5 MGD or greater, and all facilities located below the fall line, regardless of flow. For Maryland, significant facilities are those having a current flow of 0.5 MGD or greater. For Pennsylvania, significant facilities are those having average annual 1985 flows of 0.4 MGD or greater. For Delaware, West Virginia, and New York, the Chesapeake Bay Program selected as significant municipal facilities those in the EPA Permit Compliance System database with current flows of 0.5 MGD or greater.
- Significant industrial facilities have been identified as those that discharge the equivalent or greater amounts of nutrients as compared to a municipal wastewater treatment facility's discharge of 0.5 MGD. These discharge loads would roughly be equivalent to those of municipalities with flows of 0.5 MGD or greater, or a total nitrogen load of 75 pounds per day, and a phosphorus load of 25 pounds per day or greater (based on a municipal facility effluent discharge of 2.5 mg/l total phosphorus and 18 mg/l total nitrogen).
- Nonsignificant municipal facilities are those that are generally smaller than discharge flows of 0.5 MGD. Only nonsignificant municipal facilities in Maryland and Virginia are included in the database due to the availability of data. While there are approximately 185 nonsignificant municipal facilities across the Chesapeake Bay watershed, the flow and corresponding nutrient loads from these facilities are less than 5 percent of the total for all point sources.
- Combined sewer overflow loads only for the District of Colombia are included in the database because it is the only location for which the Chesapeake Bay Program has nutrient load data. Certainly other combined sewer overflows exist in the watershed, however, to date these have not been quantified in terms of nitrogen and phosphorus load discharges.

Table II-2. Summary of point source facilities within the Chesapeake Bay watershed.

Point Source Category	Description	Number of Facilities	Total 2000 Flow (MGD)
Significant Municipals*	Generally > 0.5 MGD	304	1,554.4
Significant Industrials	Discharge loads generally > 75 lb/day TN & 25 lb/day TP	49	524.7
Non-significant Municipals	Generally < 0.5 MGD	185	10.8
Combined Sewer Overflows	Only for Blue Plains	1	7.6
Total		**540**	**2,097.5**

*Including the six Virginia plants to be built by 2010.

Source: Chesapeake Bay Program website http://www.chesapeakebay.net.

Today, 83 of the 304 significant municipal wastewater treatment plants and many industrial facilities as well, are using nutrient removal technology (NRT). By 2010, that number is likely to increase to 156. Exponential advances in the development of NRT in recent years, along with performance levels beyond what was traditionally expected, have clearly shown the potential for this technology to achieve much lower levels of nitrogen in discharges than the traditionally accepted performance levels. It must be recognized that the enhanced performance seen to date is partly due to the fact that some treatment plants are operating below their design capacity, and this level of nutrient reduction may be difficult to maintain as flows increase. To date, 12 of the 49 significant industrial nutrient dischargers located in the Chesapeake Bay watershed are practicing some form of nutrient removal, and that number is expected to increase to 16 by 2010.

The nutrient load discharged from municipal point sources is directly linked to population. Because of the implementation of NRT to date, these point sources collectively have achieved a 53 percent reduction in phosphorus loads and a 28 percent reduction in nitrogen loads since 1985, despite the 15 percent increase in population since then. But because the watershed's population is expected to increase by an additional 14 percent by 2010, it will be increasingly more challenging to achieve nutrient reductions from point sources. Figures II-15 and II-16 illustrate the nitrogen and phosphorus loads, respectively, from point sources in the

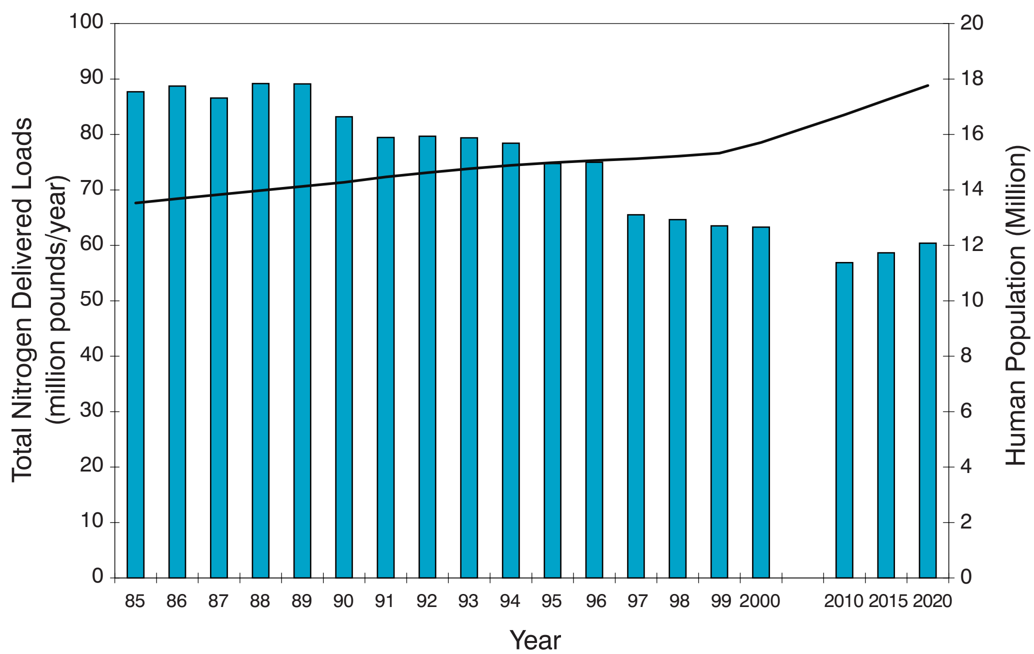

Figure II-15. Total nitrogen loads delivered to the Chesapeake Bay and its tidal tributaries from all point source facilities in the watershed (■) compared with human population trends (—) in the Chesapeake Bay watershed projected through 2020.

Source: Chesapeake Bay Program website http://www.chesapeakebay.net.

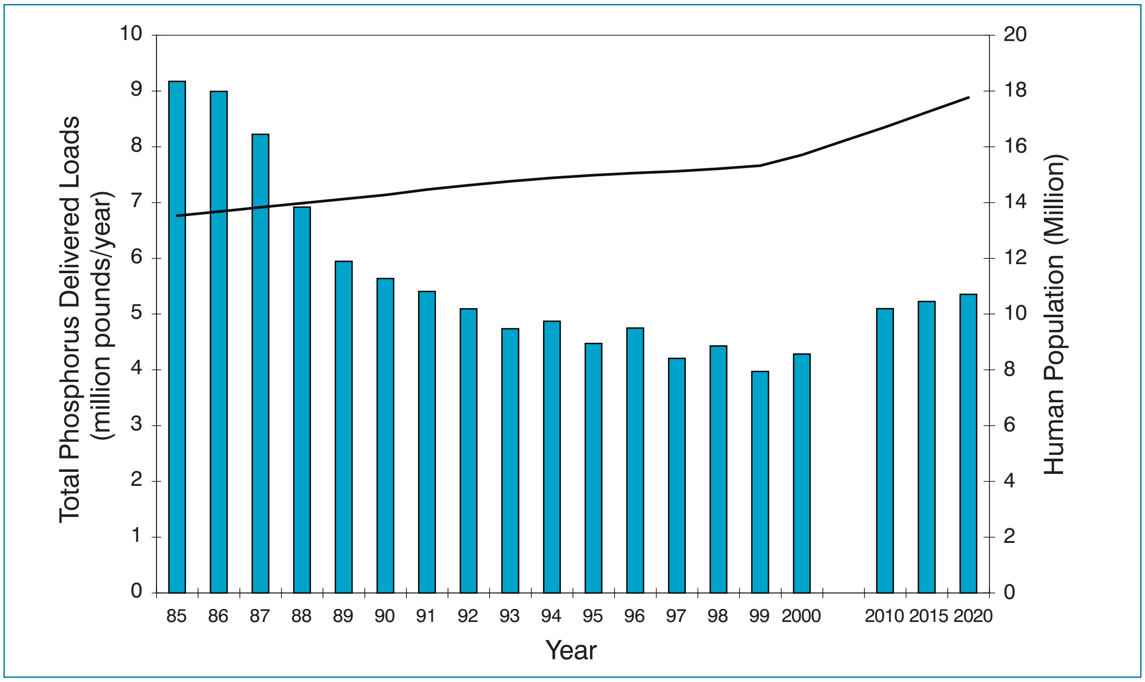

Figure II-16. Total phosphorus loads delivered to the Chesapeake Bay and its tidal tributaries from all point source facilities in the watershed (■) compared with human population trends (—) in the Chesapeake Bay watershed projected through 2020.

Source: Chesapeake Bay Program website http://www.chesapeakebay.net.

past, present and for future projections based on NRT implementation plans by 2010, and for the year 2020 if no more facilities than currently planned implement NRT. Significant progress has been made since 1985 in achieving reductions, but population growth will diminish these successes unless NRT is implemented in more of the facilities, while simultaneously reaching far greater performance levels.

ATMOSPHERIC SOURCES

The sources of nitrogen emissions which contribute to atmospheric nitrogen deposition to the Chesapeake Bay and its watershed are primarily fossil fuels combustion (e.g., electric power generation, on-road vehicles, and industry) which emit nitrogen oxides (NO_x) and agricultural activities (such as commercial fertilizers and animal manure), which release ammonia into the air. Much of the atmospheric nitrogen that deposits to the watershed and makes it way to the tidal waters originates from states located in the nitrogen (NO_x and ammonia) airsheds (Figure II-17). The NO_x airshed is roughly 1,081,600 km^2 in size and the ammonia airshed is roughly 688,000 km^2 in size.

Atmospheric nutrient pollution that falls directly on the water is displayed as a separate category and accounts for 8 percent of the total nitrogen load. Ultimately,

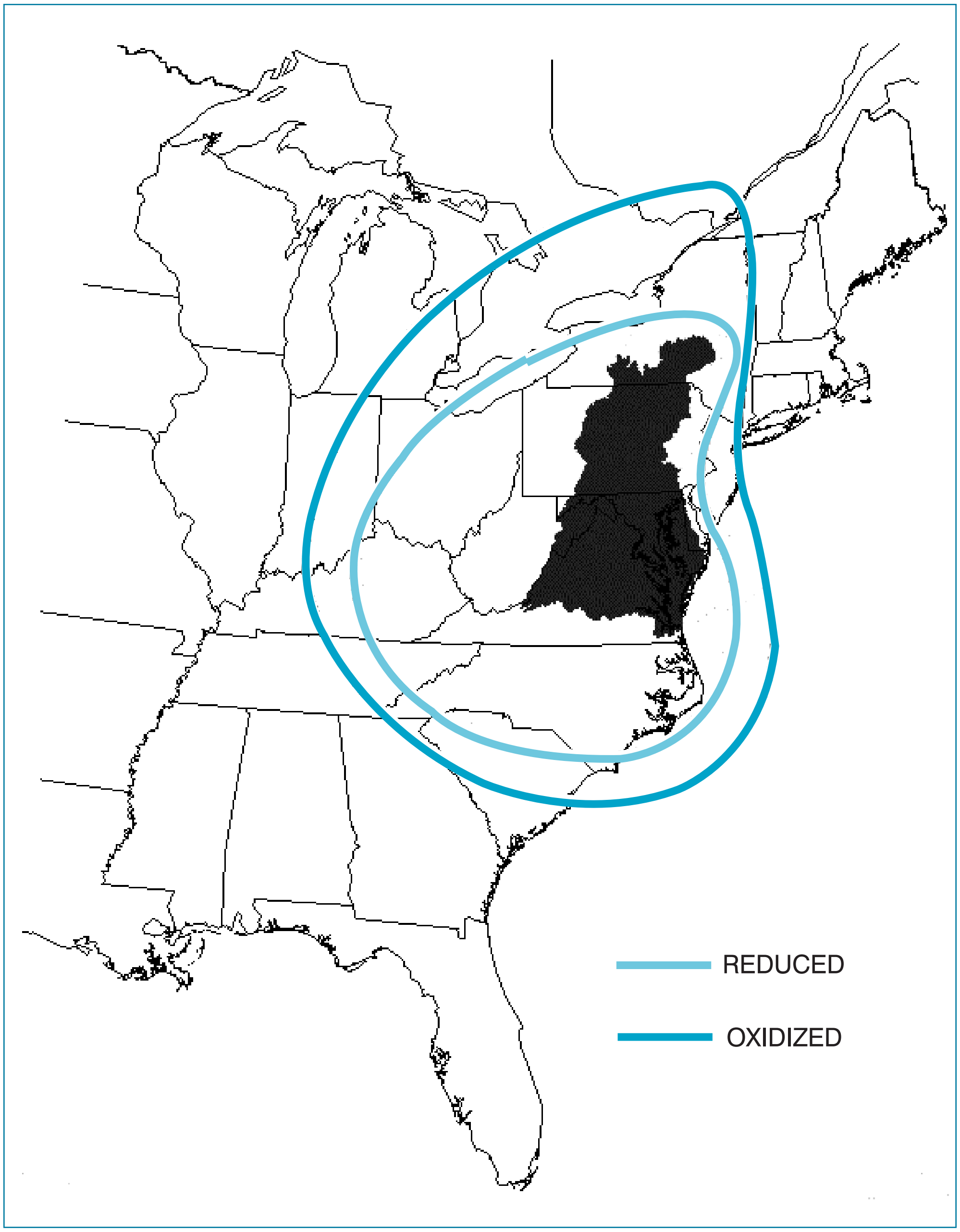

Figure II-17. Principal nitrogen airsheds for the Chesapeake Bay.

Source: Chesapeake Bay Program website http://www.chesapeakebay.net/air/air.htm.

atmospheric nitrogen emissions can be viewed as a nonpoint source when they are deposited on the land and reach the Chesapeake Bay as runoff. Atmospheric nitrogen that falls on the land accounts for an additional 24 percent of the total nitrogen load and is included as part of the agriculture, forest and urban and mixed open sources in Figures II-9 and II-10.

ANTHROPOGENIC SOURCE INPUTS

Table II-3 was developed by estimating the relative nitrogen and phosphorus source contributions from the perspective of anthropogenic inputs–atmospheric emissions, chemical fertilizers and manure. This table includes atmospheric deposition directly to tidal waters (20 million pounds), thus totaling a model-estimated 305 million pounds/year of nitrogen delivered to the Chesapeake Bay and its tidal waters instead of 285 million pounds/year as portrayed in Figures II-9 and II-10. As also shown in Table II-3, the combined atmospheric deposition directly to non-tidal and tidal surface waters is 8 percent (7 percent plus 1 percent) of the total load.

Table II-3 provides estimates based solely on proportions of anthropogenic inputs. There are three key inputs to the land surfaces–atmospheric deposition, chemical fertilizer applications, and manure applications–from which the relative contribution in delivered nitrogen loads is depicted based on their relative proportions. There are natural sources of nitrogen loads to Chesapeake Bay tidal waters that cannot be extracted and are, therefore, included in these source contributions.

Table II-3. Chesapeake Bay Airshed and Watershed Model-estimated 2000 Progress scenario sources of nitrogen and phosphorus loads (million pounds/year) delivered to the Chesapeake Bay and its tidal tributaries based on anthropogenic inputs of atmospheric deposition, chemical fertilizers, manure, point sources and septics, excluding shoreline erosion.

Source Loading Category	Total Nitrogen 2000 Progress	Total Nitrogen (% of Total) 2000 Progress	Total Phosphorus 2000 Progress	Total Phosphorus (% of Total) 2000 Progress
Atmospheric Deposition to Land	75,003,697	25%	5,900,372	29%
Atmospheric Deposition to Non-Tidal Water	3,559,840	1%	162,471	1%
Atmospheric Deposition to Tidal Water	20,467,458	7%	1,550,081	7%
Chemical Fertilizer Applications to Agricultural Land	49,353,664	16%	3,456,104	17%
Chemical Fertilizer Applications to Urban Land	18,146,154	6%	0	0%
Chemical Fertilizer Applications to Mixed Open Land	9,872,122	3%	0	0%
Manure Applications to Agricultural Land	46,048,616	15%	4,646,036	22%
Animal Feeding Operation Runoff	8,026,157	3%	696,297	3%
Point Source	62,841,812	21%	4,257,314	21%
Septic	11,904,029	4%	0	0%
Bay-Wide Total	**305,223,54**	**100%**	**20,668,675**	**100%**

Source: Chesapeake Bay Program website http://www.chesapeakebay.net.