Nutrient Trends and Drivers in the Chesapeake Bay Watershed

The Chesapeake Bay Program maintains an extensive nontidal monitoring network, measuring nitrogen and phosphorus (nutrients) at more than 100 locations on rivers and streams in the watershed. Data from these locations are used by United States Geological Survey (USGS) to assess the ecosystem's response to nutrient-reduction efforts. This fact sheet summarizes recent trends in nitrogen and phosphorus in nontidal tributaries and identifies some of the complex factors that affect local water quality, and ultimately, the Chesapeake Bay.

Watershed Trends Show Mixed Results That Differ for Nitrogen and Phosphorus

USGS updates trends in total nitrogen and phosphorus on the basis of data from the nontidal monitoring network. Trends (fig. 1) are normalized for watershed area and the magnitude of stream flow, to make it easier to compare sites and distinguish trends resulting from human actions.

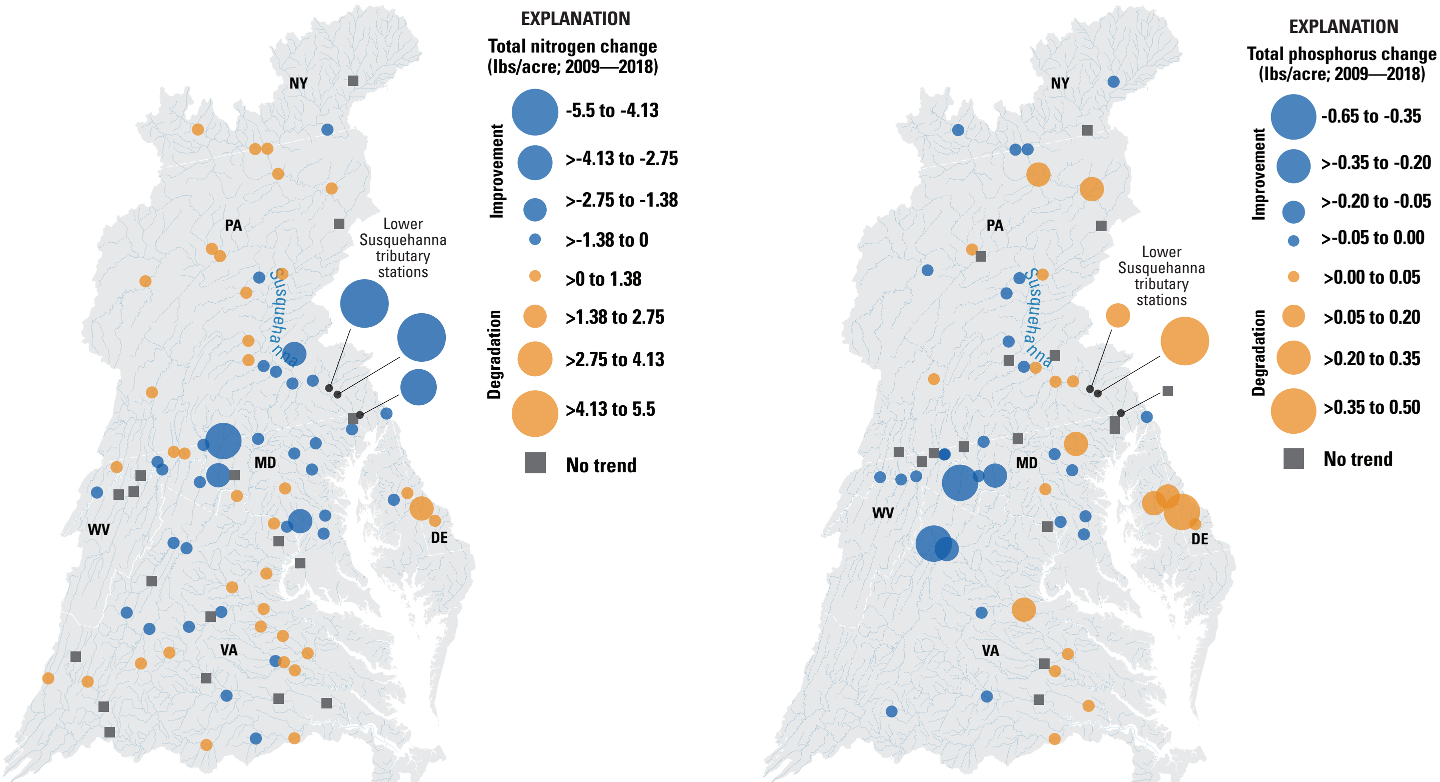

Figure 1. Total nitrogen and total phosphorus trends at nontidal monitoring stations in the Chesapeake Bay watershed. Data from Moyer and Langland (2020). (lbs, pounds; NY, New York; MD, Maryland; PA, Pennsylvania; VA, Virginia; WV, West Virginia; DE, Delaware)

Total nitrogen (N) trends (2009—2018)

- Reductions in total N at 41 percent of stations.
- Increases in total N at 40 percent of stations.
- No trend in total N at 19 percent of stations.
- Water quality (WQ) trends are improving at most sites with the largest N loads per acre, including agricultural areas of the lower Susquehanna and Potomac River watersheds.
- In Maryland, trends for the Western Shore show WQ improvement, but most trends for the Eastern Shore show degradation. Trends in the upper Susquehanna and Virginia watersheds show mixed results.

Total phosphorus (P) trends (2009—2018)

- Reductions in total P at 44 percent of stations.
- Increases in total P at 32 percent of stations.
- No trend in total P at 24 percent of stations.
- No stations in the Potomac River watershed have trends showing WQ degradation with P.
- Trends for the lower Susquehanna River Basin and most sites on the Eastern Shore of Maryland show WQ degradation with P. Trends are mixed in the Virginia watersheds.

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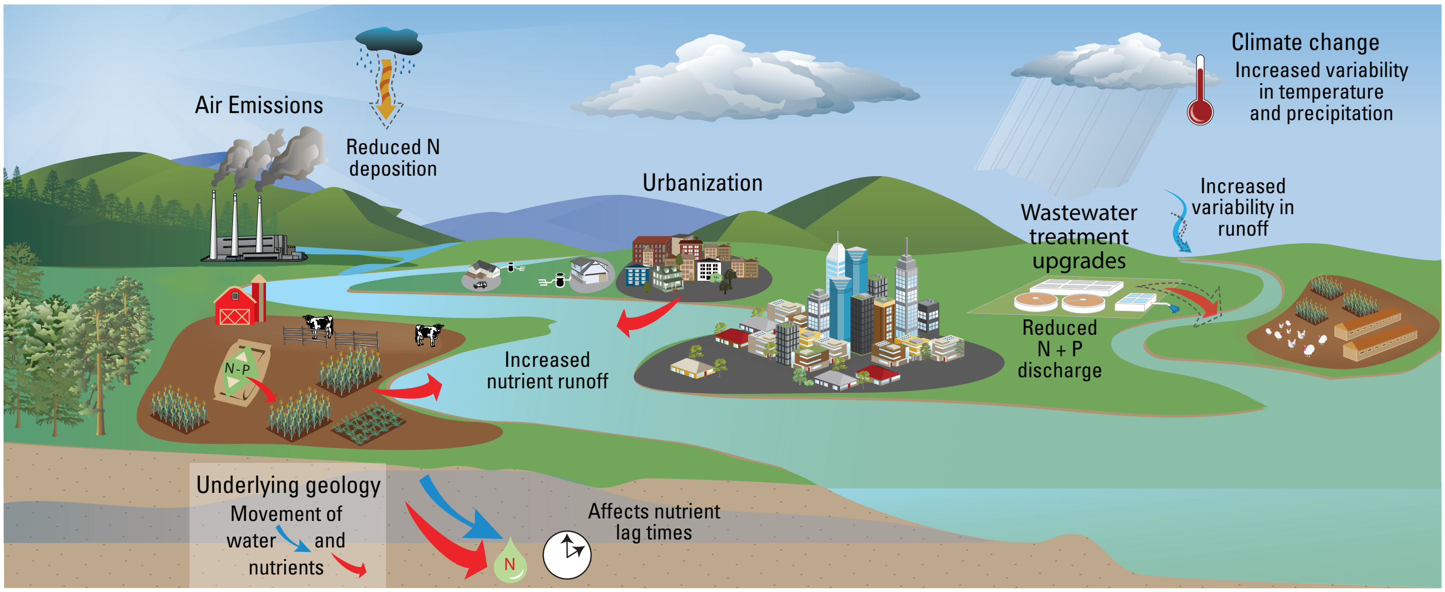
Factors Driving Nutrient Trends in the Chesapeake Bay Watershed

A myriad of factors affects the sources and transport of nitrogen and phosphorus in the Chesapeake Bay watershed (fig. 2). Sources of nitrogen and phosphorus and transport (the manners in which they reach our waterways) can differ from one another. Overall nutrient trends reflect these various sources and transport mechanisms.



Factors affecting sources of nutrients

- Air emission reductions from power plants resulting in decreased nitrogen deposition from the air.
- Wastewater-treatment plant upgrades resulting in decreased nitrogen and phosphorus loadings.
- Land conversion from pasture to cropland resulting in intensive nutrient application (for example, fertilizer and animal manure).
- Urbanization: Population growth and urban development resulting in losses of forested and agricultural land.

Factors affecting delivery of nutrients

- Climate change resulting in more variable precipitation and temperature, which affects runoff and the delivery of nutrients to streams
- Lag times (the length of time between nutrient input to the landscape and delivery into streams) are affected by groundwater age, underlying geology, sediment movement, phosphorus storage in sediments and riparian buffer age.

Figure 2. Conceptual diagram illustrating some of the complex factors affecting nutrient trends in the Chesapeake Bay watershed.

Nutrient reductions have been achieved through wastewater and atmospheric improvements

N Upgrades to wastewater treatment plants are responsible for substantial water-quality improvements in the Bay watershed and associated nitrogen loads to the Bay (fig. 3). Improvements in air quality also contribute to improved nitrogen levels in streams across the watershed, especially in forested areas. However, these changes in atmospheric deposition have limited effects on loads to the Bay, explaining only 13—14 percent of declines in nitrogen loads since the early 1990s.

P After a ban on phosphate in detergents and goals established under the 1987 Chesapeake Bay Agreement, phosphorus levels from point sources (for example wastewater-treatment plants) declined dramatically in the Chesapeake Bay watershed (fig. 4). Point-source reductions can lead to rapid improvements in water quality because nutrients from point sources are delivered directly to surface waters.

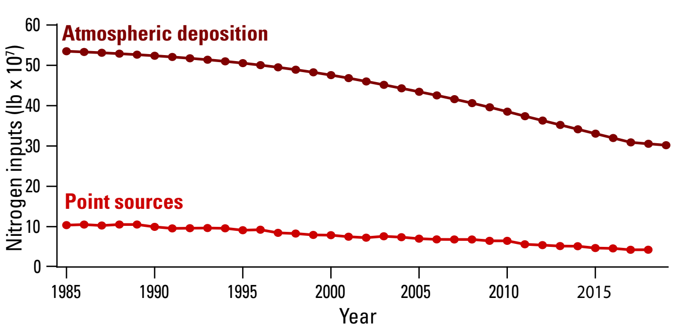


Figure 3. Nitrogen inputs to Chesapeake Bay watershed from 1985 to 2018. Data provided by Chesapeake Bay Program. (lb, pound)

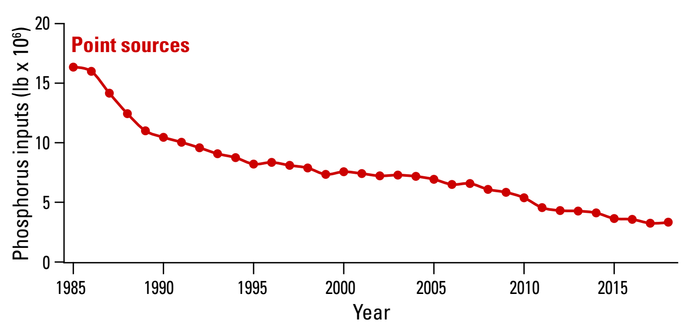


Figure 4. Phosphorus inputs to Chesapeake Bay watershed from 1985 to 2018. Data provided by Chesapeake Bay Program. (lb, pound)

Land-use change contributes to varying nutrient trends in urban streams

Between 1992 and 2012, urban areas in the Chesapeake Bay watershed expanded by 27 percent, resulting in the loss of forested and agricultural land. Water-quality changes following development can differ on the basis of prior land use. Urban development in former agricultural areas may improve nitrogen and phosphorus trends, whereas conversion from forest to urban land may degrade nutrient trends.

A mixture of nutrient trends has been observed in urban watersheds and all the drivers of these changes have not been fully resolved. Average nitrogen loads to the Bay from urban areas have decreased in recent decades; for example, nitrogen loads have decreased since the early 1990s in Accotink Creek, an urbanized watershed in Virginia that has experienced little land-use change in the past 30 years (1991—2020; fig. 5). However, nitrogen loads increased over this same time period in Difficult Run, a neighboring watershed where urban land use increased.

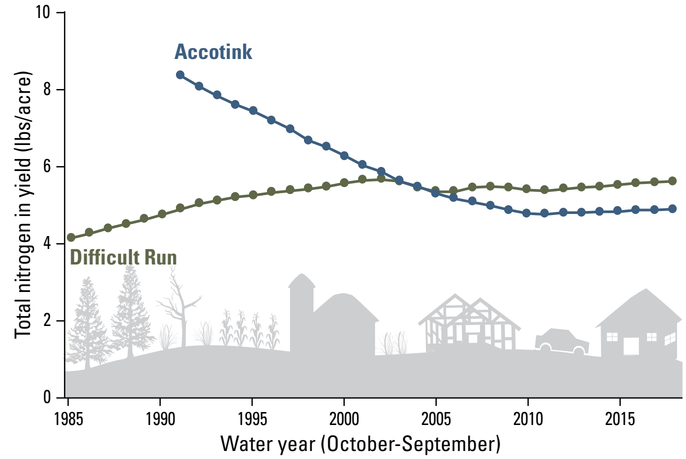


Figure 5. Total nitrogen load at Accotink Creek near Annandale, Va., and Difficult Run near Great Falls, Va. Background conceptual graphic represents land-use change from forested to agricultural to urban for some developed watersheds. Data from Moyer and Langland (2020). (lbs, pounds)

Loads in agricultural watersheds are affected by nutrient applications and other factors

The history of how manure and fertilizer were applied on agricultural lands reflects the type and intensity of the activities that took place in those areas. Despite some conversion of pasture to cropland, total farmland area in the watershed has stayed relatively constant since the early 1990s. Overall, livestock has decreased, but poultry production has increased. As a result, total manure and fertilizer inputs to the watershed have remained steady over the last several decades, but agricultural inputs have varied across local watersheds.

Other factors, such as best-management-practice implementation, variation in climate, and groundwater age, also interact to affect nutrient loads and trends in agricultural watersheds. A mixture of nutrient trends showing improvement and degradation have been observed in agricultural watersheds in recent years (fig. 6). For example, in Maryland's Choptank River watershed, phosphorus loads have increased, which may be the result of increased manure applications or legacy phosphorus in soils. In Pennsylvania's Conestoga River watershed, nitrogen loads have decreased, even though nitrogen inputs are steady. These differences highlight the complexity of associating landscape activities with nutrient trends.

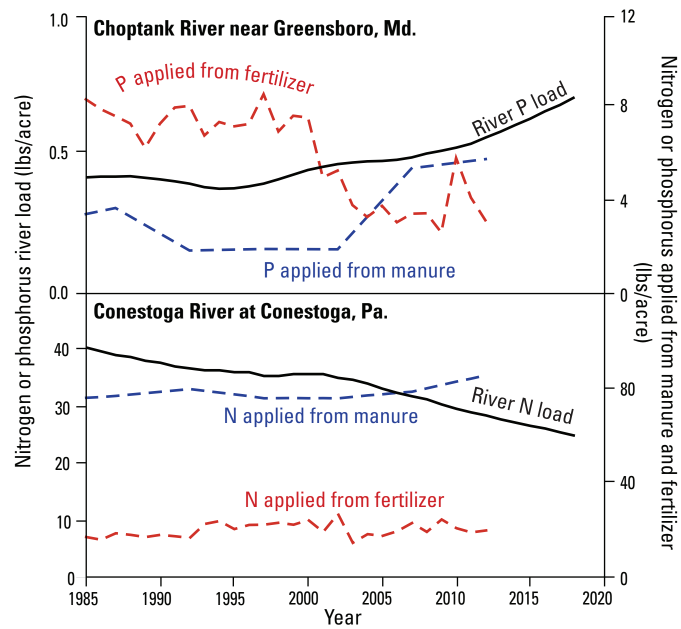
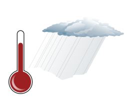


Figure 6. Total phosphorus load at Choptank River near Greensboro, Md., and total nitrogen load at Conestoga River at Conestoga, Pa., as well as associated manure and fertilizer inputs. Data from Moyer and Langland (2020) and Sekellick (2017). (lbs, pounds)

Climate change affects nutrient delivery to streams



Understanding nutrient trends in streams is complicated by increasing rainfall volume and rising air temperatures, which affect annual river flow into the Chesapeake Bay (fig. 7). Increased rainfall may lead to an increase in nutrient and sediment delivery to streams. However, rising temperatures and precipitation have been linked to declining nitrogen loads in the Bay watershed in recent decades. Declining nitrogen loads may occur in warmer and wetter conditions because of increased denitrification (conversion of nitrate to nitrogen gas) or increased plant uptake.

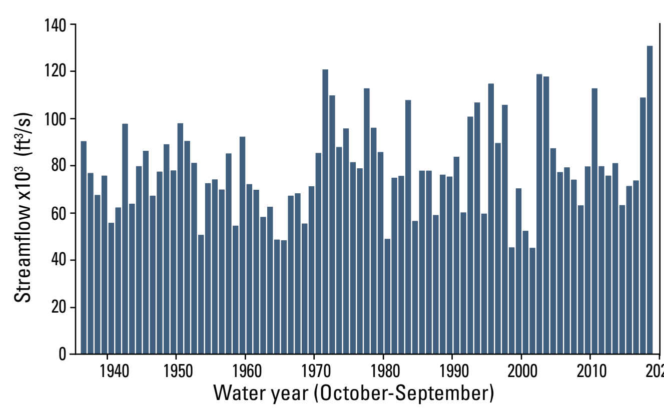


Figure 7. Annual mean streamflow into Chesapeake Bay, water years 1937-2019. USGS Freshwater Flows to the Bay website (2020). (ft^3/s, cubic feet per second)

Challenges Toward Effective Management of Nonpoint Sources

Actions taken to lessen or keep nutrient pollution from entering rivers and streams are referred to as best management practices (BMPs). BMPs exist for rural, suburban and urban areas (fig. 8). Planting winter cover crops, managing animal manure and enhancing riparian vegetation are all useful practices on agricultural lands to reduce levels of nitrogen and phosphorus in groundwater and soil. For urban regions, upgrading septic systems, as well as managing stormwater, help to decrease nitrogen and phosphorus while lessening the effect of stormwater runoff that causes erosion. BMPs can assist in reducing the additional nutrient pollution that occurs when forested land is converted for agricultural or suburban purposes.

However, note that nutrient trends may not always follow the expectations associated with the implementation of certain BMPs. To this end, it is important to recognize the following challenges:

Insufficient monitoring

Existing networks that monitor surface-water quality may not be well designed to detect changes that occur from BMP implementation. BMP effects and other watershed changes are typically most apparent when measured at the field or farm scale or in shallow groundwater.

Competing factors

Some BMP effects may be offset by effects of previous or current landscape changes, such as those caused by climate shifts, or fertilizer or manure applications.

Travel time

It can take significant periods of time, even multiple decades in some instances, for nutrients to reach local waterways. Additionally, the effects of BMPs on water quality can take years to be fully realized.

Unrealistic expectations

Many BMPs are put in place for a variety of reasons beyond reducing nutrient pollution. Expectations about the effectiveness of management practices are often based on observations from limited local studies that are rarely verified with post-restoration monitoring programs.

Figure 8. Top photo: Brubaker Farms in Lancaster County, Pa., is a 900-cow dairy farm that uses a variety of sustainable features and best management practices for reducing nutrient runoff, such as buffered streams. Photo by Steve Droter/Chesapeake Bay Program. Bottom photo: A parking lot at the U.S. Naval Academy in Annapolis, Md., features a rain garden. Rain gardens collect and slow stormwater runoff and increase infiltration to the soil. Photo by Matt Rath/ Chesapeake Bay Program.

Results from the Chesapeake Bay nontidal monitoring network provide important feedback on management actions. These efforts ensure that monitoring results will continue to inform the adaptive management of the Bay and its watershed.

For more information regarding nutrient loads and trends visit:

https://va.water.usgs.gov/storymap/NTN
https://www.usgs.gov/centers/cba

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Front-page photograph: USGS staff collecting a water-quality sample at the Dragon Swamp. Photograph from USGS.

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