Summary of Nitrogen, Phosphorus, and Suspended-Sediment Loads and Trends Measured at the Nine Chesapeake Bay River Input Monitoring Stations: Water Year 2022 Update

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The Chesapeake Bay River Input Monitoring (RIM) network consists of nine stations located near the nontidal-tidal interface of the nine largest rivers in the Chesapeake Bay watershed (fig. 1). These rivers are the Susquehanna, Potomac, James, Rappahannock, Appomattox, Pamunkey, Mattaponi, Patuxent, and Choptank. Stations are located near U.S. Geological Survey (USGS) streamgages to permit estimates of nutrient and sediment loading and trends in the amount of constituents delivered downstream. The Chesapeake Bay partnership uses results from this monitoring network to determine the amounts of, and trends in, nitrogen, phosphorus, and suspended sediment delivered annually from the nontidal portion of the Chesapeake Bay watershed.

A summary (table 1) of water year 2022 trends is presented below. Changes in loads for nitrogen, phosphorus, and suspended sediment are provided for two time periods: 1985-2022 (long term) and 2013-2022 (short term). The RIM stations where loads are lower in the end year than in the start year are classified as having improving conditions, whereas stations where the loads are higher in the end year than in the start year are classified as having degrading conditions (improving/degrading conditions are based on a likelihood estimate probability score of greater than or equal to 67 percent). A station is classified as having no trend if there is no discernable difference between the loads in the start year and those in the end year (based on a probability score greater than 33 and less than 67 percent).

Table 1. Summary of long-term (1985-2022) and short-term (2013-2022) trends in nitrogen, phosphorus, and suspended- sediment loads for the River Input Monitoring stations. “Improving” or “Degrading” trends are classified as likelihood estimates greater than or equal to 67 percent, whereas “No trend” estimates are greater than 33 and less than 67 percent.

RIVER INPUT MONITORING STATION	TOTAL NITROGEN LOAD		TOTAL PHOSPHORUS LOAD		SUSPENDED-SEDIMENT LOAD	
	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term
SUSQUEHANNA RIVER AT CONOWINGO, MD	*Improving*	*Improving*	*No Trend*	*Improving*	*Degrading*	*Improving*
POTOMAC RIVER AT CHAIN BRIDGE, MD	*Improving*	*Improving*	*Improving*	*Improving*	*Improving*	*No Trend*
JAMES RIVER AT CARTERSVILLE, VA	*Improving*	*Improving*	*Improving*	*No Trend*	*No Trend*	*No Trend*
RAPPAHANNOCK RIVER NEAR FREDERICKSBURG, VA	*Improving*	*Degrading*	*Degrading*	*Degrading*	*Degrading*	*Degrading*
APPOMATTOX RIVER AT MATOACA, VA	*Degrading*	*Degrading*	*Degrading*	*Degrading*	*Degrading*	*Degrading*
PAMUNKEY RIVER NEAR HANOVER, VA	*No Trend*	*No Trend*	*Degrading*	*No Trend*	*Degrading*	*Improving*
MATTAPONI RIVER NEAR BEULAHVILLE, VA	*Improving*	*Degrading*	*No Trend*	*No Trend*	*Degrading*	*Degrading*
PATUXENT RIVER AT BOWIE, MD	*Improving*	*Improving*	*Improving*	*Improving*	*Improving*	*Improving*
CHOPTANK RIVER NEAR GREENSBORO, MD	*Degrading*	*Degrading*	*Degrading*	*Degrading*	*Improving*	*Degrading*

Methods

Loads, and changes in loads, of nitrogen, phosphorus, and suspended-sediment in rivers across the Chesapeake Bay watershed are calculated using monitoring data from the RIM stations for the period 1985 to 2022 (Mason and Soroka, 2023). Additional information for each monitoring station is available through the USGS "Chesapeake Bay Water Quality Loads and Trends" site (usgs.gov/CB-wq-loads-trends). This website provides State, Federal, and local partners, as well as the general public, ready access to a wide range of data for nutrient and sediment conditions across the Chesapeake Bay watershed. In this summary, results are reported from two time periods: a long-term time period (1985-2022), and short-term time period (2013-2022). All annual results are based on a water year, which extends from October 1 through September 30 and is reported as the year in which that period ends.

The USGS computes load and trend results from the RIM network to provide (1) monthly and annual loads of nitrogen, phosphorus, and suspended sediment; and (2) the trends in these loads. The nine RIM stations have monitoring data that extends back to at least 1985. Load results from each of the nine RIM stations are combined, for nitrogen, phosphorus, and suspended sediment, to represent a total load from the nontidal portion of the Chesapeake Bay watershed.

Loads are computed using Weighted Regression on Time, Discharge and Season (WRTDS) bootstrap models (Chanat and others, 2015), which are then flow-normalized (FN) to produce the published trend estimates. These models are calibrated using sampling data collected monthly and during eight additional storm-events each year to obtain a minimum of 20 samples per year, representing a range of streamflow and constituent-loading conditions. The WRTDS serial error from each daily load model is then leveraged using a dynamic auto-correlation Kalman-filter adjustment to produce the published loads (Zhang and Hirsch, 2019). Ultimately, trends in loads at the RIM stations go through the FN process to remove the year-to-year variability in river flow; by doing so, changes in nitrogen, phosphorus, and suspended-sediment loads resulting from changing sources, delays associated with storage and transport of historical inputs, and (or) implemented management actions are better identified.

Patterns in Annual Freshwater Flow and Combined RIM Loads Delivered to Tidal Waters

The USGS combined the load results from the nine RIM stations shown in figure 1 to quantify the total nitrogen, phosphorus, and suspended-sediment loads delivered from the watershed to tidal waters. Together, the nine RIM stations reflect loads delivered from 78 percent of the 64,000-square-mile Chesapeake Bay watershed.

- Estimated annual-mean streamflow entering the Chesapeake Bay in 2022 was 73,000 cubic feet per second (cfs), about 7.5 percent (6,000 cfs) below the long-term (1937-2022) annual-mean streamflow of 79,000 cfs (fig. 2), which indicates a slightly below average total streamflow amount for the year. How did this mean annual streamflow rank? The year 2022 saw the 55th highest streamflow since 1937 (86 years).
- New for the 2023 release of load and trend results is the inclusion of streamflow trends for the long-term period of record. Trends in annual-mean streamflow were computed using a Mann-Kendall test; the rate of change was determined from the slope of a Thiel-Sen line. Trends in annual-mean streamflow show seven of nine RIM stations having a positive trend, with only one station (Choptank) being statistically significant.
- In 2022, the combined loads from the nine RIM stations were as follows:
    - Total nitrogen (TN): 160 million pounds (Mlb), 43 Mlb less than the long-term average of 203 Mlb for 1985-2022 (fig. 3).
    - Total phosphorus (TP): 7.5 Mlb, 4.4 Mlb less than the long-term average of 11.9 Mlb for 1985-2022 (fig. 4).

- Suspended sediment (SS): 2 million tons (Mton), 2 Mton less than the long-term average of 4 (Mtons) for 1985-2022 (fig. 5).

The Chesapeake Bay Program uses these RIM loads, and estimated loads from the remaining unmonitored areas, to compute a total nutrient and sediment load to the Bay.

Trends in Loads Delivered to Tidal Waters from the RIM Stations

Changes in loads for nitrogen, phosphorus, and suspended sediment were estimated for two time periods: 1985-2022 (long term) and 2013-2022 (short term). The trend qualifiers "improving," "degrading," and "no trend" are based on Chesapeake Bay Restoration goals for water-quality attainment (reduction of nutrients and sediments) in the bay. The terminology "no trend" indicates that an "improving/degrading" trend is about as likely to exist as it is not to exist, based on a middling probability score from the trend-estimation model.

Changes in total nitrogen loads

- Long-term trends in total nitrogen loads indicate improving conditions at six stations, including the four largest rivers (Susquehanna, Potomac, James, and Rappahannock, along with the Patuxent and Mattaponi). The Choptank and Appomattox are the only stations where conditions are degrading. The Pamunkey shows no trend (meaning a trend was deemed as likely to exist as not) for this time period.
- Short-term trends in total nitrogen loads indicate improving conditions at four stations (Susquehanna, Patuxent, Potomac, and James) and degrading conditions at four stations (Choptank, Rappahannock, Mattaponi, and Appomattox). The Pamunkey shows no short-term trend.

Changes in total phosphorus loads

- Long-term trends in total phosphorus loads indicate improving conditions at three stations (Patuxent, Potomac, and James) and degrading conditions at four stations (Choptank, Rappahannock, Pamunkey, and Appomattox). Data from the Susquehanna and Mattaponi indicate no discernable long-term trend.
- Short-term trends in total phosphorus loads indicate improving conditions at three RIM stations (Susquehanna, Potomac, and Patuxent), degrading conditions at three stations (Choptank, Rappahannock, and Appomattox), and no discernable trend at the James, Pamunkey, and Mattaponi.

Changes in suspended-sediment loads

- Long-term trends in suspended-sediment loads indicate improving conditions at three stations (Choptank, Patuxent, and Potomac), degrading conditions at five stations (Susquehanna, Rappahannock, Pamunkey, Mattaponi, and Appomattox), and no discernable trend in conditions at the James.
- Short-term trends in suspended-sediment loads indicate improving conditions at three of the nine stations (Susquehanna, Patuxent, and Pamunkey), degrading conditions at four stations (Choptank, Mattaponi, Rappahannock, and Appomattox), and no discernable trend for conditions at the Potomac or James stations.

References Cited

Mason, C.A. and Soroka, A.M., 2023, Nitrogen, Phosphorus, and suspended-sediment loads and trends measured at the Chesapeake Bay River Input Monitoring stations: Water years 1985-2022: U.S. Geological Survey data release, doi.org/10.5066/P97IFYES.

Chanat, J.G., Moyer, D.L., Blomquist, J.D., Hyer, K.E., and Langland, M.J., 2015, Application of a weighted regression model for reporting nutrient and sediment concentrations, fluxes, and trends in concentration and flux for the Chesapeake Bay Nontidal Water-Quality Monitoring Network, results through water year 2012: U.S. Geological Survey Scientific Investigations Report 2015–5133, 76 p., accessed January 14, 2015, at pubs.er.usgs.gov/publication/sir20155133/.

Zhang, Q. and Hirsch, R. M., 2019, River water-quality concentration and flux estimation can be improved by accounting for serial correlation through an autoregressive model: Water Resources Research, 55, 9705–9723. doi.org/10.1029/2019WR025338.

Additional Information and USGS Contacts

For more information on this topic, visit the "Water-Quality Loads and Trends at Nontidal Monitoring Stations in the Chesapeake Bay Watershed" website at usgs.gov/CB-wq-loads-trends, or contact:
Chris Mason **camason@usgs.gov**
Alex Soroka **asoroka@usgs.gov**

For more information on USGS Chesapeake Bay studies, visit chesapeake.usgs.gov/, or contact
Ken Hyer, **kenhyer@usgs.gov**.

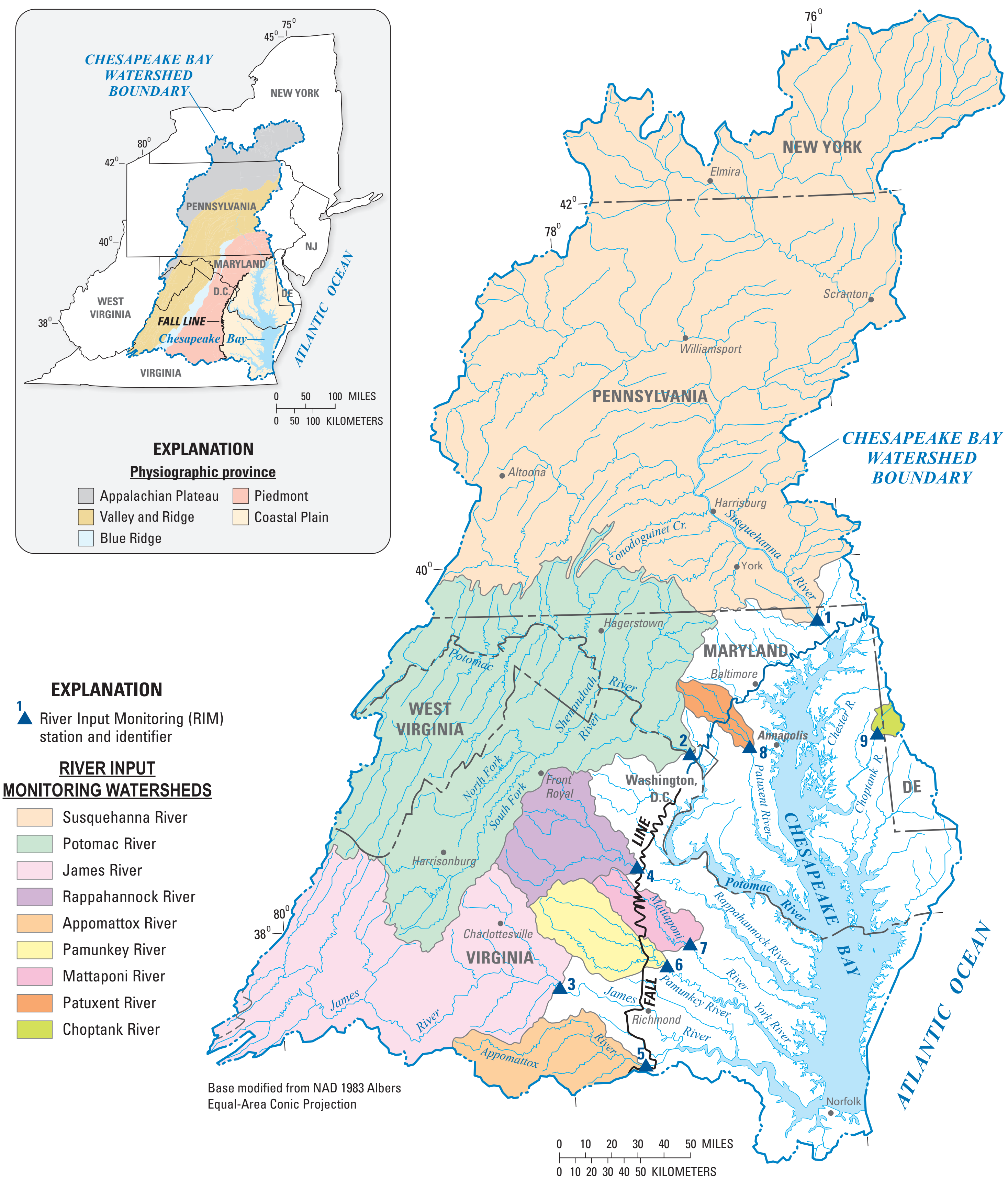

Figure 1. Location of the nine River Input Monitoring (RIM) stations in the Chesapeake Bay watershed. Station names are provided in Table 1.

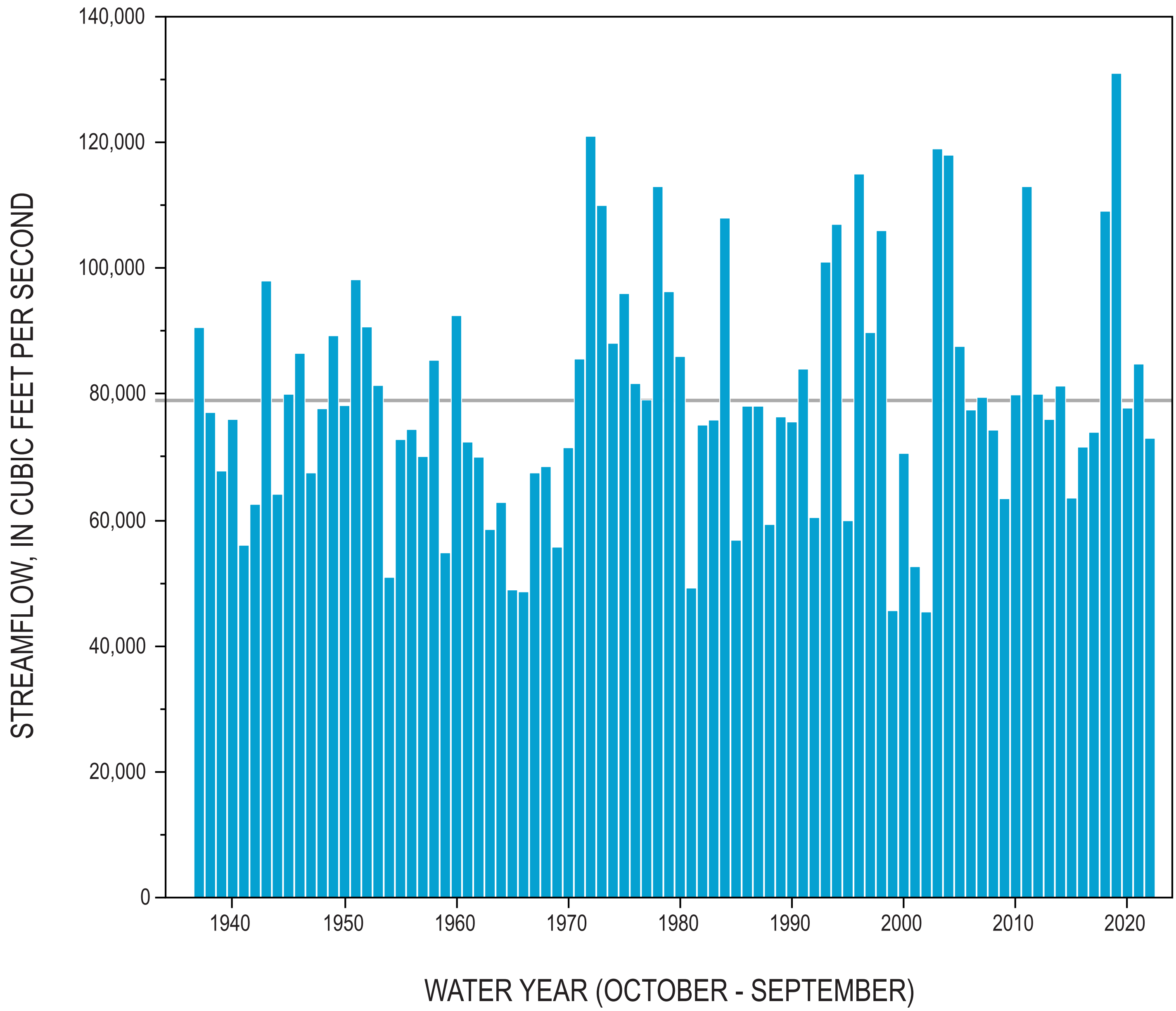

Figure 2. Estimated annual-mean streamflow entering the Chesapeake Bay. Gray line represents the average annual-mean streamflow of 79,000 cubic feet per second.

[SOURCE: usgs.gov/centers/cba/science/freshwater-flow-chesapeake-bay?qt-science_center_objects=0#qt-science_center_objects]

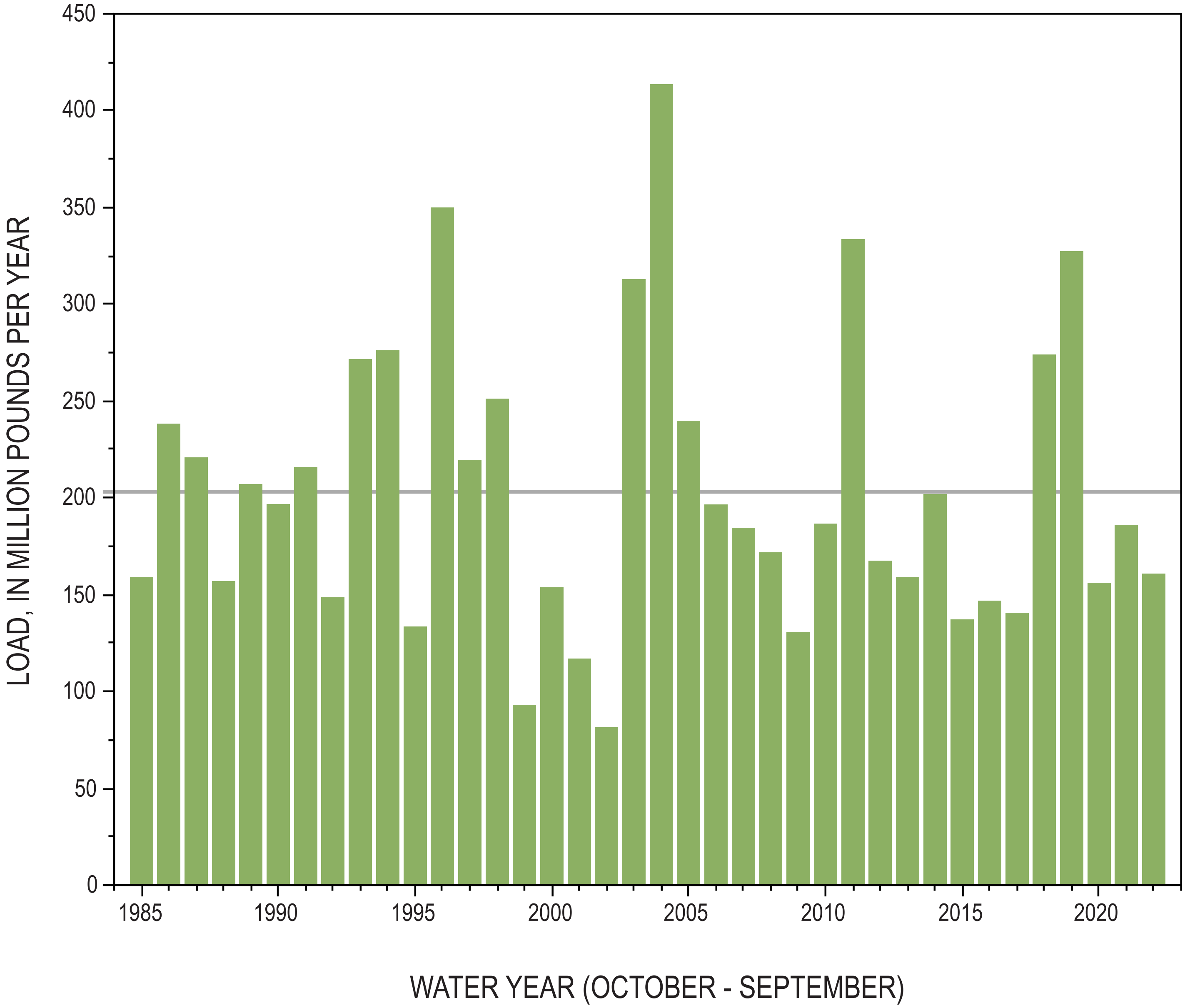

Figure 3. Combined annual total nitrogen delivered from the nine River Input Monitoring stations to the Chesapeake Bay. Gray line represents the mean annual combined load of 203 million pounds per year.

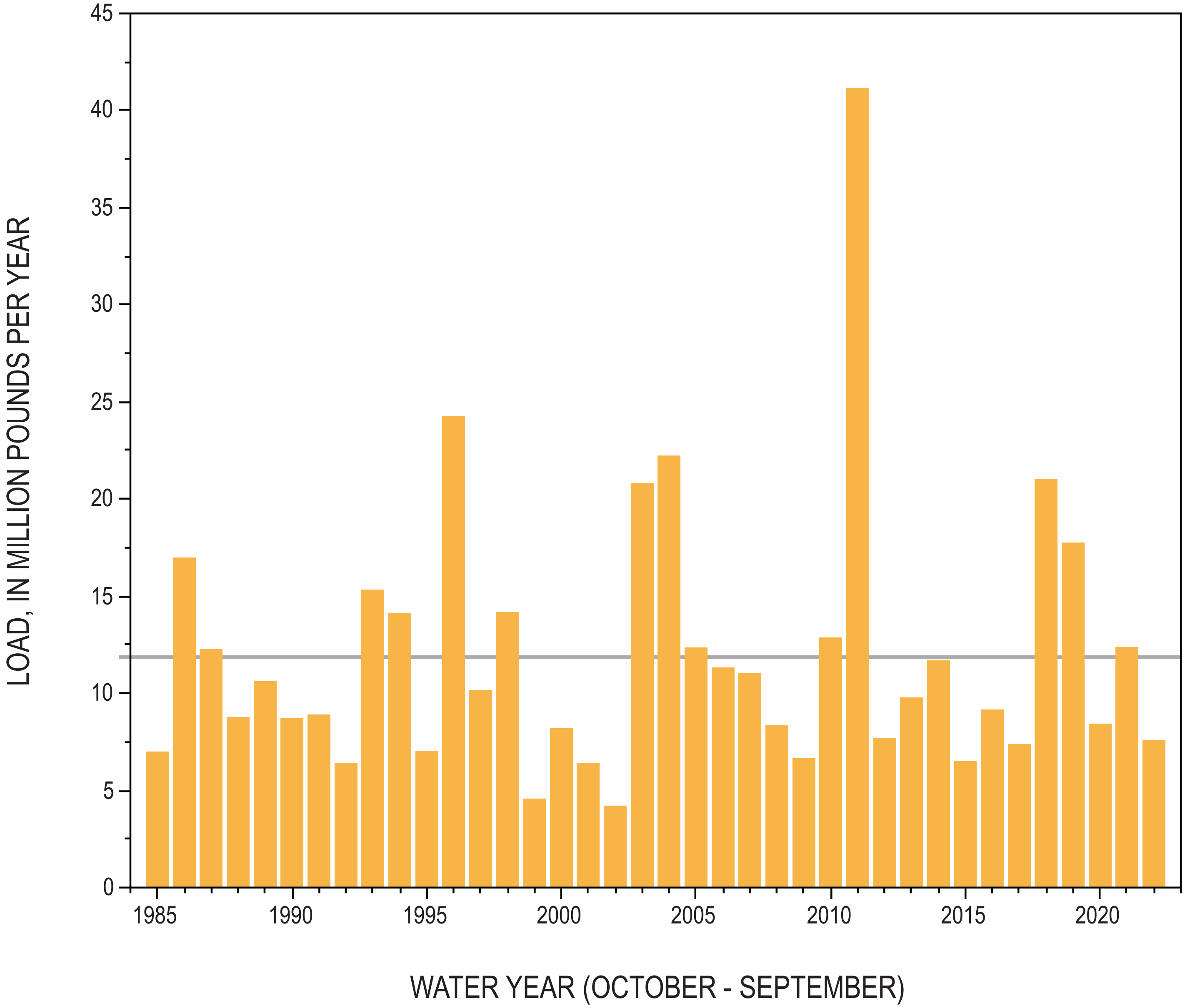

Figure 4. Combined annual total phosphorus delivered from the nine River Input Monitoring stations to the Chesapeake Bay. Gray line represents the mean annual combined load of 11.9 million pounds per year.

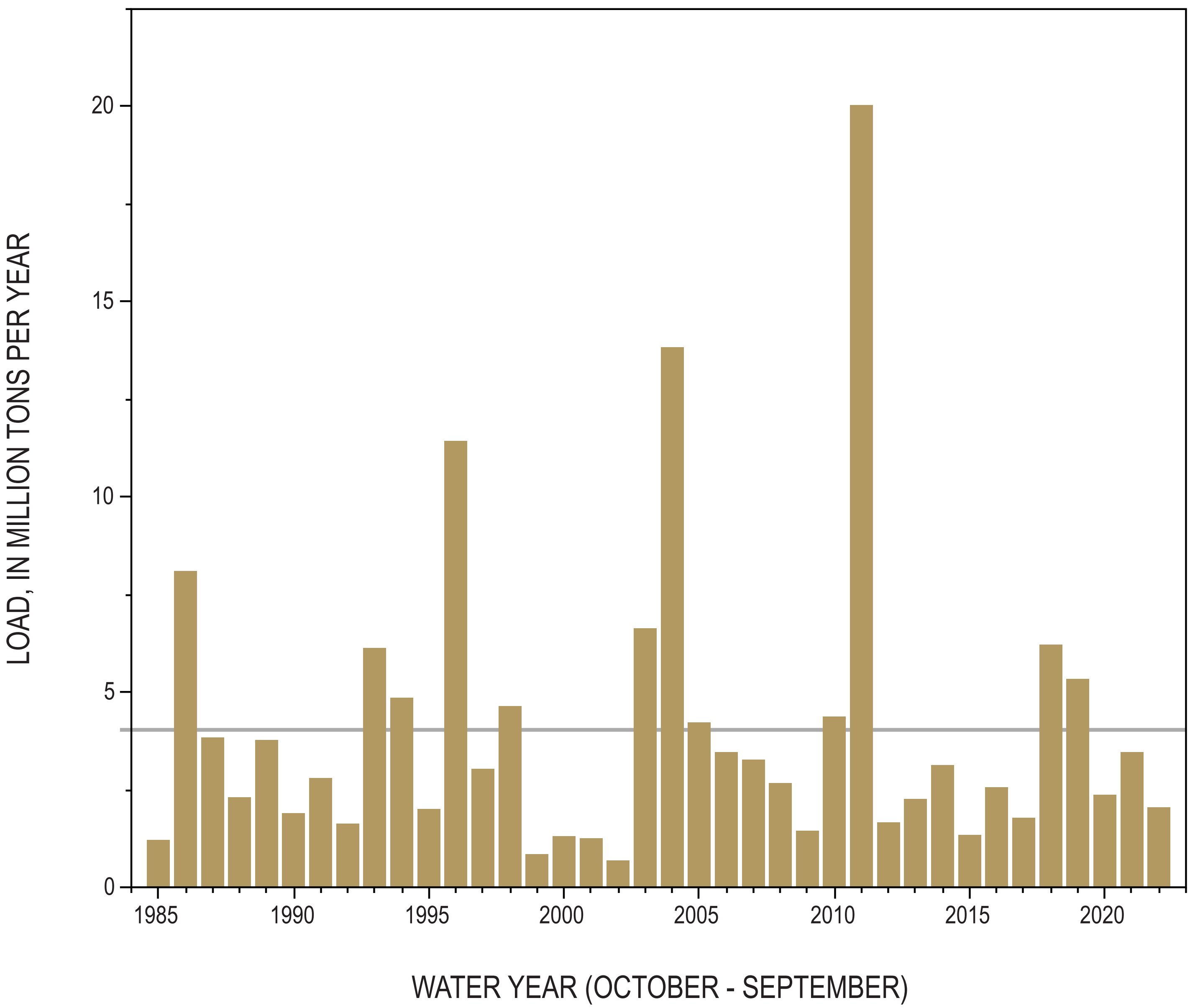

Figure 5. Combined annual suspended-sediment load delivered from the nine River Input Monitoring stations to the Chesapeake Bay. Gray line represents the mean annual combined load of 4 million tons per year.