Chesapeake Bay Program | Indicator Analysis and Methods (A&M) Document
Modeled Load Reduction Indicator

Each Indicator update must include an Analysis and Methods document that explains how the data are collected, analyzed, interpreted, and communicated to ensure transparency and consistency. Outcome Representatives and subject-matter experts complete the document during an Indicator's first iteration—addressing analytical methods, trends, and data quality—and update it with each new data release. The document is posted on ChesapeakeProgress with the associated data file, which contains more detailed metadata and reported metrics, for internal and external audiences across the Chesapeake Bay Program.

Relevant *Chesapeake Bay Watershed Agreement* Outcome(s): Reducing Excess Nitrogen, Phosphorus, and Sediment (RENPS)

Relevant Outcome Target(s): Through 2030, signatories will continue to accelerate completion of all interim water quality planning targets through implementation of Chesapeake Bay Watershed Implementation Plans, two-year milestone commitments and other innovative strategies to achieve and maintain reduced levels of nitrogen, phosphorus and sediment.

Link to Management Strategy: The Management Strategy will be developed by Summer 2027.

Location within Indicators Framework (i.e., Output or Performance): Performance

A. Analysis and Methods Document Metadata
Additional supporting metadata for this document is available in the associated Indicator data file; this document and the data file should be updated together to remain consistent.

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2. **Resource Date:** June 25, 2026

B. Analysis and Interpretation
Where appropriate, please provide references or location(s) of documentation (e.g., link to downloadable dataset, story map, tool, report).

1. Briefly describe the dataset. What parameters are directly measured? What parameters are derived through calculation? For what purpose(s) are the data used? Progress for this indicator is estimated by using up-to-date wastewater discharge data and tracked Best Management Practice (BMP) implementation data reported to EPA's Chesapeake Bay Program Office (CBPO) by Bay watershed jurisdictions. The CBPO assesses the current or "progress" condition of nutrient and sediment loads to the Chesapeake Bay using Phase 6 of the Watershed Model (i.e., Chesapeake Assessment Scenario Tool (CAST)). The Watershed Model estimates pollutant loads from all major sources including wastewater, agricultural runoff and discharges, urban and suburban runoff, septic fields, and

air deposition and reports these fluxes based on average weather conditions. Data are used for planning, tracking, research, long-term monitoring, and estimating progress toward the partnership's adjusted Interim Target with changing environmental conditions (CEC) (previously known as the Phase III planning targets) and the jurisdictions' Phase III Watershed Implementation Plans (WIPs) commitments. The combined jurisdictions' Phase III WIP commitments and the adjusted Interim Target with CEC meet Bay water quality standards (WQS).

Annual jurisdictional submissions of both monitored and estimated wastewater effluent concentrations and flows as well as BMP data for nitrogen, phosphorus, and sediment from point and nonpoint sources are tracked and reported by jurisdictions using the Chesapeake Bay Program Office's Point Source Data Application and via the BMP Data Submission Portal on CAST. This document and the accompanying data spreadsheet reports 2025 progress using the CAST-2023 version of the Phase 6 model (also referred to as CAST-23).

2. What methods are used to collect, process, model, analyze, and/or transform raw data into the Indicator? Please cite methods, analytical tools, modeling programs, and relevant documentation. Documentation for the Phase 6 Watershed Model is available through CAST at https://cast.chesapeakebay.net/Documentation/ModelDocumentation.

   For more information on modeling at the Chesapeake Bay Program, visit https://www.chesapeakebay.net/what/programs/modeling.

   Verification protocols were established through the Bay Program Partnership's Verification Framework in 2014. This framework established the key component of "Oversight and Evaluation" which allows EPA to oversee the annual review of BMP submissions conducted by Bay Program Staff. The purpose of these annual reviews is to confirm that submitted practices have been verified, follow the quality assurance and quality control (QA/QC) procedures documented in the jurisdictions' BMP Quality Assurance Program Plans (QAPPs), and represent real on-the-ground management actions. The protocols were developed to set the expectations for the timely submission of accurate data and the appropriate reporting format. Since 2014, annual verification reviews have been completed, and EPA CBPO has worked with the jurisdictions to resolve any identified areas of concern. If the identified areas of concern do not follow the verification procedures outlined in the QAPP, represent` data found to be erroneous through the evaluation process, and/or represent data reported without Bay partnership approval, EPA CBPO may use the previous year's data submission for the applicable practice or remove the record from the dataset.

BMP verification is the process through which agency partners ensure practices, treatments and technologies resulting in reductions of nitrogen, phosphorus and/or sediment pollutant loads are implemented and operating correctly. It can be viewed as a life cycle process that includes initial inspection, follow-up checks and evaluation of BMP performance. This methodology has largely stayed the same since 2014, with adjustments approved by the Partnership provided on the Chesapeake Bay BMP Verification webpage. All elements of the Bay Program framework for BMP verification are documented on the BMP Verification webpage.

Wastewater: Data sets from more than one source of wastewater information are typically merged at the relevant jurisdictional agency to accommodate different types of point sources, municipal and industrial, significant and non-significant. These jurisdictional data sets are uploaded to the Point Source Data Submission Application. Data sets from each of the seven jurisdictions, in turn, are merged at the Chesapeake Bay Program Office.

Agriculture, Developed, Septic and Air: The procedures for managing the data and the quality of the results of the methods are described in each jurisdiction's BMP Verification Program Plan published through the CBP Program Plans and Resources site.

The BMP data from the seven Bay jurisdictions are merged at the Chesapeake Bay Program Office through the Data Submission Portal on CAST, a repository for BMP data covering hundreds of BMP types reported at many spatial scales and time periods across all sectors.

3. Are there established targets, thresholds, reference conditions, or desired-state values for this Indicator? If yes, describe them and how they were derived.
   Targets for this indicator were set by EPA's December 2010 *Chesapeake Bay Total Maximum Daily Load (TMDL) for Nitrogen, Phosphorus, and Sediment*. The TMDL is designed to ensure that all nitrogen, phosphorus and sediment reductions needed to fully restore the Bay and its tidal rivers are in place by 2025, with controls, practices, and actions in place by 2017 that would achieve at least 60% of the reductions from 2009 necessary to meet the TMDL.

   Under the partnership Accountability Framework, DE, DC, MD, NY, PA, VA, and WV developed Phase I–III Watershed Implementation Plans (WIPs) describing actions sufficient to meet those allocations. In 2022, partners acknowledged the 2025 goals will not be met on schedule; in September 2023 the Principals' Staff Committee (PSC) adopted Interim Targets with Changing Environmental Conditions (CEC) while post-2025 targets are set. These Interim Targets include "unaccounted additional loads" (UALs)—the positive difference between Phase III WIPs run on CAST-2023 and CAST-2017 after within-jurisdiction N and P

exchanges—added to the 2025 Planning Targets and slated for incorporation into Phase 7 of the Watershed Model. The PSC also approved WQGIT-recommended allocation methods for UALs (a decrease of 9.7 million lbs. nitrogen and 0.1 million lbs. phosphorus developed by the Urban Stormwater Workgroup nutrient task force and Agricultural Fertilizer Expert Group for CAST-23).

Separately, on December 17, 2020, the PSC directed jurisdictions to address additional nutrient loads due to 2025 CEC via Phase III WIP addenda and/or two-year milestones beginning in 2022. The desired state includes loads less than or equal to the 2025 Interim Targets with CEC (N, P, sediment) for each jurisdiction's portion of the major tributaries. These targets represent a condition where all practices are in place by 2025 that will achieve the Bay's dissolved oxygen, water clarity/SAV and chlorophyll-a standards. Pennsylvania's amended Phase III WIP does not meet the Phase III planning targets and includes supplemental documentation for additional reductions.

This indicator assesses progress toward those targets using Phase 6 CAST scenario loads that reflect the combined effects of BMP implementation, wastewater discharges, and changing watershed conditions. The model simulations represent "what-if" management scenarios, providing comparisons among historic and current watershed conditions and a future condition that would restore water quality and living resources in the Chesapeake Bay. Reported loads from the Watershed Model for non-wastewater source pollutants are estimates of what would occur under average weather conditions in a single year's watershed conditions.

4. Have there been any changes to targets, thresholds, data sources, methodology, or analytical approaches since the last reporting period? If yes, describe what changed and why. Yes. Targets and allocation methods were updated to incorporate Changing Environmental Conditions (CEC): an additional 5.0 million pounds of nitrogen and 0.6 million pounds of phosphorus were addressed via a Water Quality Goal Implementation Team-recommended approach (discussed Jan–Sep 2020) that reduces loads in areas where CEC increases are occurring; this load-based method was approved by the Management Board (10/15/2020) and Principals' Staff Committee (12/17/2020), included in 2022–2023 milestones, and slated for additional implementation by 2025, with a reevaluation of 2035 CEC underway in 2026. New York also amended its Phase III WIP (2019) to meet interim targets using nitrogen and phosphorous exchange ratios—1:5 (P→N) and 15:1 (N→P)—applied within/between major basins; the technical basis is in Section 6.4.6 of Establishing Allocations for the Basins-Jurisdictions, and these adjustments, combined with other states' Interim

Targets with CEC, meet Bay water quality standards. Interim targets reflecting CEC are posted on CAST.

C. Communicating the Data

Where appropriate, please provide references or location(s) of documentation (e.g., link to downloadable dataset, story map, tool, report).

1. Define the Outlook[1] toward achieving the Outcome as On Course, Off Course, Uncertain, or Completed. Off Course for the RENPS Outcome. The MLRI compares 2025 progress-year modeled loads to the 2025 Interim Targets with CEC versus 2009; because nitrogen and phosphorus are off course, the overall outcome is Off Course. Current RENPS goals are being carried forward from 2025 to 2030 from the prior 2025 WIPs Outcome.

   Nitrogen 2025 Interim Target with CEC: Reduce by 77.6 million lbs. from 297.1 to 219.6 million lbs. (26.1% reduction).
   - Status: −44.4 million lbs. since 2009 (15% reduction) to 252.7 million lbs. in 2025.
   - Outlook: BMPs are in place to achieve an estimated 57% of the nitrogen load reductions necessary by 2025 to meet water quality standards as compared to 2009.

   Phosphorus 2025 Interim Target with CEC: Reduce by 4.0 million lbs. from 16.8 to 12.8 million lbs. (23.8% reduction).
   - Status: −3.6 million lbs. since 2009 (21.4% reduction) to 13.2 million lbs. in 2025.
   - Outlook: BMPs are in place to achieve an estimated 90% of the phosphorus load reductions necessary by 2025 to meet water quality standards as compared to 2009.

   Sediment 2025 Target: Reduce by 243 million lbs. from 18,830 to 18,587 million lbs. (1.3% reduction).
   - Status: −1,275 million lbs. since 2009 (6.8% reduction) to 17,555 million lbs. in 2025.
   - Outlook: BMPs are in place to achieve 100% of the sediment load reductions necessary by 2025 to meet water quality standards as compared to 2009.

2. What do the most recent data show compared to the previous reporting period? Are there any short-term trends? Nitrogen loads to the Bay increased by an estimated 1.1 million pounds/yr from 2024 to 2025 compared to the average annual load reduction of 3.0 million pounds/yr over a period of 15 years from 2009 to 2024. Since 2009, 64% of the nitrogen load reductions came from

wastewater treatment plants, 24% from reductions in atmospheric deposition, and 9% from the agricultural sector. Over the most recent progress year, 54% of the nitrogen load reductions came from wastewater treatment plants, 0% from the agriculture sector, 35% from reductions in atmospheric deposition, and 0% from the developed sector. While not a key focus for Nitrogen reductions, an additional 10% of reductions came from the natural sector.

Phosphorus loads to the Bay increased by an estimated 0.1 million pounds from 2024 to 2025 compared to the average annual load reduction of 0.2 million pounds/yr over a period of 15 years from 2009 to 2024. Since 2009, 61% of the phosphorus load reductions came from wastewater treatment plants, 16% from the natural sector and 16% from the agricultural sector. Over the most recent progress year, 100% of the phosphorus load reductions came from wastewater treatment plants.

Bay-wide, 100% of the reduction goal for sediment has been achieved. Sediment loads to the Bay increased by an estimated 165 million pounds/yr from 2024 to 2025 compared to the average annual load change of 96 million pounds/yr over a period of 15 years from 2009 to 2024. Since 2009, 43% of the sediment load reductions came from the agriculture sector and 55% of reductions from the natural sector. Over the most recent progress year, there were zero reductions in sediment from any sector.

The reported loads are annual averages for a year of average hydrology or precipitation, even though the hydrodynamic version of CAST is calibrated at much finer time steps over a period going back to 1984.

Full implementation of the BMP Verification Protocol and unresolved data issues led to upward revisions in modeled loads for Pennsylvania and Maryland. In Pennsylvania, wetland mitigation is not an accepted BMP per the Wetland Verification Guidance in Appendix B of the Basin-wide Verification Framework; mitigation acres previously reported as wetland or stream restoration were removed, increasing 2025 loads by 12,699.6 lbs. nitrogen, 3,088.2 lbs. phosphorus, and 7,952,561.2 lbs. sediment. In Maryland, the dairy precision feeding BMP was adjusted to remove phosphorus credit—because the state's monitoring survey tracks only nitrogen—resulting in a 904.2 lbs. increase in phosphorus load.

3. What is the long-term trend since data collection began? Computer simulations for the entire Chesapeake Bay watershed (all sources combined) show that between 1985 and 2025: nitrogen loads decreased by 118.1 million pounds from 370.8 to 252.7 million pounds (32% reduction); phosphorus loads decreased by 16.0 million pounds from 29.2 to 13.2 million pounds (55% reduction); and

sediment loads decreased by 2,763 million pounds from 20,318 to 17,555 million pounds (14% reduction).

4. What is the key story told by this Indicator? Explain the "why" behind the data in clear, plain language. (e.g., Are there specific geographic areas of concern? Are there broader factors influencing the results?) Excess nitrogen and phosphorus are two of the leading causes of the Chesapeake Bay's poor health. When nitrogen and phosphorus enter rivers, streams, and the Bay, they fuel the growth of algae blooms that lead to low oxygen "dead zones" that are harmful to fish, shellfish and other aquatic life. In general, nitrogen and phosphorus reach the Bay through several primary sources, including wastewater treatment plants; urban, suburban and agricultural runoff; and air deposition. The TMDL limits the amount of nutrients and sediment that can enter the Bay if it is to achieve water quality standards for dissolved oxygen, chlorophyll-α, clarity, and Submerged Aquatic Vegetation (SAV) coverage. Excess sediment is another one of the leading causes of the Chesapeake Bay's poor health. While loose particles of sand, silt and clay are natural parts of the environment, too much sediment can cloud the waters of the Bay and its tributaries, harming underwater grasses, fish and shellfish. Sediment enters the Bay when land, stream banks and shorelines erode. Erosion increases when land is cleared for agriculture and development. The TMDL limits the amount of sediment that can enter the Bay if it is to achieve water quality standards.
    i. What management actions or strategies have most influenced trends in the data? The trends are most influenced by two management components: broad implementation and verification of best management practices (BMPs), with emphasis on nonpoint sources in agriculture and unregulated developed areas and point source upgrades at wastewater facilities aligned with permit limits and available funding, which reduce discharges. Supporting strategies that shape these trends include sustained water quality monitoring to interpret responses and guide adaptive management; coordinated communication and collaboration across jurisdictions, local governments, and federal partners; and targeted funding and technical assistance to build local implementation capacity. Management also increasingly accounts for Changing Environmental Conditions (CEC), directing additional reductions where loads increase due to climate or other shifts. Evolving watershed conditions (e.g., land use and crop shifts, nutrient inputs, animal and human populations, septic, atmospheric deposition) can raise or lower loads; effective management strategies can offset adverse changes through BMPs and improved nutrient management (e.g., reducing overapplication on turf and crops).
    ii. Are there any projects or case studies that showcase successful examples of progress? Provide contact information for individual projects or case studies, if possible. N/A

iii. What obstacles or challenges (e.g., resources, capacity, funding) currently limit progress? Progress is limited by implementation gaps relative to jurisdictions' WIPs and two-year milestones that are quantified annually in CAST and driven by capacity shortfalls. Key constraints include insufficient financial resources to oversee and implement MS4 and other stormwater programs; inadequate financial, technical, and regulatory capacity to deliver priority practices in priority watersheds; weak or incomplete BMP tracking, verification, and reporting; and limited funding to maintain new and existing practices. These gaps are reflected in current performance toward interim targets with CEC: about 57% of the nitrogen target and 90% of the phosphorus target are achieved, short of the 100% needed by 2025. Closing the gap will require new incentives, enhanced state/local regulatory programs, market-based tools, added technical and financial assistance, potential legislative authorities, and greater partner capacity from federal agencies, local governments, the private sector, and NGOs.

D. Data Quality

Where appropriate, please provide references or location(s) of documentation (e.g., link to downloadable dataset, story map, tool, report). For more information on metadata standards, see Chesapeake Bay Program Metadata Specification document.

1. Were the data collected and processed under an EPA-approved Quality Assurance Project Plan (QAPP)? Yes. The quality of the data reported annually by stakeholders is described in each jurisdiction's BMP Verification Program Plan. These are EPA-approved Quality Assurance Project Plans that are part of the Partnership's TMDL verification program, last approved in July 2026.

2. Were sampling and analytical procedures consistent throughout the data record? Note any deviations, transitions, or merging of datasets that may affect interpretation. For wastewater, facilities largely used EPA-approved standard sampling and analysis methods documented in Discharge Monitoring Reports, with jurisdiction and Bay Program QA/QC via the Point Source Data application; however, early record gaps required protocols to fill missing data, facilities were added/retired over time, and calculation methods for converting flows and effluent concentrations to end-of-pipe loads were refined. For agriculture, developed, septic, and air sectors, jurisdictions rereported historic BMP implementation under Phase 6 guidelines to improve logic and fill gaps; reported levels sometimes changed due to new tracking systems or revised resource assessments rather than on the ground shifts.

E. Additional Information (Optional)

Where appropriate, please provide references or location(s) of documentation (e.g., link to downloadable dataset, story map, tool, report).

For 2025 Progress, EPA applied the partnership's BMP Verification Protocols and conducted annual evaluations of each jurisdiction's verification program (e.g., implementation rates, new practices, reported implementation and inspection dates). Loads to the Bay were simulated with the CBP Phase 6 Watershed Model (CAST), which explicitly models atmospheric nitrogen deposition using the Chesapeake Bay Airshed Model (a regression model for wet deposition plus the continental CMAQ model for dry deposition); see model documentation under "Terrestrial Inputs." For TMDL tracking, each scenario incorporates atmospheric deposition at forecasted levels; EPA calculates atmospheric deposition to the watershed by subtracting "allocation air" (loads assuming full Clean Air Act implementation) from loads with actual year-specific deposition. Urban runoff and septic loads typically rise with development unless offset by BMPs, while forest buffer/tree plantings expand forest area and reduce total loads because forests export fewer nutrients and sediment than agricultural or urban lands.

[1]*Outlook:* Outlook is the forecasted trajectory for whether the Chesapeake Bay Program is on course to achieve the Outcome. An Outcome's Outlook may be On Course, Off Course, Uncertain, or Completed.