Understanding Chesapeake Bay Modeling Tools: *A history of updates, governance, policy and procedures*

Chesapeake Bay Program Modeling Tools

The Chesapeake Bay Program uses state-of-the art science and monitoring data to replicate conditions of the Chesapeake Bay watershed. This information is then used by decision-makers at the federal, state and local levels to determine how best to restore and protect local waterways, and ultimately, the Chesapeake Bay. By combining advanced modeling tools and real-world monitoring data, we gain a comprehensive view of the Chesapeake ecosystem—from the depths of the Bay to the upper reaches of the watershed.

The suite of computer modeling tools developed by the Chesapeake Bay Program divides the 64,000-square-mile watershed into thousands of smaller segments and helps us predict the impacts of best management practices (BMPs) and policies at the regional and local level. The most significant value of the suite of modeling tools is the ability to predict how the Chesapeake Bay may respond to future conditions such as pollutant loads, land use changes and climate change.

Chesapeake Bay Total Maximum Daily Load

The Chesapeake Bay Total Maximum Daily Load (Bay TMDL) identifies the necessary pollution reductions from major sources of nitrogen, phosphorus and sediment across the seven watershed jurisdictions—Delaware, the District of Columbia, Maryland, New York, Pennsylvania, Virginia and West Virginia—and sets pollution limits necessary to meet water quality standards across the Chesapeake Bay. The Bay TMDL calls for all pollution control programs and practices to be in place by 2025 that will result in the eventual attainment of these water quality standards. Each jurisdiction prepares a Watershed Implementation Plan (WIP) to guide their efforts in reducing nitrogen, phosphorus and sediment pollution.

Extensive measures exist to ensure accountability for reducing pollution and meeting target dates for progress under the Bay TMDL. As part of this accountability framework, two-year milestones are in place to increase restoration work and ensure progress.

The Chesapeake Bay Program uses adaptive management in our decision-making framework, which allows us to learn while doing. Through adaptive management, we predict (plan) using the model, we implement BMPs and take management actions (act) to reduce nitrogen, phosphorus and sediment loading, we follow up by observing the response of the ecosystem (monitor) and then we adjust our approach and assumptions (adapt) based on what was predicted versus what actually happened. We make changes to our tools, update monitored and measured inputs, incorporate new science and revisit our predictions to formulate the next set of actions to take. This is how the partnership utilizes the principals of adaptive management.

Chesapeake Bay Watershed Model

The Chesapeake Bay Program has a suite of modeling tools that work together to determine how much nitrogen, phosphorus and sediment pollution is entering local waterways, where it is coming from, how local actions will help reduce it and much more. However, it is the Chesapeake Bay Watershed Model that estimates the amount of nitrogen, phosphorus and sediment pollution reaching the Chesapeake Bay.

The Chesapeake Bay Watershed Model is available as a free, web-based tool called the Chesapeake Assessment Scenario Tool (CAST), that helps users determine which BMPs may be the most cost-effective and relevant to meeting nitrogen, phosphorus and sediment pollutant reduction goals for a given area. To get started with CAST, users specify a region and then select BMPs to apply on that area. CAST then builds a scenario, which provides estimates of how much nitrogen, phosphorus and sediment pollution will

be reduced. The estimated cost of this scenario is also provided so that users may select the practices that may be the most economical.

The tool is in use by counties, states, watershed groups and other units of local government across the Chesapeake Bay watershed for total maximum daily loads (TMDLs), nonpoint source pollutant management and municipal stormwater programs. It can help users better understand:

- Which BMPs could provide the greatest load reduction.
- The extent to which these BMPs could be implemented based on available resources and land availability, as well as the cost of implementation.
- How to refine the selected BMPs to meet planning needs.

CAST is one of four measures used by the Chesapeake Bay Program to assess progress toward meeting restoration goals. The other three measures look at tidal water quality trends, non-tidal loading trends (what and where conditions are improving, degrading or staying constant) and programmatic actions (such as policies, regulations and incentive programs) that the jurisdictions commit to implement through their WIPs and milestones.

Updating the Watershed Model

The Chesapeake Bay Program strives to use the best available science, data and information to inform and support our shared restoration efforts and collective decision-making processes. Given that scientific methods and data evolve over time, the partnership has discussed and debated how it can use and incorporate new methods and data into its modeling tools, while also retaining some amount of stability in the planning and implementation processes. In the past, updates to the model occurred whenever new data and information became available, without a defined schedule, causing logistical and communication challenges.

In 2014, the Modeling Workgroup under the Water Quality Goal Implementation Team (GIT) conducted a year-long investigation that deliberated how best to introduce new data and methods into the Chesapeake Bay Program modeling tools. The reason for this investigation was the 2012 U.S. Department of Agriculture (USDA) Census of Agriculture, 2011 National Land Cover Dataset and projections of human population growth from the jurisdictions. The impact of adding these new datasets was an increase in modeled nitrogen loads for Maryland, New York, Pennsylvania and West Virginia, and decreases in modeled nitrogen loads for Delaware, the District of Columbia and Virginia. Upon completing the investigation, the Milestone Workgroup made the recommendation to the Water Quality GIT that all jurisdictions should be evaluated with the same model that they used to develop their two-year milestones.

In December 2015 and January 2016, the Water Quality GIT and the Management Board, respectively, reached consensus on the recommendations from the Modeling Workgroup. It was decided that with the development of each jurisdiction's 2016-2017 milestones, the partnership would hold the assumptions set at the beginning of the milestone period constant over the following two years. Any changes to the decision to update the model every two years requires formal review and approval by the partnership.

Land uses would be predicted at the beginning of the milestone period and these projections would not be changed. At the end of the two years, Bay Program partners would factor in new information, BMP efficiencies and data previously approved by the partnership, into past and present progress runs, going back to 2009. With the introduction of new BMPs into the model, the jurisdictions then had the opportunity to go back and update their past reporting, using this new information.

The process for updating the model and transitioning to new versions is approved and directed by the partnership. By holding assumptions constant for the milestone period and updating with new data and information every two years, the model more accurately reflects what is happening on the ground. Changing conditions in the watershed can have as much, if not more, of an effect on nutrient and sediment pollutant loads, than BMP implementation.

Rationale

By consistently adding and refining new science, data, information and methods used in the model every two years, we get a better understanding of how our management actions and decisions may be impacting water quality and living resources across the Chesapeake Bay watershed. Some of these updates may include changes in livestock populations or land cover (e.g. forested land becoming urban). Accurately capturing these changes on a regular basis helps us understand if overall watershed health is improving or not, and why. These changes also measure historical progress and trends over time.

Updates to the model can change the amount of pollution estimated to enter the Bay from the rest of the watershed. For example, if there are more chickens in a given geographic area than previously reported and reflected in the model, this may show an increase in estimated nutrient loads because of additional manure. Subsequently, when new datasets are released, such as from the USDA Census of Agriculture, or high-resolution land cover, estimated pollutant loads may increase or decrease, particularly if future projections are being adjusted to account for the latest data. These adjustments, while having a potential impact on pollutant loads, are critical to the model as they show the most accurate representation of changes that have occurred over the last two years or more for a given geographic area.

These changes could mean that jurisdictions may have to adjust their implementation efforts to account for any increases in estimated pollutant loads. However, these potential changes in pollutant loads do not call for edits to a jurisdiction's WIP or local action plan. WIPs do not change unless a jurisdiction decides to do so, since they are official state documents.

There are technical and communication challenges with updating the model every two years. Although the 2025 Phase III WIP planning targets do not change, a given year's target and the level of effort needed to achieve the 2025 goal can modify, because historical progress runs will shift when they are re-calculated using new data and information.

New data means incorporating the effects of an ever-changing landscape (e.g., forest lands can become developed or turned into agricultural land). New data means a better estimate of animal populations and the amounts of crops grown. New data means updated science and our ability to incorporate information like high resolution land cover/land use. Finally, in this not all-inclusive list is updating BMP information to include new practices not previously included in the model, as well as updated efficiencies for existing BMPs.

These updates may impact a jurisdiction's level of effort in meeting their pollutant reduction goals. For example, if there was a huge increase in the acreage of soybeans being grown compared to what was previously reported, this will show as a rise in estimated pollutant loads as nitrogen from the roots, leaves and pods (that are not harvested) die and decompose, running off the land into the water. If previously reported lands used for agricultural production are taken out of use, there will be a decrease in estimated pollutant loads.

The differences show both greater improvements and degradations than were previously estimated – depending on the scale. This all leads to the Environmental Protection Agency (EPA) conducting two assessments of progress – one with the older version of the model and one with the updated version of the model. Each progress run will show different levels of achievement toward pollutant reduction goals. It can be difficult to explain to other partners and stakeholders the rationale behind these two assessments, and questions often arise about which version of the model should be and is available to use, for the next two-year milestone period.

If the model remains unchanged over time, no new BMPs will be added, no changes will be made to reflect BMP efficiencies, no updates will exist for land use/land cover data and there will be no realization of changes to livestock populations—just to name a few examples.

In making the decision to update the model every two years, the partnership evaluated the impact of allowing for changes versus locking the information down. It was known and understood that these updates would cause changes in pollutant loads for each jurisdiction.

The argument for model updates

TMDLs are plans put into place to restore impaired waterways by identifying the amount of pollution that a water body can receive while still meeting water quality standards. In particular, TMDLs address impairments to water quality that are not fully removed through point sources. In regard to the Bay TMDL, if new science, data and information are not incorporated into the model to reflect the best estimates of nutrient and sediment pollutant loads, then the model will not accurately predict how the actions taken today by each jurisdiction to reduce pollutant loads are helping to improve Bay water quality standards.

The partnership has invested millions of dollars into updating the Chesapeake Bay Program's suite of modeling tools in preparation for the Phase III WIPs and two-year milestones. The updates began in 2016 with the original high-resolution land cover analysis and continues to this day with the current six-year contract with the Chesapeake Conservancy.

Incorporating updated science, data and information, not only improves the accuracy of the model, but also helps restoration and conservation efforts from a variety of stakeholders. Additionally, it informs the ongoing collective efforts of Bay Program partners to better understand trends in water quality.

Updates are essential to maintaining public trust in the integrity of the restoration effort, particularly at the local level where people can easily verify whether our data reflects current conditions. Model updates are also essential for ensuring that our investments in restoration don't veer off course due to changing conditions in the watershed or scientific understanding.

How EPA uses the updated model

Before the model is updated, Chesapeake Bay Program partners can review any new data and information that is to be incorporated to ensure its accuracy. For the most recent round of updates (CAST-19), the Water Quality GIT began reviewing initial updated datasets in the summer of 2019. Once the updates are incorporated into the model, the partnership can run scenarios using the new version to see what changes have occurred for nutrient and sediment pollutant loads. For the newest version of the model, CAST-19, the Water Quality GIT has been reviewing the results of these scenario runs since fall 2019. The expectation is that this model will be used for the next two-year milestone period (2020-2021). The updated model will also be used for the annual BMP progress submissions and assessments over that same two-year period.

EPA uses the Chesapeake Bay Program approved suite of modeling tools – whether that be the current version, CAST-17, or the new version, CAST-19 – to assess progress for future milestone evaluations. EPA has also emphasized that its evaluations of progress are based on the partnership's decision that the Phase III WIP planning targets for 2025 will not change. If needed, it is the prerogative of each jurisdiction to revise their WIPs to adaptively manage their conservation efforts.

WIP targets and two-year milestones remain constant

In July 2018, the Principals' Staff Committee made the decision to approve the 2025 Phase III WIP planning targets for nutrient and sediment loads, using the Phase 6 Watershed Model, and stated that these targets would not change between that time and 2025, even with the addition of new science, data and information. Keeping the 2025 goals constant is intended to provide stability to state and local jurisdictions, while also allowing for the incorporation of the best available science, data and information into the model.

It is up to each jurisdiction to determine how they will reflect changes in pollutant loads into their WIPs and two-year milestones, as these are state-led efforts and official documents. It is not an EPA decision or expectation as to whether a jurisdiction should update its WIP or two-year milestones to reflect changes in pollutant loads. For example, it is the discretion of the Pennsylvania Department of Environmental Protection, in coordination with their local partners, to determine whether they want to update county targets to reflect the results from an updated version of the model or keep those targets the same. It is also a jurisdictional decision as to whether they should ask their counties for more reductions to account for any changes in pollutant loads. EPA's role in the partnership's accountability framework is to assess and report on the jurisdictions' progress toward for achieving the 2025 Phase III WIP planning targets, not each jurisdiction's localities (e.g. counties, townships), and to take appropriate federal actions, where warranted, at the jurisdiction level.

EPA and the Chesapeake Bay Program will continue to work closely with each jurisdiction on understanding and communicating shifts in pollutant loads due to model updates, and will continue to provide resources (e.g. staffing, financial) and technical assistance to support WIP and two-year milestone planning and implementation efforts.

Re-running old scenarios

When an updated version of the model is ready for use, EPA will use the new version to assess annual progress and evaluate future two-year milestones. It is recommended that users either re-run or create new scenarios in the updated version of the model to be consistent, but that is up to each user to determine. It is likely that re-running a scenario in an updated model could result in different numbers. A comparison tool between the older and newer version of the model will be available to help users understand any changes in the results between various scenarios. Chesapeake Bay Program management and staff continue to be available to provide technical assistance, including communications support, to help jurisdictions understand and apply any model updates to restoration planning and implementation.

Messaging challenges

Further discussions are needed by the partnership to determine options and approaches for how best to communicate this information to both targeted audiences and the general public. At a minimum, it is not just CAST users that should be aware of these updates but also program managers who are responsible for directing staff and resources toward providing and reviewing the information that informs these two-year model updates.

The following are new datasets available in CAST-19:

- **Land Use and Populations**
  - The latest high-resolution land cover data will greatly improve forecasts acres of land across dozens of land use categories for all source sectors *(updated every two years; CAST 2021 and every model version thereafter).*
  - County-level and/or Census zone population, housing and employment projections *(updated every two years; CAST 2019 and every model version thereafter).*
  - US Census Bureau human population *(updated every ten years from the Census Bureau but more frequent from states; CAST 2023 and every model version thereafter).*
  - Zoning *(updated every two years; CAST 2019 and every model version thereafter).*
  - State-specific land use data, especially where it relates to land use by agency type *(updated every two years; CAST 2019 and every model version thereafter).*
  - The Association of American Plant Food Control Officials (AAPFCO) fertilizer sales for non-farms *(updated every two years; CAST 2019 and every model version thereafter).*
  - Sewer service area boundaries *(updated every two years; CAST 2019 and every model version thereafter).*
  - MS4 area boundaries *(updated every two years; CAST 2019 and every model version thereafter).*
  - Septic system growth by county and/or model land-river segment *(updated every two years; CAST 2019 and every model version thereafter).*

- **Agricultural Data**
  - Animal populations and crop acres by county from the 2017 USDA National Agricultural Statistics Service (NASS) and 2022 USDA Census of Agriculture *(incorporated every five years except for some animal types where annual data are incorporated every two years; CAST 2019 and CAST 2025).*
  - USDA- NASS annual poultry production data (*incorporated every two years; CAST 2019 and every model version thereafter).*
  - Nutrient concentrations for animal manure *(every two years; minimum of three-year trend needed; CAST 2019 and every model version thereafter).*
  - Manure or litter mass produced per animal *(updated every two years; CAST 2019 and every model version thereafter*).
  - AAPFCO fertilizer sales for farms *(updated every two years; CAST 2019 and every model version thereafter).*
  - USDA-NASS crop yield data *(updated every two years; CAST 2019 and every model version thereafter).*
  - Soil phosphorus data by crop type and county *(updated as part of the calibration of the Watershed Model; currently using data through 2014).*

- **BMPs**
  - New BMPs approved by the Chesapeake Bay Program (*added every two years).*