Phase 6 Approval Process

Background

The Principal Staff Committee (PSC) of the Chesapeake Bay Program (CBP) directed development of the 2017 modeling tools in order to 1) help guide implementation of CBP watershed implementation plans from 2018 to 2025, 2) assess the implications of Conowingo Dam infill on tidal water quality, and 3) assess the influence of future projected increased temperatures and watershed flows on tidal water quality. The CBP partnership have built the suite of 2017 modeling tools over the past half-decade through a multitude of decisions made by the PSC, the Water Quality Goal Implementation Team (WQGIT) and its sub-groups, and the Modeling Workgroup of Scientific Technical Assessment Reporting (STAR). The Phase 6 Model represents the work of hundreds of partners from these groups, as well as in expert panels, and through other modes of participation. The review has been ongoing since 2012, with detailed, intensive effort during 2016. Additionally, STAC has sponsored independent scientific peer reviews of the major, salient aspects of the Partnership's modeling tools that support upcoming key 2017 Midpoint Assessment decisions including impacts of Conowingo infill, climate change, inputs to the Phase 6 Watershed Model, and independent peer reviews of new features of the Phase 6 Watershed Model and the Bay Model (Water Quality and Sediment Transport Model – WQSTM).

According to the schedule that will under consideration by the WQGIT at their April 10 meeting, and contingent upon all partnership data and decisions being supplied to the CBPO by April 1, 2017, calibration of the draft Phase 6 model will occur through April and May, with a release of the draft Phase 6 model on June 1, 2017. The partnership requested fatal flaw review of the draft Phase 6 watershed model is scheduled for the period June 1 to July 31, 2017, with issue resolution in August 2017.

On June 1st the CBP partnership will be supplied with documentation and load tables from the Phase 6 Watershed Model, access to the online version CAST and to model inputs, model calibration results, and various tools and resources designed to facilitate review. Key scenarios—Everyone Everything Everywhere (E3), No Action, Watershed Implementation Plan (WIP2), etc.—will be provided to the CBP partnership by June 15, 2017.

Phase 6 Simulation Advances

Since the application of the Phase 5 Watershed Model in 2010 considerable refinements have been made in the understanding of major watershed processes with incorporation of the new findings into the Phase 6 Model structure. Most importantly, the Phase 6 simulation is based on a multiple model approach which provides better data and results in better quantification of the emergent watershed behavior from multiple well-found mechanistic simulations of the watershed. The tradeoffs between complex and simplified models are well documented in the literature. In contrast to the Phase 5 Model, the Phase 6 model tends toward a simplified structure with parameters that are well-supported by multiple lines of evidence rather than a complex model approach that is calibrated to specific sites in the watershed. The simplified, transparent structure leads to better understanding of the model by the stakeholder community.

A major area of improvement in the Phase 6 Model is the representation of phosphorus in the landscape and rivers. In the Phase 5 Model, the export of phosphorus from the landscape was primarily driven by phosphorus application. The Phase 6 simulation includes phosphorus soil storage as the most sensitive input in the prediction of export as recommended by the CBP partnership's Scientific and Technical Advisory Committee (STAC).

The Phase 6 simulation features a fine-scale land cover. Fine-scale 1-meter resolution land cover improved on the previous Phase 5 version in both accuracy and detail, adding for the first time wetland land uses, and several new classes of urban land uses.

Representation of riverine transport of nutrients and sediment is another major improvement compared to Phase 5. The Phase 6 simulation includes the first explicit representation of nutrient attenuation in small streams that are tributary to the large river reaches simulated in the Watershed Model. Also, additional calibration stations were added to the Phase 6 riverine simulation and the calibration period was extended eight years and now covers all years between 1985 and 2013 resulting in a significant increase of the information used to calibrate the model.

Explicit simulation of the changes over time in the net transport of nutrients and sediment in the Conowingo Reservoir due to reservoir infill is another major advance of the Phase 6 simulation. In Phase 6 the Conowingo Reservoir infill occurs over time and is calibrated to long-term river monitoring stations above and below the Conowingo. In Phase 5 the Conowingo had only a general representation of its long-term average behavior, and the simulation lacked the dynamic changes observed in the reservoir over the past several decades. Representation of numerous other reservoirs were added, either explicitly or implicitly, to the Phase 6 simulation which were absent in the Phase 5 simulation.

The Phase 6 watershed model includes about 270 Best Management Practices (BMPs) guidelines and performance estimates, a 23 percent increase over the BMPs simulated in Phase 5. Many were newly developed or revised by expert teams and reviewed and approved by the partnership.

In the Phase 6 simulation, accounting for major loads from atmospheric deposition, manure, and fertilizer applications were greatly improved over the Phase 5 simulation. The history of atmospheric deposition loads of nitrogen was improved through better histories of emissions in national data sets (National Emission Inventory (NEI)) and through a greatly improved simulation of ammonia atmospheric transport and chemistry in the airshed model. Significant refinements were made with respect to manure and litter mass generation and nutrient concentrations and the partitioning of animal loads to confinement and riparian areas. The Phase 5 “Degraded Riparian Pasture” land use was eliminated in favor of a direct deposition approach. The history of fertilizer use in the watershed was greatly improved by through the joint consideration of unmet application goals after manure application and previously unused watershed-wide fertilizer sales.

Fatal Flaw Review of the Partnership’s Phase 6 Models

A fatal flaw may be the basis for the implementation of changes to the draft Phase 6 models. A fatal flaw is defined as a ***significant*** impediment, based on a weight of evidence approach, of the ability of the partnership to establish reasonable planning targets or evaluate progress toward achieving the planning targets due to:

- A calculation or method that does not follow the documented final decisions of the CBP partnership
- A calculation or method, or combinations thereof, that produce illogical results that result in significant impediment
- The omission of data submitted by the CBP partnership subject to established deadlines

- The overall failure of the model calibration to match observed flows and loads when compared to the level of performance in previous models

Disagreement with a final decision that has been made by the partnership or with a scientific or technical method or product in favor of another method or product are not fatal flaws. Nor are failures to match loads for particular monitoring stations or constituent nutrients fatal flaws unless they create a significant impediment to planning target development or progress evaluation. This is because the planning target development process provides jurisdiction allocations at the State/Basin scale, and model performance should be judged primarily at that scale with respect to fatal flaws. However, comments regarding model performance at smaller scales are welcomed when the reviewer perceives potential adverse impacts to local targeting, implementation, or crediting.

Schedule for Fatal Flaw Review

During June and July, the fatal flaw review will be ongoing with the potential for changes to be made during this time. In August all fatal flaws identified through the partnership review will be resolved through the procedures described below. The Modeling Workgroup and the WQGIT will meet in late summer for final approval of the Partnership's suite of Phase 6 models to be used for the 2017 Midpoint Assessment.

Process for the Partnership and Jurisdictional Fatal Flaw Review of the Suite of Chesapeake Bay Program Partnership Models

The suggested approach is to divide up and assign responsibilities for reviewing the calibrations and model responsiveness to early versions of a suite of ranging scenarios across the full suite of Chesapeake Bay Program partnership models. The proposed approach is based on a series of conversations with a number of involved jurisdictional partners and their requests and recommendations as well as an initial round of review by the Partnership's Modeling Workgroup, Agriculture Workgroup and members of the WQGIT's Model Review Strategy Team.

Prior to the Fatal Flaw Review

<u>Schedule Webinars Explaining Each of the Models/Critical Components</u>

- The Modeling Workgroup will schedule and coordinate a series of webinars to provide partners and stakeholders an insider's look at the overall model structure model and important components of each Phase 6 model including how and why they were developed, what's different in the Phase 6 version, and how they will be applied in support of management decision making. The webinars will include 1) an Overview of Partnership's Models, the Midpoint Assessment Decisions the Models Were Designed to Address, and the Decision Framework of Standards, Models, and Planning Target Method, 2) Phase 6 Inputs, 3) Phase 6 Loads, 4) Phase 6 Physical Transport, and 5) Phase 6 Sediment Simulation. The complete list of webinars with their descriptions and prospective dates can be found on page 8.

<u>Provide Access to Full Model Documentation</u>

- Charge the Modeling Workgroup to continue to oversee development of and on-line publication of comprehensive documentation of Watershed Model and Water Quality and Sediment Transport Model (WQSTM) structures, set-ups and calibrations. Documentation for the draft

Watershed Model will be published prior to the start of the fatal flaw review period and will include airshed model documentation. Documentation for the draft WQSTM will be provided approximately one month later, concurrent with its release for fatal flaw review.

Develop New Model Review Tools and Enhance Existing Tools

- Charge the appropriate Chesapeake Bay Program Partnership Office teams with responsibility for enhancing existing model input review tools (e.g., Tableau) and development of new model output review tools (e.g., scenario visualization, WQSTM output) to facilitate the below described reviews by the Partnership's workgroups and jurisdictional partners.
- The existing, enhanced, and new model review tools will be developed, field tested by small groups of partners, and made publically accessible on-line prior to the start of the two-month model fatal flaw review period.
- Training on the use of these model review tools will be conducted for the appropriate source sector and technical support workgroups as well as jurisdictional representatives in advance of the two-month model fatal flaw review period.

Responses to Key Recommendations from STAC Model Uncertainty Workshop

- The Modeling Workgroup will make progress on the February 2016 STAC Model Uncertainty Workshop recommendations to "do something now" and will make initial progress on uncertainty prior to the start of the two-month model fatal flaw review period. The work will include:
    - *Listing uncertainties*, with a better description of these uncertainties in the model documentation.
    - *Identification of the most sensitive parameters*: Expand upon the Chapter 4 of the Phase 6 Watershed Model documentation which is already devoted to sensitivities and include nitrogen- and phosphorus-specific tables.
    - *Automation of calibration*: This is accomplished for the Watershed Model, but still not possible given the very long run times for the Water Quality/Sediment Transport Model. Initial efforts will be to apply the WQSTM geo-sensitivity scenarios on a cloud based computing system.
    - *Data and skill assessment results*: These data and results are available for the Watershed Model and will be compiled and published on-line for the Water Quality/Sediment Transport Model as part of the fatal flaw review process.

Phase 6 Watershed Model

Dividing Up and Assigning Responsibilities

- Ask each of the Partnership's technical support and source sector workgroups to take on the responsibility for: 1) ensuring the collective partnership-based decisions have been fully carried out (omissions review), and 2) evaluating model calibration inputs and outputs specific to their respective land uses (evaluate illogical outcomes or unintended consequences) or larger source categories.

- Modeling Workgroup[1]
  - Read watershed model documentation Chapter 1 for an overview of the work.
  - Review watershed model documentation Chapters 2, 4, 7, 9, and 10.
  - Review the watershed model calibration:
    - Review the summary statistics for the overall calibration
    - Review the individual station calibration plots looking for overall patterns with respect to region, scale, or nutrient species.
    - Review the web-enabled Phase 6 vs WRTDS time series of monthly loads at WRTDS monitoring sites.
  - Review sensitivity analyses generated for other workgroups below.
  - Develop webinars as previously described to directly engage source group and other Phase 6 Model reviewers and to deepen the review though questions raised in the webinar process.

- Watershed Technical Workgroup
  - Read watershed model documentation Chapter 1 for an overview of the work.
  - Review Chapter 6 on BMPs.
  - Review Chapter 3 on nutrient inputs.
  - Review sensitivity analyses generated for other workgroups as detailed below.

- Land Use Workgroup
  - Read watershed model documentation chapter 1 for an overview of the work.
  - Review Chapter 5 on land use.
  - Coordinate with Modeling Workgroup on requests for specific sensitivity analysis through the scheduled interactive webinars or through other means.

- Agriculture, Urban Stormwater and Forestry Source Sector Workgroups
  - Read watershed model documentation Chapter 1 for an overview of the work.
  - Review Chapter 2 on how their sector loads compare with other sectors.
  - Review Chapter 3 for inputs of interest to their workgroup.
  - Request and review scenarios showing the effects of BMPs.
  - Coordinate with Modeling Workgroup on requests for specific sensitivity analysis through the scheduled interactive webinars or through other means.

- Wastewater Treatment Workgroup
  - Read watershed model documentation Chapter 1 for an overview of the work.
  - Review watershed model documentation Chapter 8.

[1] Recognizing most source sector and technical support workgroups do not have the modeling expertise or needed experience to conduct or review sensitivity and other model suitability/scale analyses, the Modeling Workgroup through the CBPO Modeling Team, is charged with developing a series of interactive webinars to assist in the reviews and analyses. The Modeling Workgroup will also be responsible for responding to webinar questions and preparing and sharing detailed and summary information as requested by source sector and other technical support workgroups to facilitate their separate reviews described here.

    - Review the change in discharged loads over time to ensure it aligns with data provided by jurisdictions and the model simulated loads reasonably reflects what has occurred over time.
    - Coordinate with Modeling Workgroup on requests for specific sensitivity analysis through the scheduled interactive webinars or through other means.

- The WQGIT will request that the seven watershed jurisdictions take on the responsibility for 1) evaluating how well the model simulates watershed loads at key stations and watersheds within their respective jurisdictions; and 2) reviewing results from the early versions of a suite of management ranging scenarios comparing a change in outputs from Phase 5.3.2 scenarios and Phase 6 scenarios, specific to their jurisdiction.[2]
    - Focus on calibration results from: 1) relevant river input monitoring stations; and 2) the subset of monitoring stations which best capture loads leaving each individual jurisdiction
    - Comparison of Phase 5.3.2 and Phase 6 scenario outputs for a suite of ranging scenarios including 1985, Phase II WIPs, E3, No Action, All Forest, and recent progress runs specific to their jurisdiction.
    - The CBPO Modeling Team can schedule jurisdiction specific webinar-based review sessions at the request of individual jurisdictions.

<u>Enhancement of Watershed Model Review Tools</u>[3]

- Expand the existing Tableau watershed model input data review tool to include the same functionality for reviewing and evaluating Phase 6 watershed calibration and preliminary scenario results and outputs at the full array of available scales and cross comparisons.
    - Provide functionality for evaluating output and making cross comparisons down to the individual county scales.
    - Break out the incremental loads, for the appropriate scales, on the 'way to delivery to tidal waters'—edge of small stream, edge of large river, and delivered to tidal waters—so that the progression of attenuation can be viewed and understood.
    - Provide charting capacity to easily cross compare from one county to another, from one watershed to another.
    - Provide the ability to compare relative loads across source sectors by major land uses.
    - Expand years beyond just the calibration period to view calibration data/early ranging progress scenario results for the entire record 1985-2016 so partners can see how well the model captures long term trends and responses to management action with a particular focus on the post 2013 years.
    - Set up ability to conduct comparisons of model simulated loads from the Partnership's old (Phase 5.3.2) and new (Phase 6) approaches to simulating nutrient management.

[2] The relevant comparisons in the jurisdictions' review are the changes between a base load and the scenario load, not a comparison of absolute numbers between Phase 5.3.2 and Phase 6.

[3] Reflects the direct input and ideas from a number of partners called and consulted prior to drafting this proposed approach to model review by the Partnership and the jurisdictional partners. The CBPO will strive to produce the best tools possible in the time available prior to the start of the fatal flaw review.

- Build into the CAST user interface the ability to easily and rapidly run a series of sensitivity scenarios to fully understand the model's responses to individual BMPs and multiple stacked BMPs as well as varying model inputs such as fertilizer and manure applications.

- Expand the comparison of WRTDS calculated loads with Phase 6 watershed model simulated scenario loads to include all monitoring stations with a sufficient temporal record of observations to support USGS's WRTDS calculations.

- Generate summaries of the extensive and detailed calibration data analyses at scales of interest to the jurisdictions.

- Expand the capability to geographically map out/visualize watershed model calibration outputs and the output of early ranging scenarios at the full range of spatial scales supported by the model and enable side by side comparisons between different scenarios

Chesapeake Bay Water Quality and Sediment Transport Model

Dividing Up and Assigning Responsibilities

- The Modeling Workgroup will take responsibility for ensuring: 1) the collective partnership-based decisions have been fully carried out; and 2) the estuarine hydrodynamic, water quality, and lower trophic level processes and rate functions are consistent with current scientific understanding;

- The WQGIT will request that the tidal water states of Maryland, Virginia, Delaware, and the District to take on the responsibility for: 1) evaluating how well the model simulates tidal water quality conditions over time at key stations and segments within their jurisdiction's tidal waters; and 2) reviewing results from a suite of ranging scenarios comparing outputs from the Phase 5.3.2 and Phase 6 versions of the Bay Water Quality and Sediment Transport Model relevant to their jurisdiction.

Enhancement of Water Quality Sediment Transport Model Review Tools

- Take the Maryland Department of the Environment's developed approach[4] of statistically analyzing and graphing Water Quality/Sediment Transport Model calibration output in Maryland waters and expand and enhance it to generate results for all calibration stations in all 92 TMDL segments and for all tidal water States in the partnership. The analysis will include:
    - Graphical time series plots, boxplots and target plots
    - Statistical analyses including standard regression, dimensionless (NSE), and error index (PBIAS)

Chesapeake Bay Airshed Model

Dividing Up and Assigning Responsibilities

[4] MDE's approach as presented to the Partnership's Modeling Workgroup on February 15, 2017 can be accessed at http://www.chesapeakebay.net/channel_files/24718/wqstm_accuracy_assessment_2_13_17.pdf.

- The Modeling Workgroup is responsible for reviewing outputs of the enhanced versions of the Penn State Chesapeake Bay atmospheric deposition model and the national Community Multi-scale Air Quality (CMAQ) model to:
    - Ensure the collective partnership-based decisions have been fully carried out in upgrading both the Penn State deposition model and the national CMAQ model.
    - Comparing the wet and dry atmospheric deposition loading rates direct to the watershed and tidal waters and the fraction of those loads that reach tidal waters between the Phase 5 and Phase 6 versions of both models under a range of early scenarios.

Process for Cataloging and Resolving Identified Issues

- Communicate all identified model calibration issues directly to the appropriate Chesapeake Bay Program Office Modeling Team lead for cataloging:
    - Gary Shenk: Watershed Model
    - Lew Linker: Water Quality and Sediment Transport Model
    - Lew Linker: Airshed Model

- Gary Shenk/Lew Linker will then assign each issue to the Partnership's appropriate technical support/source sector workgroup or Chesapeake Bay Program Office team for resolution.

- The chair and coordinator for each technical support/source sector workgroup assigned a model or calibration issue for resolution has the lead for confirming partnership support for the proposed resolution issue.

- If consensus decisions on issue resolution are not reached at the source sector workgroup level, those decisions will be elevated through the Partnership's management groups, starting with the WQGIT, and then up to the MB and PSC, as necessary.

- Chesapeake Bay Program Office staff will then document resolution of each identified model or calibration issue and the subsequent workgroup/WQGIT concurrence.

Links to Documentation, Scenarios, and Model Inputs

- Documentation and load tables from the Phase 6 Watershed Model: Under Construction, available June 2017.

- Access to the online version CAST: Under Construction, available June 2017.

- Access to model inputs: Under Construction, available June 2017.

- Model calibration results, and various tools and resources designed to facilitate review: Under Construction, available June 2017.

- Key scenarios (Everyone Everything Everywhere (E3), No Action, Watershed Implementation Plan (WIP2), etc.) when available: Under Construction, available June 2017

- Documentation of the WQSTM: Under Construction, available July 2017 (Note: This is an early version of the documentation that will be made available just as the WQSTM has completed its final calibration. The final WQSTM documentation will be available later in the summer of 2017 and will include final calibration results.)

- Documentation of the Airshed Model: Under Construction, available June 2017.

Model Review Webinars

- Overview of the Integrated Air Watershed and Bay Models, the Midpoint Assessment Decisions the Models Were Designed to Address, and the Decision Framework of Standards, Models, and Planning Target Method, Lew Linker and Jeff Sweeney Leads. Scheduled for Late April or Early May.
A description of the integrated models and the decisions the PSC and other groups directed the models to address including an improved approach to get to the Phase III WIPs, Conowingo infill impacts to water quality and an assessment of the influence climate change has on tidal water quality standards.

- Phase 6 Sediment Simulation Webinar, Gary Shenk lead. Scheduled for April 19.
The overall simulation of sediment from estimated target load, land surface detachment, and transport and fate in the watershed will be reviewed.

- Phase 6 Inputs Webinar, Matt Johnson Lead. Scheduled for early May.
Overall review of Phase 6 inputs.

- Phase 6 Loads Webinar, Gary Shenk Lead. Scheduled for late May.
The nutrient loading rates, how the rates are calculated and how the loading rates are modified due to sensitivities, and sediment.

- Phase 6 Physical Transport Webinar, Gary Shenk and Gopal Bhatt leads. Scheduled for early June.
The processes of riverine and small stream transport and attenuation of nutrient and sediment loads will be reviewed in detail. Included also are the land to water factors for nitrogen and phosphorus loads.

Model Review Schedule

Phase 6 Watershed Model Inputs Review	April 1 – April 28, 2017*
Response and Resolution to Phase 6 Model Inputs Review	May 1 – May 31, 2017*
Phase 6 Watershed Model Calibration	April 1 – May 30, 2017
Phase 6 Water Quality Sediment Transport Model Calibration	June 1 – June 30, 2017
Partnership's Fatal Flaw Review of the Phase 6 Modeling Tools • Phase 6 model documentation available • All Forest, E3, 2016 Progress, and other key scenarios • Other scenarios requested by the partners	June 1, 2017 – July 31, 2017

Potential re-calibration of Beta 6 Watershed Model based on Phase 6 Scenario Builder Outputs Review	June 1 – August 31, 2017*
Resolution of Fatal Flaws Identified Through Partnership Review, Final Calibration (if appropriate), and Partnership Approval of Phase 6 Modeling Tools	August 1 – August 30, 2017
WQGIT Revisits Midpoint Assessment Schedule based on Phase 6 Fatal Flaw Review Period	August 14, 2017 WQGIT Call

*The modeling team has initiated Phase 6 Watershed Model calibration with inputs provided by April 1, 2017. Complete documentation of processes used will be unavailable for all inputs until June 1, 2017. Nevertheless, if the input review process identifies errors that the Partnership deems necessary to correct, and for which Watershed Model recalibration is necessary, then the planned June 1, 2017 start date for the fatal flaw review cannot be accommodated, thereby invalidating subsequent schedule dates, including dates for WQSTM model calibration.