Application of Multiple Models to Support Chesapeake TMDL

Scientific and Technical Advisory Committee Quarterly

June 14, 2023

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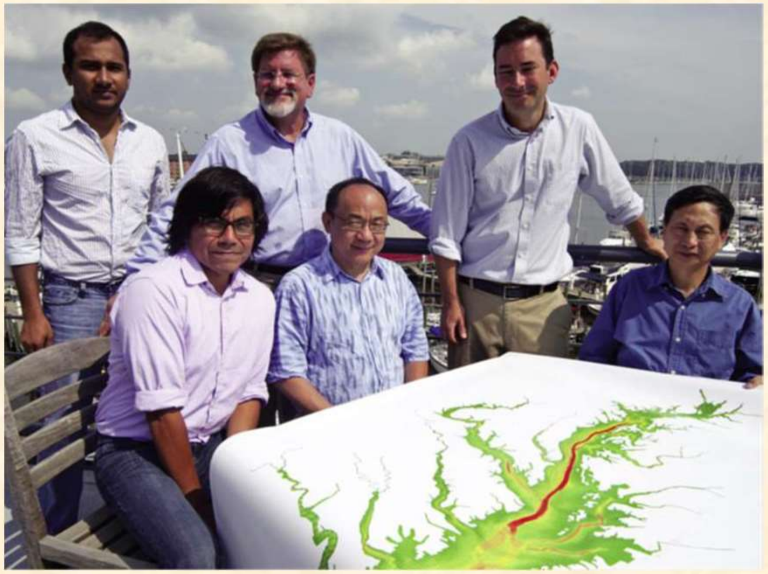

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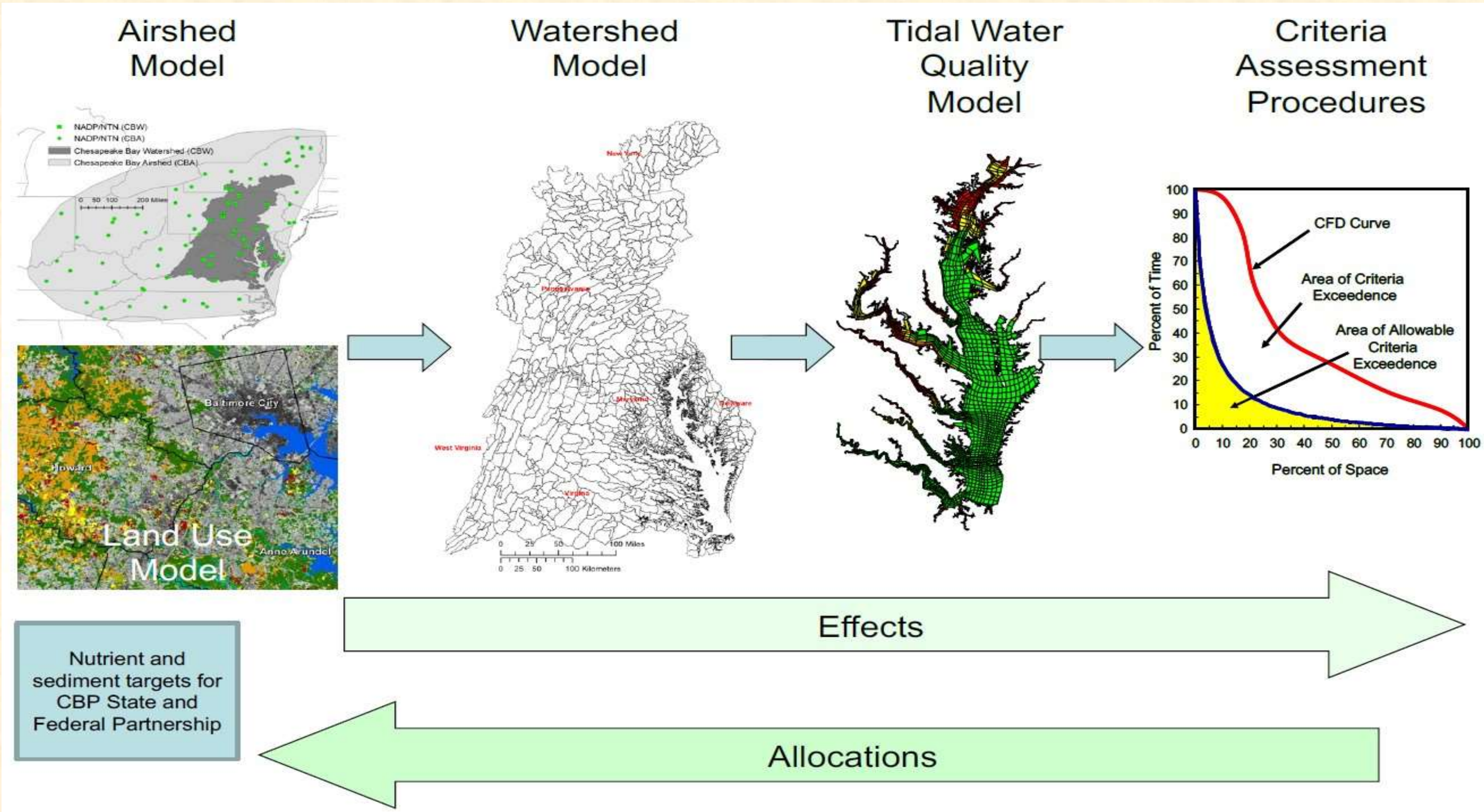
The CBP Climate Change Assessment



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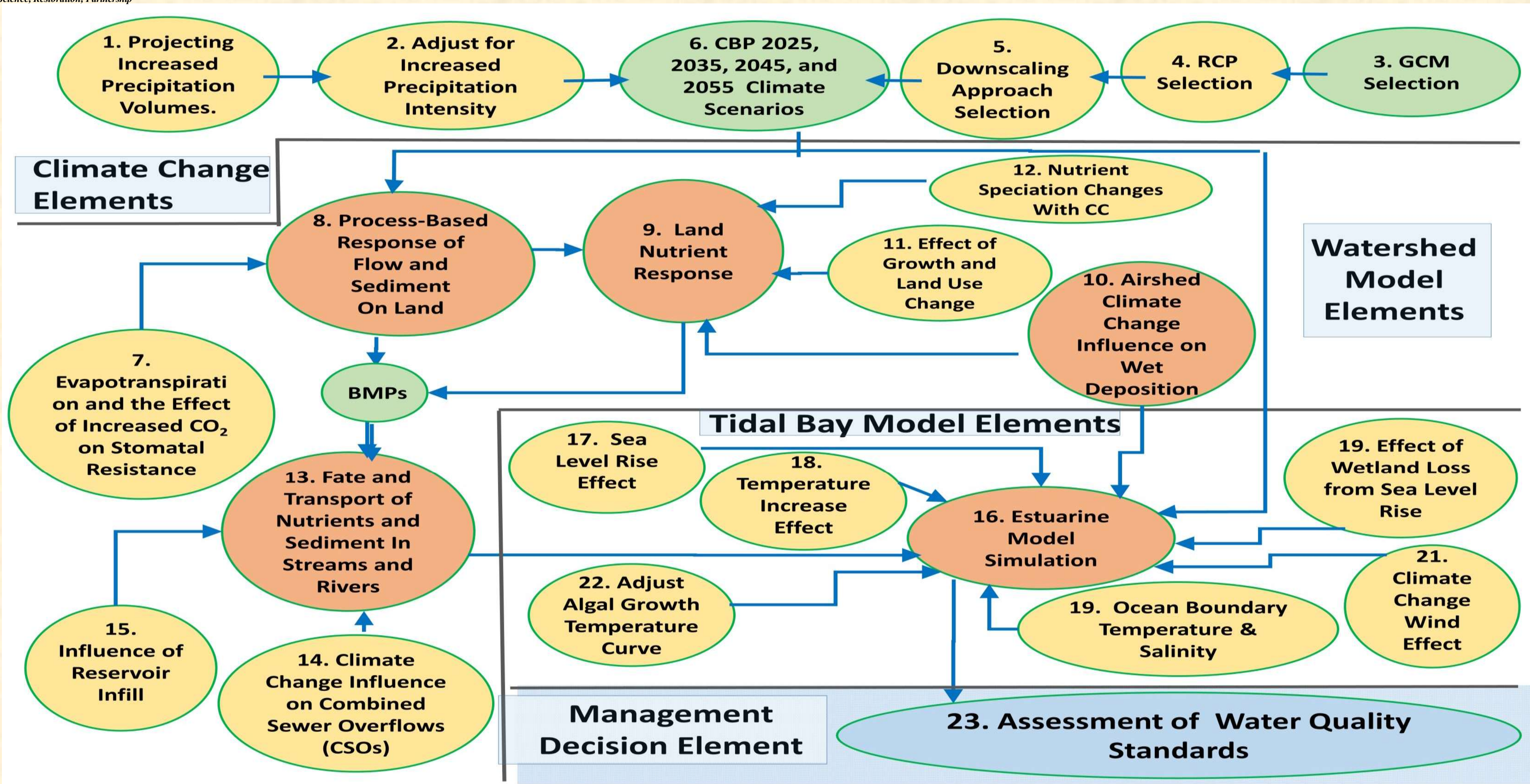
Elements of Chesapeake Water Quality Climate Risk Assessment



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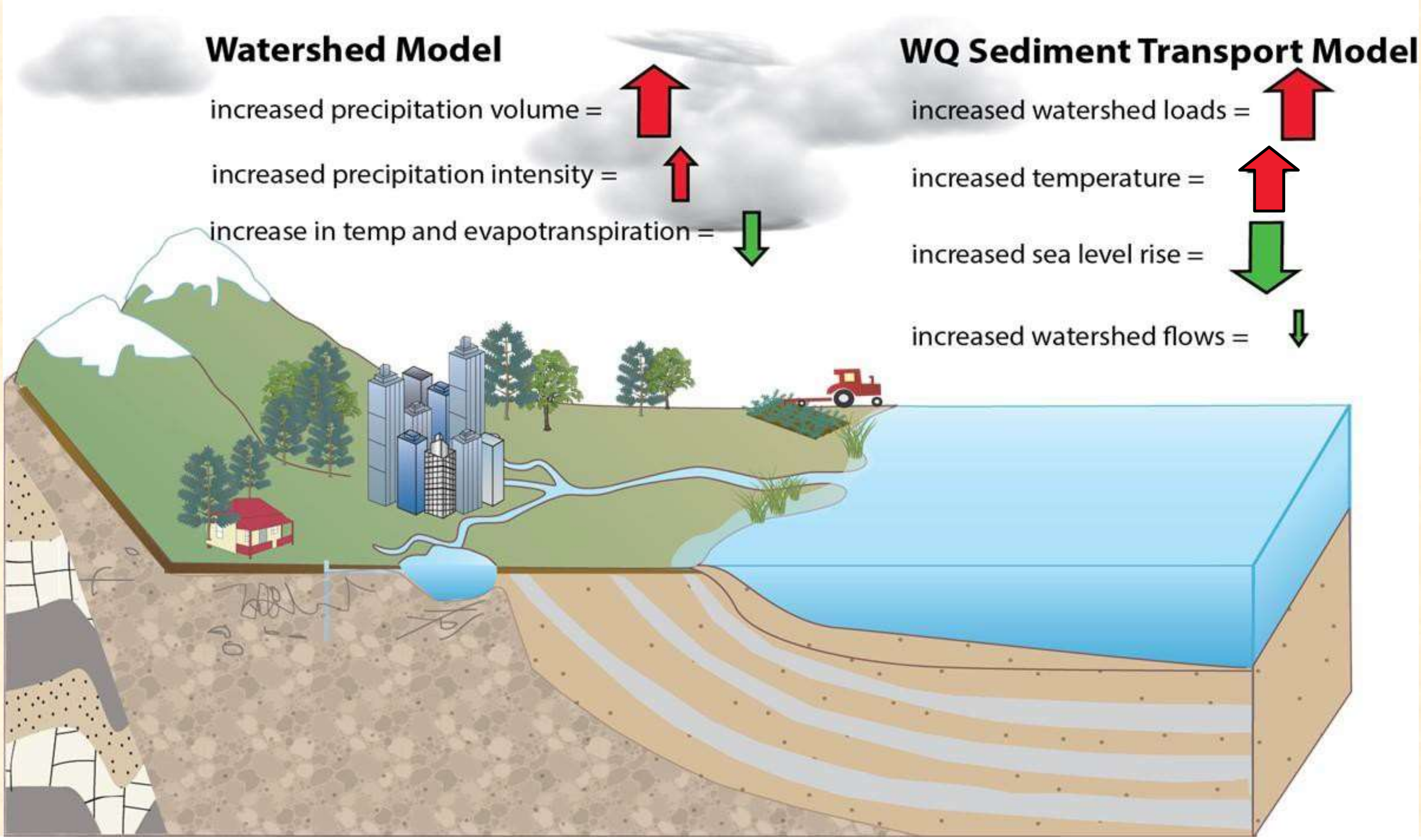
Components of Climate Change – Effect on Tidal Dissolved Oxygen



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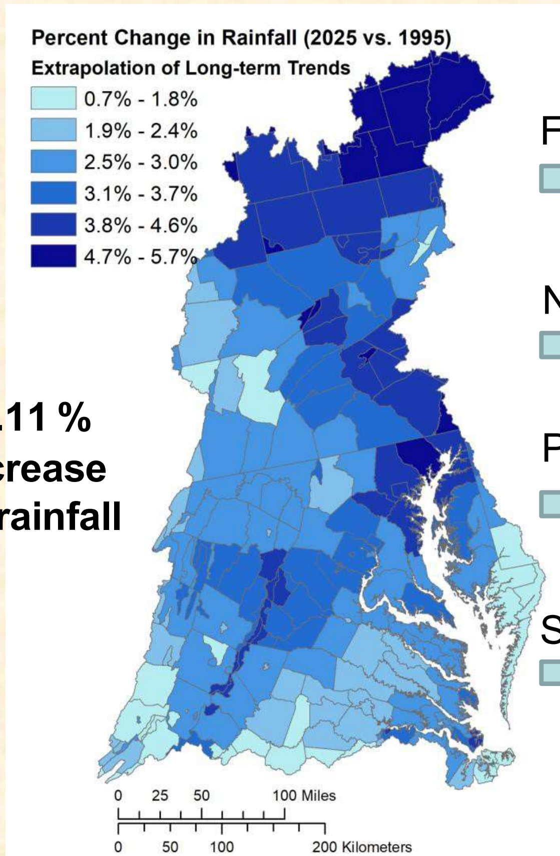
Elements of 2025 Climate Change (1995-2025)

Air-temperature increase: 1.06 °C

+3.11 % Increase in rainfall



Phase 6 Watershed Model

Flow

2.4% Increase

Nitrogen Load

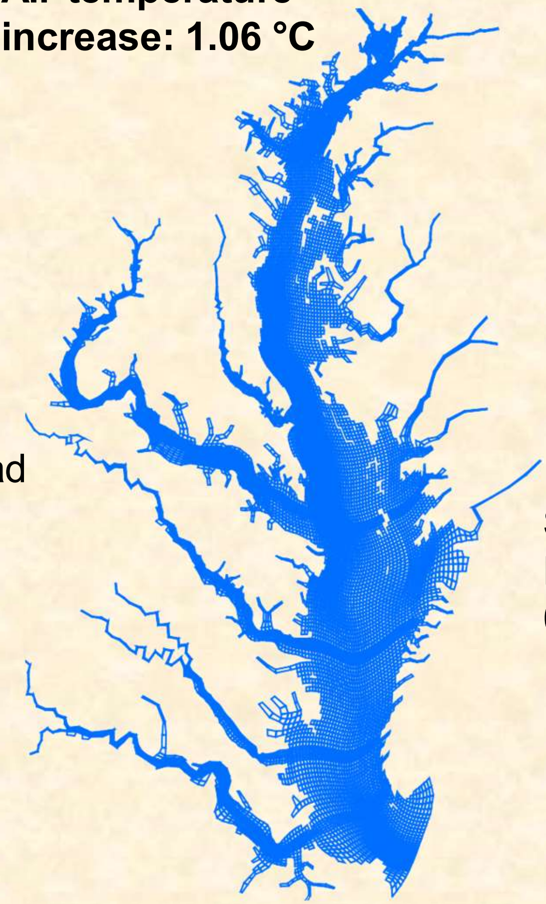
2.6% Increase

Phosphorus Load

4.5% Increase

Sediment Load

3.8% Increase



Model: CH3D-ICM
400m-1km Resolution

Sea Level Rise: 0.22m

Open boundary:
Temperature: +0.95 °C;
Salinity: +0.18 psu
(Thomas et al., 2017)

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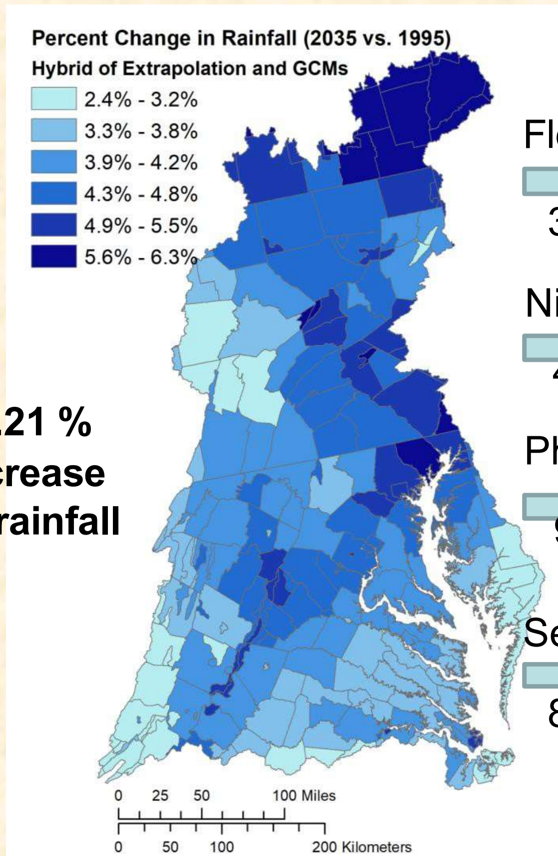
Elements of 2035 Climate Change (1995-2035)

Air-temperature increase: 1.39 °C

+4.21 % Increase in rainfall



Phase 6 Watershed Model

Flow
3.7% Increase

Nitrogen Load
4.7% Increase

Phosphorus Load
9.9% Increase

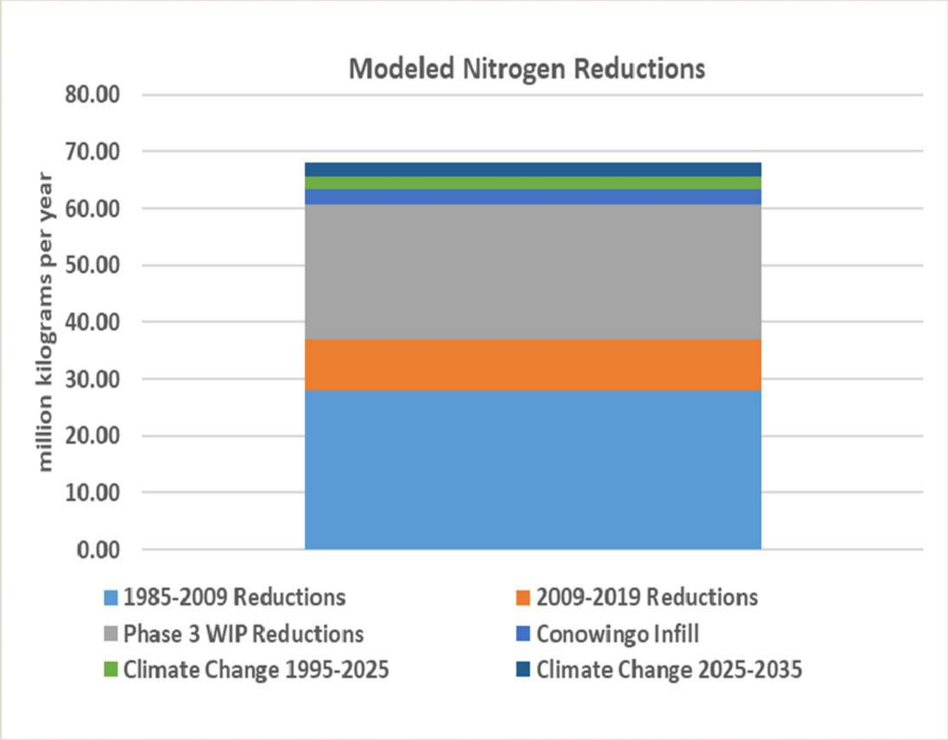
Sediment Load
8.5% Increase

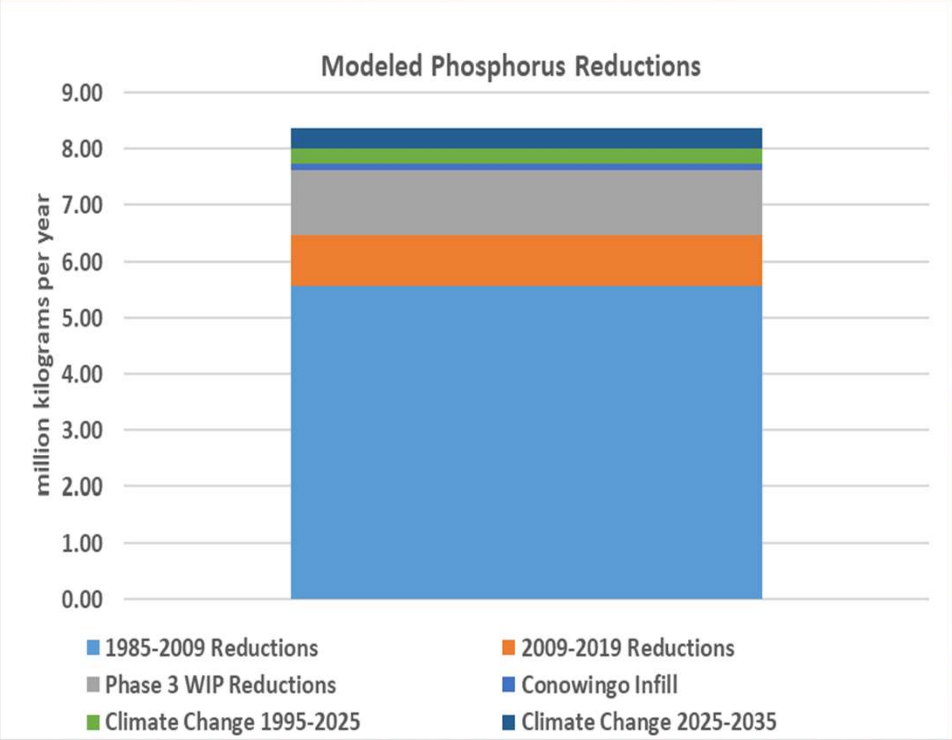
Model: CH3D-ICM
400m-1km Resolution

Sea Level Rise: 0.31m

Open boundary:
Temperature: +1.32 °C;
Salinity: +0.25 psu
(Thomas et al., 2017)

Climate Target Loads in Perspective





Overall, the CBP found that a target load of 5 million pounds nitrogen and 0.6 million pounds phosphorus will be sufficient to offset 30 years of climate change in the Chesapeake Bay.

Model load reduction estimates from CAST-2019 (current version of the CBP watershed model)

Recommendations of STAC's Chesapeake Bay Program Modeling in 2025 and Beyond: A Proactive Visioning Workshop

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- Potential future development of the hydrodynamic and biogeochemical models should focus on transition to a hydrodynamic model with an unstructured grid that can provide much greater resolution in the shallow tributaries of the Bay.
- The current living resource simulation in the CBP water quality model, which includes submerged aquatic vegetation (SAV) and oysters, should continue to be developed with the goal of improving these models.
- The approaches, processes, and parameterizations used in the CBP models for estimating the impacts of climate change and sea level rise on the TMDL should be reexamined in detail.
- The CBP partnership models should strive to provide outputs related to local ecosystem services and economic impacts that are of direct interest to local stakeholders.

Hood, R.R., G. Shenk, R. Dixon, W. Ball, J. Bash, C. Cerco, P. Claggett, L. Harris, T.F. Ihde, L. Linker, C. Sherwood, and L. Wainger. 2019. Chesapeake Bay Program Modeling in 2025 and Beyond: A Proactive Visioning Workshop. STAC Publication Number 19-002, Edgewater, MD. 62 pages.

Recommendations of STAC's Chesapeake Bay Program Modeling in 2025 and Beyond: A Proactive Visioning Workshop

- The CBP should continue to work toward strengthening its ties with the scientific community and it should continue to support adaptive management.
- Future model development should continue to be driven by management needs and future models must support time-certain management deadlines.
- The 2025 next generation CBP suite of models should provide support of better understanding across a wide range of scales. Models that use unstructured grids are particularly well suited to cover this wide range of scales.

Hood, R.R., G. Shenk, R. Dixon, W. Ball, J. Bash, C. Cerco, P. Claggett, L. Harris, T.F. Ihde, L. Linker, C. Sherwood, and L. Wainger. 2019. Chesapeake Bay Program Modeling in 2025 and Beyond: A Proactive Visioning Workshop. STAC Publication Number 19-002, Edgewater, MD. 62 pages.

Overview of Bay Designated Uses

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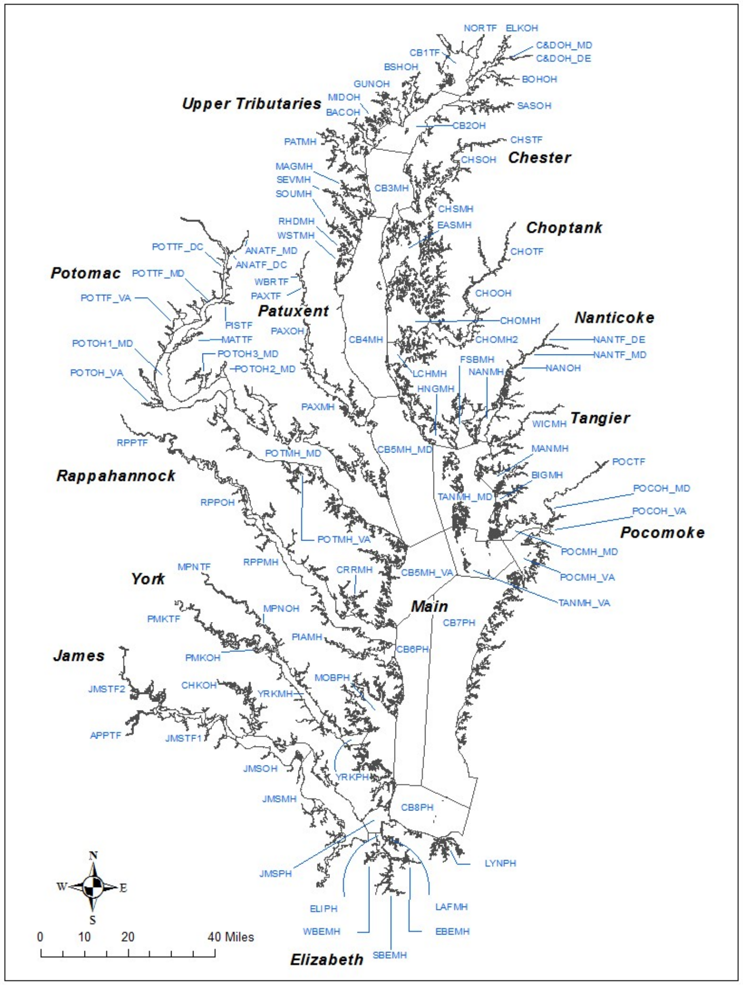
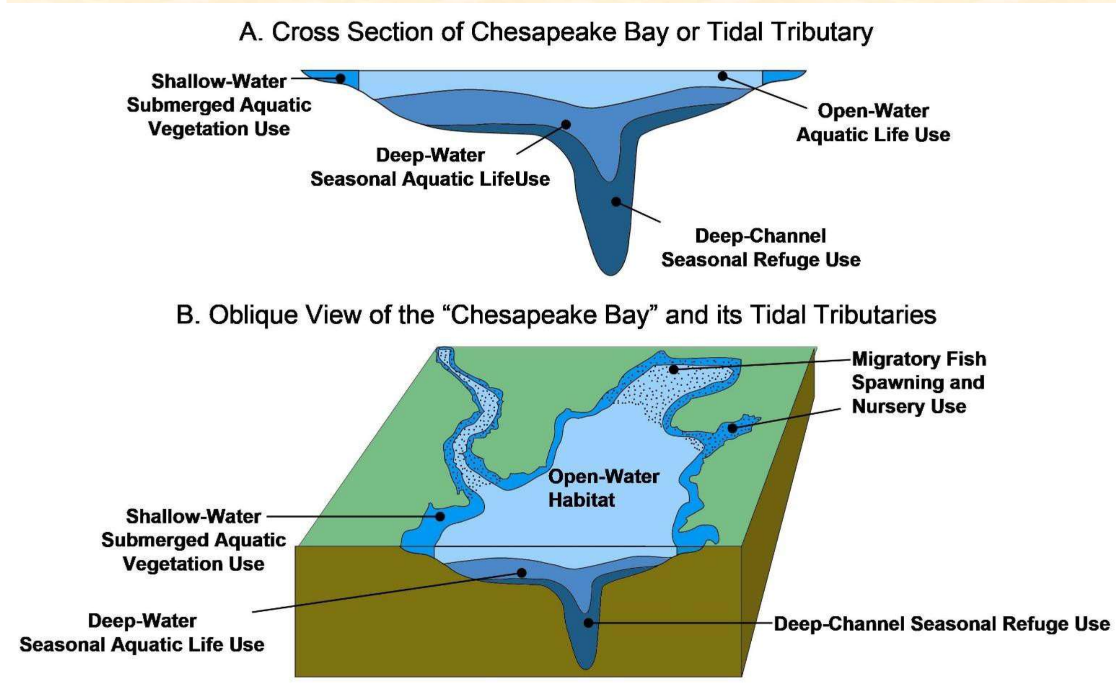
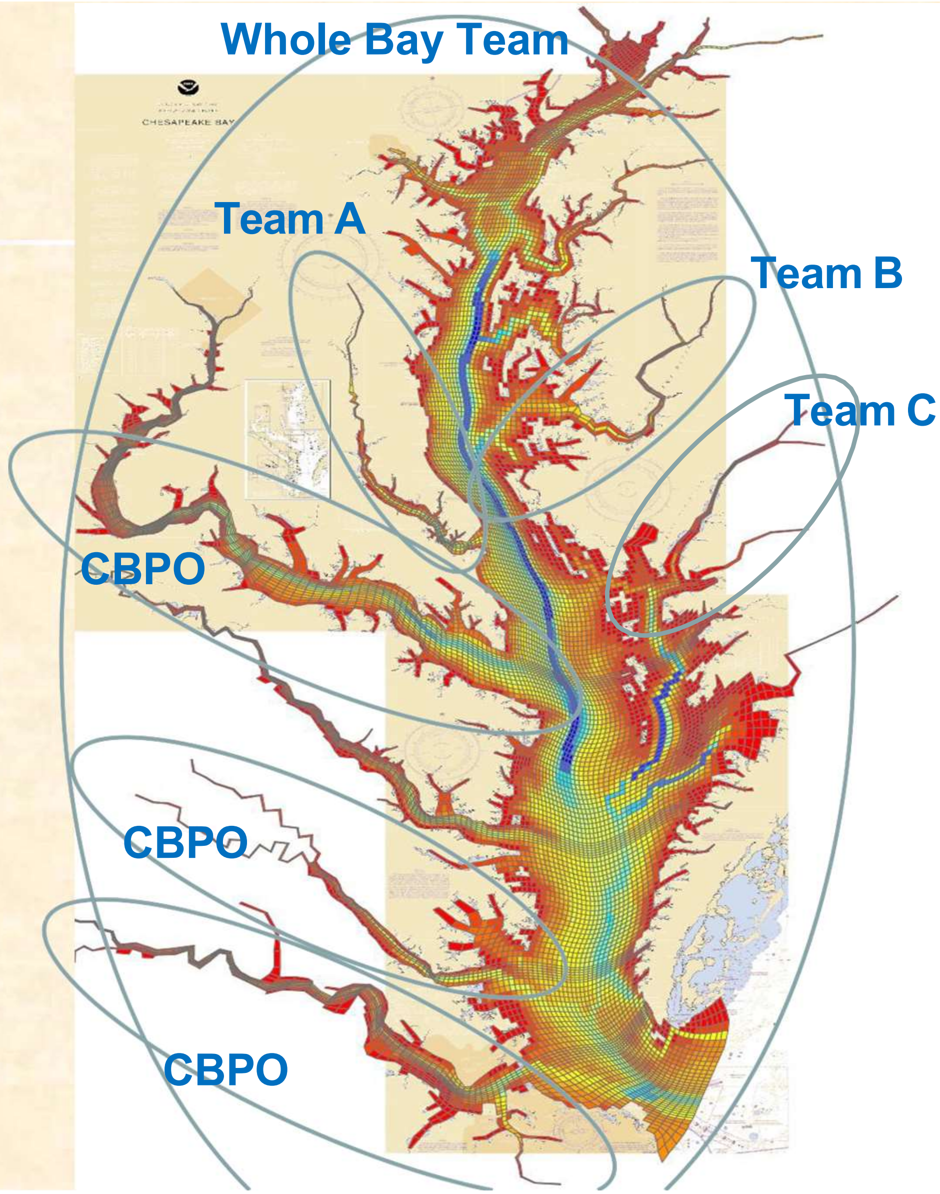




An Unstructured Grid Model in the Chesapeake with Multiple Model Teams

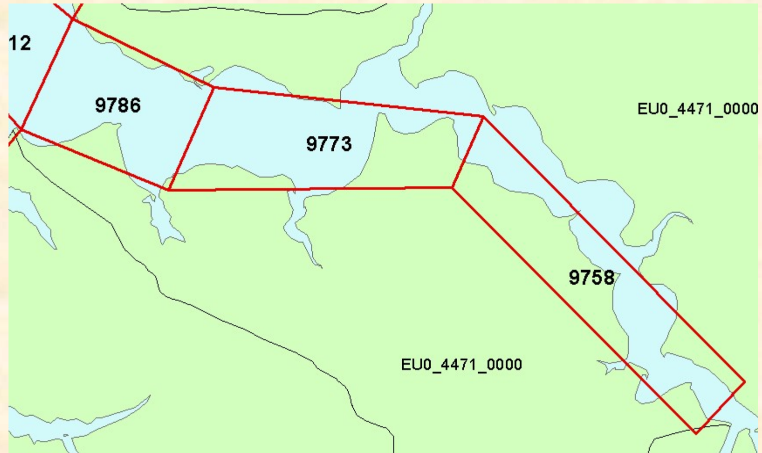
- Main Bay Model (MBM) of all tidal waters is used for integration of MTM findings and for CBP TMDL management.
- Multiple Tributary Model (MTM) teams working in tributaries and sharing collaboratively information with all model teams on a monthly basis.
- Similar to CMAQ multiple model approach.
- CBPO in-house teams should do Potomac, James, and York.



Improved Assessment of Shallow Water Processes. The MTMs will be able to better assess shallow water processes in the shallow Open-Water regions of the Bay. The majority of the 93 Chesapeake TMDL segments, also called designated uses, have only an Open-Water DO water quality standard and entirely lack Deep-Water DO and Deep Channel DO standards. The current 2017 CBP Bay Model is unable to effectively simulate shallow water Open-Water DO standards under climate change conditions. Generally, the simulation of shallow water processes are poorly understood and documented. The MTM models will provide the CBP partners with enhanced decision support tools for determining how to best restore and protect the Bay's extensive shallow water habitats. Also, the ability to better simulate the fate of key living resources under climate change such as SAV, tidal wetlands, etc. will be improved with MTMs.

Improved Assessment of Shallow Water Processes

The 2017 Bay Model had a three segment Corsica River. The Corsica River Shallow Water Test Bed for the MBM and MTMs has 5,029 cells with up to 20 m resolution and 5 sigma layers of depth.



The Watershed Model loading to the Corsica River in 2017 was on an order of a 30 square mile watershed that in Phase 7 will be quantified at about a one square mile watershed.

Motivation for Development and Application of MTMs

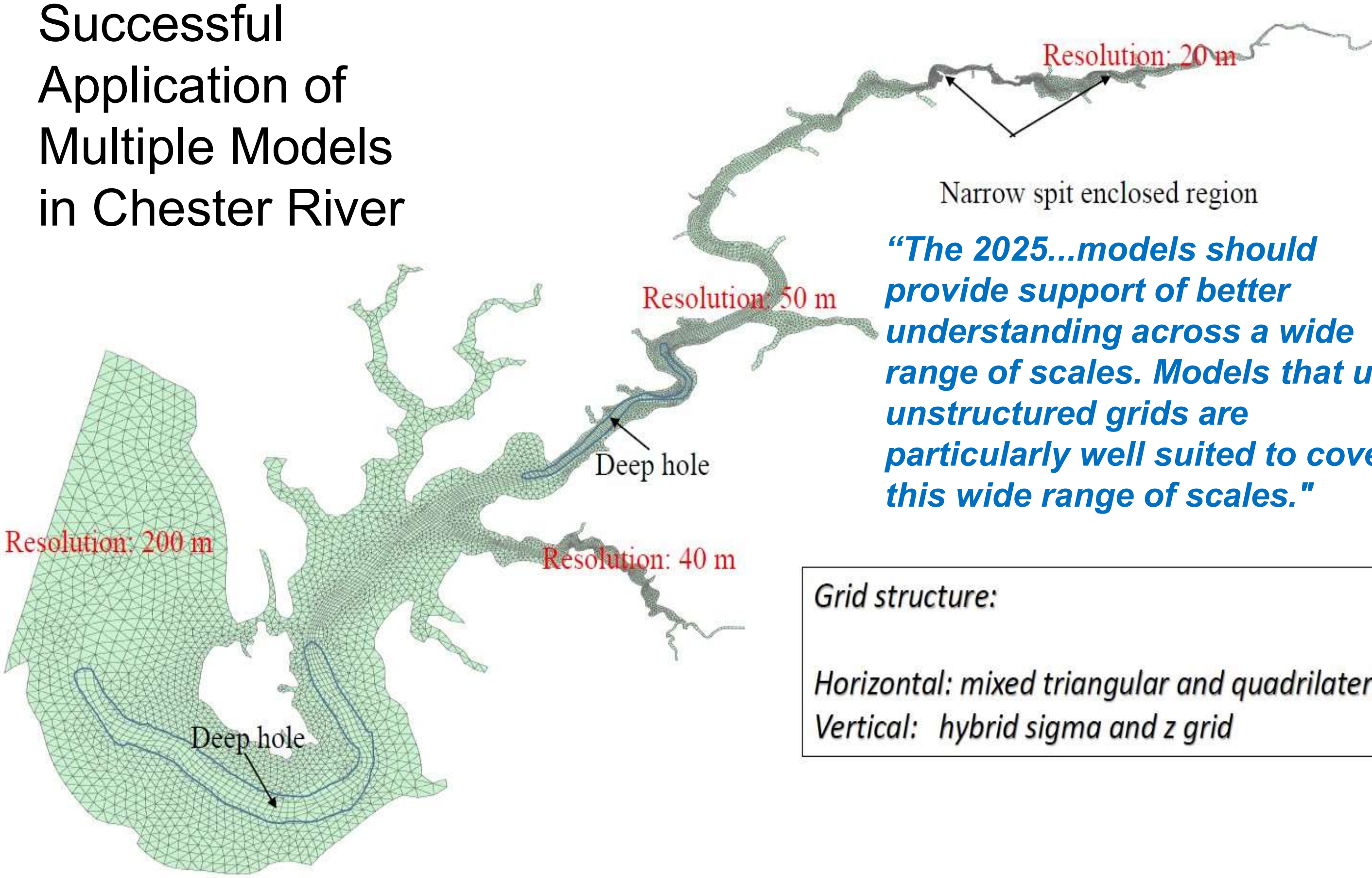
Assisting and Improving All Tidal Chesapeake TMDLs and Water Quality Assessments. The MTMs will be able to bring all the TMDLs in Chesapeake tidal waters up to date and link with the latest 2025 watershed, airshed, and estuary models. This will allow an updating and integration of local tidal Bay TMDLs completely into CBP's 2025 Chesapeake TMDL. A major advantage of the MTMs would be the ability for updating of all Chesapeake tidal water TMDLs to future climate change conditions and to have them be entirely consistent among themselves and to the overall Chesapeake TMDL.

Motivation for Development and Application of MTMs

Resolving Special Issues - James River Chlorophyll Assessment. The MTMs will be able to resolve special issues like the James Chlorophyll Assessment. The James River chlorophyll Assessment is currently oriented to 2025 climate change conditions but there is an interest in updating the assessment for climate change conditions anticipated beyond 2025. With the MTMs this can be done by taking advantage of the CBP work in the assessment of 2035 conditions with updated watershed, airshed, and estuary models and in leveraging the combined analysis to provide the most complete assessment available for the James Chlorophyll Assessment at least cost.

An Example of an Unstructured Grid Model in the Chesapeake

Successful Application of Multiple Models in Chester River



"The 2025...models should provide support of better understanding across a wide range of scales. Models that use unstructured grids are particularly well suited to cover this wide range of scales."

Grid structure:

Horizontal: mixed triangular and quadrilateral
Vertical: hybrid sigma and z grid

Source: Chester River Hydrodynamic and Water Quality Modeling using SCHISM/HEM3D. Wang, Zhang, et al. *STAC Shallow Water Modeling Workshop* April 20, 2016

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Overview of the Main Bay Model (MBM) and Multiple Tributary Model (MTM) Workplan: Interim Development Phase (2023-2024)

Calendar Year		2023				2024				2025			
Calendar Quarter		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Project Year		Year 2				Year 3				Year 4			
Task 2 Interim MBM and MTM Development (2023 – 2024)	Task 2												
2-1. Initiate MTM activities (Q1-Q2: 2023).	Task 2.1												
2-2. Kick-off joint meetings of MBM and MTM Teams with Mod WG (Q1-Q2: 2023)	Task 2.2												
2-3. Conduct full initial calibration and verification of hydrodynamic and WQ model output (Q3-Q4: 2024).	Task 2.3												
2-4. Address important knowledge gaps in ICM (All Qs: 2024).	Task 2.4												
2-5. Begin completion of work to improve shallow water dynamics in MBM (All Qs: 2024).	Task 2.5												
2-6. Begin completion of work to improve shallow water dynamics in MTMs (All Qs: 2024).	Task 2.6												
2-7. Completion of work on basic living resource linkages of refined chlorophyll, wetland, and SAV simulation an	Task 2.7												
2-8. Completion of work using MBM and MTMs to better resolve CBP problem segments (All Qs: 2024).	Task 2.8												
2-9. Completion of work examining CC influence on SAV, shallow water, & phenology of CC watershed loads an	Task 2.9												
Task 3 Final MBM and MTM Development (2005)	Task 3												
3-1. Provide a fully operational MBM that meets the needs of CBP (Q2-Q3: 2025).	Task 3.1												
3-2. Finish documentation on the software package in a report that will include detailed documentation on model st	Task 3.2												
3-3. Demonstrate feasibility and utility of using a state of the science UG model to better estimate Chesapeake WQ	Task 3.3												
3-4. Transfer the software package to CBPO for operational testing, and work with CBPO personnel to test the mo	Task 3.4												
3-5. All MBM and MTMs fully operational (Q4: 2025).	Task 3.5												

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Overview of the MBM & MTM: Final Model Development (2025)

Calendar Year		2025
Calendar Quarter		Q1 Q2 Q3 Q4
Project Year		Year 4
Task 3 Final MBM and MTM Development (2005)	Task 3	
3-1. Provide a fully operational MBM that meets the needs of CBP (Q2-Q3: 2025).	Task 3.1	
3-2. Finish documentation on the software package in a report that will include detailed documentation on model st	Task 3.2	
3-3. Demonstrate feasibility and utility of using a state of the science UG model to better estimate Chesapeake WQ	Task 3.3	
3-4. Transfer the software package to CBPO for operational testing, and work with CBPO personnel to test the mo	Task 3.4	
3-5. All MBM and MTMs fully operational (Q4: 2025).	Task 3.5	
3-6. Conduct full review of al MBM and MTMs with CBP technical and management groups and with STAC (All	Task 3.6	
3-7. Review all recent studies related to Bay WQ processes and work with CBP and Mod-WG to identify key miss	Task 3.7	
3-8. Provide estuarine models, analysis tools, and initial scoping scenarios, final code version and other materials	Task 3.8	
3-9. Finalize work to improve shallow water dynamics in MBM (Q1-Q2: 2025).	Task 3.9	
3-10. Finalize work to improve shallow water dynamics in MTMs (Q1-Q2: 2025).	Task 3.10	
3-11. Finalize work on basic living resource linkages of refined chlorophyll, wetland, and SAV simulation and pot	Task 3.11	
3-12. Finalize work using MBM and MTMs to better resolve CBP problem segments (Q1-Q2: 2025).	Task 3.12	
3-13. Finalize work examining CC influence on SAV, shallow water, and phenology of CC watershed loads and ti	Task 3.13	

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MBM and MTM Review (2026) and Application (2027)

Calendar Year		2026				2027			
Calendar Quarter		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Project Year		Year 5				Year 6			
Task 4. MBM and MTM Review (2026) and Application (2027)									
4-1. Provide final estuarine models, analysis tools, model documentation and other materials to CBPO (Q1:2026).									
4-2. Improve the CBP management decisions through the successful application of developing quantitative assessments									
4-3. Provide initial (2026) and final (2027) scoping scenarios, analyses, and other materials to support Chesapeake prot									
4-4. Develop user-friendly interfaces with model software and technical transfer training so that a variety of stakeholder									
4-5. Develop and apply 2035 CC and all other management MBM and MTM scenarios as determined by CBP decision									
4-6. Document the findings and recommendations in the final report (Yr 6: 2027).									
4-7. Provide final TMDL scenario simulation results to address the needs and requirements of CBP decision makers and									

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MBM and MTM Continuous Activities (2022 - 2027)

Calendar Year		2026				2027			
Calendar Quarter		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Project Year		Year 5				Year 6			
Task 5. Continuous Activities	Task 5								
5-1. Support the Modeling Workgroup, WQGIT, and other technical and management po	Task 5.1								
5-2. Host a dedicated website for the new Main Bay Model (MBM	Task 5.2								
5-3. Submit annual reports with detailed docu	Task 5.3								
5-4. Disseminate resear	Task 5.4								
5-5	Task								

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MBM and MTM Outcomes

1. Reduced nitrogen, phosphorus, and sediment delivered to tidal Bay waters appropriate to respond to 2035 and future climate change in order to achieve Bay water quality standards.

2. Amount of habitat restored as represented by achievement of the Chesapeake living-resource-based water quality standards and direct simulation, e.g., oysters, SAV, or linkages to higher trophic levels, e.g., finfish.

3. Improved knowledge about the critical load of nutrients that the Chesapeake Bay would have under 2035 and future climate change via ensemble simulations.

4. Improved CBP decision making and leadership in responding to future climate change conditions through a flexible MBM-MTM modeling framework

5. Providing improved community model and analysis tools to serve both scientific community and stakeholders by supporting a large user community (<u>many eyes</u>).

6. Training of next-generation scientists including graduate students in Bay ecology, hydrodynamics, and biogeochemistry toward increasing scientific capacity for environmental problem solving in the region, by leveraging the education capacity in PIs' home institutes (<u>many hands</u>).

Motivation for Development and Application of MTMs

Improving CBP Science, Analysis, and Implementation for Chesapeake Climate Change Impacts. The MTMs will fully integrate and dovetail into the MBM by increasing the CBP science teams looking into Chesapeake water quality issues. Over the course of the project, five MTM modeling teams will apply a fine scale grid in the tributaries that will share the same unstructed model codes, water quality state variables, and watershed and airshed loading as the MBM. The MTM teams will improve Chesapeake Bay shallow water simulations of dissolved oxygen, chlorophyll, suspended solids, and water clarity in order to better understand the impacts of alternative management strategies on water quality and living resources in the tidal Chesapeake Bay. In addition, the MTMs will be able to utilize the CBP investment in shallow water continuous monitoring for the first time in the Chesapeake TMDL. The MTMs will augment the MBM in a collaborative investigatory approach with the MBM team collaborating and coordinating with the five MTM teams on a monthly basis over the entire project period. Under this structure the MBM and MTM teams will learn from each other in understanding and simulating newly developed shallow water nutrient dynamics and processes, improving both the MBM and the MTMs and the estuarine restoration implementation work they support.