A Vision for the 2025 Chesapeake Bay Program Models

STAC Workshop: Chesapeake Bay Program Modeling in 2025 and Beyond

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Lew Linker and the CBP Modeling Team

linker.lewis@*epa.gov*

Chesapeake Bay Program
Science, Restoration, Partnership

Overview:

- For the first time in the Chesapeake Bay Program we have the computational ability, tools, and inputs to build a distributed watershed model that will more effectively link the small scale implementation by counties, municipalities, conservation districts or other local entities to large scale State-basin TMDL targets.
- This could be linked to a small scale unstructured grid in the tidal Bay to develop, a full representation of shallow waters, tidal tributaries, and embayments.

A “see how far we’ve come moment…”

1982 – First watershed model of the Chesapeake with 63 model segments, a 2-year calibration period form March to October only, with 5 land uses and run on an IBM mainframe platform. The big question: Just what are the point and nonpoint source loads to the Bay from major basins?

1992 – Phase 2 Watershed Model with first linkage to estuary and airshed models. Model had 63 model segments, a 4-year calibration period (1984-87), 9 land uses and was run on a DEC VAX mainframe platform. Primary product: first nutrient allocations to major Chesapeake basins.

And so forth into our modern times…

You say want to have a revolution, well you know...

Beatles

Trends From 1982 to 2016 in Chesapeake Modeling

- Expansion of spatial detail/segmentation and simulation periods.
- More simulation detail.
- Deeper integration with other key modeling efforts such as CMAQ, SPARROW, APPLE, SWAT, and others – the models in models of Phase 6.
- Increased web-based distribution of open source, public domain model code, model operations (CAST), data, results, documentation, support of community modeling, and basically everything we do.
- Expanding incorporation of key living resources to examine the interaction of living resources and water quality, for example the current Bay model simulation of oysters, SAV, and menhaden (we need to do a more here going forward).

But keep in mind that trends in CBP Modeling can only tell us so much

“**Never bow to precedent**. As the pace of change accelerates, the value of precedent will continue to wane. A healthy disrespect for precedent is the ultimate advantage in a world where the future is less and less an extrapolation of the past."

Gary Hamel

Q: What Do Managers Want?
A: Models with Relevance

They want to know:

- What are my loads?
- What are the loads of others?
- How much of my loads do I need to control?
- What are the most efficient and cost effective controls to achieve the needed load reductions?
- How do my pollution management programs at different scales covering the same region fit together?
- Will the decision models be on schedule and support time-certain management deadlines: 2010 TMDL, 2017 Midpoint Assessment, etc.

Q: What Do Managers Want? A: Models with Relevance

That is to say, the standard operating procedures of all previous six modeling phases are likely to still be in play in the 2025 build of the CBP models:

“We build the CBP models and analyses in order to

1) make the nutrient reduction plans to,
2) track management practice implementation to,
3) make the nutrient reductions to,
4) restore the Chesapeake watershed and Bay.”

<u>From this perspective, the CBP modeling tools are a **means to a management end**.</u>

But Not So Fast Bucko……..

True statement: The numbers generated by the CBP models are less relevant than the understanding they develop in Chesapeake watershed restoration.

Developing understanding involves support to Chesapeake and coastal watershed restoration science through:

- Collaboration with PIs and project teams
- Supporting connections of monitoring, research, modeling
- Providing the possibility for model based experiments
- Corroboration of CBP model findings
- And just as important, contradictions and refutations of CBP model findings

Not So Fast……..

That is to say, the collaboration and cooperation with PIs in the watershed and beyond will only deepen going forward:

"We build the models and analyses in order to

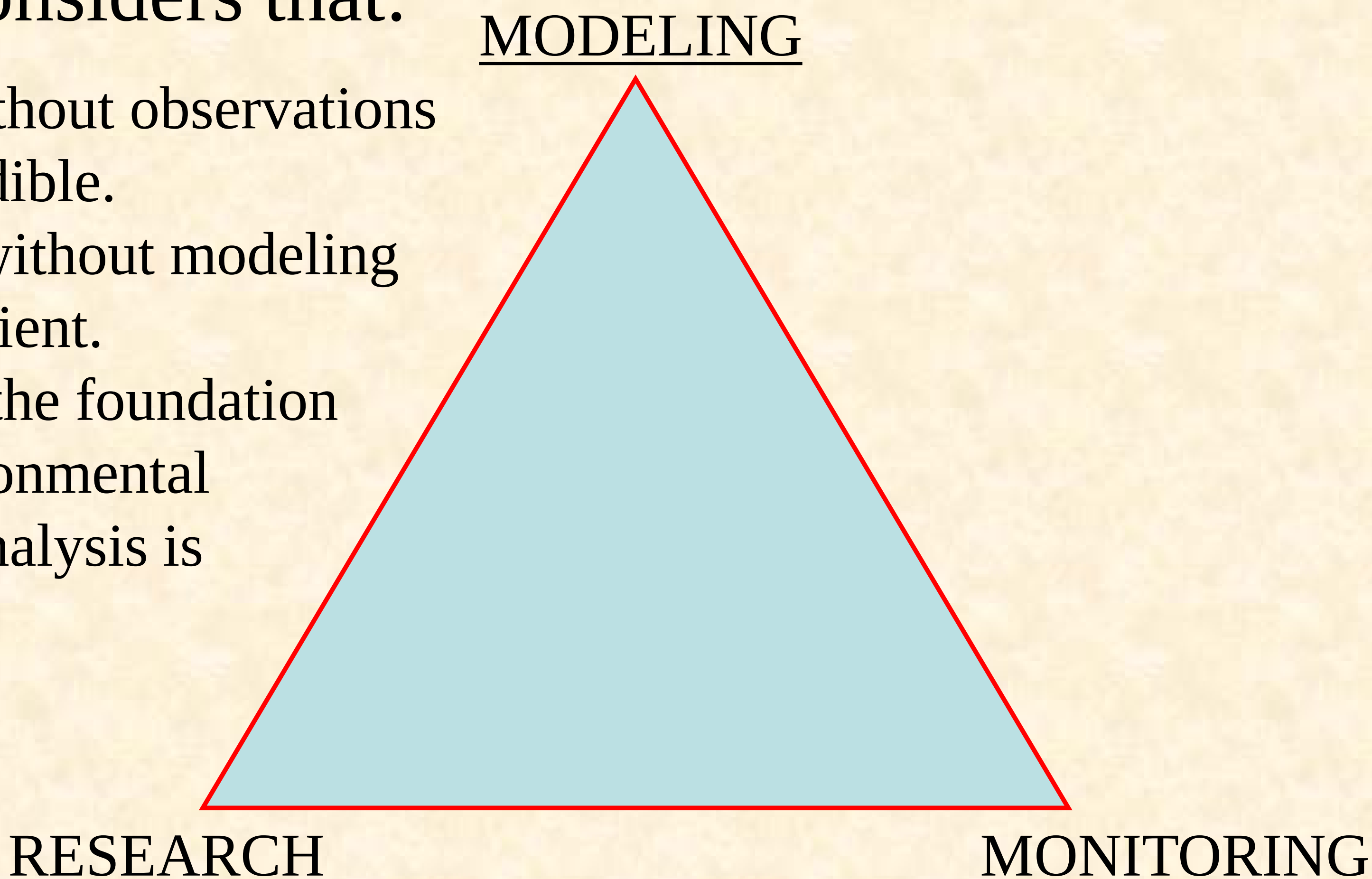
1) collaborate with PIs to,
2) support their research to,
3) improve the synergy among observation, research, and modeling to,
4) deepen of understanding of how to restore the Chesapeake watershed and Bay."

<u>From this perspective, the CBP modeling tools are a also a **means to support the science of coastal watershed restoration**.</u>

Triad of Modeling, Monitoring, and Research

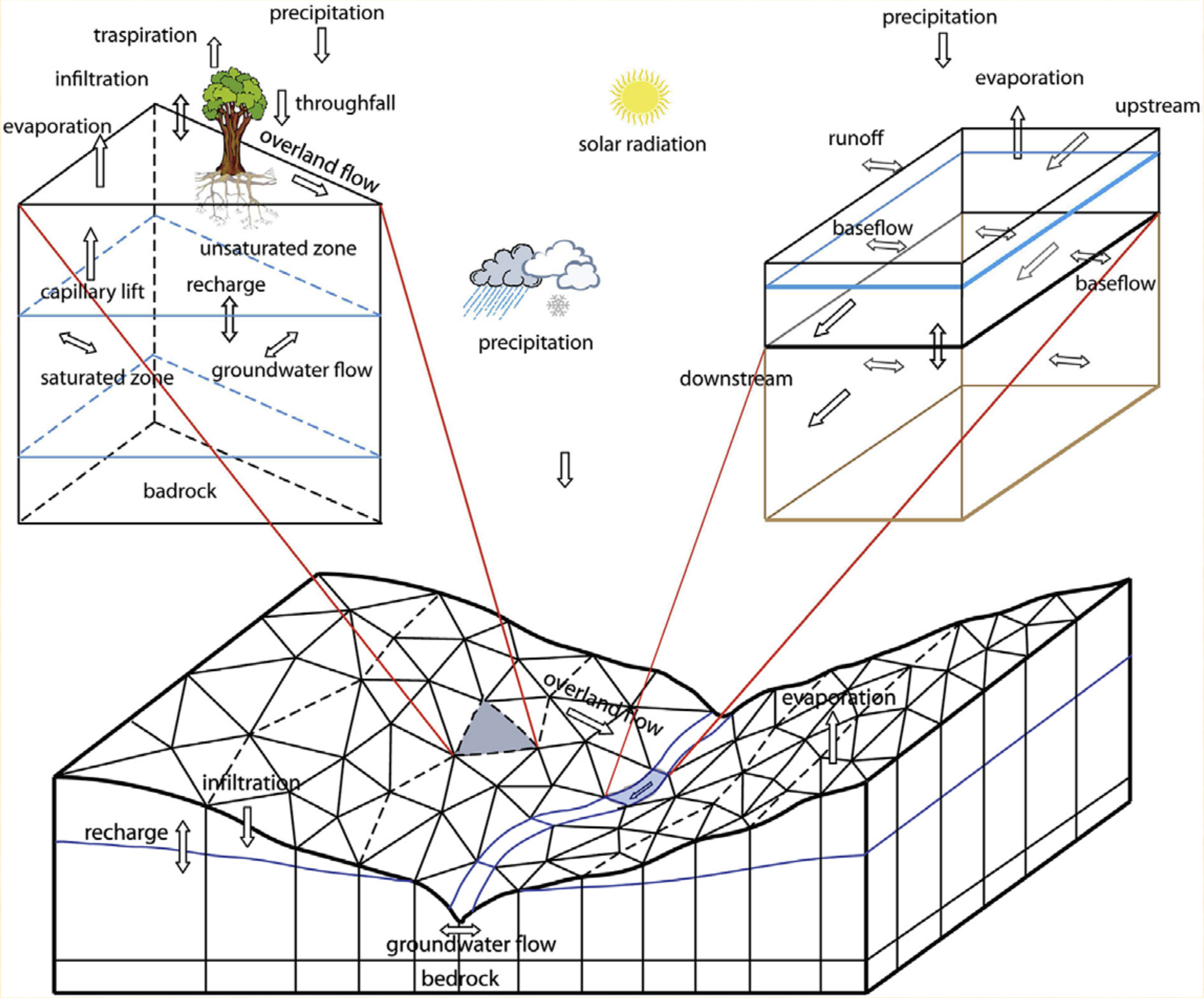
The current state of the science considers that:

- Modeling without observations to be not credible.
- Monitoring without modeling to be insufficient.
- Research is the foundation that all environmental restoration analysis is built on.



An Example of a Distributed Watershed Model

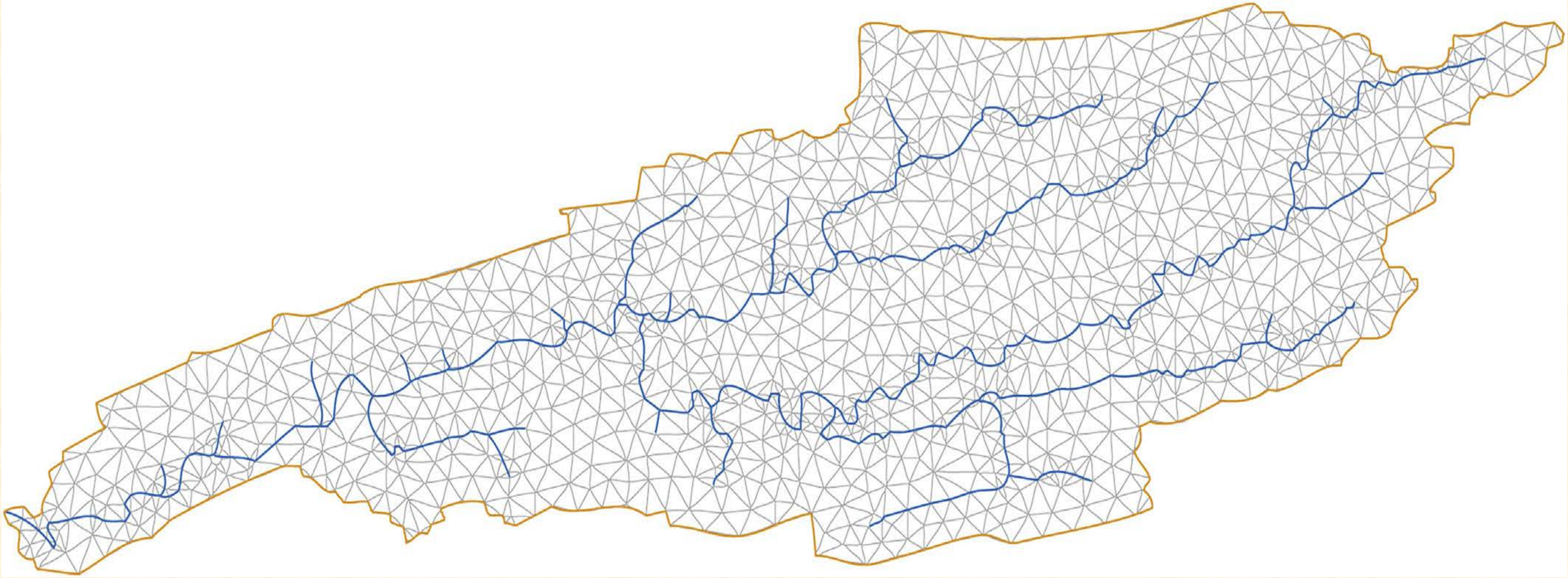
The Penn State Integrated Hydrologic Model (PIHM) is a multiprocess, multi-scale hydrologic model where the major hydrological processes are fully coupled using the semi-discrete finite volume method.



Source: Bhatt et al., 2014. A tightly coupled GIS and distributed hydrologic modeling framework. *Environmental Modelling & Software 62 (2014) 1-15*

An Example of a Distributed Watershed Model

Fig. 8. Domain decomposition of Mohantango Creek watershed into 2,606 triangular mesh elements and 509 linear stream elements using Domain Decomposition toolset. Quality constraint of 20° for minimum angle of a triangle, and 400,000 square meters for maximum area were used.

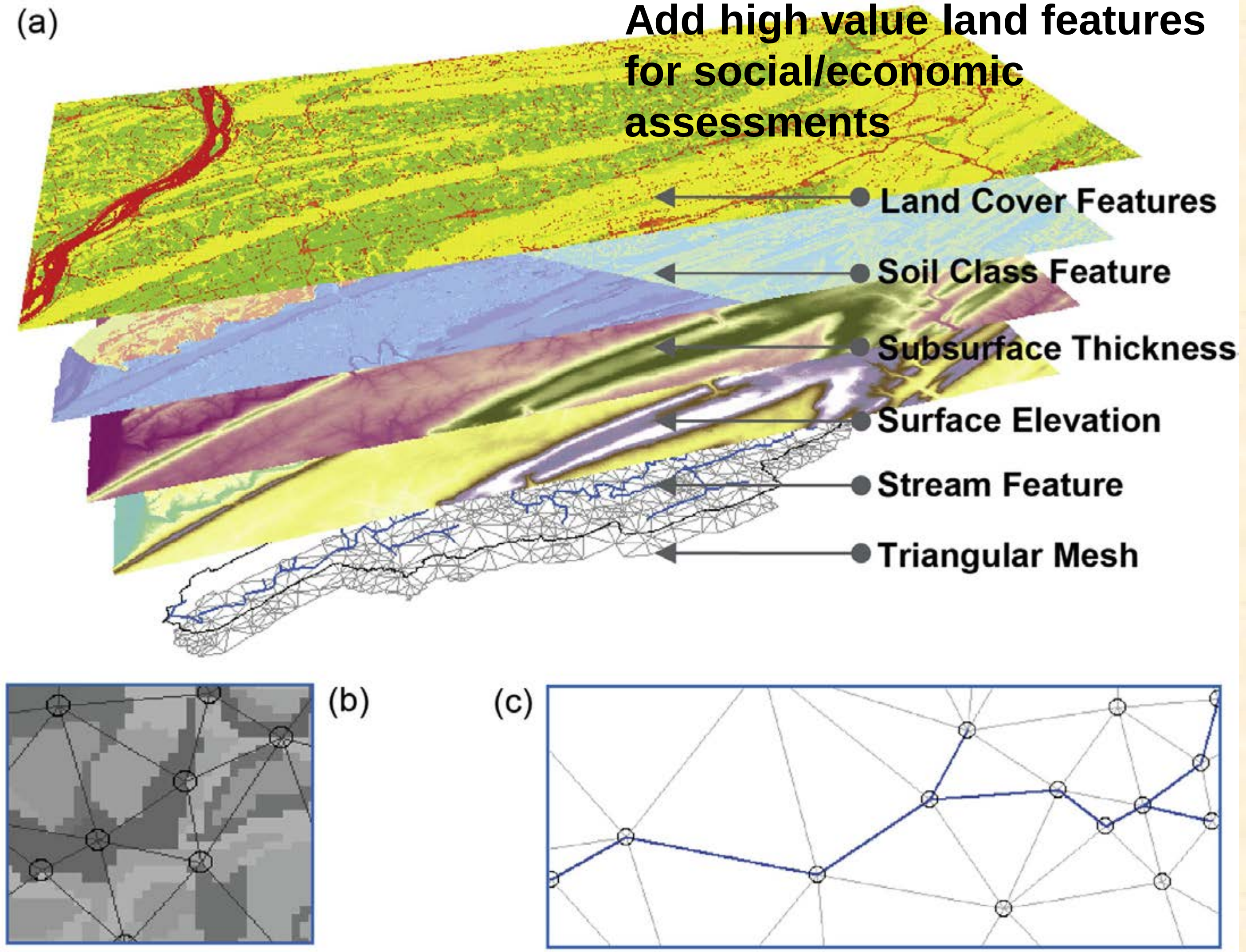


Source: Bhatt et al., 2014. A tightly coupled GIS and distributed hydrologic modeling framework. *Environmental Modelling & Software 62 (2014) 1-15*

An Example of a Distributed Watershed Model

The model itself is "tightly-coupled" with PIHMgis, an open-source Geographical Information System designed for PIHM. The PIHMgis provides the interface to PIHM, access to the digital data sets (terrain, forcing and parameters) and tools necessary to drive the model, as well as a collection of GIS-based pre- and post-processing tools.

Source: Bhatt et al., 2014. A tightly coupled GIS and distributed hydrologic modeling framework. *Environmental Modelling & Software 62 (2014) 1-15*

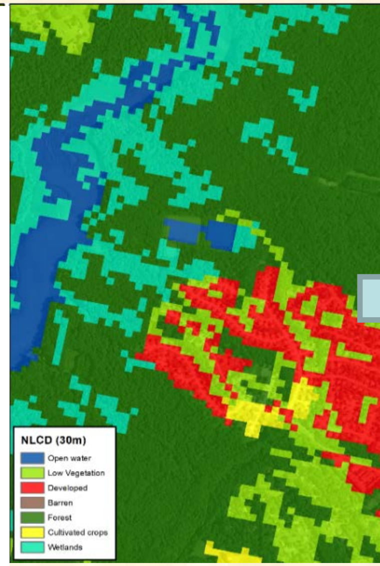


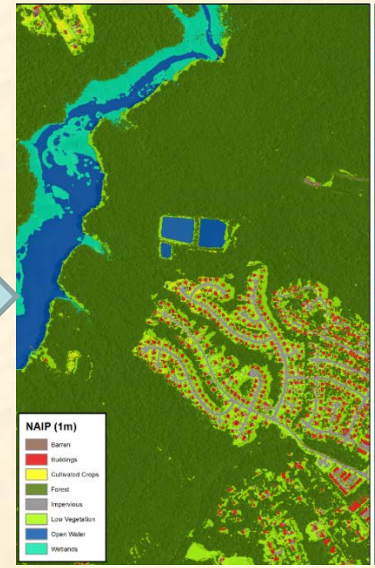
Data Parameterization: assigns classification of each geospatial data layer to triangular mesh elements.

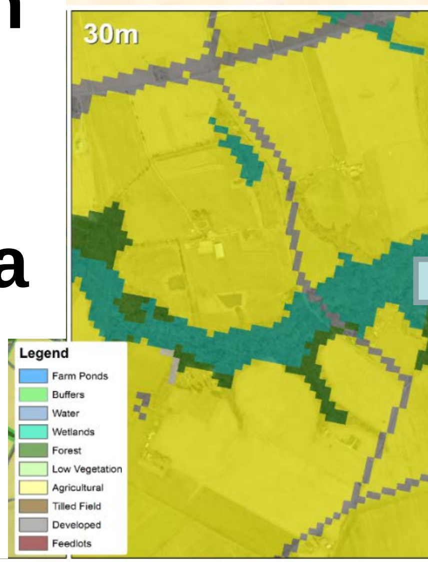
Topology for stream segments: established by From- and To- Node, Up- and Down- stream segment, Left- and Right- mesh element.

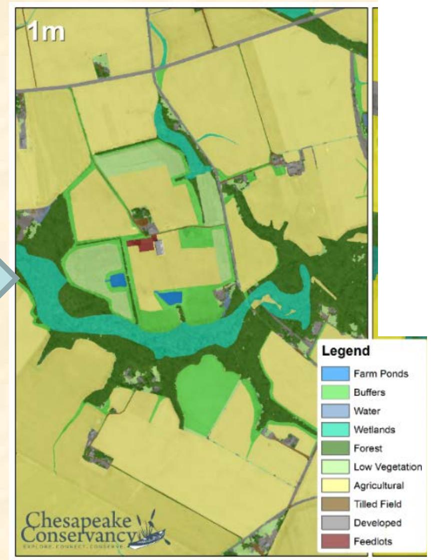
Fine Scale Land Use Support for a Distributed Watershed Model in the Chesapeake

Phase 5 30-Meter Resolution Land Use/Land Cover Data





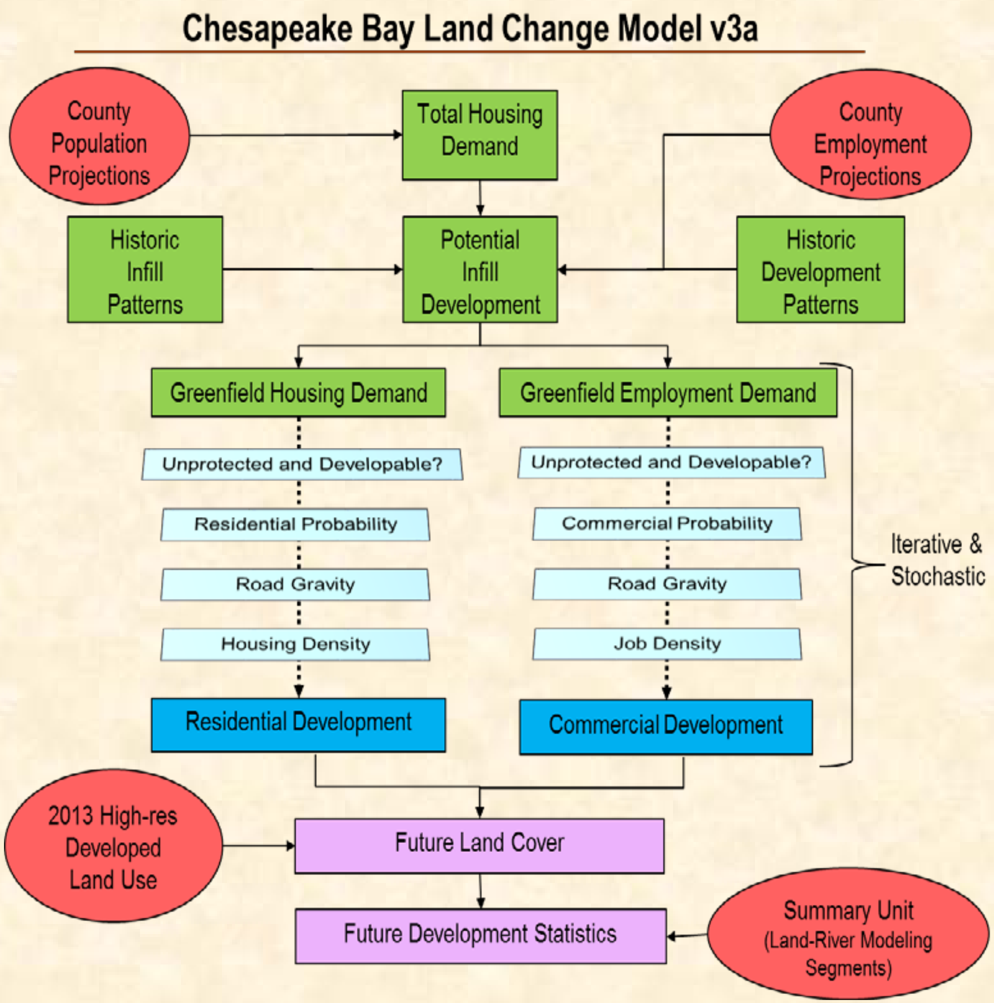


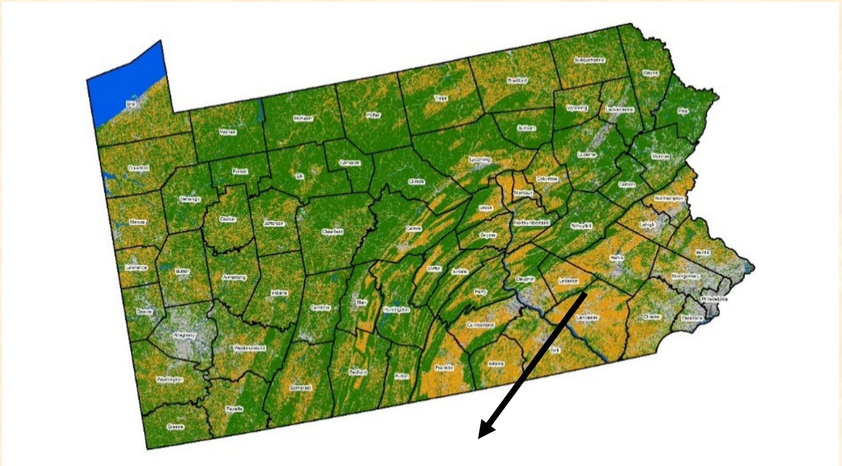


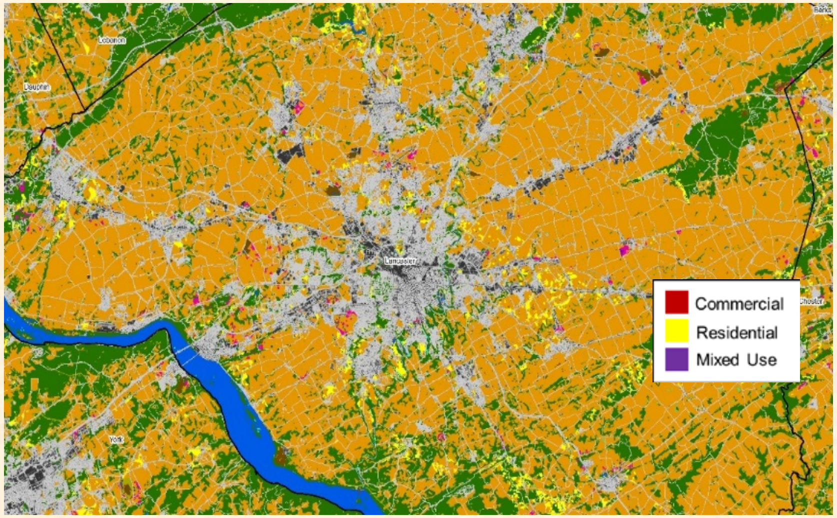
Phase 6 1-Meter Resolution Land Use/Land Cover Data

Source: PSC 2017 Midpoint Assessment Decision Meeting Dec. 19-20, 2017

Partnership’s Chesapeake Bay Land Change Model





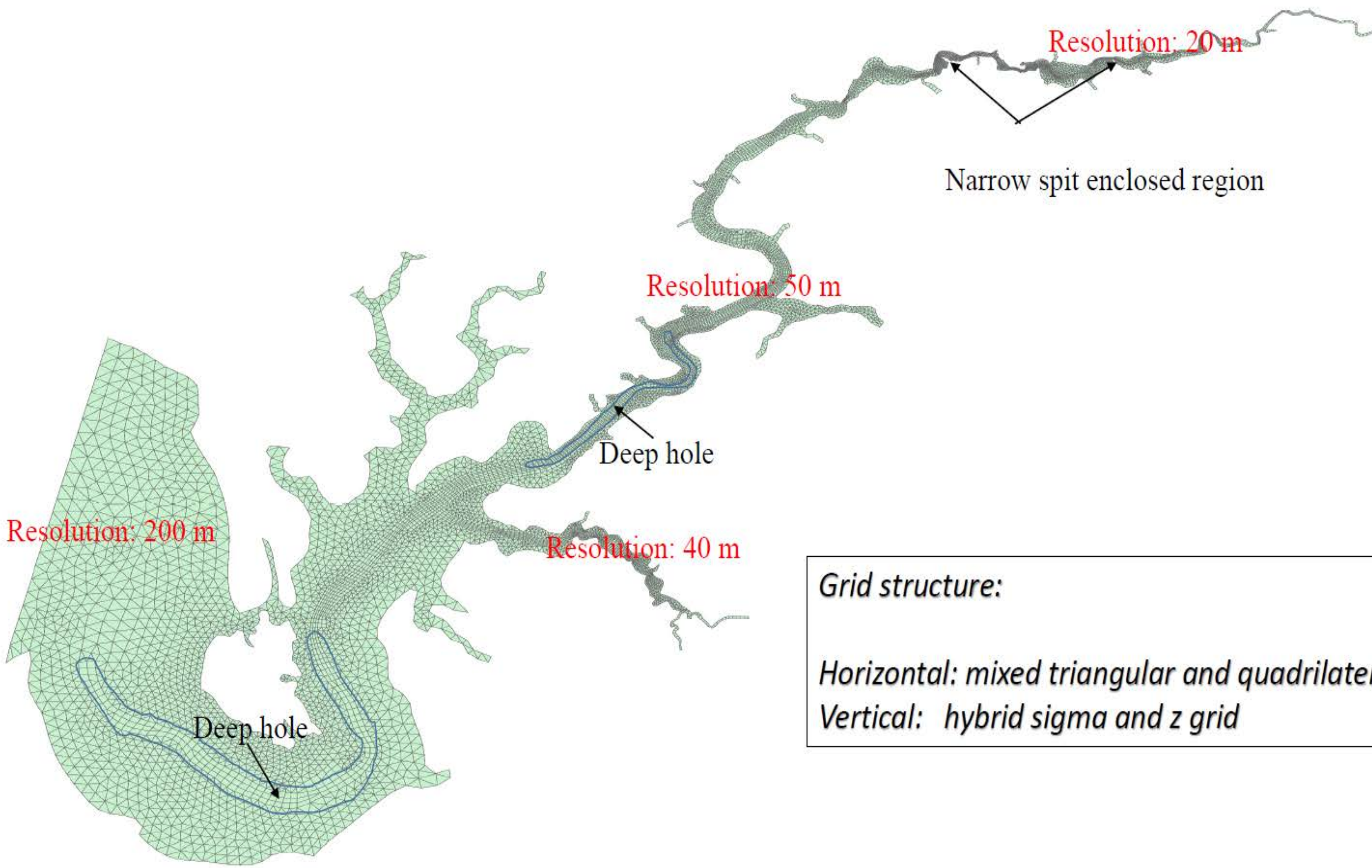


The Steps Might Be:

1. a distributed temporal hydrologic model
2. a distributed temporal water quality process-based model to be used for insight/understanding of salient processes across scale.
3. a distributed static or temporal water quality model that is like Phase 6 to be used for insight/understanding, but also quantification for management, i.e., incorporates multiple models and lines of evidence at multiple scales
4. a coarser-scale static model that can be used efficiently by managers for application at all scales.

An Example of an Unstructured Grid Model in the Chesapeake

I.1 Modeling Grid

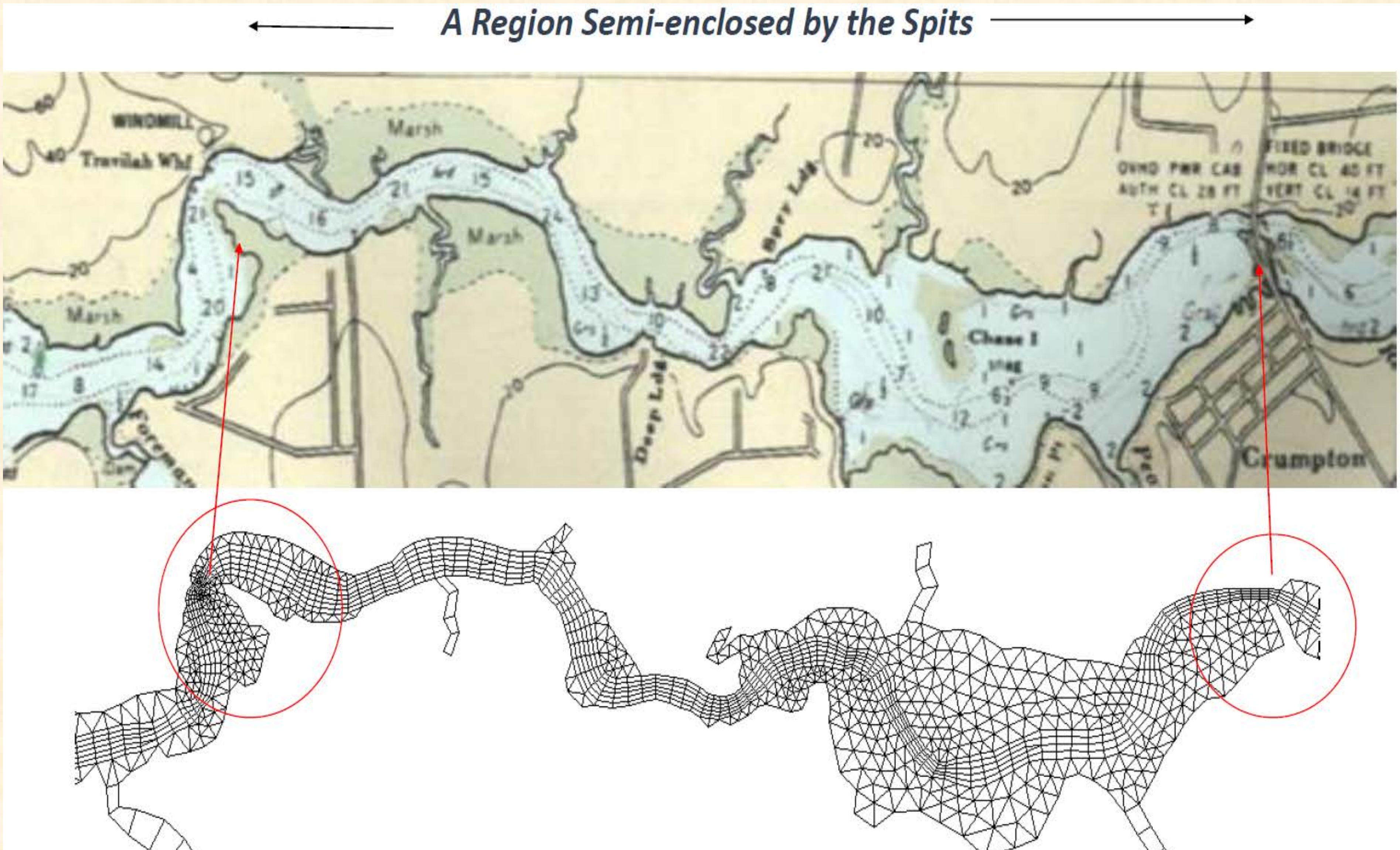


Grid structure:

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

An Example of an unstructured grid model in the Chesapeake

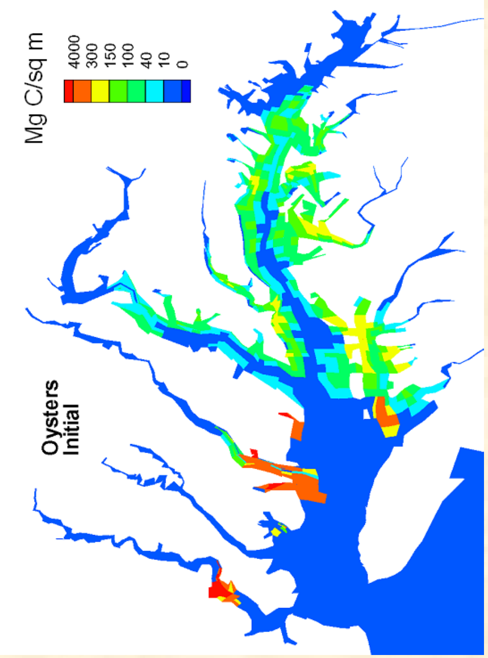


Source: Chester River Hydrodynamic and Water Quality Modeling using SCHISM/HEM3D. Wang, Zhang, et al. *STAC Shallow Water Modeling Workshop* April 20, 2016

Future Directions in Chesapeake Tidal Water Modeling

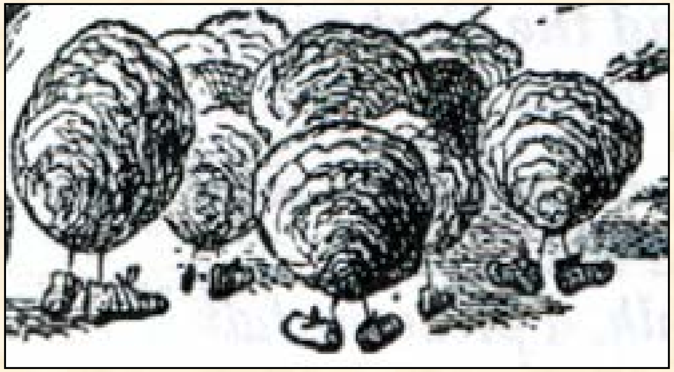
- An unstructured grid allowing the resolution necessary for salient features
- Fine scale depth and wetting and drying is necessary for accurate representation of SAV, benthic algae, and bottom light conditions in the shallows.
- Parallel computing is a requirement because of the operational requirement of no more than a two-day turn around time in management models.
- Multiple sediment particle classes are necessary
- Wave resuspension and sediment transport is a required feature.
- Sediment diagenesis is a required feature.
- Influences of tidal wetlands on shallow water quality need to be estimated.
- Linkages to key living resources made.

Coupled Living Resource Models

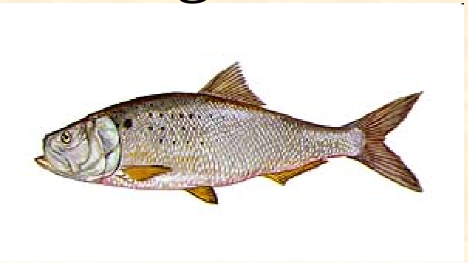


- The clarity/SAV standard is for the restoration of SAV, yet increased SAV biomass has positive feedbacks on the improving clarity.

- For more than a decade oysters have been demonstrated to improve water quality, particularly in shallow water habitat for both oysters and SAV.

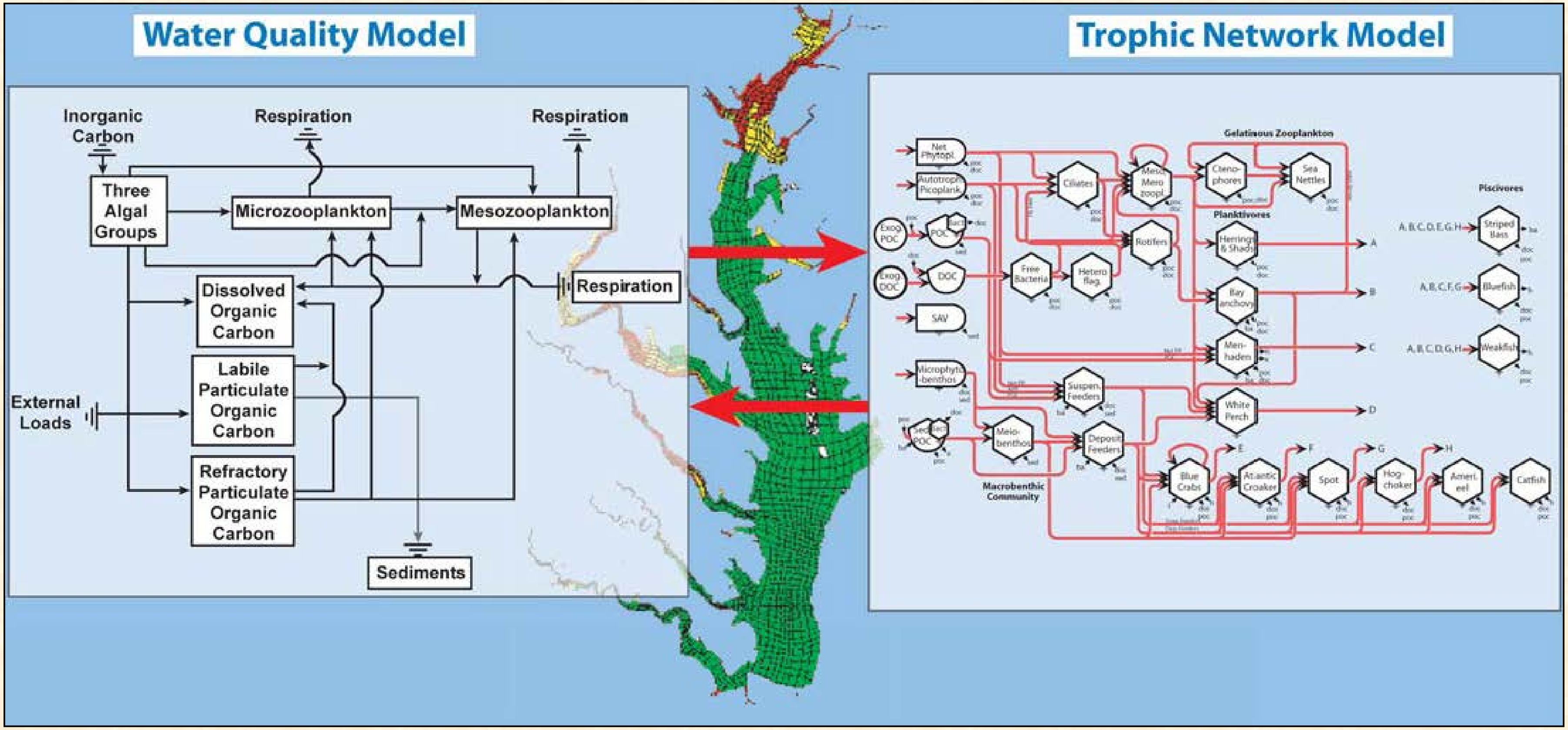


- The influence of menhaden on water clarity is being examined with the current CBP models.



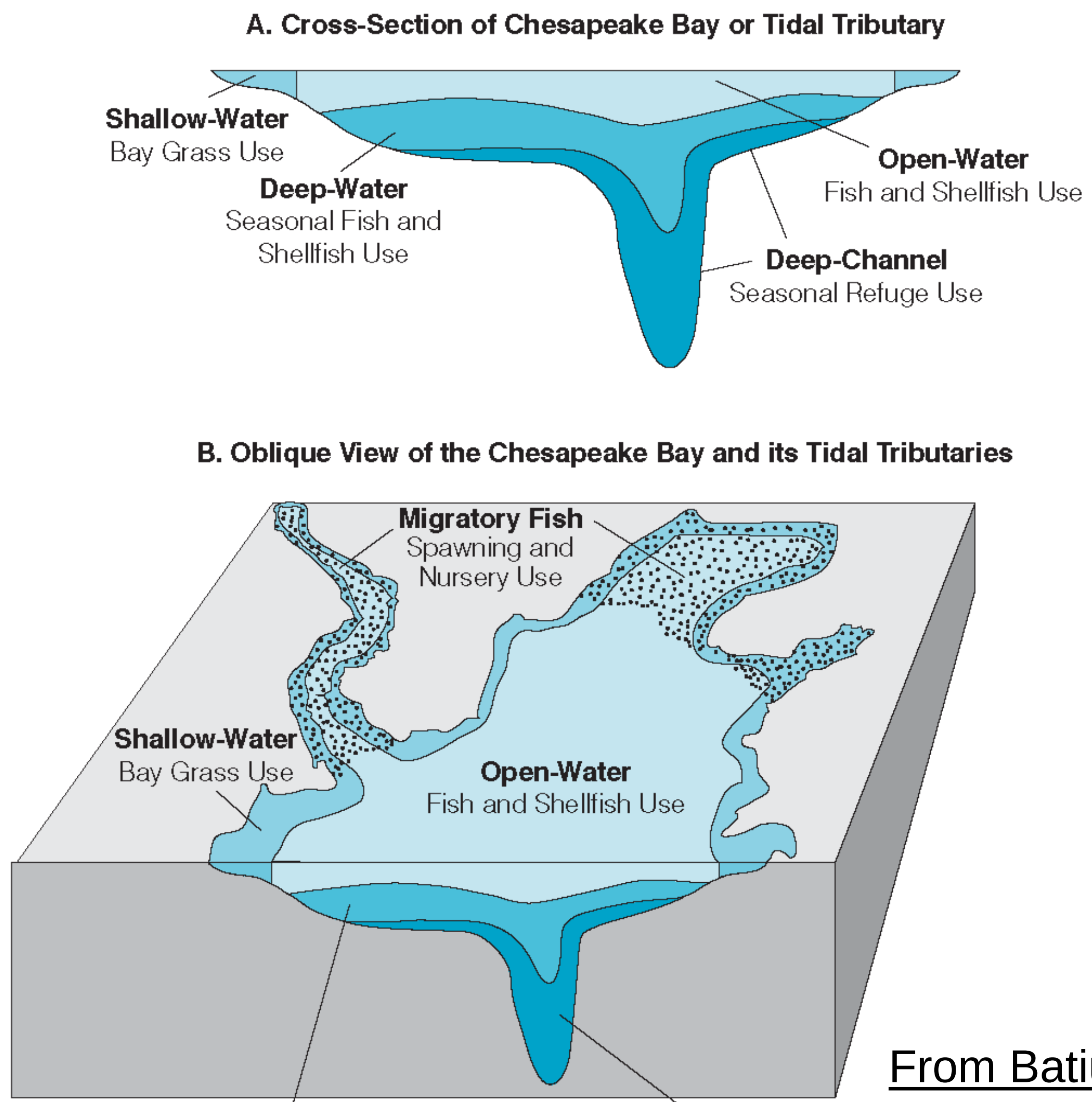
Living Resource Models of Trophic Interactions

Coupling the Ecopath with Ecosim ecological model to the Water Quality Model will examine the Bay's future trophic system when nutrient loads are about half what they were at their zenith in the 1980s.



What tools do we have to get started?

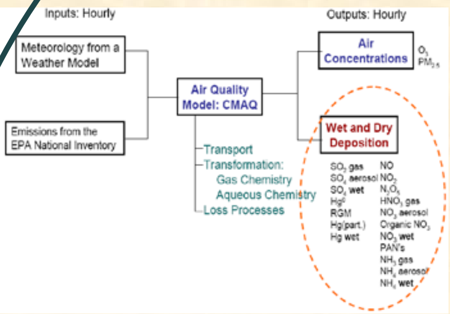
A good TMDL starts with good water quality standards. Standards of Deep Water, Deep Channel, Open Water, and Shallow Water Dissolved Oxygen (DO) are key for protection of living resources. Chlorophyll and SAV/clarity standards are also designed to protect living resources.

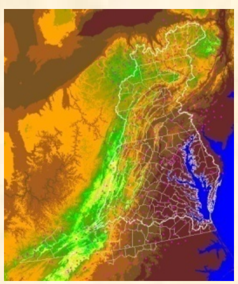


From Batiuk (2003)

Nutrient Allocation Decision Support System

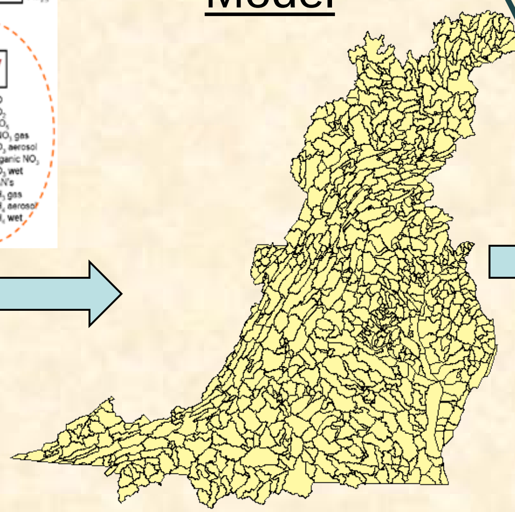
Airshed Model



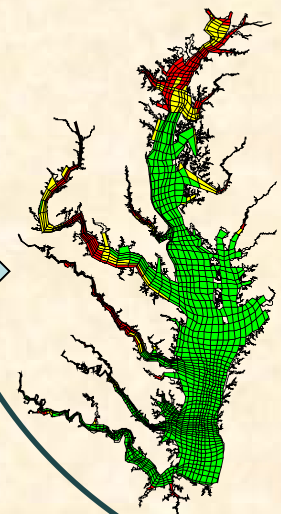


Land Use Model

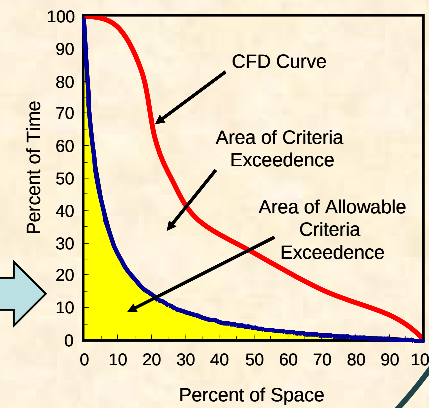
Watershed Model



Bay Model



Criteria Assessment Procedures



Used to Assess Allocations or Target Loads

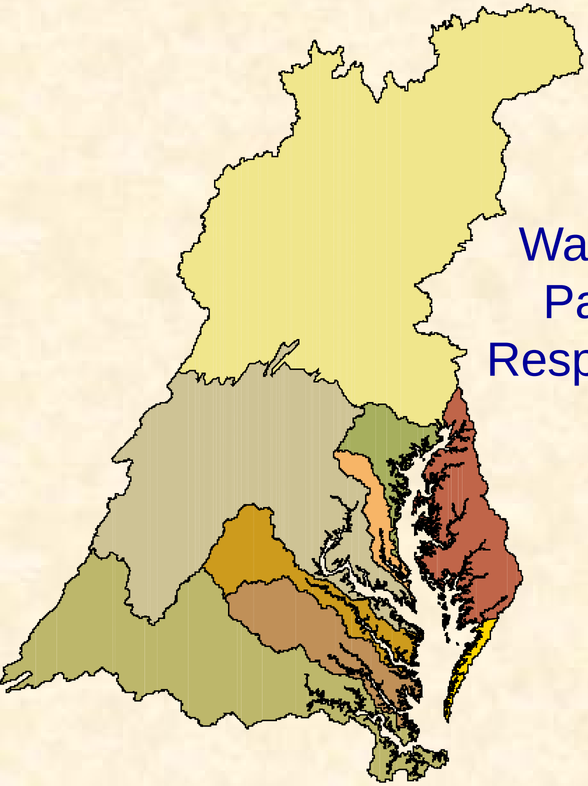
Used to Assess Target Load Achievement

Effects

Allocations

Good Governance: Load Allocation Process

By **9** major river basins



Watershed Partners Responsibility

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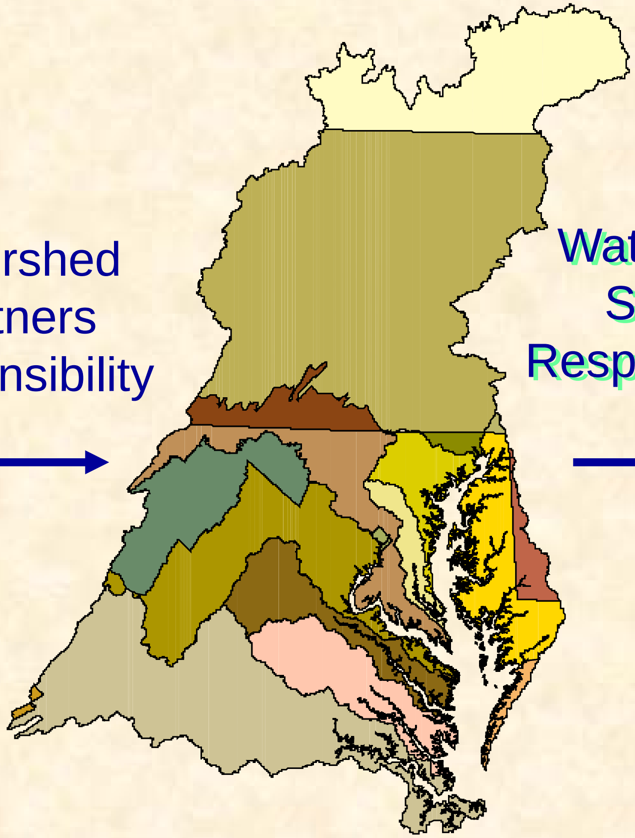
...then by **20** major tributary basins by jurisdiction



Watershed States Responsibility

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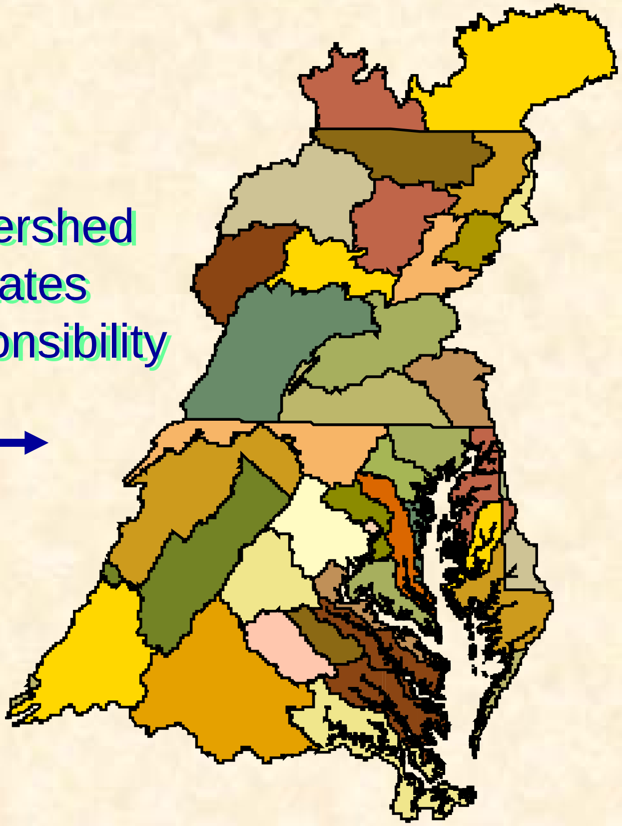
…then by **44** state-defined tributary strategy subbasins



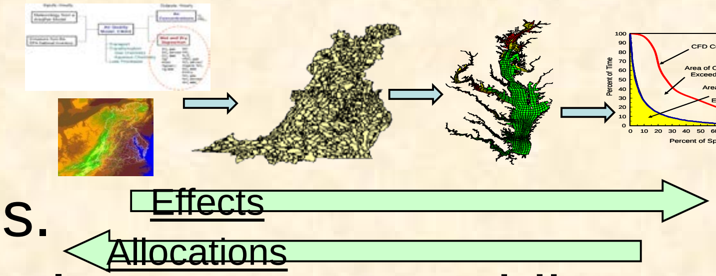
Potential Applications of a 2025 Next Generation CBP Suite of Models

- Support for across all scales including local watershed TMDLs with fine scale land use and distributed watershed model. (MD has > 300 nontidal TMDLs).
- Support local tidal water TMDLs with unstructured grid tidal Bay model (MD has > 90 tidal water TMDLs)
- Expand and support ecological modeling.
- Social sciences what if we engaged in a discussion of local scale modeling and there was no one on the other side of the discussion.
- Optimization and the need for better economic assessments – benefit value and social outcomes like more fish, water clarity, swimmable water, etc.

Will we seeing a change in focus for 2025 In Chesapeake Bay Management and Models?

The hope is that we’ll be turning a corner in 2025 – moving from determined, ongoing year-by-year nutrient reductions, despite the headwinds of growth and climate change, toward a maintenance phase of Chesapeake restoration.

Why is Integrated Modeling Across Scales Needed?



- Model integration creates:
  - Cooperation between parties.
  - More useful and accurate models.
  - Better integration of environmental programs providing better environmental protection at least cost.
- Model integration across scales provides a more complete analysis of issues:
  - Environmental fate and transport among different media at all scales.
  - Improving environmental management by taking into account cross-media and cross scale effects.
  - More complete economic analysis of benefits and costs.
  - To better understand impacts of actions and policies at all scales.