Chesapeake Bay Watershed Model Evolution Over 30 Years

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Chesapeake Bay Watershed Model Evolution over 30 years

50 Years of Watershed Modeling Conference
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We need to view the CBP integrated models of the airshed, watershed, and tidal Bay models as a whole. Together they relate the watershed and airshed loads to water quality impairments in the Chesapeake.
Low to no dissolved oxygen in the Bay and tidal rivers every summer
Water Quality 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.
Nutrient Allocation Decision Support System

Airshed Model
- Inputs: Hourly
  - Meteorology from a Weather Model
- Outputs: Hourly
  - Air Quality Models: CMAQ
- Emitters from the EPA National Inventory
  - Greenhouse Gas
  - Oxidant
  - Fine Particles
  - Nitrogen Oxides
  - Sulfur Dioxide
  - VOCs
  - Particulate Matter
- Wet and Dry Deposition

Watershed Model

Bay Model

Criteria Assessment Procedures
- CFD Curve
- Area of Criteria Exceedence
- Area of Allowable Criteria Exceedence

Effects

Allocations
Sources of Nitrogen to the Bay

- Agriculture-Manure (17%)
- Agricultural Atmospheric Deposition (6%)
- Atmospheric Deposition-Mobile, Utilities and Industries (19%)
- Atmospheric Deposition-Natural (1%)
- Atmospheric Deposition to Tidal Waters (7%)
- Septic Systems (4%)
- Developed Lands-Chemical Fertilizer (10%)
- Municipal and Industrial Wastewater (19%)

Note: Does not include loads from the ocean or tidal shoreline erosion. Wastewater loads are based on measured discharges; other loads are based on an average-hydrology year using the Chesapeake Bay Program Watershed Model Phase 4.3 (Chesapeake Bay Program Office, 2009). Values do not add up to 100% due to rounding.
Relative Effect of a Pound of Pollution on Bay Water Quality

Effectiveness
Nitrogen
- 0.0 - 1.2
- 1.3 - 2.7
- 2.8 - 4.2
- 4.3 - 5.5
- 5.6 - 7.1
- 7.2 - 10.3

Effectiveness
Phosphorus
- 0.0 - 1.6
- 1.7 - 3.1
- 3.2 - 4.8
- 4.9 - 5.7
- 5.8 - 7.1
- 7.2 - 10.3
Estimated total nitrogen loads from key scenarios. Loads in millions of kilograms.
Load Allocation Process

By **9** major river basins

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

...then by **44** state-defined tributary strategy subbasins
A Quarter Century of Watershed Model Development

Phase 1
- Completed in 1982.
- 63 model segments.
- 2 year calibration period (Mar.- Oct.).
- 5 land uses.

Phase 4
- Completed in 1998.
- 94 model segments.
  - 9 land uses.
- 14 year calibration period (1984-97) using automated input and output model processors.

Phase 5
- May 2009 roll-out
- ~ 1,000 model segments.
- 21 year calibration period (‘85-'05).
- ~ 25 land uses using time-varying land use & BMPs.
Trends From 1982 to 2012 in Chesapeake Bay Modeling:

- Expansion of spatial detail/segmentation and simulation periods.
- More simulation detail. Example - BMP performance in different physiographic regions.
- Increased web-based distribution of open source public domain model code, data, results, documentation and support of community modeling.
- Integration with other key modeling efforts such as CMAQ and climate models.
First Version of the Watershed Model:

- Completed in 1982.
- 63 model segments.
- 2 year calibration period (Mar.- Oct.).
- 5 land uses.
- IBM mainframe platform.
Primary Products of the First Version of the Watershed Model:

First estimate of relative point source and NPS loads for each major basin.

Demonstration of the importance of controlling NPS loads in the Chesapeake.

"Framework for Action" report, the first basin by basin assessment of Chesapeake nutrient loads.
Watershed Model - Phase 2:

- 63 model segments.
- 4 year calibration period (1984-87).
- 9 land uses.
- DEC VAX mainframe platform.
Primary Products of Phase 2:

- First nitrogen and phosphorous allocations for each major basin.
- First linkage to water quality model of the estuary.
- First linkage to the airshed model (RADM) and estimates of atmospheric loads for each major basin.
Watershed Model - Phase 4:

- Completed in 1998.
- 94 model segments.
- 9 land uses.
- 14 year calibration period (1984-97) using automated input and output model processors.
- Sun (UNIX) workstation platform.
Primary Products of Phase 4:

- Tributary allocations for the lower tributaries of the Rappahannock, York, and James (2000) and for all basins in the 2003 Allocation.

- Began open source, public domain, web distribution of preprocessors, post processors, and open source code. Begin broad use in the community for research, TMDLs, and analysis.
Watershed Model - Phase 5:

- Completed in April 2010.
- > 1,000 model segments.
- ~20 land uses using time-varying land use & BMPs.
- Multiple platforms, web distribution.
History of Watershed Model Operations:
[LU x parameters x (segments + reaches) x time steps]
Conclusions:

Future Directions of Watershed Modeling

- Distributed watershed models at the Chesapeake watershed scale.
- Greater integration with airshed, coastal, living resource, and climate change models.
Now have a working hydrology model of Juniata basin (1/20th CB watershed operational on 87,000 partitions and running 1 year in 1 hour.)
The future of CBP Modeling...2010 and beyond:

“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
Lessons Learned

Management Models in the Chesapeake

• Too much stakeholder input is not enough
• KISS
• Agility is key

Empower the community to create, understand, and use the model.
Chesapeake Bay Program Partners

- Signatories to the Chesapeake Bay Agreement
  - PA, MD, VA, DC
  - CBC
  - EPA

- Headwater States
  - DE, NY, WV

- Federal Agencies
  - NOAA
  - USDA
  - USGS
  - NPS
  - USFW
  - DOD
  - NASA
  - NCPC
  - D.Ed.
  - USPS
  - GSA
How many meetings did it take to create the Chesapeake TMDL?

- TMDL on the agenda: about 375 since 2005
- TMDL a principal topic: about 450 since 2008
- Model development started in 1999
Chesapeake Bay Program

Citizen’s Advisory Committee

Local Government Advisory Committee

Scientific & Technical Advisory Committee

Management Board

Chesapeake Executive Council
Principals Staff Committee

Independent Evaluator

Watershed Technical Workgroup
Agriculture Workgroup
Urban Stormwater Workgroup
Forestry Workgroup
Ad-Hoc Panels

Scientific, Technical Assessment & Reporting

Modeling Workgroup

Goal Implementation Teams

Sustainable Fisheries
Protect & Restore Vital Habitats
Protect & Restore Water Quality
Maintain Healthy Watersheds
Foster Chesapeake Stewardship
Enhance Partnering & Leadership
Agricultural Workgroup

- **Federal**
  - USDA, EPA
- **State**
  - Chesapeake Bay Commission, Delaware Department of Agriculture, Maryland Department of Agriculture, NY DEC, PA Department of Environmental Protection, Pennsylvania Department of Environmental Protection, Pennsylvania State Conservation Commission, VA DCR, VA DEQ, West Virginia Department of Agriculture, WV DEP
- **University**
  - Chesapeake Research Consortium, Cornell University, Penn State University, University of Delaware, University of Maryland, West Virginia University
- **Industry Groups**
  - Delaware Maryland Agribusiness Association, Delaware Pork Producers Association, Delmarva Poultry Industry, Inc., MD Farm Bureau, VA Farm Bureau, VA Grain Producers Producers Association, Virginia Agribusiness Council, Virginia Poultry Association, U.S. Poultry & Egg Association,
- **Local organizations**
  - Cortland County Soil and Water Conservation District, Lancaster County Conservation District, Madison Co. SWCD, Upper Susquehanna Coalition
- **NGOs**
  - American Farmland Trust, Environmental Defense Fund, Keith Campbell Foundation for the Environment, MidAtlantic Farm Credit, PA NoTill Alliance
One Ad-Hoc Subgroup of the Agricultural Workgroup

Mid-Atlantic Water Program, U.S. Department of Agriculture-Natural Resources Conservation Service, Virginia Department of Conservation and Recreation, Virginia Department of Forestry, Pennsylvania State Conservation Commission, Pennsylvania Department of Conservation and Natural Resources, Pennsylvania Department of Environmental Protection, Maryland Department of Agriculture, Maryland Department of Natural Resources, Maryland Department of the Environment, University of Maryland Cooperative Extension, University of Maryland-College Park, Delaware Department of Agriculture, Delaware Department of Natural Resources and Environmental Control, Delaware Maryland Agribusiness Association, West Virginia Department of Agriculture, West Virginia Department of Environmental Protection, Cacapon Institute - West Virginia, New York Department of Environmental Conservation, Upper Susquehanna Coalition, American Farmland
# Expert Review Panels; Planned and Active

## Agriculture
- Nutrient Management
- Poultry Litter
- Conservation Tillage
- Cover Crop Panel
- Manure Treatment Technologies
- Animal Waste Storage Systems
- Manure Injection/Incorporation
- Cropland Irrigation Management

## Urban
- Urban Retrofits
- Performance Based Management
- Stream Restoration
- LID and Runoff Reduction
- Urban Fertilizer Management
- Erosion and Sediment Control
- Illicit Discharge Elimination
- Impervious Disconnect
- Floating Wetlands
- MS4 Minimum Management Measures

## Forestry
- Riparian Buffers
- Urban Tree Planting
- Forest Management
- Urban Filter Strips and Upgraded Stream Buffers
Too much is not enough

- Stakeholder input and access has helped the modeling and management processes

- But …
  - Increase in the stakes has increased scrutiny
  - Increase in understanding by the users has increased demand for more complexity
  - Management-driven complexity has created difficulty in understanding and opportunity for detractors
Lessons Learned
Management Models in the Chesapeake

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• Agility is key

Empower the community to create, understand, and use the model.
Lessons Learned through TMDL

• The CBP Partnership wants
  – Simplicity
  – Scalability
  – Serviceability
  – Stability

• Quote from State Government Representative:
  “We want to be able to explain the models to our stakeholders and have them be relevant at the local scale.”
Simulated BMPs vs Percent Reduction

• Which Description Works Best for Management?

• What’s my reduction from Nutrient Management?
  – Well, based on the rules developed by the partnership and the data supplied by national sources and the states, the balance of inputs and outputs for your land use is such that there is an overabundance of manure in your county, as opposed to the next county over where nutrient management has almost no effect. Now when you apply nutrient management, that will attract manure to the nutrient management land use, so it will have a higher load, but since it’s pulling manure from other land uses, the total segment load will usually decrease, however in some circumstances when nutrient management is applied to pasture, it can push so much manure back on to other land uses, that the marginal effect …

• What’s my reduction from Cover Crops?
  – Based on the Cover Crop Panel, who based their decision on multiple referenced data sources and models, your reduction for Early Drilled Barley in the Valley and Ridge Carbonate region is 38%
Management vs Research Model

- Management models should integrate knowledge, rather than create knowledge.

- The Watershed model does not tell us anything we don’t already know, it just puts all of the knowledge in one place and allows us to see how different sources, watershed processes, and management practices interrelate.
Lessons Learned
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- KISS
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Number of Scenarios

- Mid 1980s: 0
- Early 1990s – phase 2: <10
- Late 1990s phase 4.1: 37
- Early 2000s – phase 4.3: 400+
- 2009-2010 – phase 5.3.0: 300+
- 2011 - 2012 - phase 5.3.2: 300 thru Sept

Scenario automation in the early 2000s greatly expanded the use of the watershed model.
Data flows

Feds, States and DC

submit Non-Point Source Load, Practices/Verification using NEIER

Wastewater Point Source / Data Direct Reporting

Back-end – BayTAS O&M Team and State Access (QA, data entry, review etc.)

To Chesapeake Stat for Presentation

Final TMDL, Baseline Progress, Other data.

Watershed Model runs measure loadings progress.

Scenario Builder

BayTAS (In CBPO IT Infrastructure)

1/3 of this code is SPF

Agility
Calibration automation made calibration possible

Automation will allow fast turnaround of model versions during the next development phase
Lessons Learned
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Management Modeling Maxims

• Absolute Rule #1
  – Always Improve and Never Change

• Absolute Rule #2
  – Include Everything and Keep it Simple