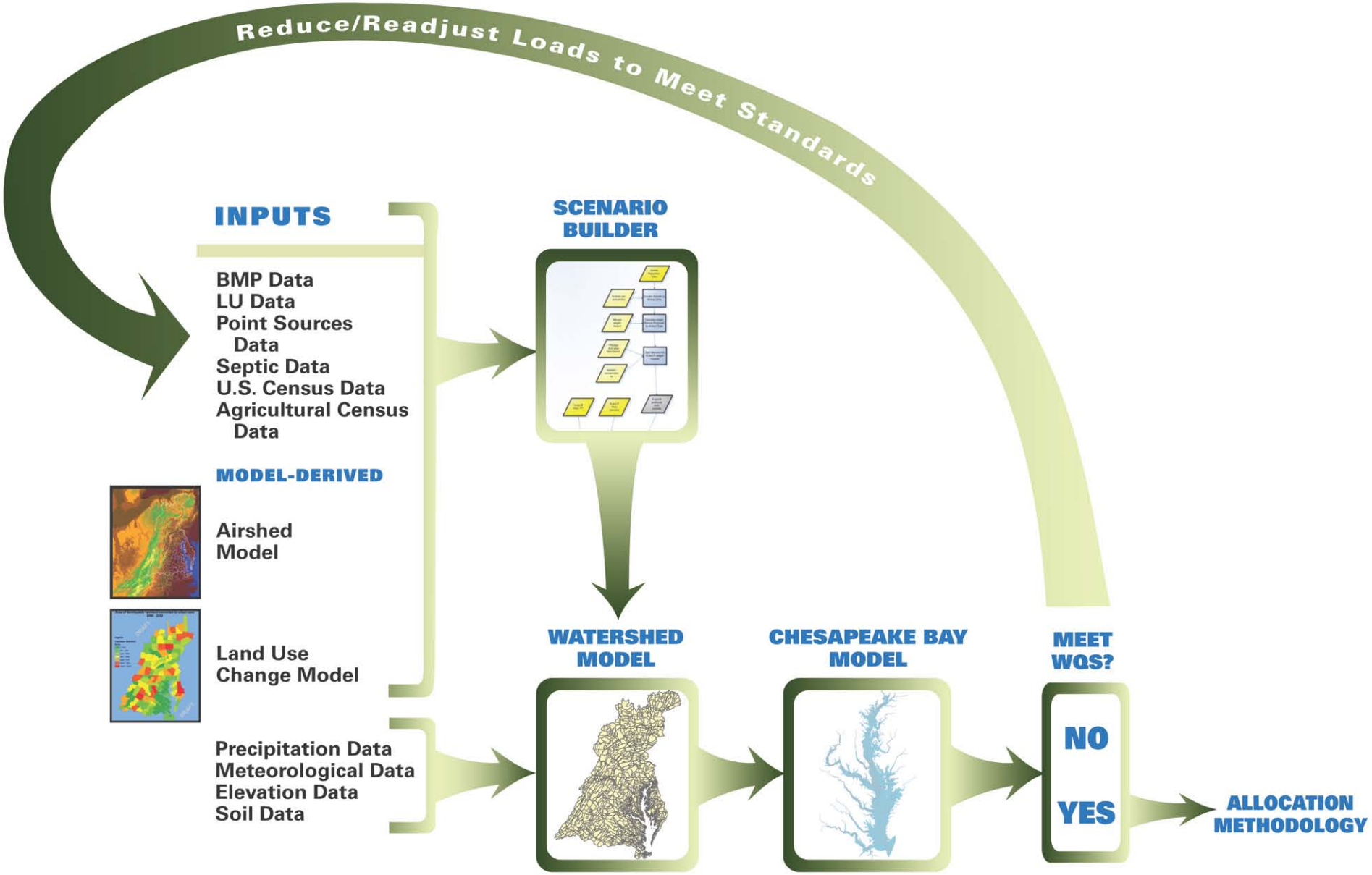
The Chesapeake Bay Program Partnership's Watershed Model

Gary Shenk

STAC Healthy Watersheds Workshop

Frederick, MD 3/8/2012

Chesapeake Bay Partnership Models

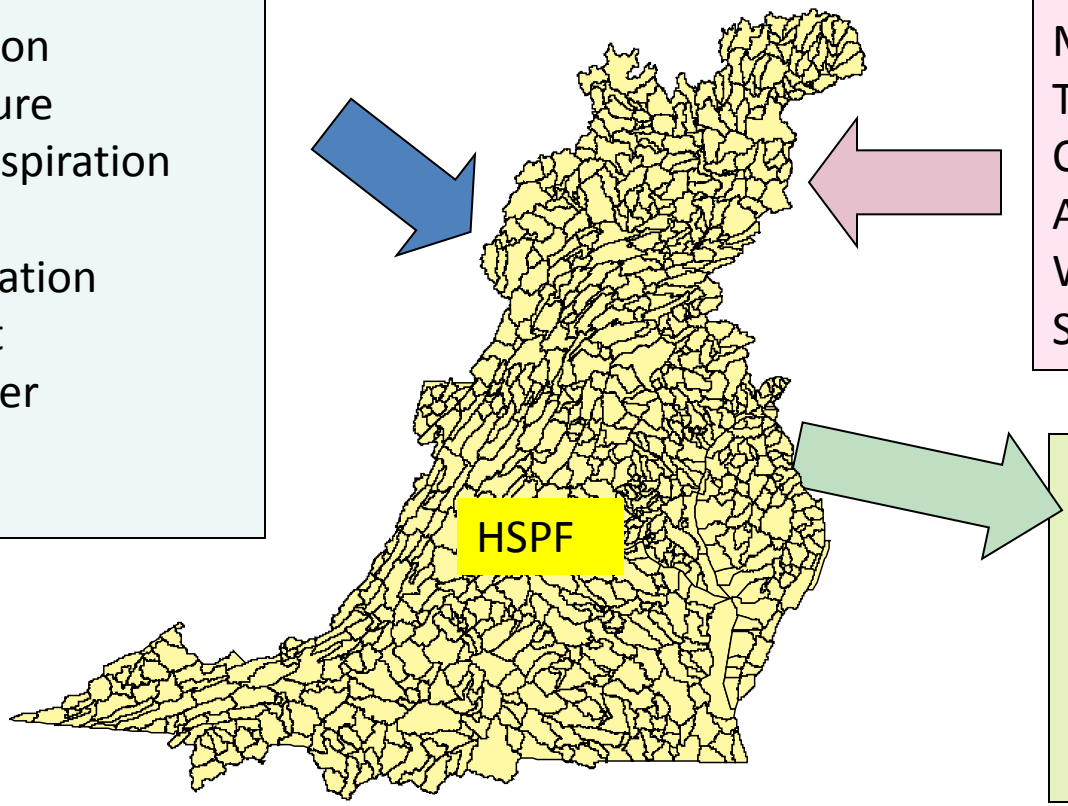


How the Watershed Model Works

Calibration Mode

Hourly or daily values of Meteorological factors:

Precipitation
Temperature
Evapotranspiration
Wind
Solar Radiation
Dew point
Cloud Cover



Annual, monthly, or daily values of anthropogenic factors:

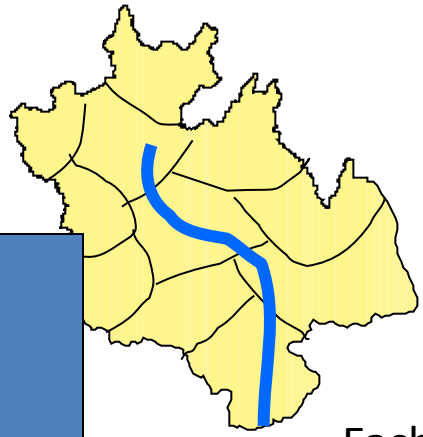
Land Use Acreage
BMPs
Fertilizer
Manure
Tillage
Crop types
Atmospheric deposition
Waste water treatment
Septic loads

Daily flow, nitrogen, phosphorus, and sediment compared to observations over 21 years

How the Watershed Model Works

Each segment consists of 30 separately-modeled land uses:

- Regulated Pervious Urban
- Regulated Impervious Urban
- Unregulated Pervious Urban
- Unregulated Impervious Urban
- Construction
- Extractive
- Combined Sewer System
- Wooded / Open
- Disturbed Forest

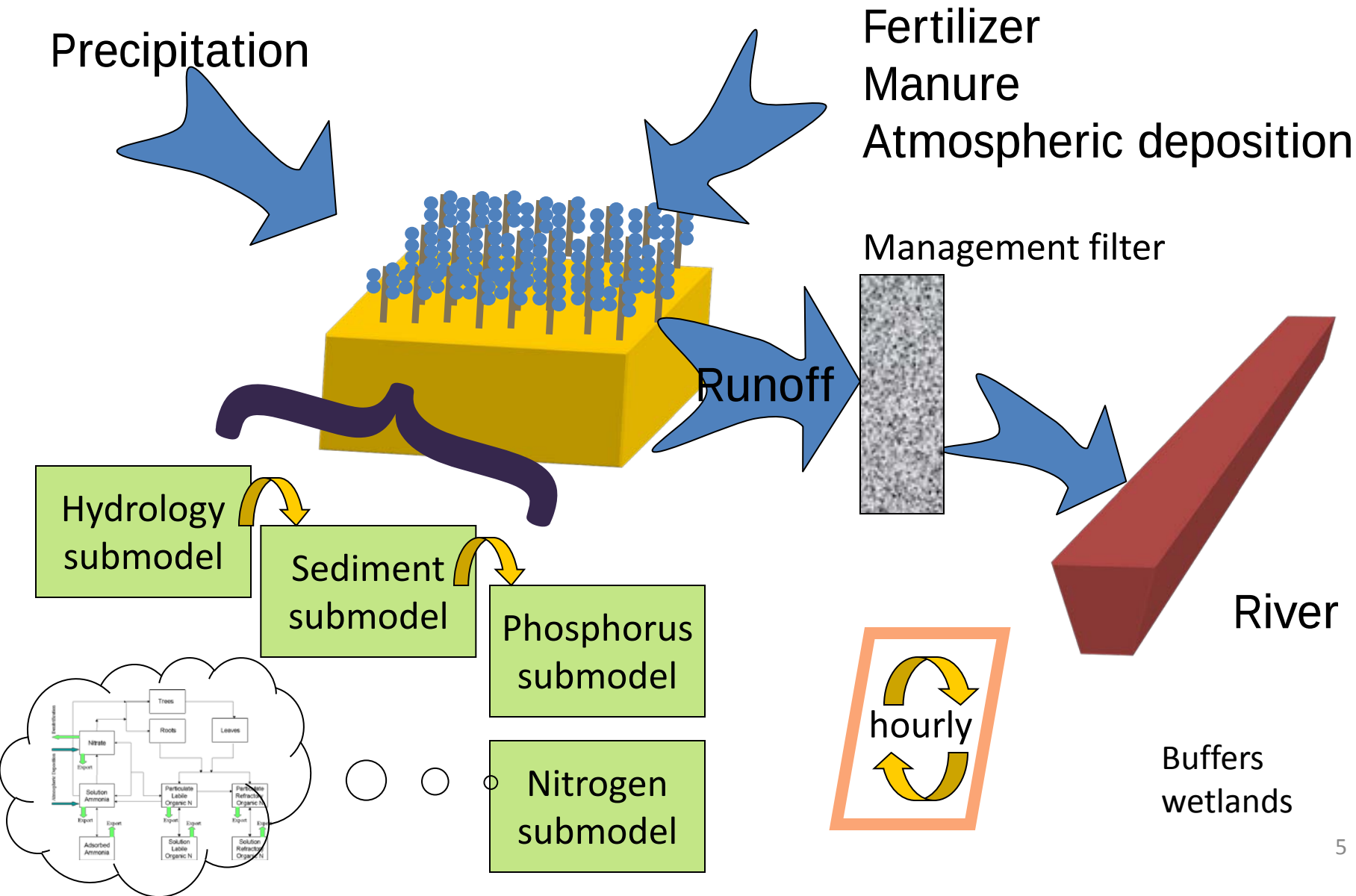


Plus: Point Source and Septic Loads, and Atmospheric Deposition Loads

- Corn/Soy/Wheat rotation (high till)
- Corn/Soy/Wheat rotation (low till)
- Other Row Crops
- Alfalfa
- Nursery
- Pasture
- Degraded Riparian Pasture
- Afo / Cafo
- Fertilized Hay
- Unfertilized Hay
  - Nutrient management versions of the above

Each calibrated to nutrient and Sediment targets

How the Watershed Model Works

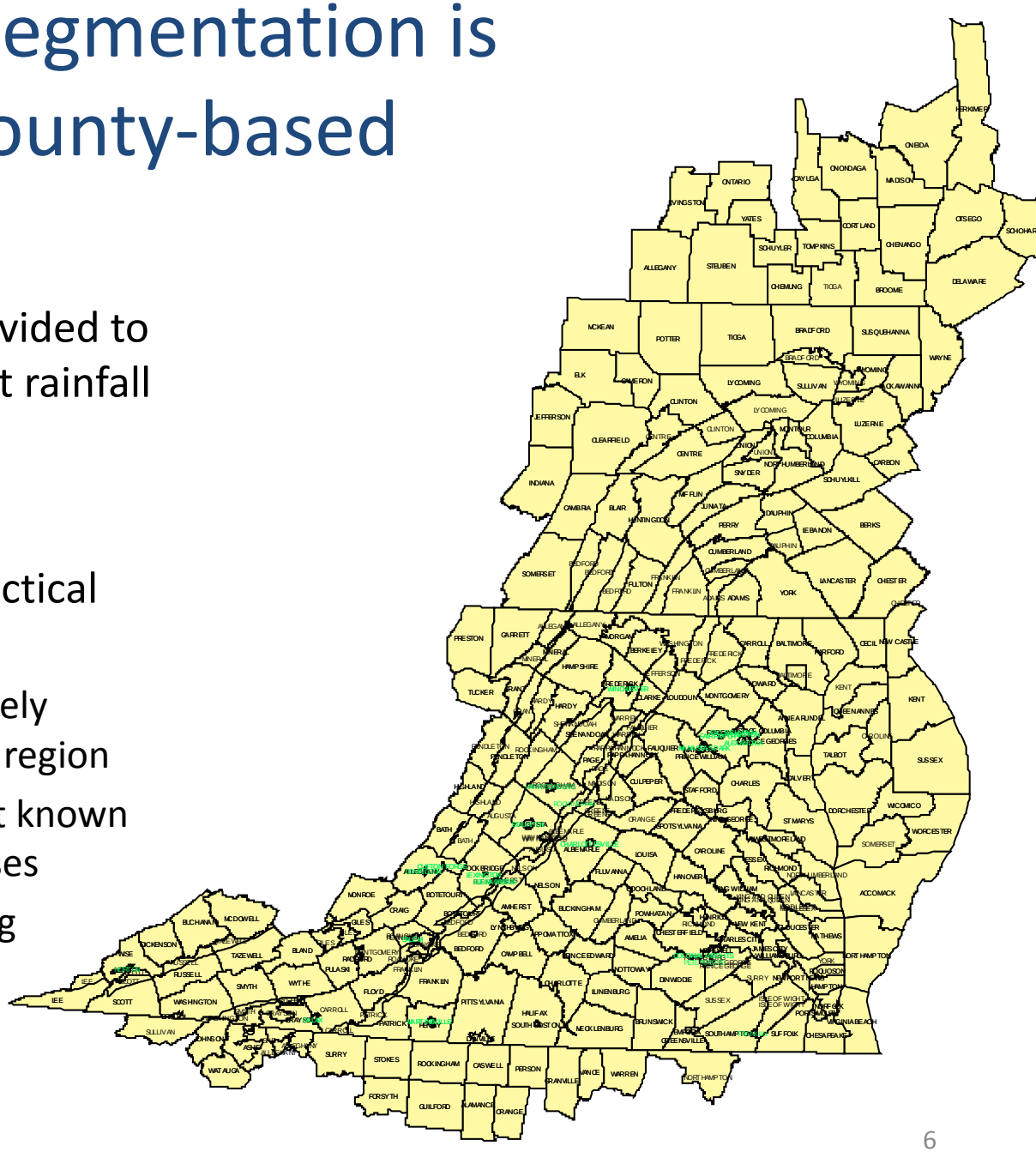


Phase 5 land segmentation is primarily county-based

- Some counties were divided to accommodate different rainfall patterns.

Reasons why counties are a practical choice for segmentation:

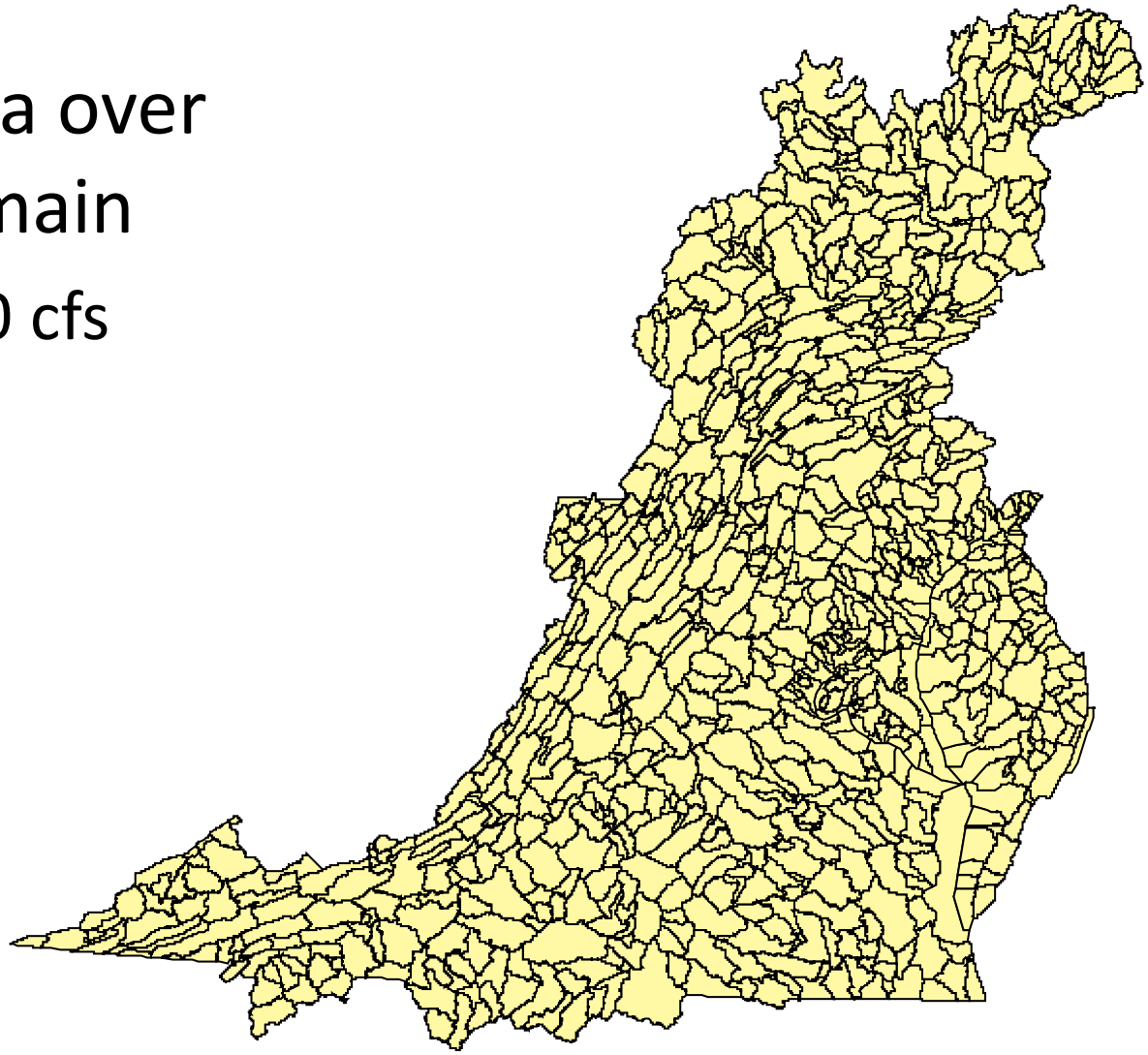
- Most counties are completely within a hydrogeomorphic region
- BMP and Crop data are not known on a finer scale in most cases
- Near the limit of computing capacity



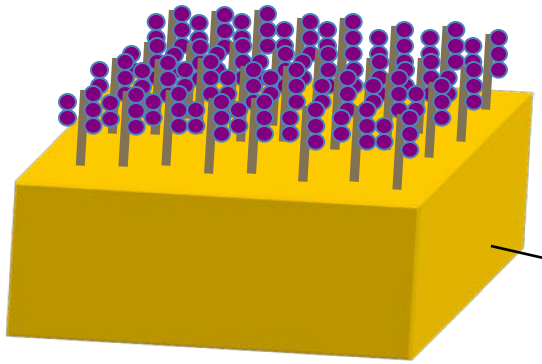
Phase 5 river segmentation

- Consistent criteria over entire model domain
  - Greater than 100 cfs

    or
  - Has a flow gage
- Near the limit of meaningful data



Scale in Phase 5 - Sediment



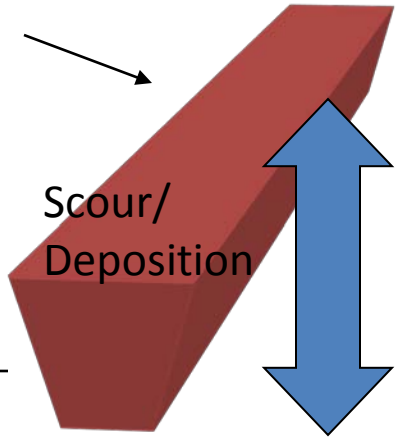
Edge of Field
Expected loads from one acre

BMP Factor

Land Acre Factor

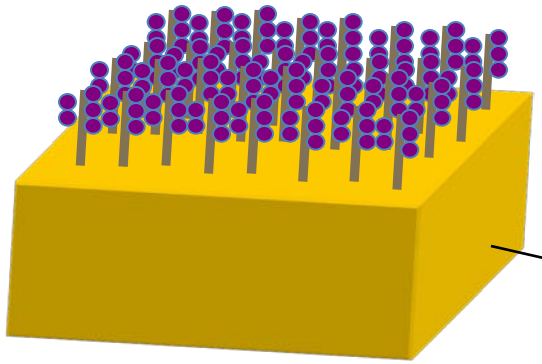
Delivery Factor

Edge of Stream
60-100 sq miles



In Stream Concentrations

Scale in Phase 5 - Nutrients



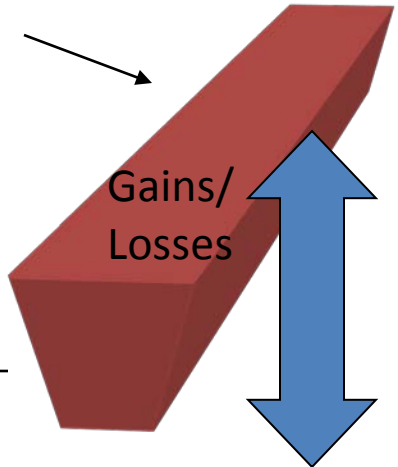
Edge of **Stream**
Expected loads from one acre that reach 100 cfs stream or tidal waters

BMP Factor

Land Acre Factor

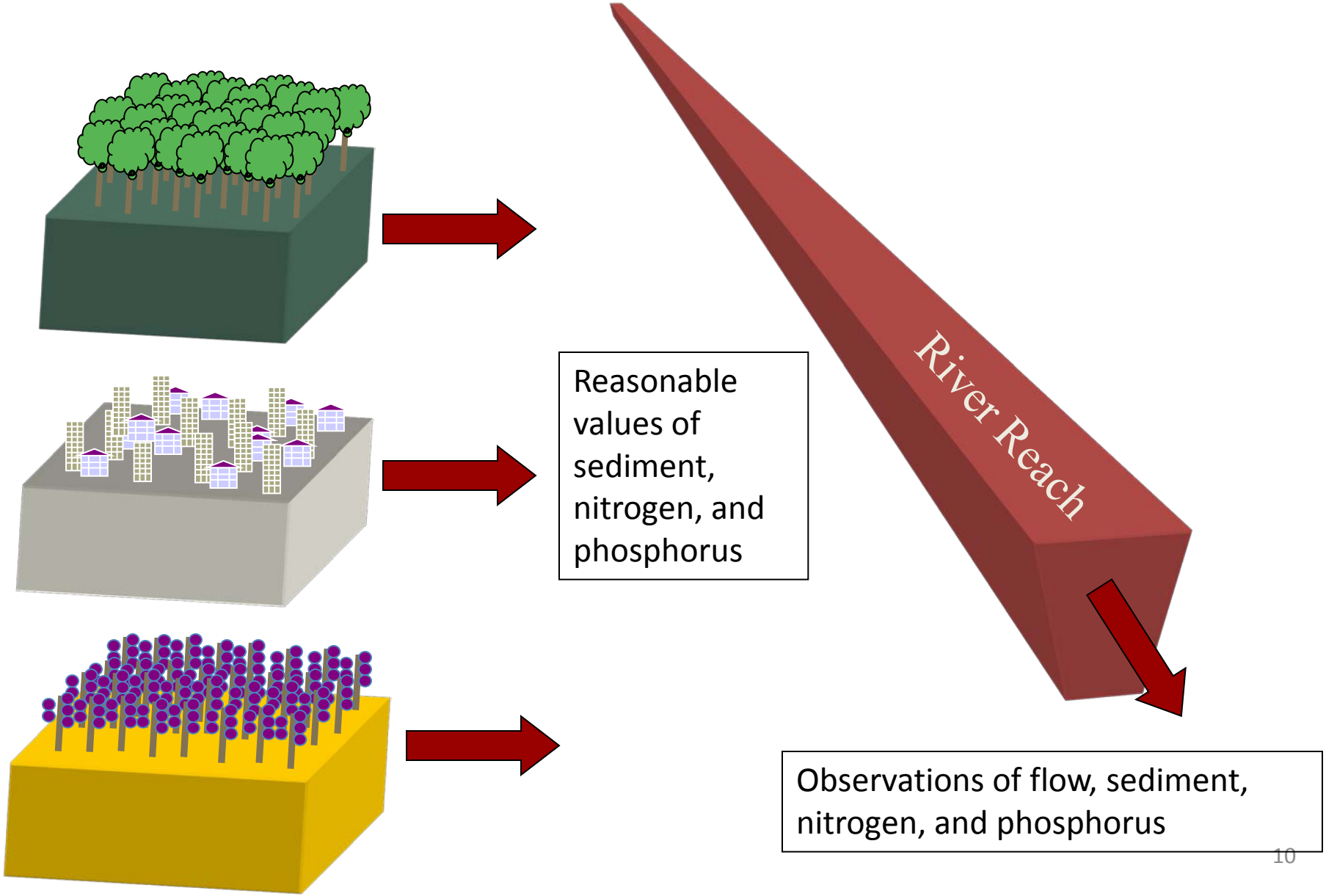
Regional Factor

Edge of Stream
60-100 sq miles



In Stream Concentrations

How do we calibrate?



Reasonable values of sediment, nitrogen, and phosphorus

Observations of flow, sediment, nitrogen, and phosphorus

Calibration Strategy

- Match observations in rivers
- Match properties and trends
  - Groundwater recession curve
  - Crop uptake
- Match literature and other models
  - Reasonable rates of nutrient export
  - USGS estimator and sparrow models

11

Sources of Data

- Literature Reviews
  - Beaulac & Reckhow (1982)
  - Sweeney (2001)
  - Lin (2004)
  - Primary Sources (about 30)
- Previous Modeling Studies
  - Phase 4.3
  - Sparrow

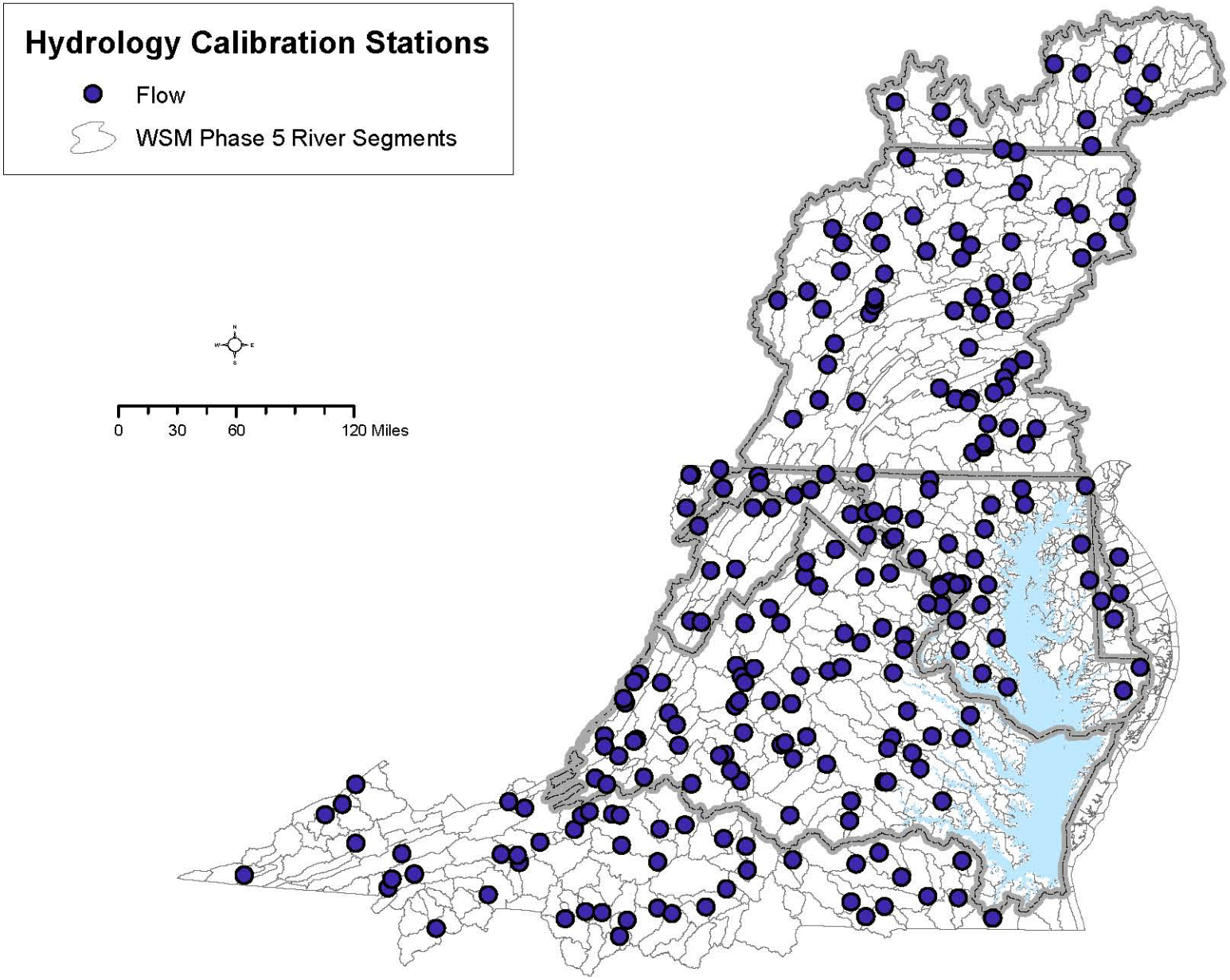
Average Targets

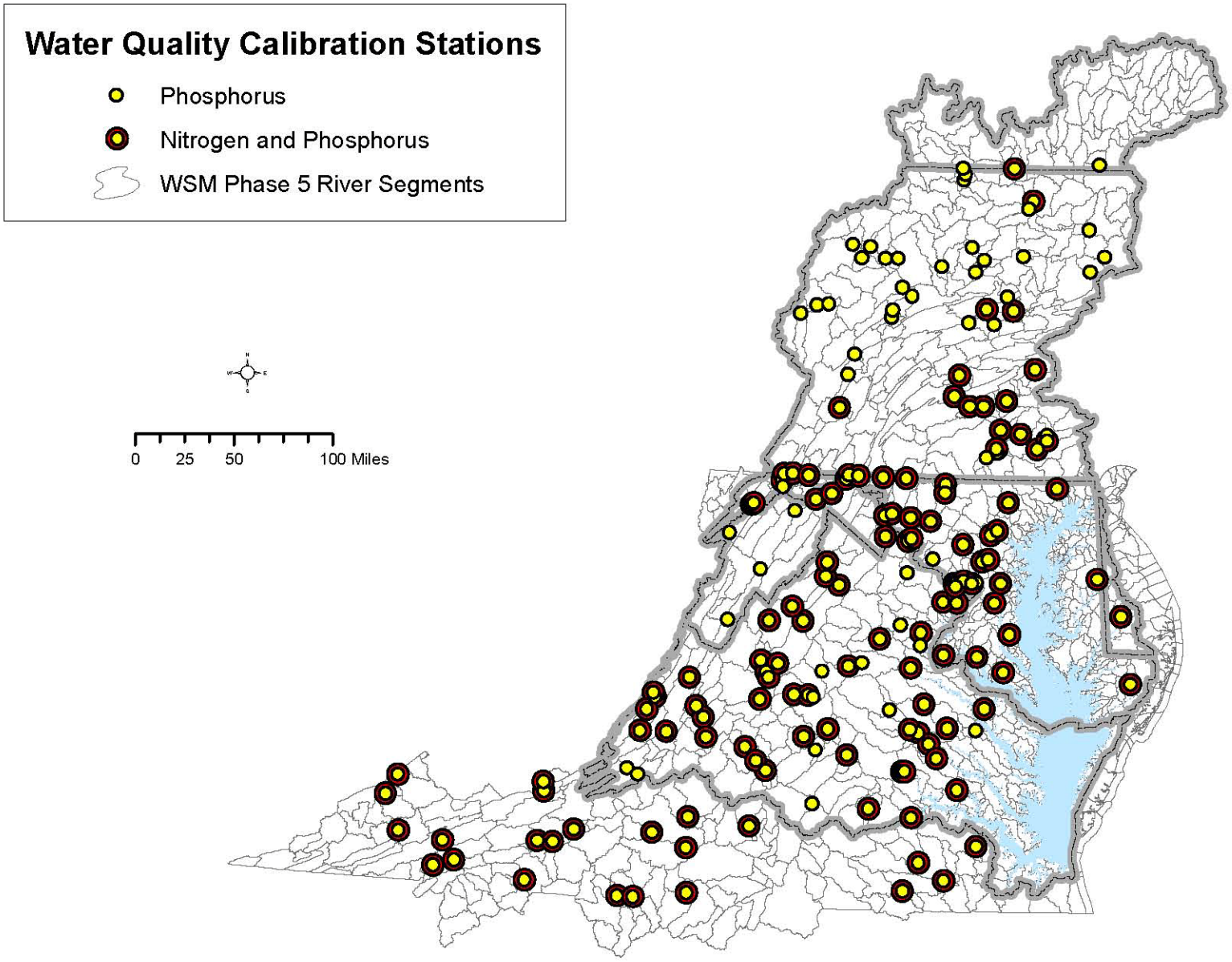
Land Use	**TN**	**TP**
Forest	2.0	0.15
Harvested Forest	20.0	0.80
Crop	23.0	2-2.5
Hay	6.0	0.4-0.8
Pasture	4.5	0.7
Urban	9.3	1.5
Extractive	12.5	3.5
Nursery	240	85

- Vary spatially according to input/output

Nitrogen vs Nitrate

- Nitrogen from forested areas is predominately Nitrate
- Nitrogen from urban areas is predominately ammonia and organic (TKN)
- Agriculture is more of a mixture


Hydrology Calibration Stations
Flow
WSM Phase 5 River Segments
0
30
60
120 Miles

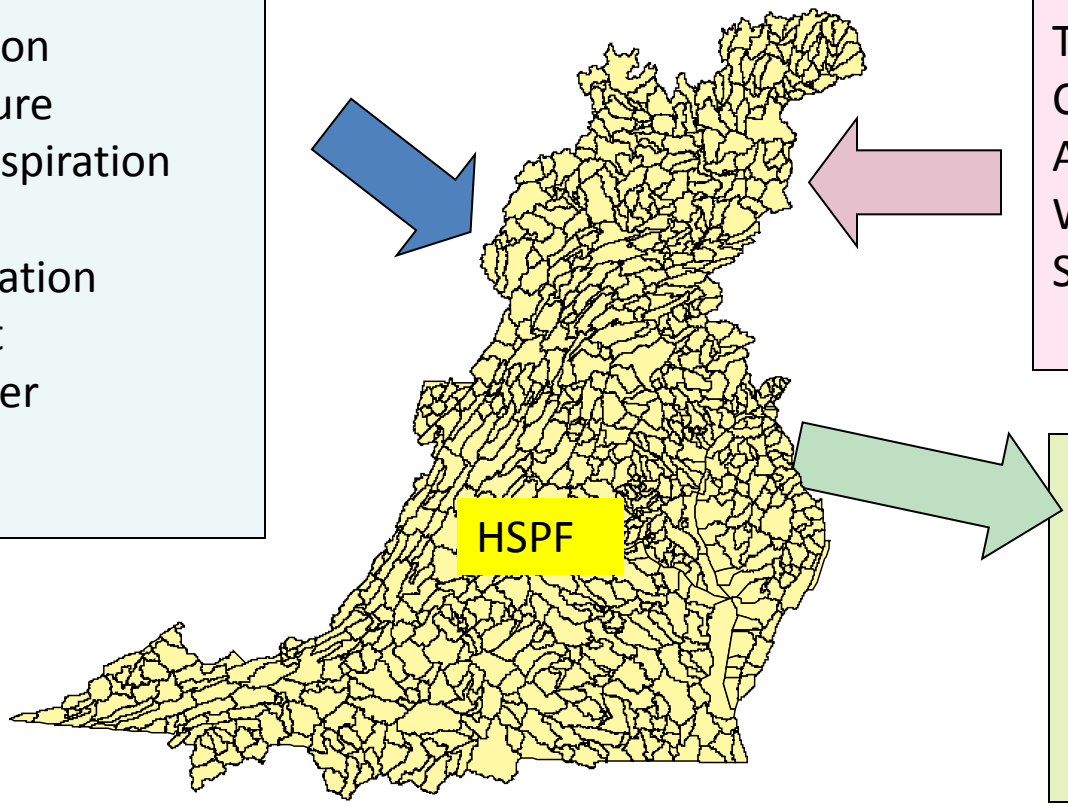

Water Quality Calibration Stations
Phosphorus
Nitrogen and Phosphorus
WSM Phase 5 River Segments
0
25
50
100 Miles

How the Watershed Model Works

Scenario Mode

Hourly or daily values of Meteorological factors:

Precipitation
Temperature
Evapotranspiration
Wind
Solar Radiation
Dew point
Cloud Cover



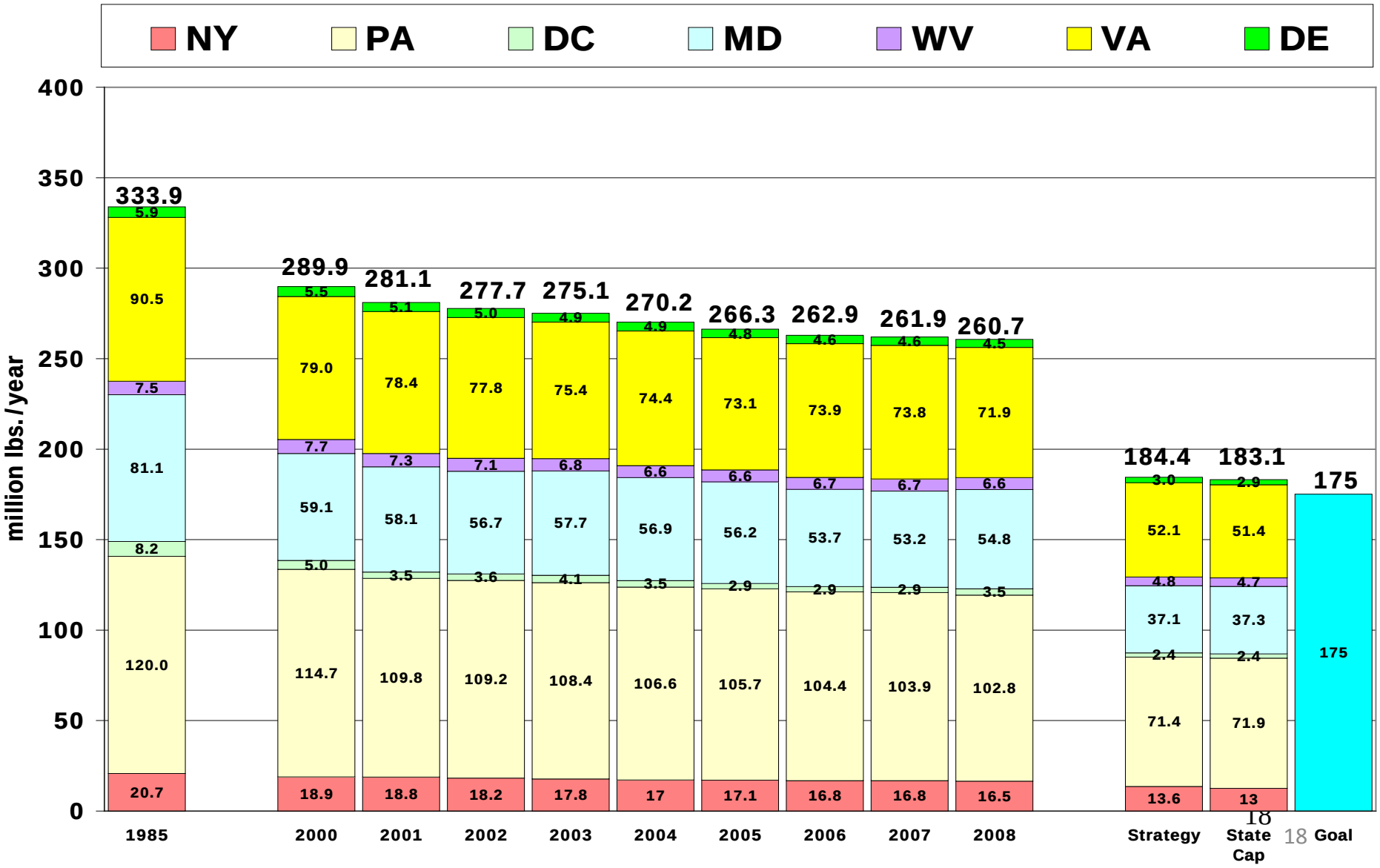
Constant values of anthropogenic factors:

Land Use Acreage
BMPs
Fertilizer
Manure
Tillage
Crop types
Atmospheric deposition
Waste water treatment
Septic loads

Run for 1984-2000
Average 1991-2000
For 'flow-normalized average annual loads'

Nitrogen Loads Delivered to the Chesapeake Bay By Jurisdiction

Point source loads reflect measured discharges while
nonpoint source loads are based on an average-hydrology year



18

- BMP Type and location (NEIEN/State supplied)
- Land acres
- Remote Sensing, NASS Crop land Data layer
- Crop acres
- Yield
- Animal Numbers (Ag Census or state supplied)
- Land applied biolsolids
- Septic system (#s)

Inputs

Parameters

(Changeable by user)

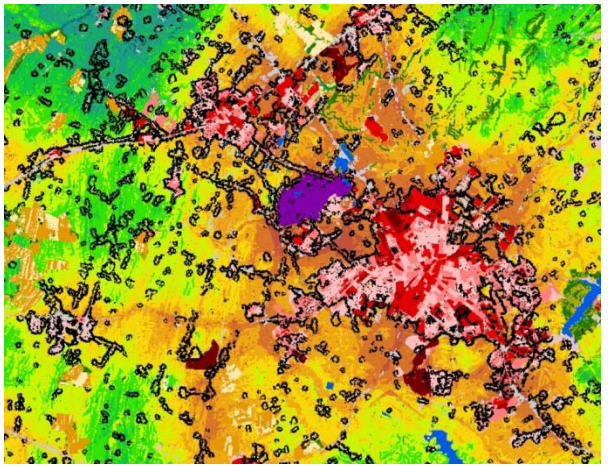
- BMP types and efficiencies
- Land use change (BMPs, others)
- RUSLE2 Data: % Leaf area and residue cover
- Plant and Harvest dates
- Best potential yield
- Animal factors (weight, phytase feed, manure amount and composition)
- Crop application rates and timing
- Plant nutrient uptake
- Time in pasture
- Storage loss
- Volatilization
- Animal manure to crops
- N fixation
- Septic delivery factors

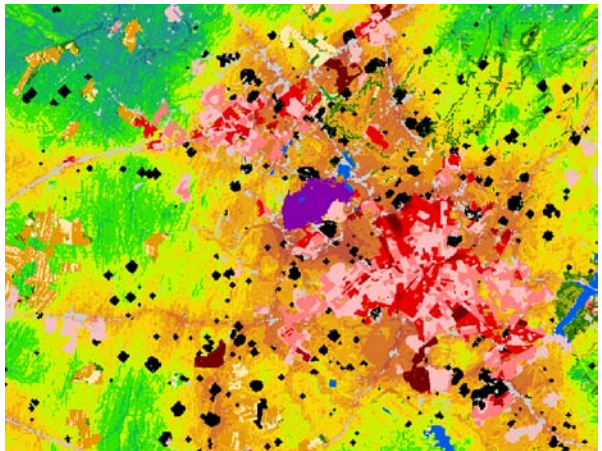
- BMPs, # and location
- Land use
- % Bare soil, available to erode
- Nutrient uptake
- Manure and chemical fertilizer (lb/segment)
- N fixation (lb/segment)
- Septic loads

Outputs

Land Change Modeling at the CBP

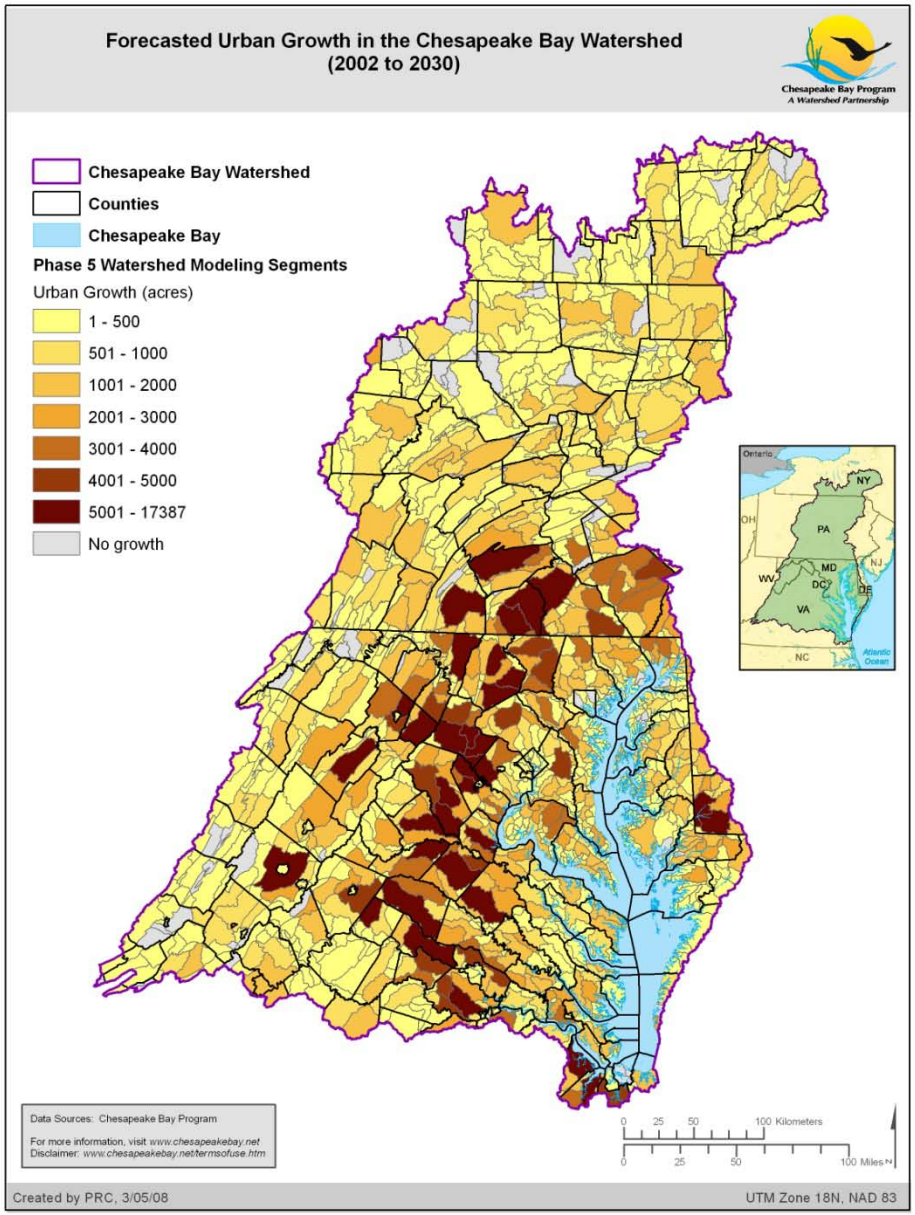
- 1980s – 1990s – simple empirical relationships
- CBLCM
  - v1 – Sleuth
  - V2 –empirical relationships
  - V3 – Patch-based growth
    - Existing Lu/Lc
    - Topographic/Geologic data
    - Population Projections



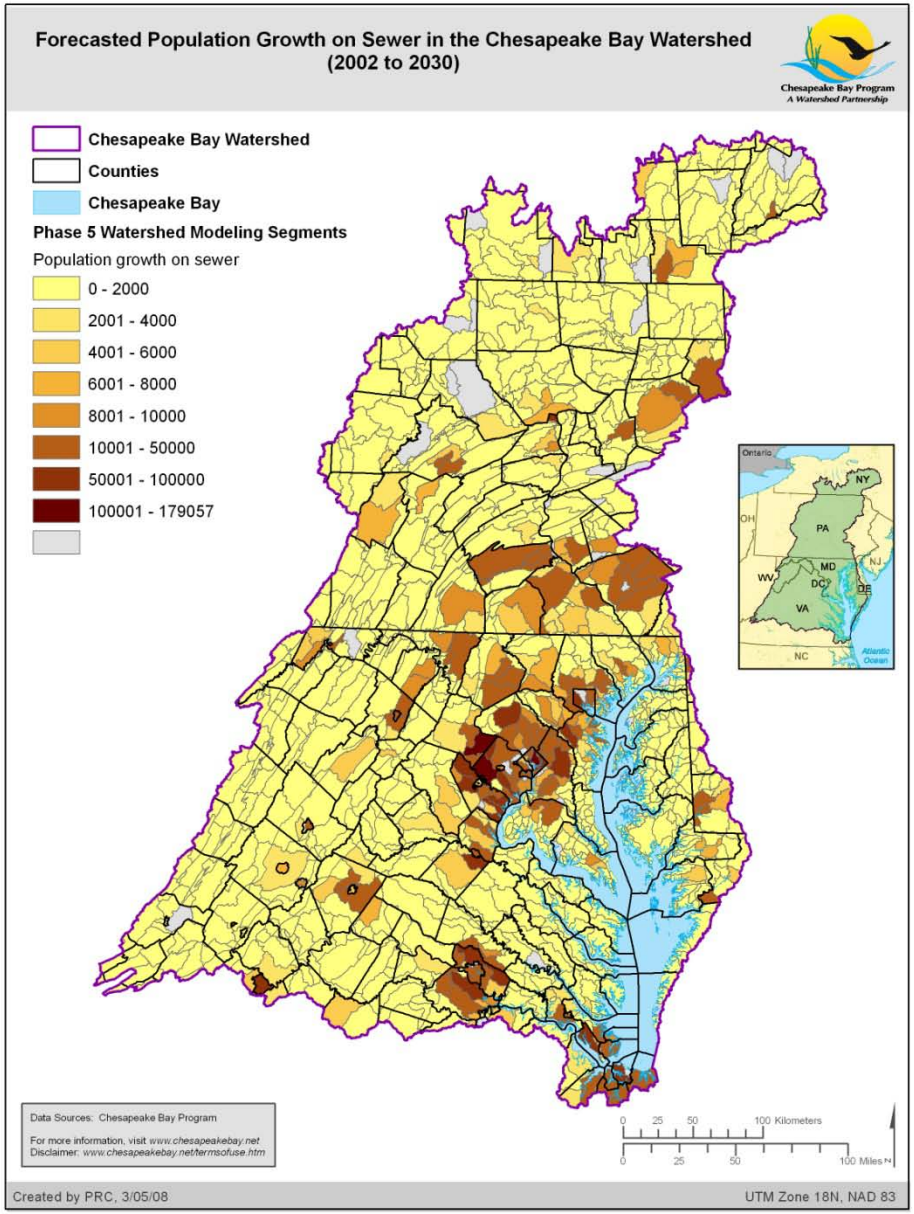


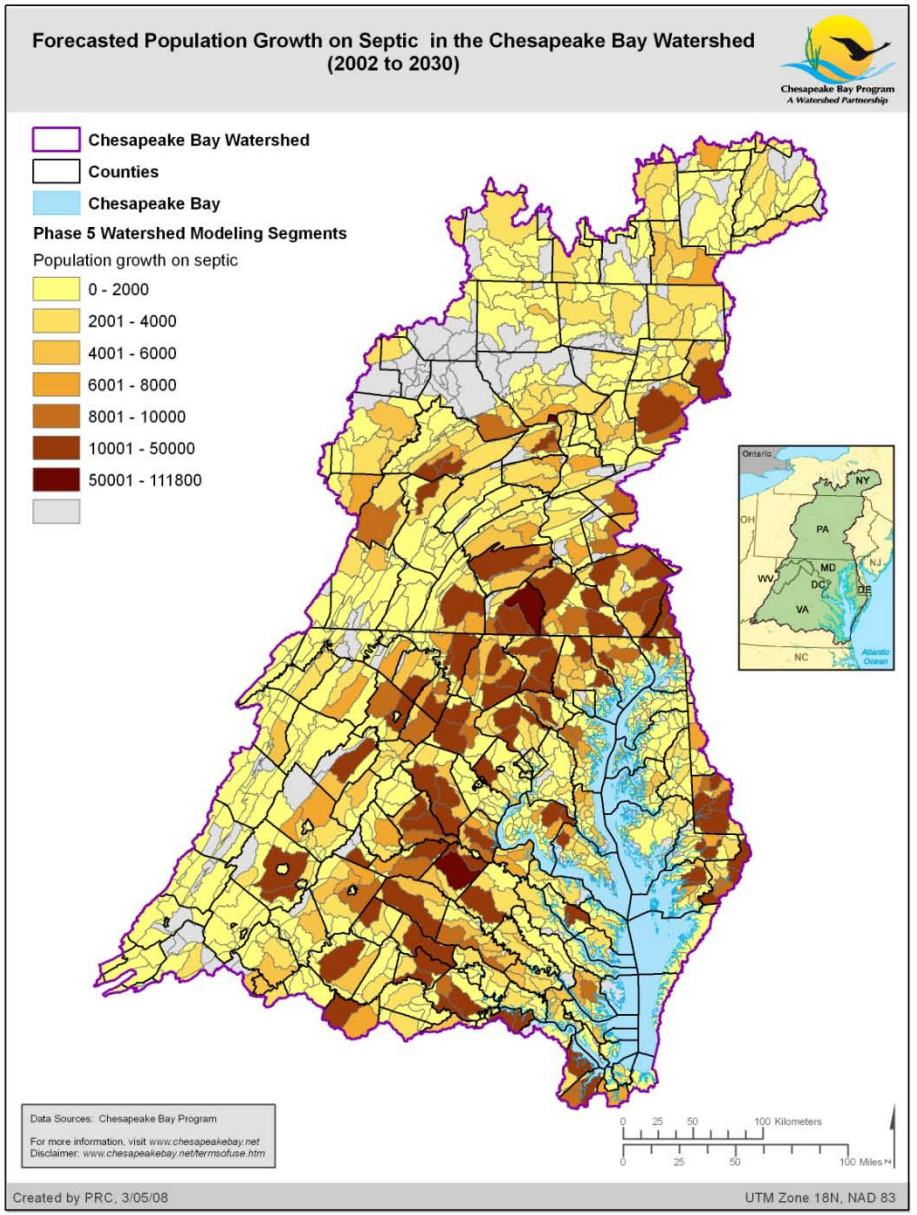
Probability surface

Forecasted Urban Growth (2000 to 2030)

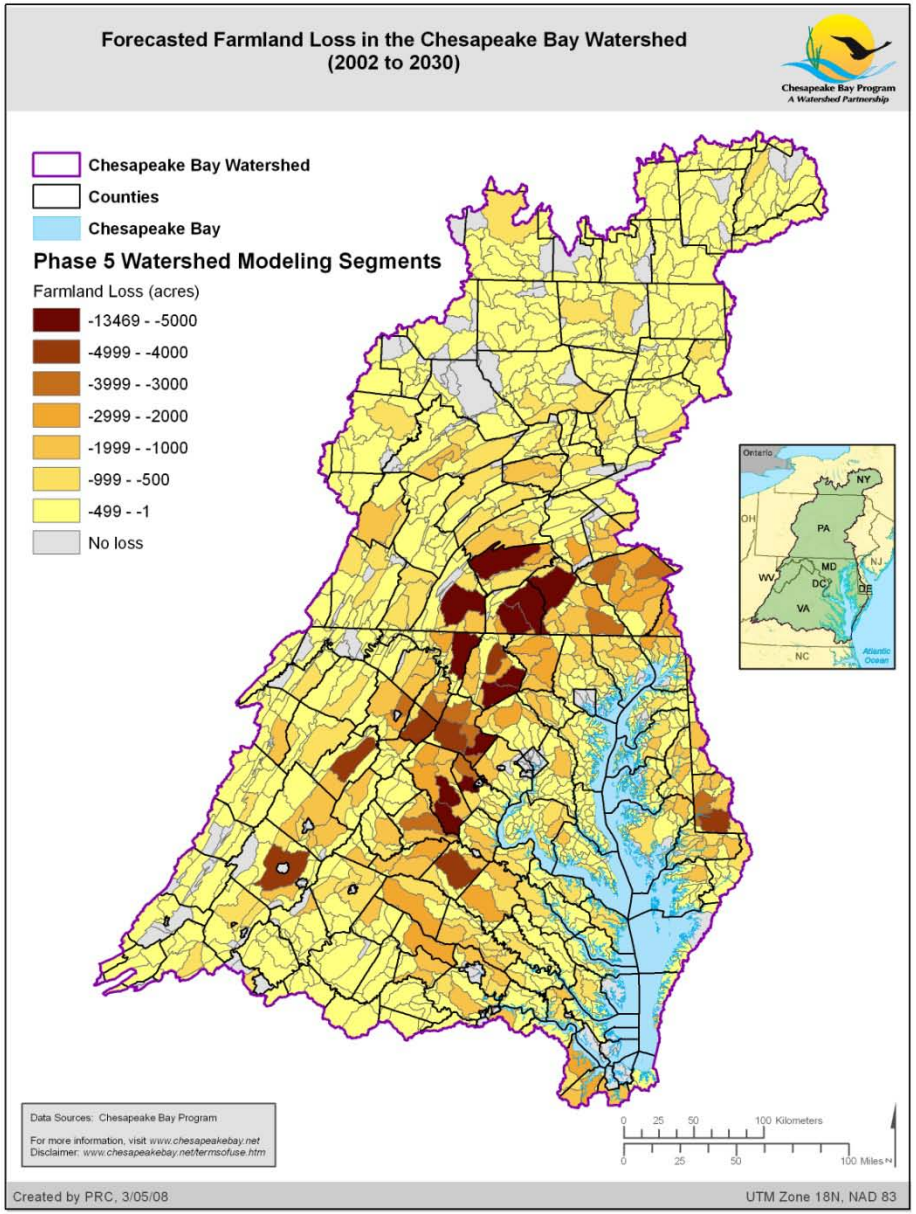


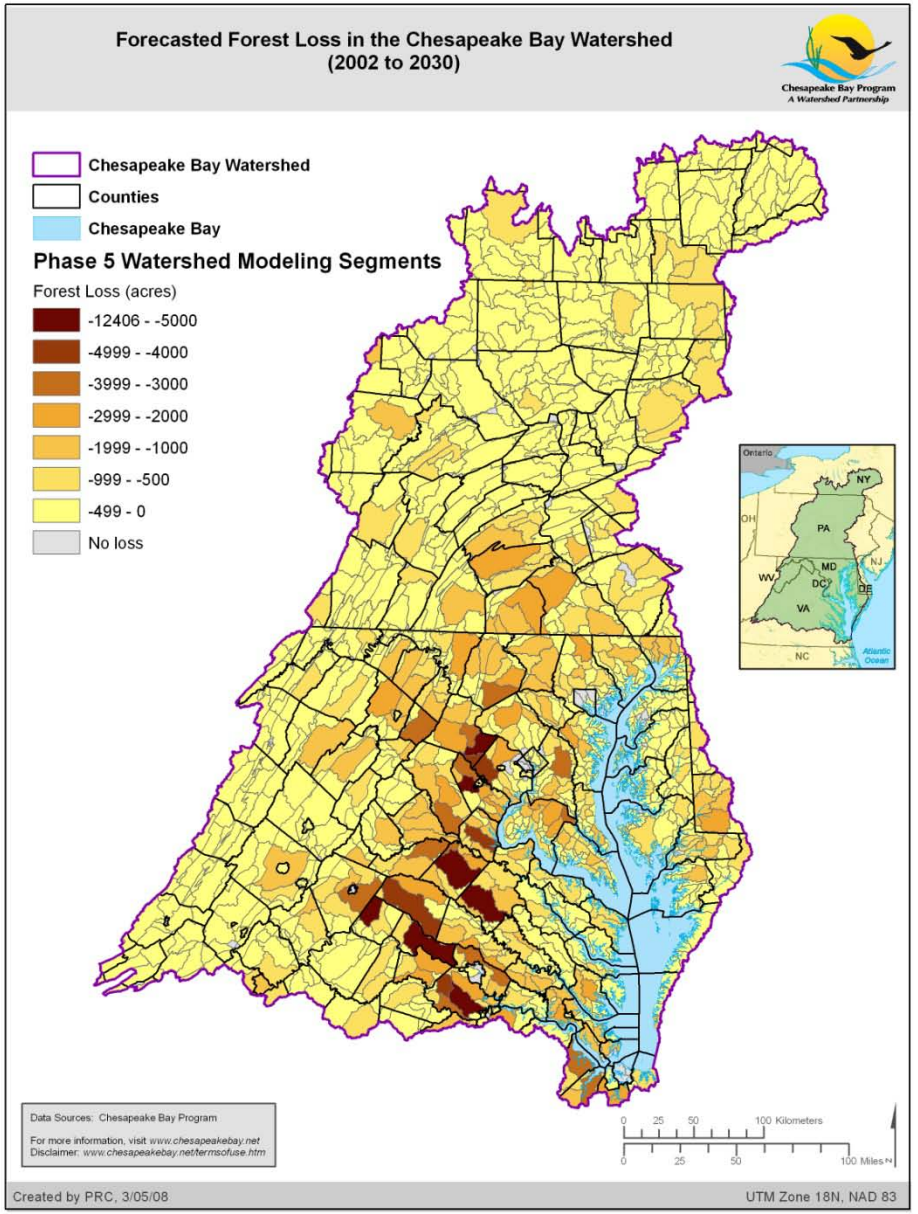
Forecasted Population Growth on Sewer vs. Septic (2000 to 2030)



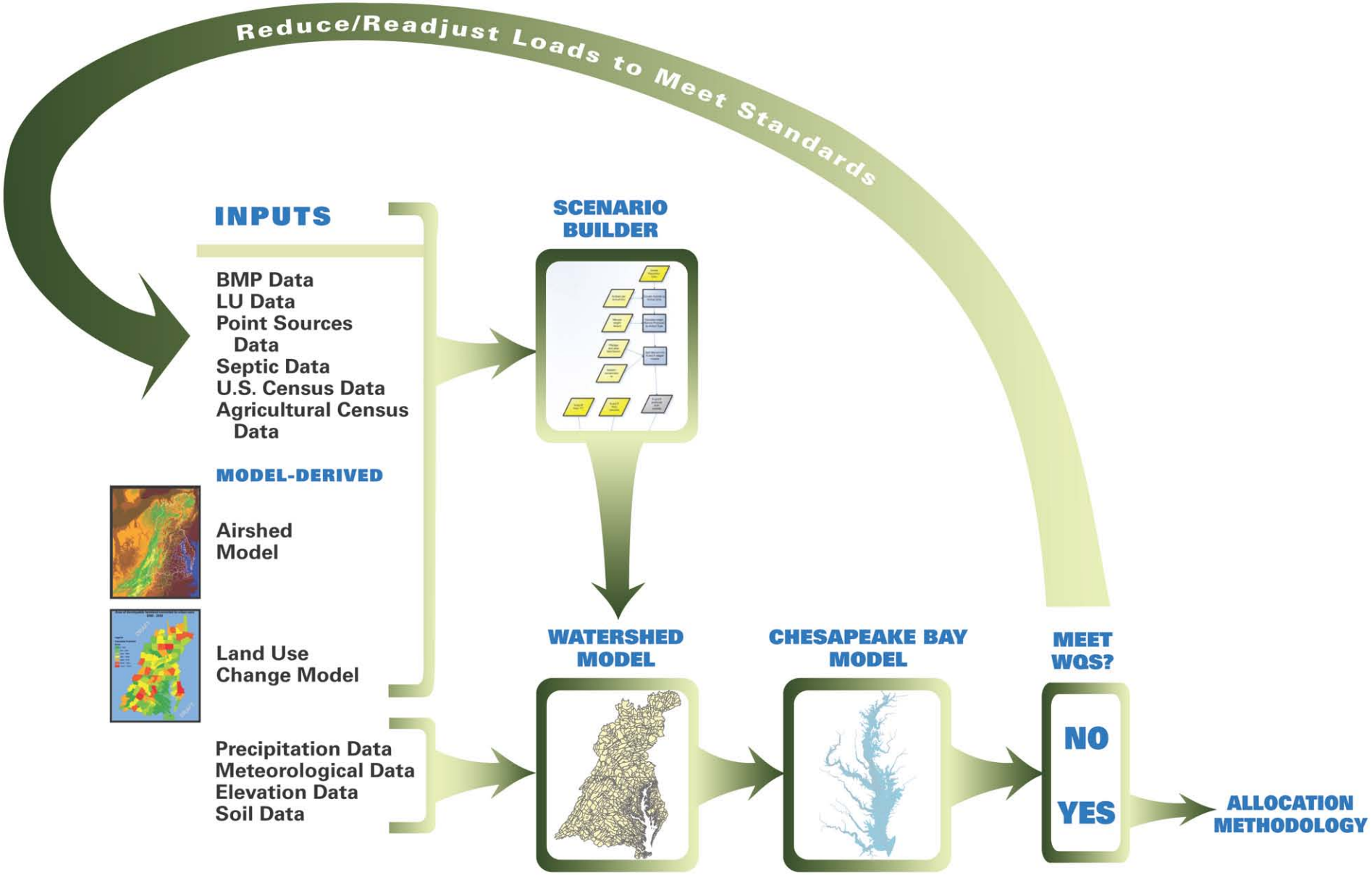


Farmland and Forest Land Loss (2000 to 2030)

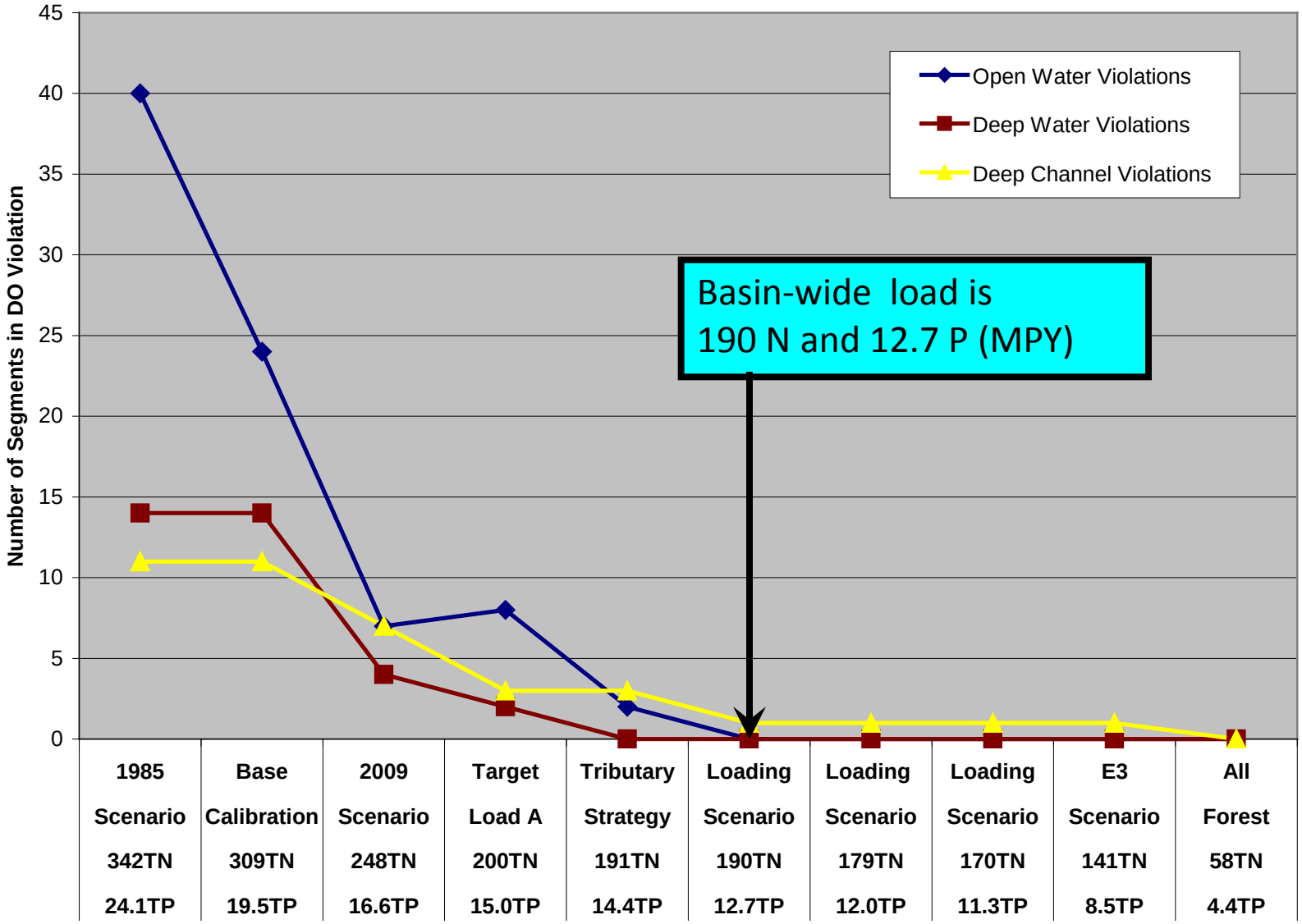




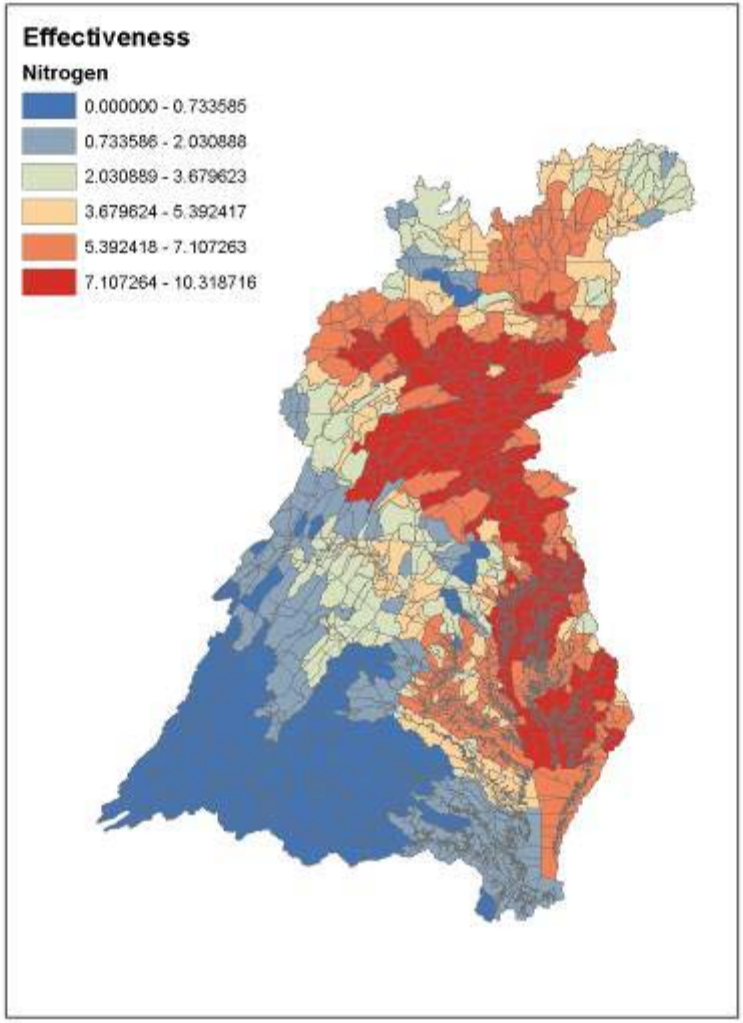
Chesapeake Bay Partnership Models

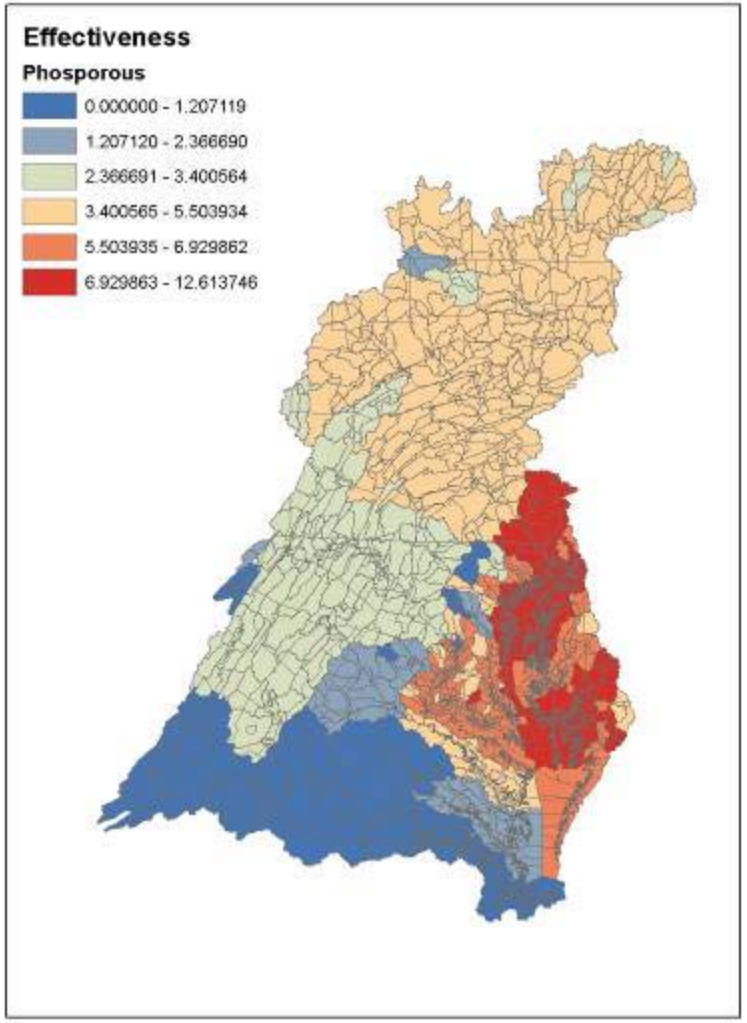


Use of modeling suite in the Chesapeake TMDL

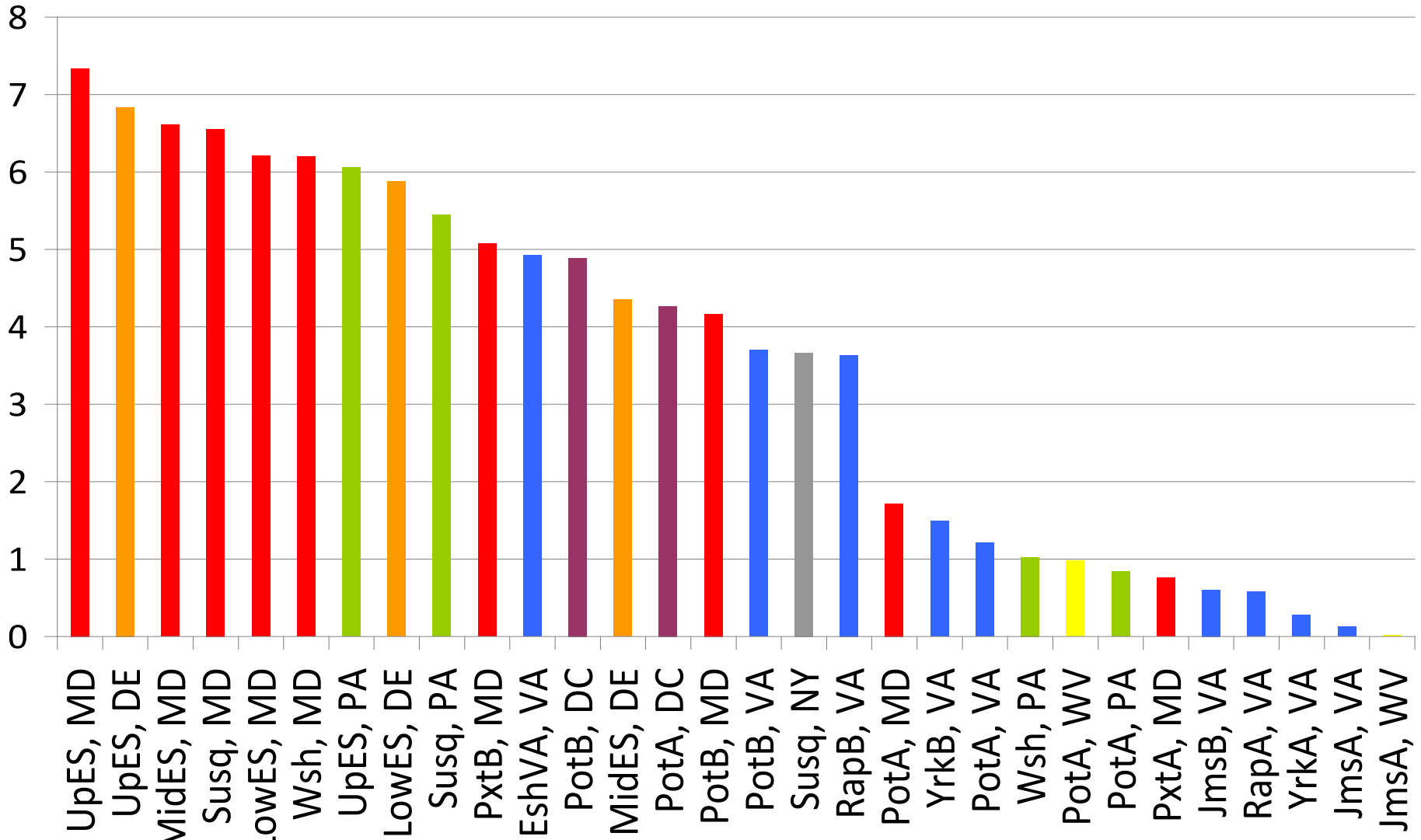


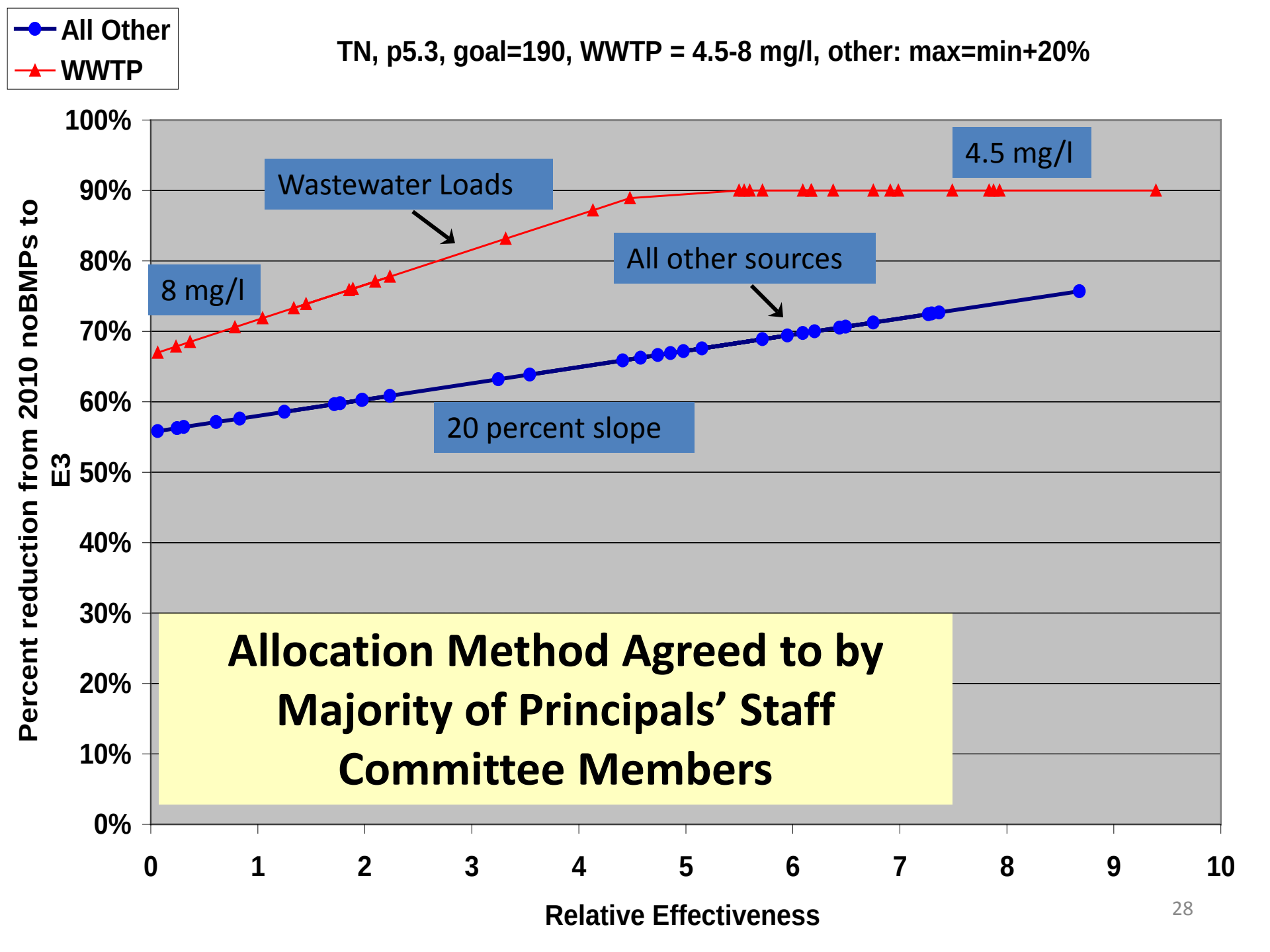
Nutrient Impacts on Bay WQ

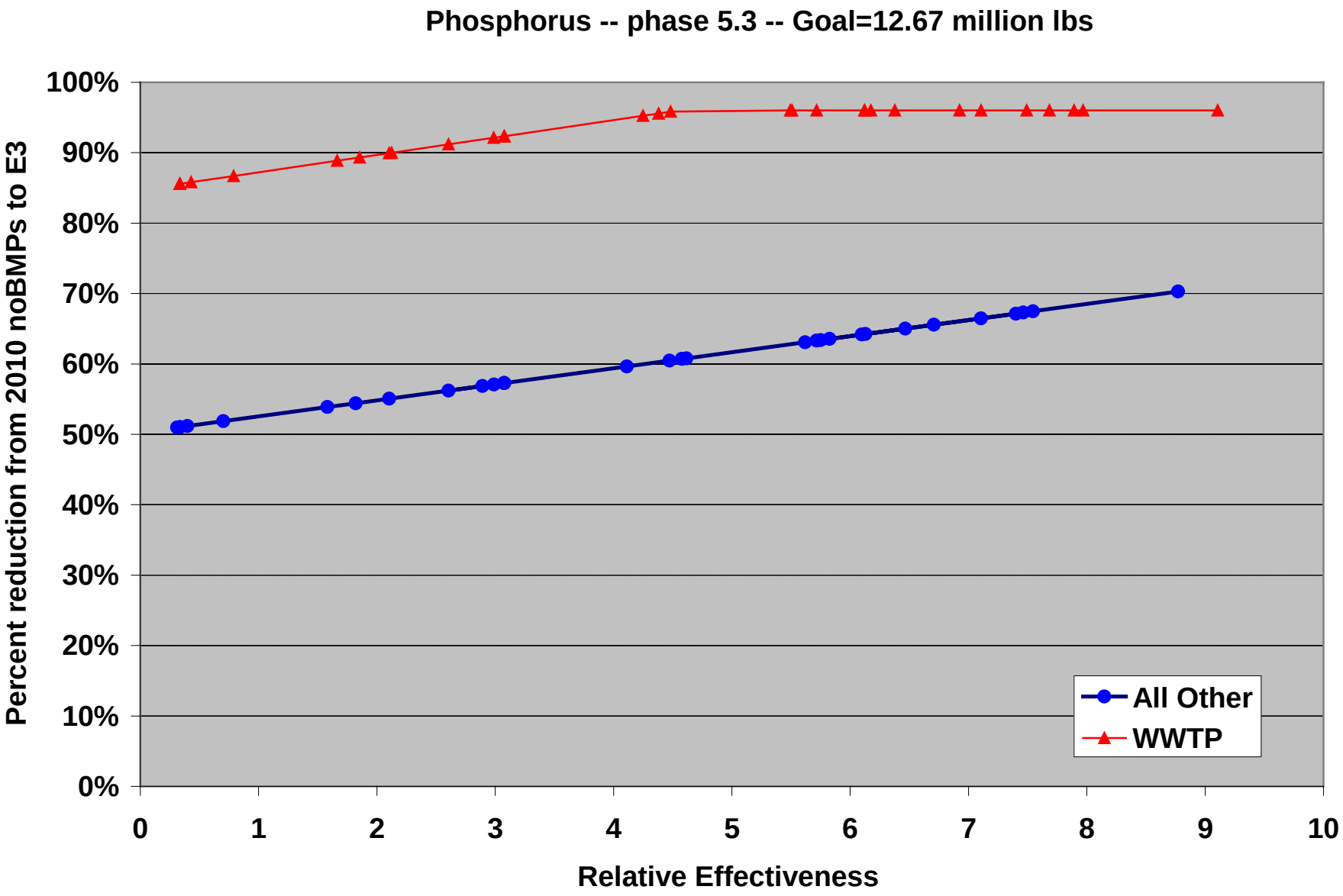




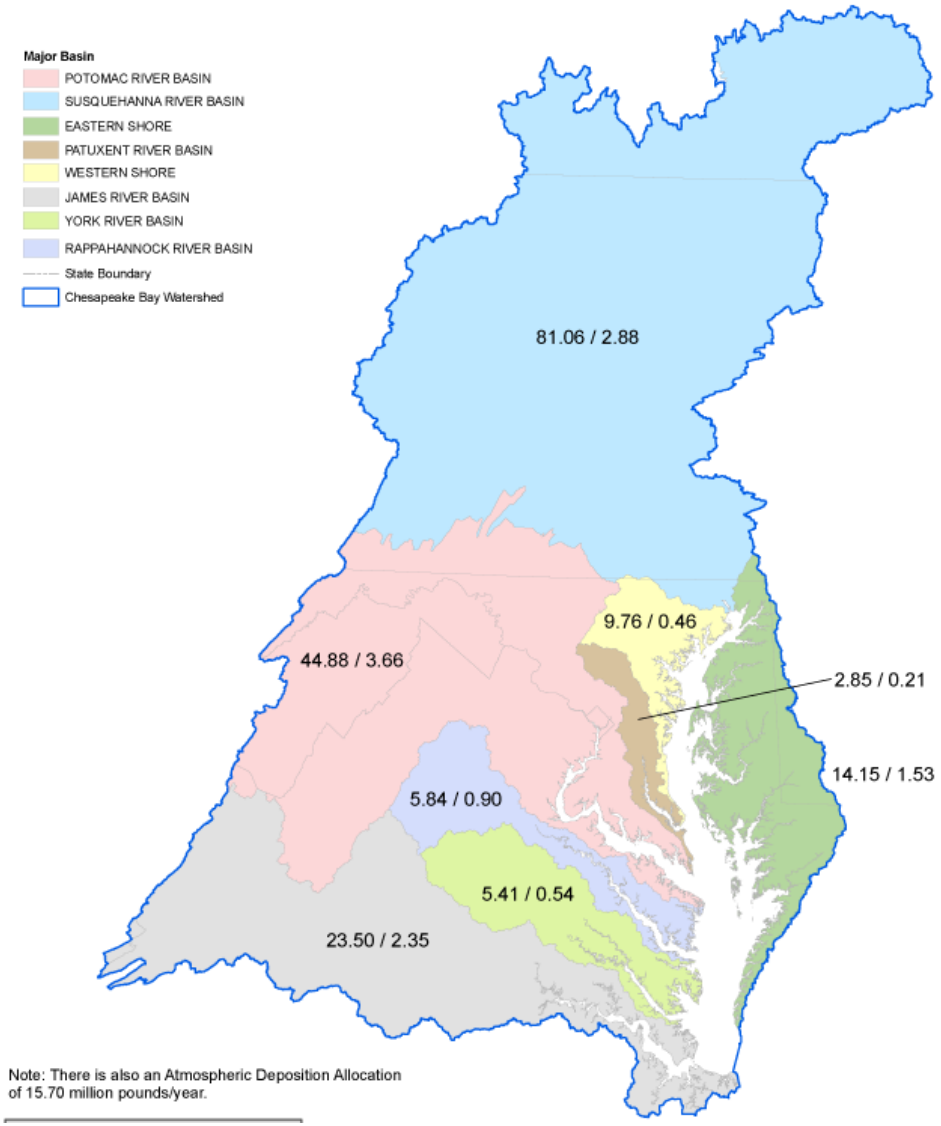
Major River Basin by Jurisdiction Relative Impact on Bay Water Quality



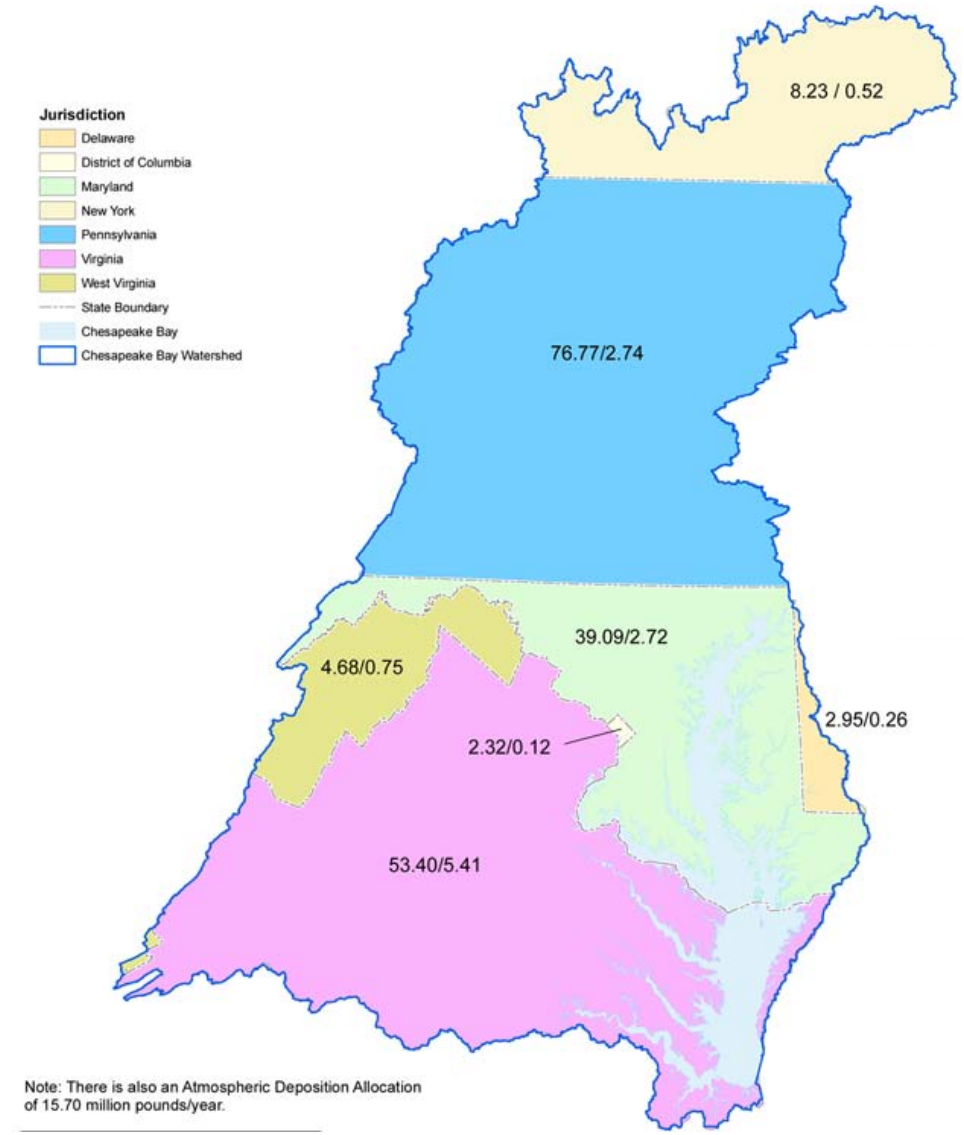

All Other
WWTP
TN, p5.3, goal=190, WWTP = 4.5-8 mg/l, other: max=min+20%
Percent reduction from 2010 noBMPs to E3
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
6
7
8
9
10
Relative Effectiveness
Wastewater Loads
4.5 mg/l
8 mg/l
All other sources
20 percent slope
Allocation Method Agreed to by Majority of Principals' Staff Committee Members


Phosphorus -- phase 5.3 -- Goal=12.67 million lbs
Percent reduction from 2010 noBMPs to E3
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
6
7
8
9
10
Relative Effectiveness
All Other
WWTP

Pollution Diet by River



Pollution Diet by State



Modeling Direction

- Water Quality Goal Implementation Team
  - Watershed Technical Workgroup
  - Agriculture Workgroup
  - Urban Stormwater Workgroup
  - Forestry Workgroup
  - Sediment Workgroup
- Modeling Workgroup
- Scientific and Technical Advisory Committee
- Principals' Staff Committee (state secretary)

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 Trust, Chesapeake Bay Commission, U.S. Forest Service, U.S. Fish and Wildlife Service, U.S. Geological Survey, U.S. Environmental Protection Agency, Keith Campbell Foundation for the Environment, Pinchot Institute, Piedmont Environmental Council

Updates to the models

- Many options available over the long term
- Interim BMPs for new practices being approved on an ad-hoc basis.

Management Modeling Maxims

- Absolute Rule #1
  - Always Improve and Never Change
- Absolute Rule #2
  - Include Everything and Keep it Simple

Management vs Research Model

- Management Models do not create knowledge; they integrate 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.

Discussion Points

- Buffer efficiencies based on region, size, age, etc
- Differences in stream processing based on
  - Width, Hydrologic mods, Shading, Sedimentation
- 'Effective' land use loads weighted by distance from stream
- Deposition Trends
- Wetland and Floodplains: Enough Data?
- Others