Chesapeake Bay Program Partnership Watershed Model

Model Overview

Use in TMDL Accounting

Governance Process

Future Development

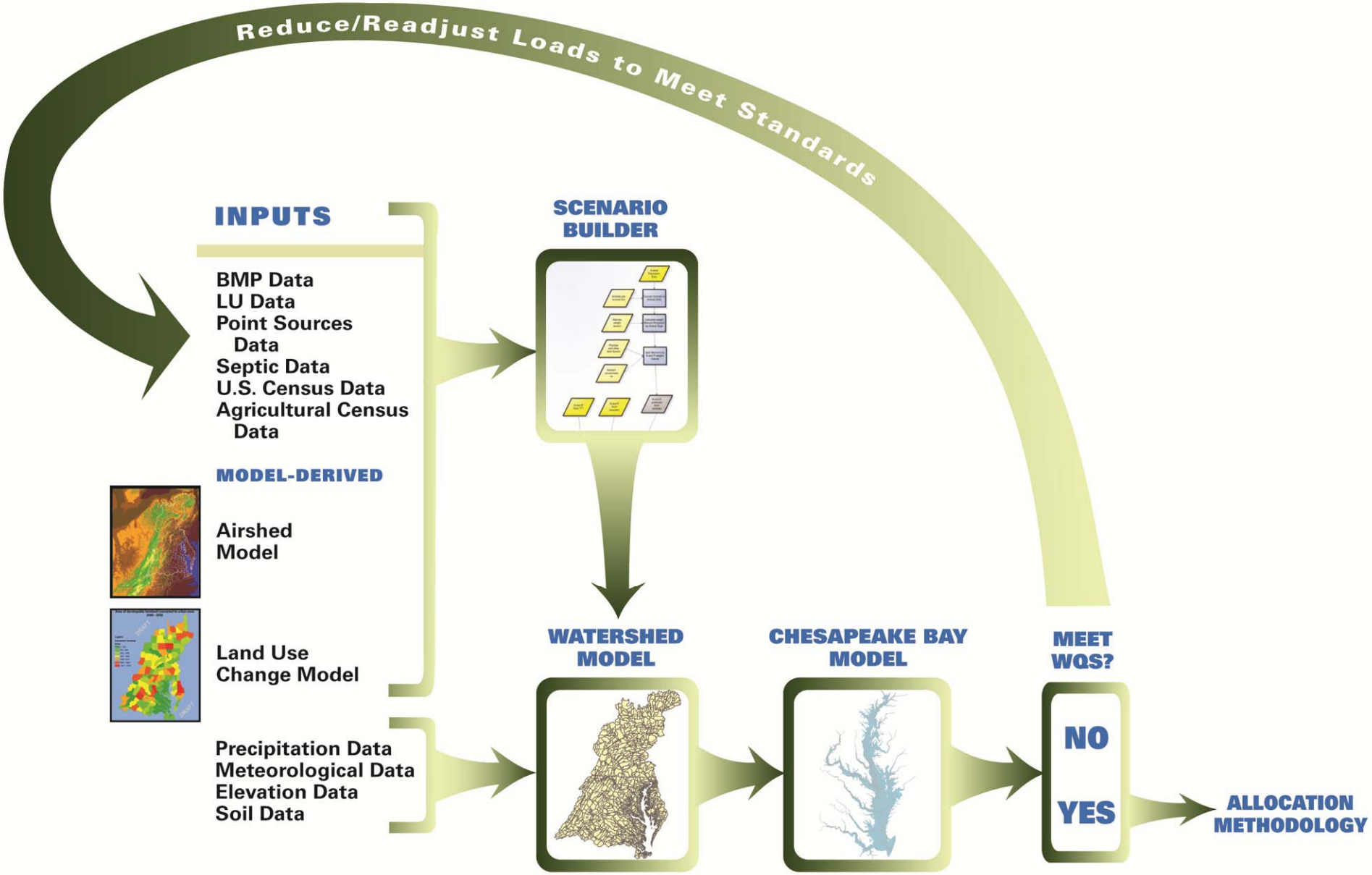
Identified Issues

Gary Shenk

Presentation to MDE WIP Technical Meeting

7/8/2013

Chesapeake Bay Partnership Models



CBP Modeling Tools

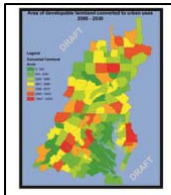
Interaction Tools

NEIEN
Environmental Information eXchange Network

CAST

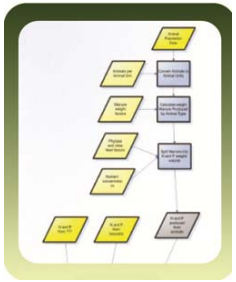
ChesapeakeStat
BayTAS
Chesapeake Bay TMDL Tracking and Accounting System

Decision Models/ Databases


Land Use Change Model

CMAQ
NOAA
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

SCENARIO BUILDER

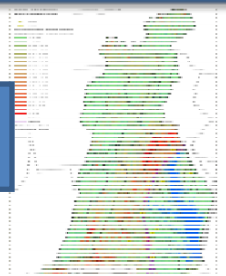


WATERSHED MODEL

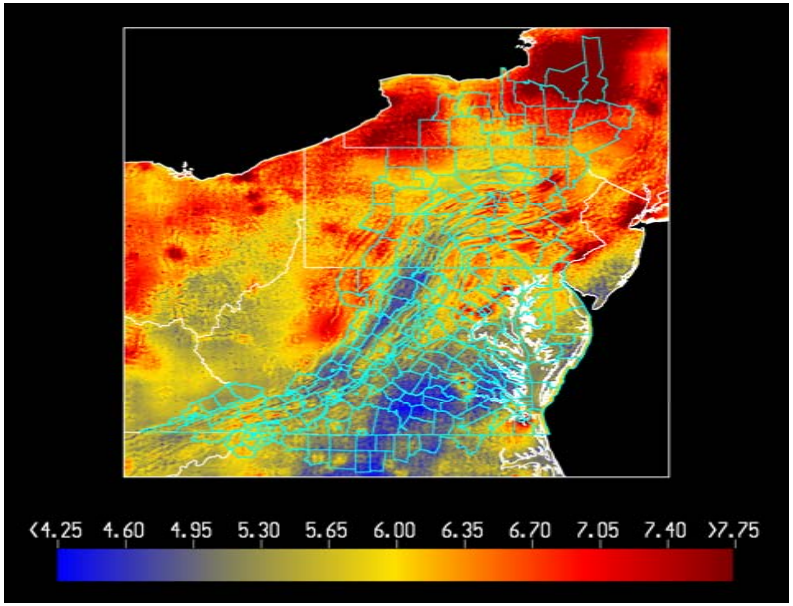
Bay WQSTM

Related Tools

sparrow

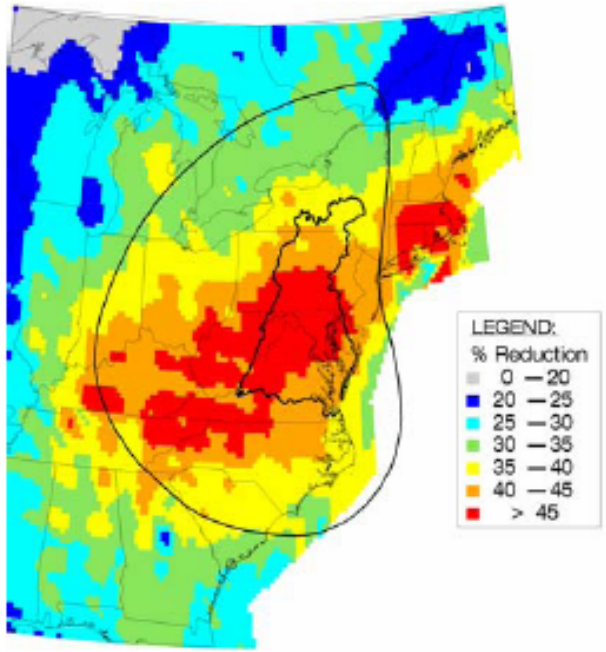


Atmospheric Deposition Estimates

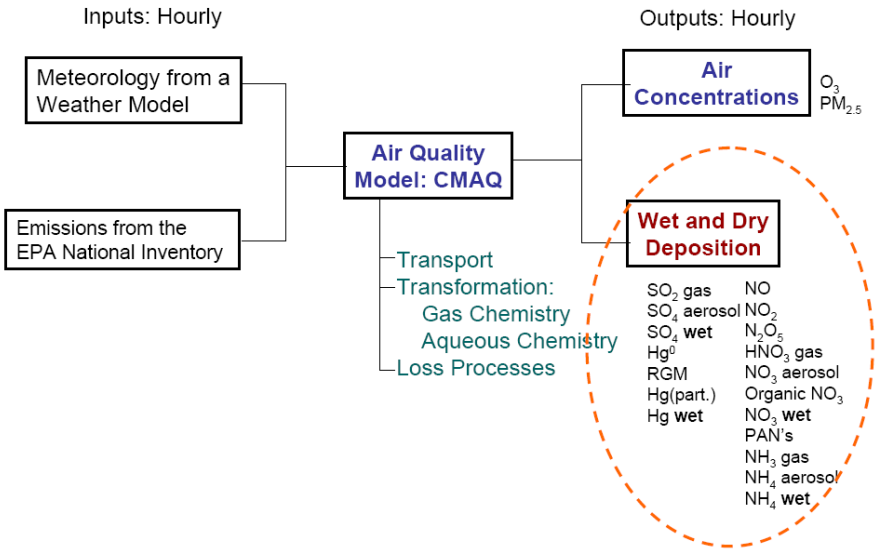


Combining a regression model of wetfall deposition...

NOx SIP Reg +
Tier II Mobile +
Heavy Duty Diesel Regs
2020
ox-N Dep % Change from 1990



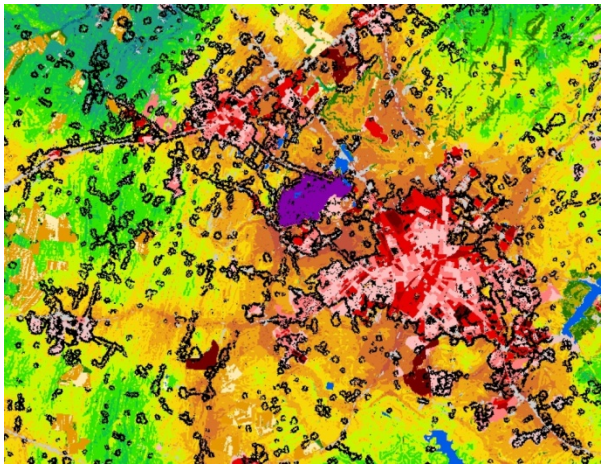
…with CMAQ estimates of dry deposition for the base…

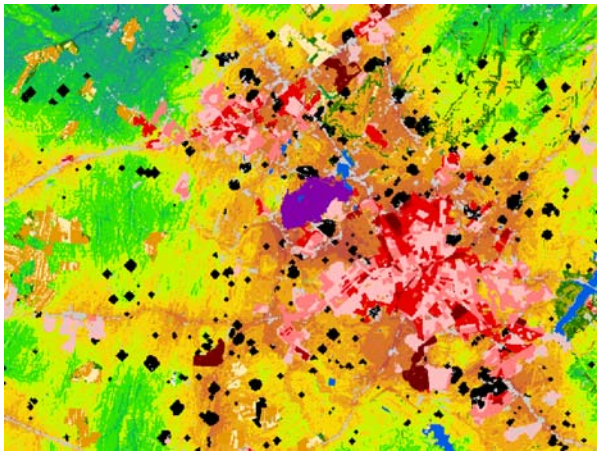


…and using the power of the CMAQ model for scenarios.

Land Change Modeling at the CBP

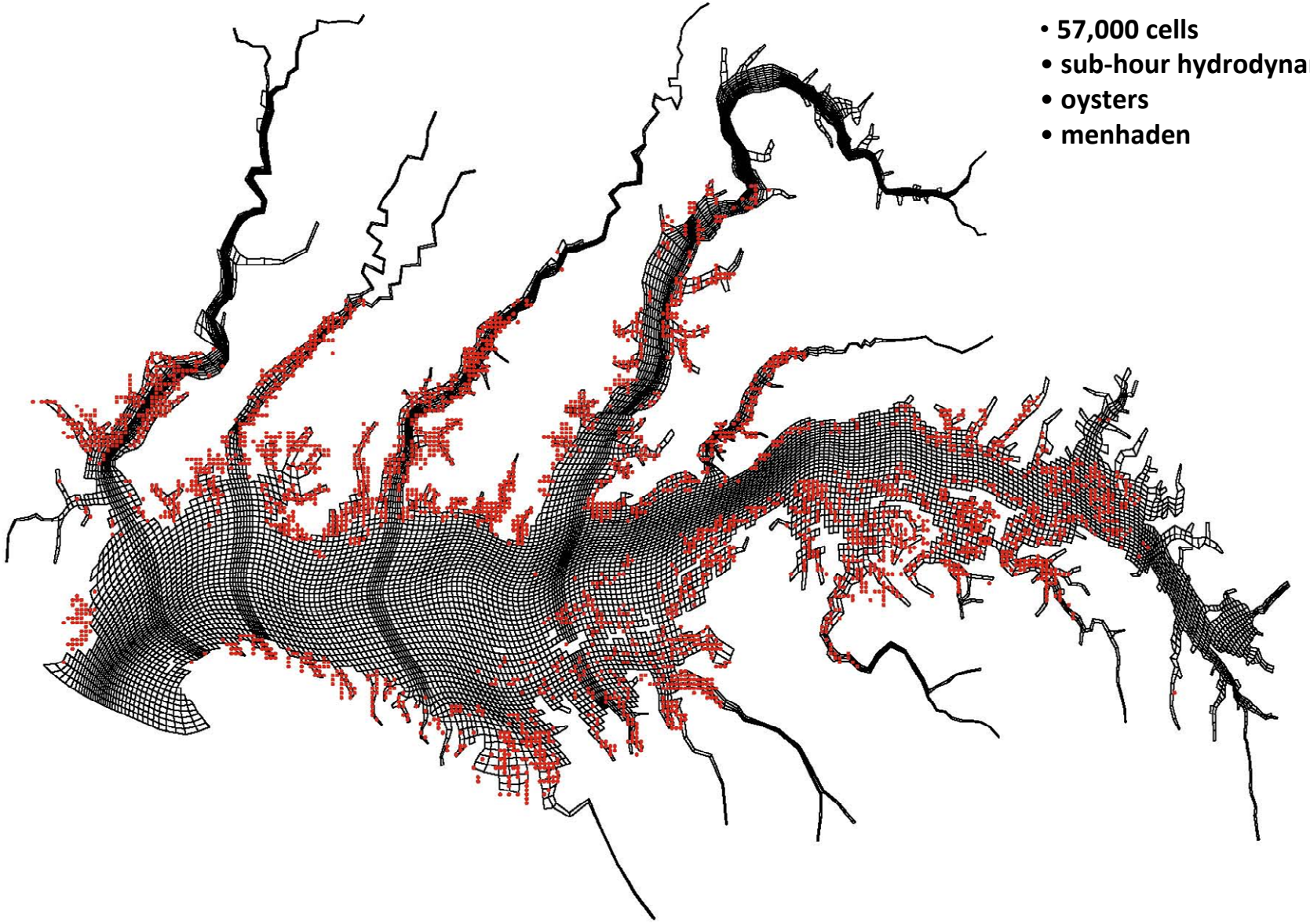
- 1980s – 1990s – simple empirical relationships
- CBLCM
  - v1 – Sleuth
  - V2 –empirical relationships
  - V3 – Patch-based growth
    - Existing Lu/Lc
    - Topographic/Geologic data
    - Population Projections





Probability surface

Estuarine Model



- 57,000 cells
- sub-hour hydrodynamics
- oysters
- menhaden

- 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

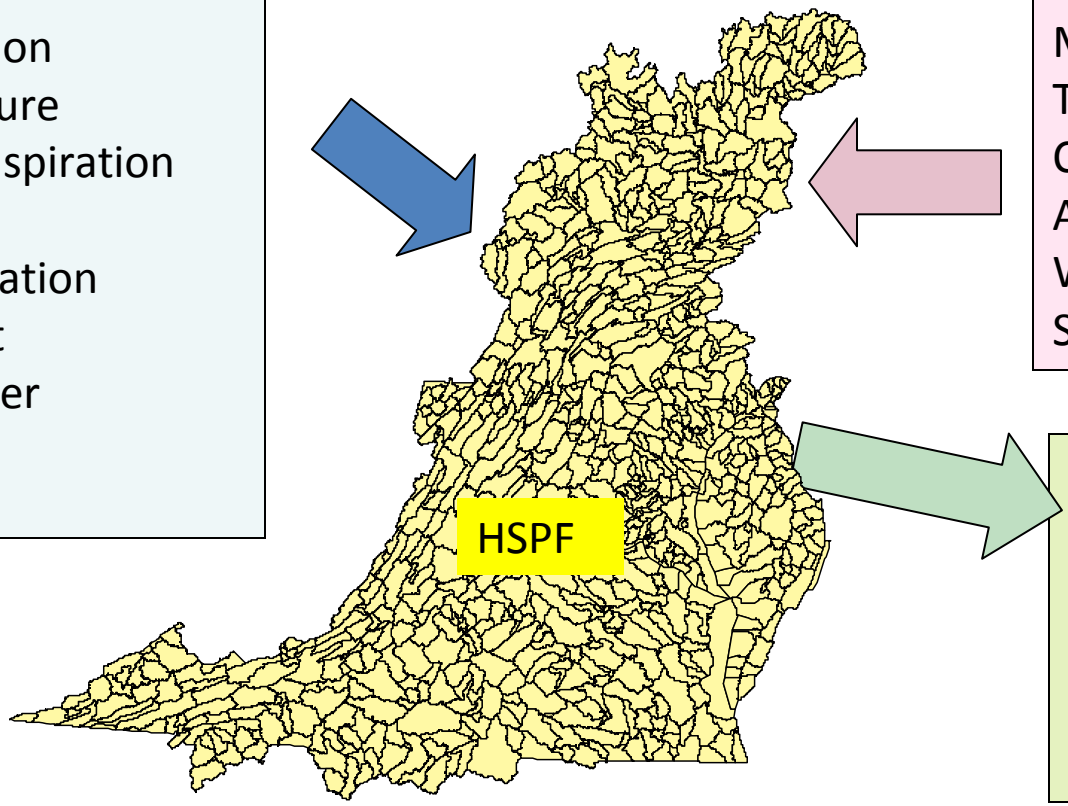
Outputs

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:

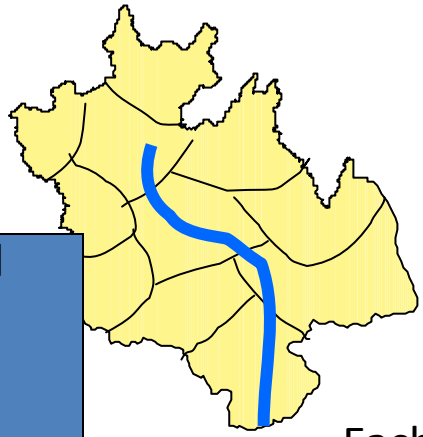
Land Use Acreage
BMPs
Fertilizer
Manure
Tillage
Crop types
Atmospheric deposition
Waste water treatment
Septic loads

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

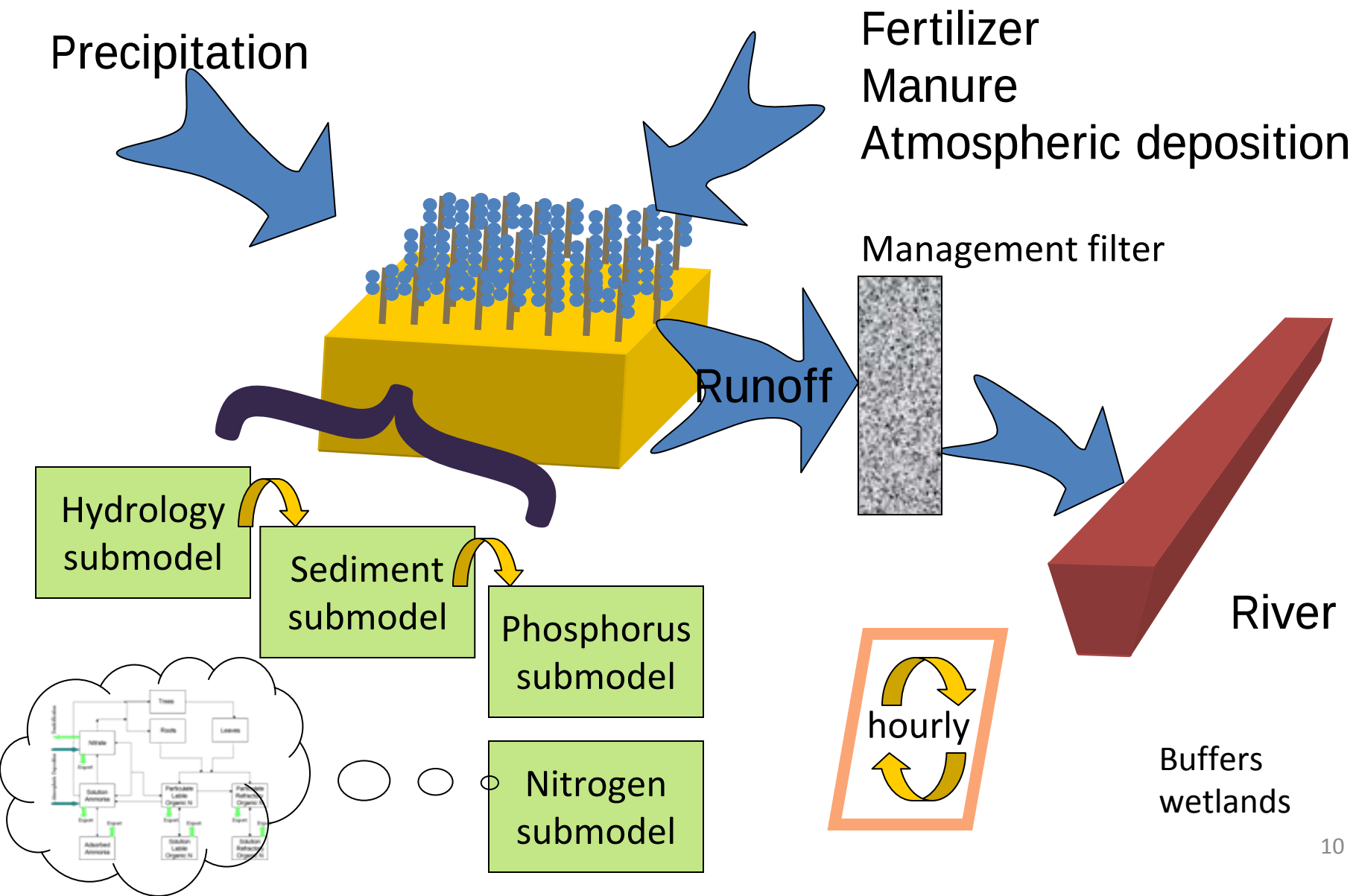


Plus: Point Source and Septic Loads, and Atmospheric Deposition Loads

- 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

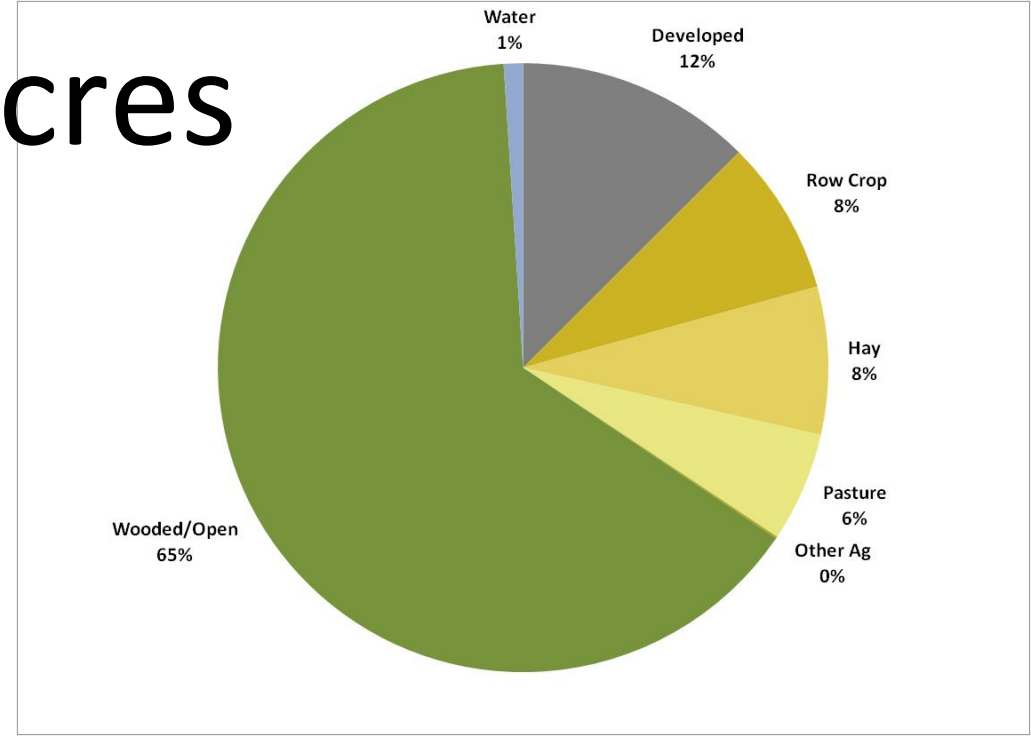
Each calibrated to nutrient and Sediment targets

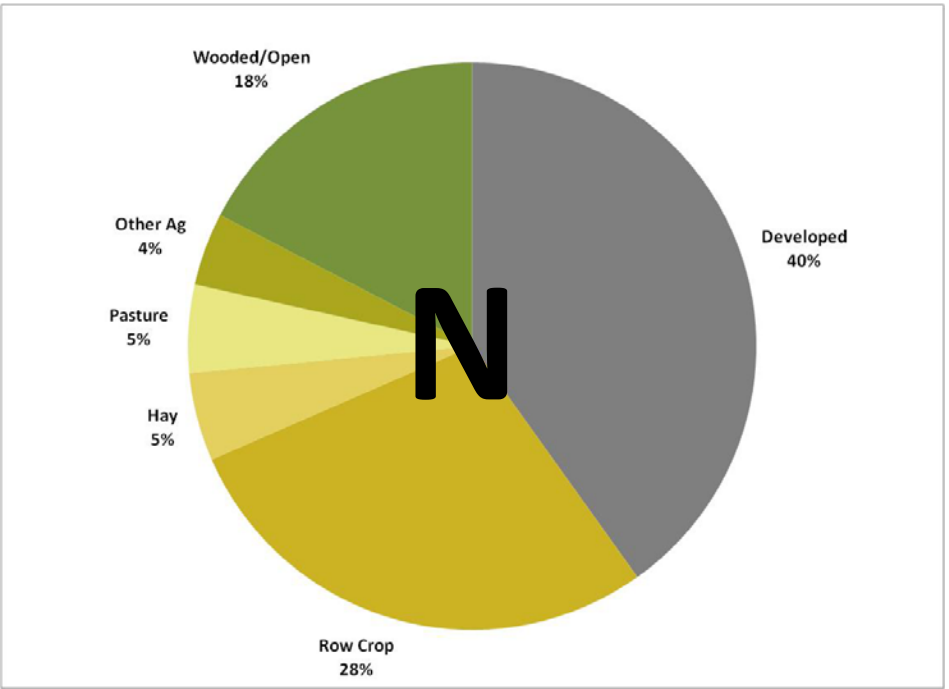
How the Watershed Model Works

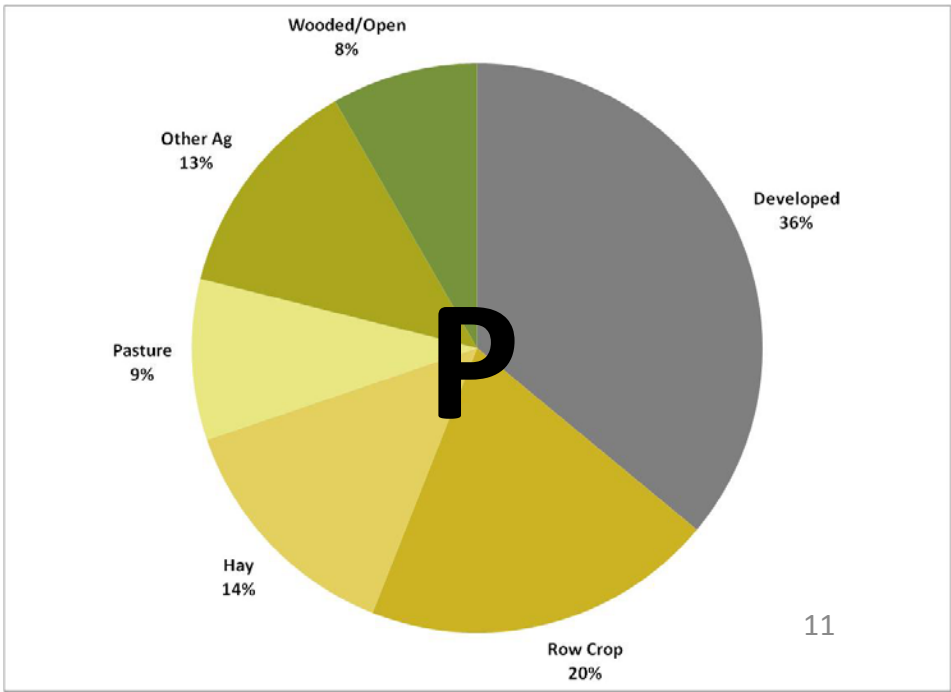


Land Use and Nutrient Sources 2010

Acres

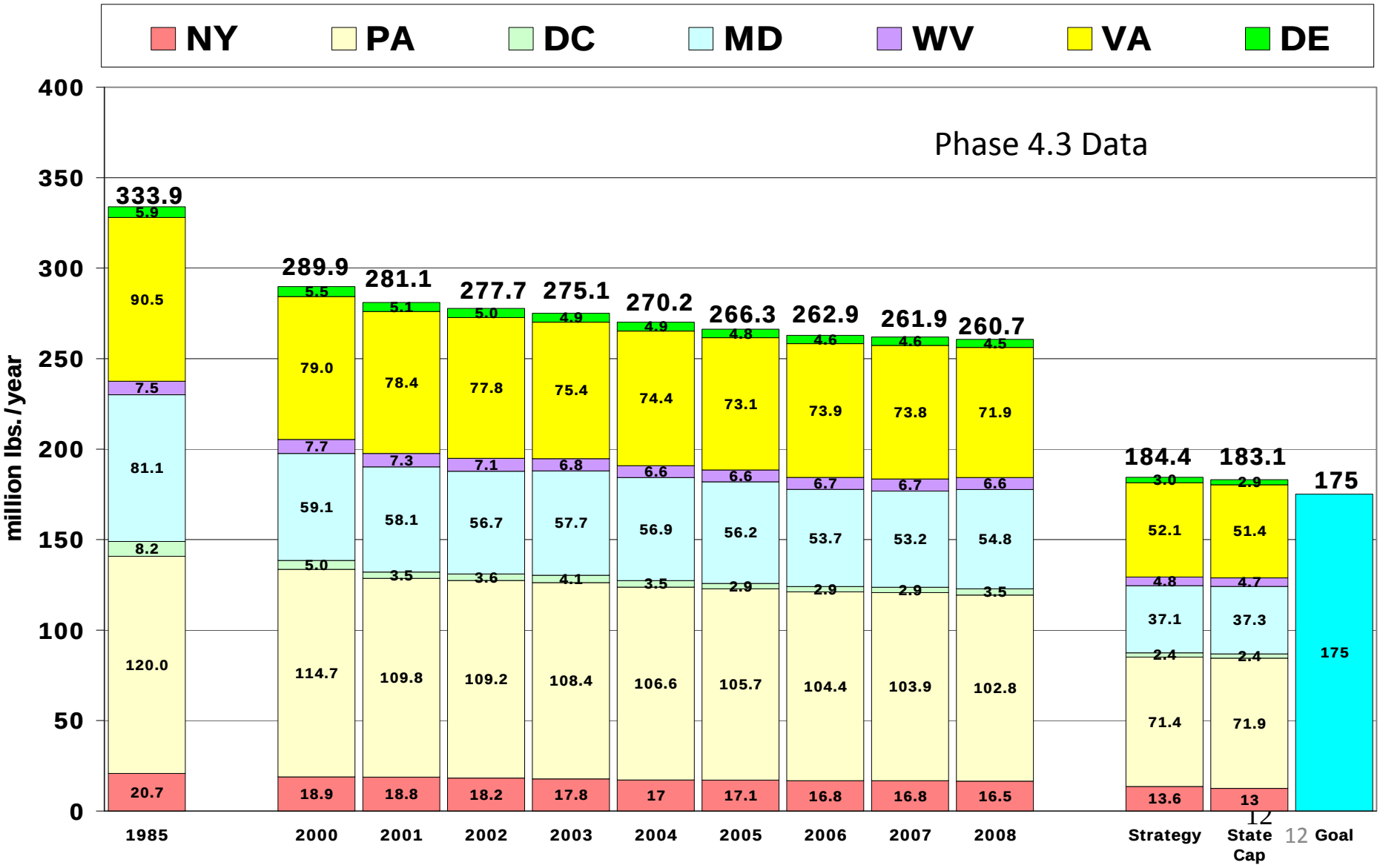




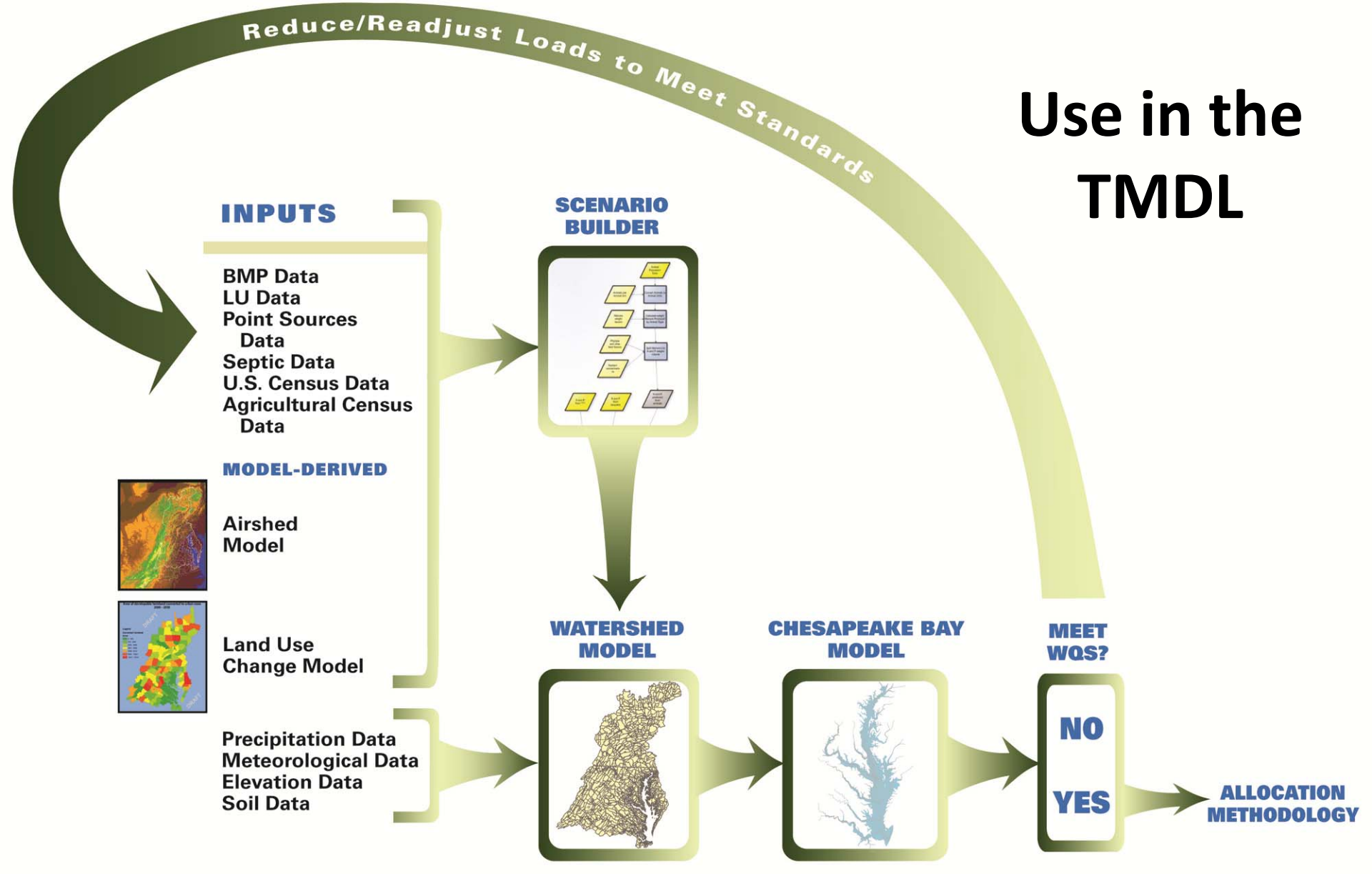


Nitrogen Loads Delivered to the Chesapeake Bay By Jurisdiction

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

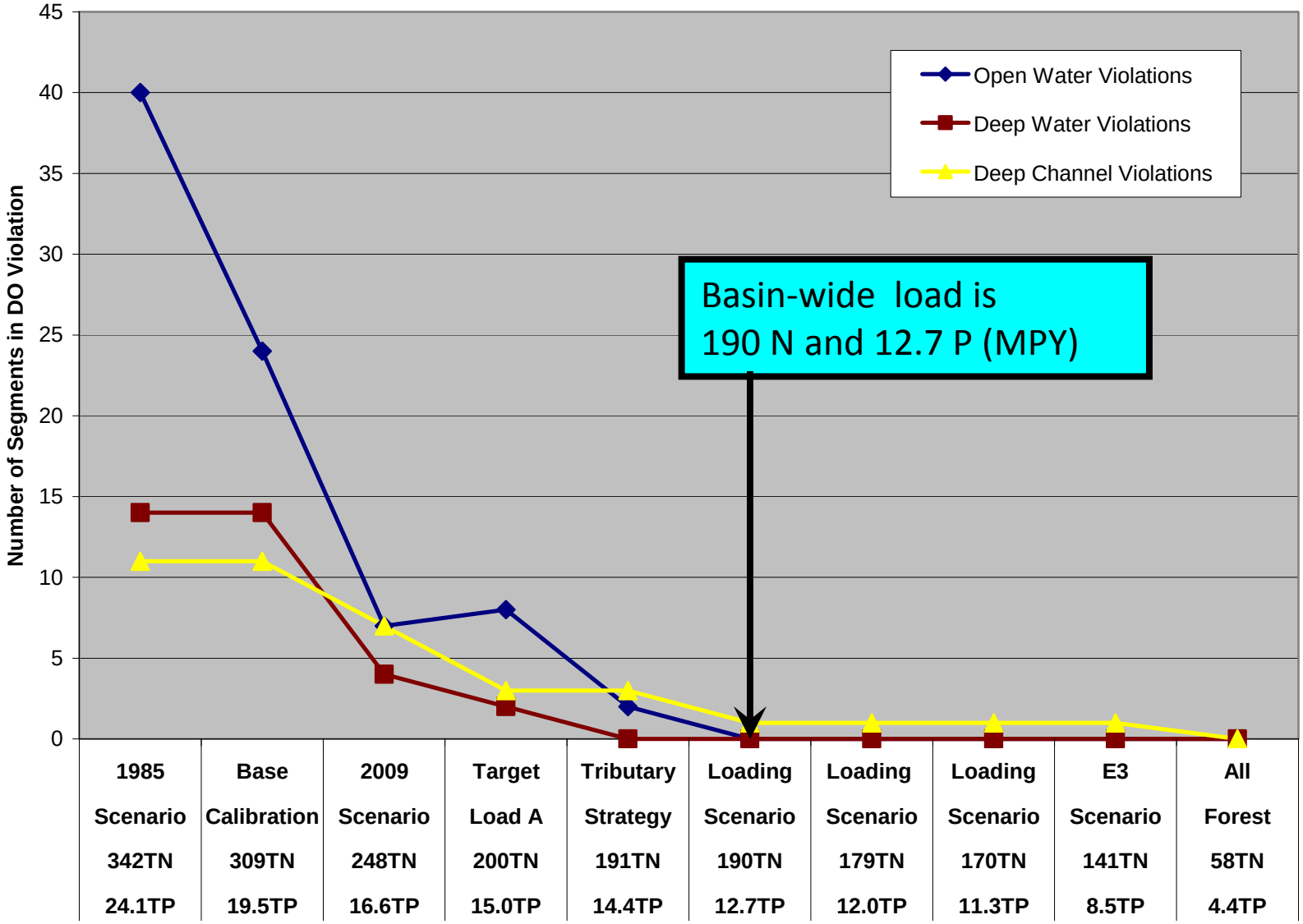


Chesapeake Bay Partnership Models

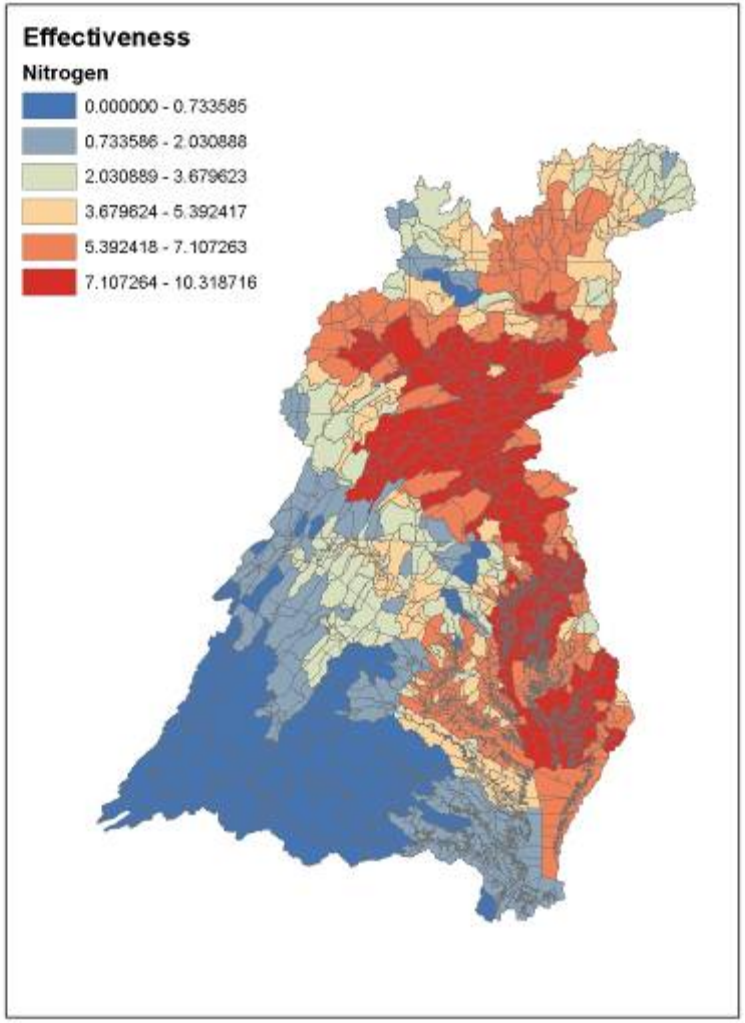


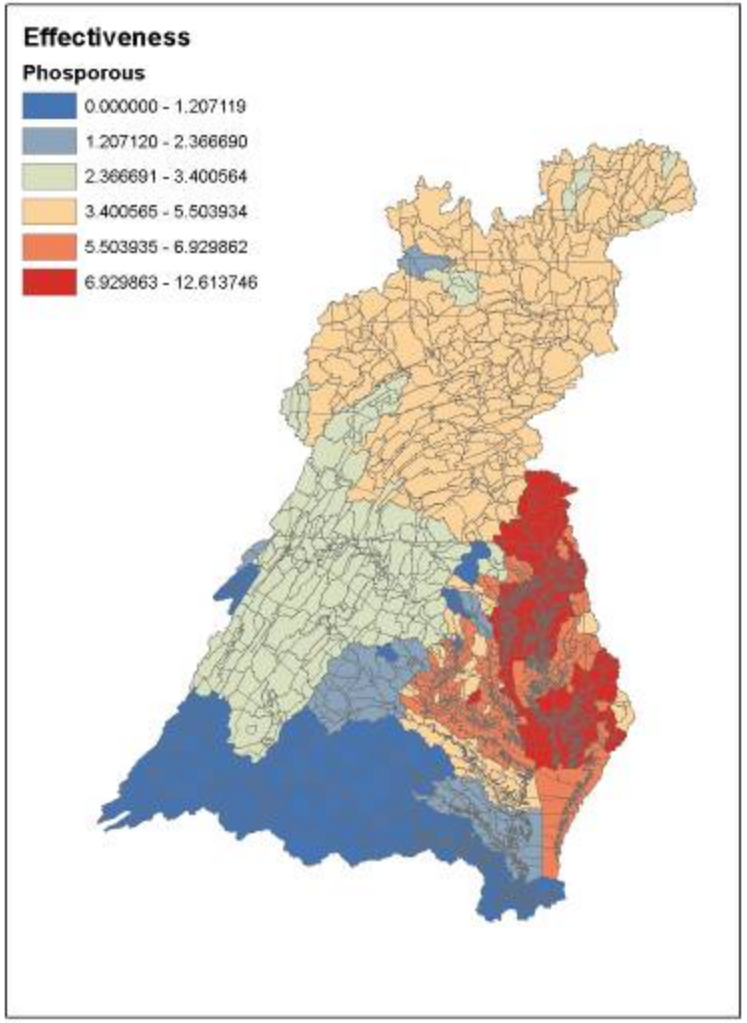
Use in the TMDL

Use of modeling suite in the Chesapeake TMDL

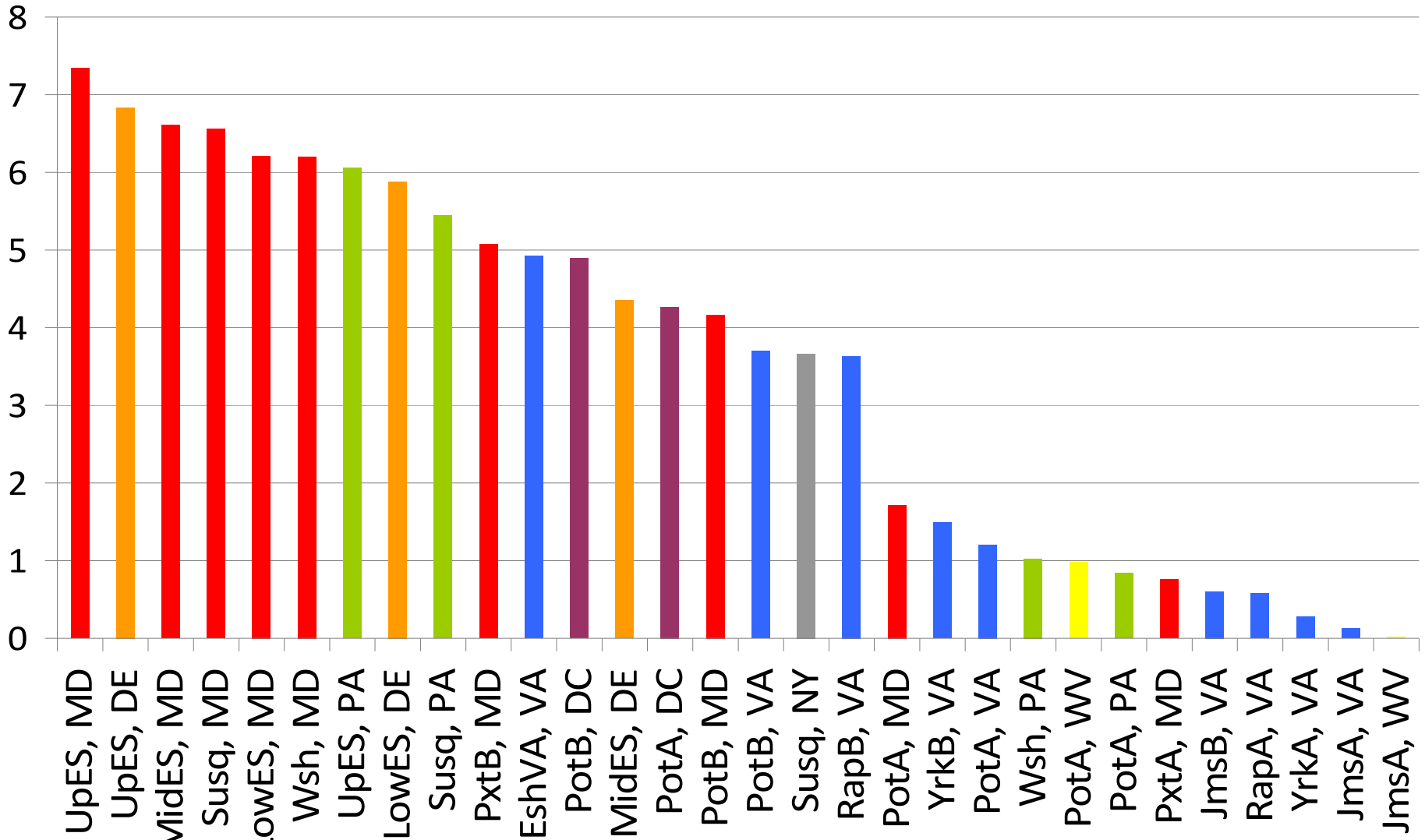


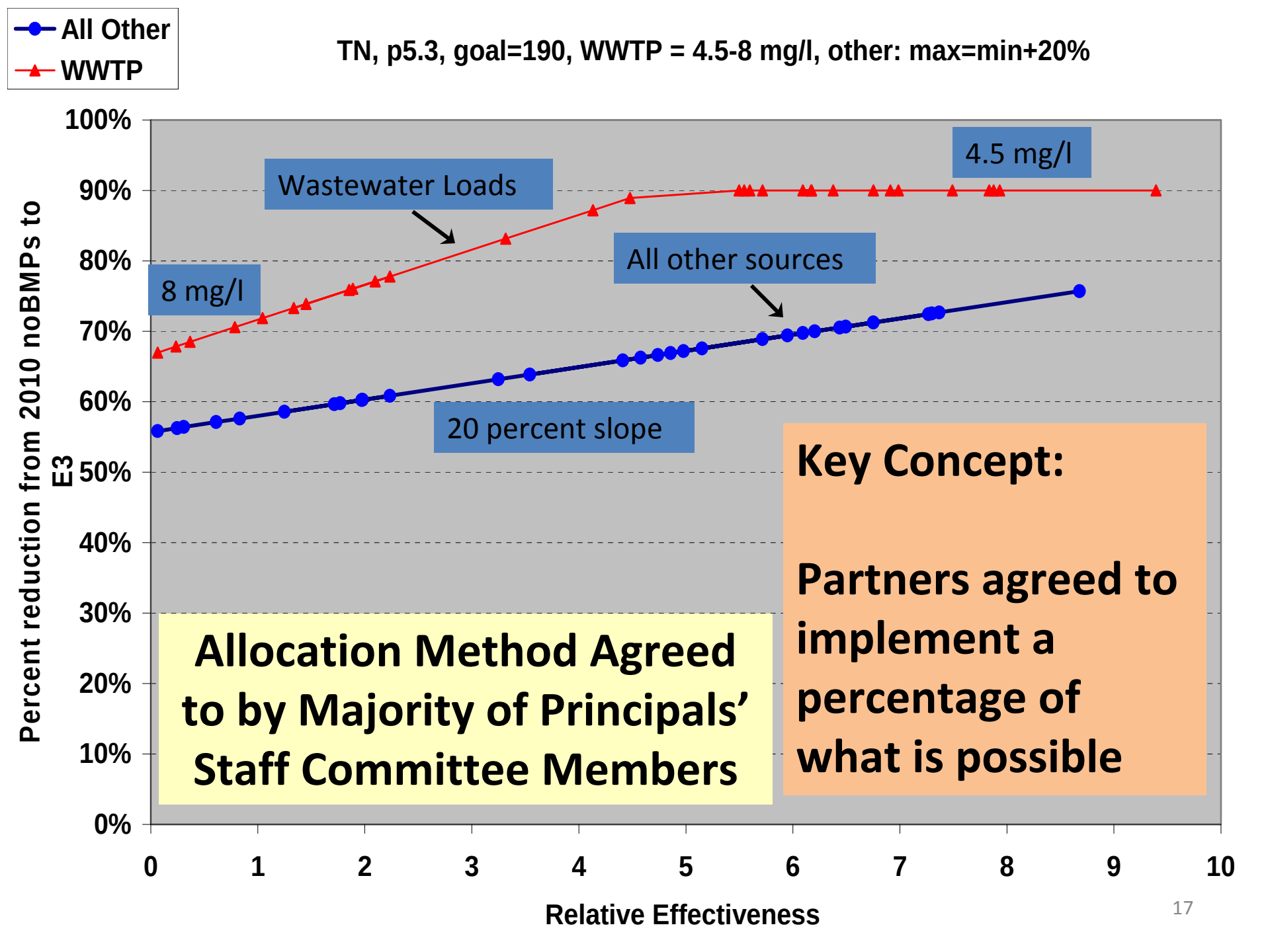
Nutrient Impacts on Bay WQ



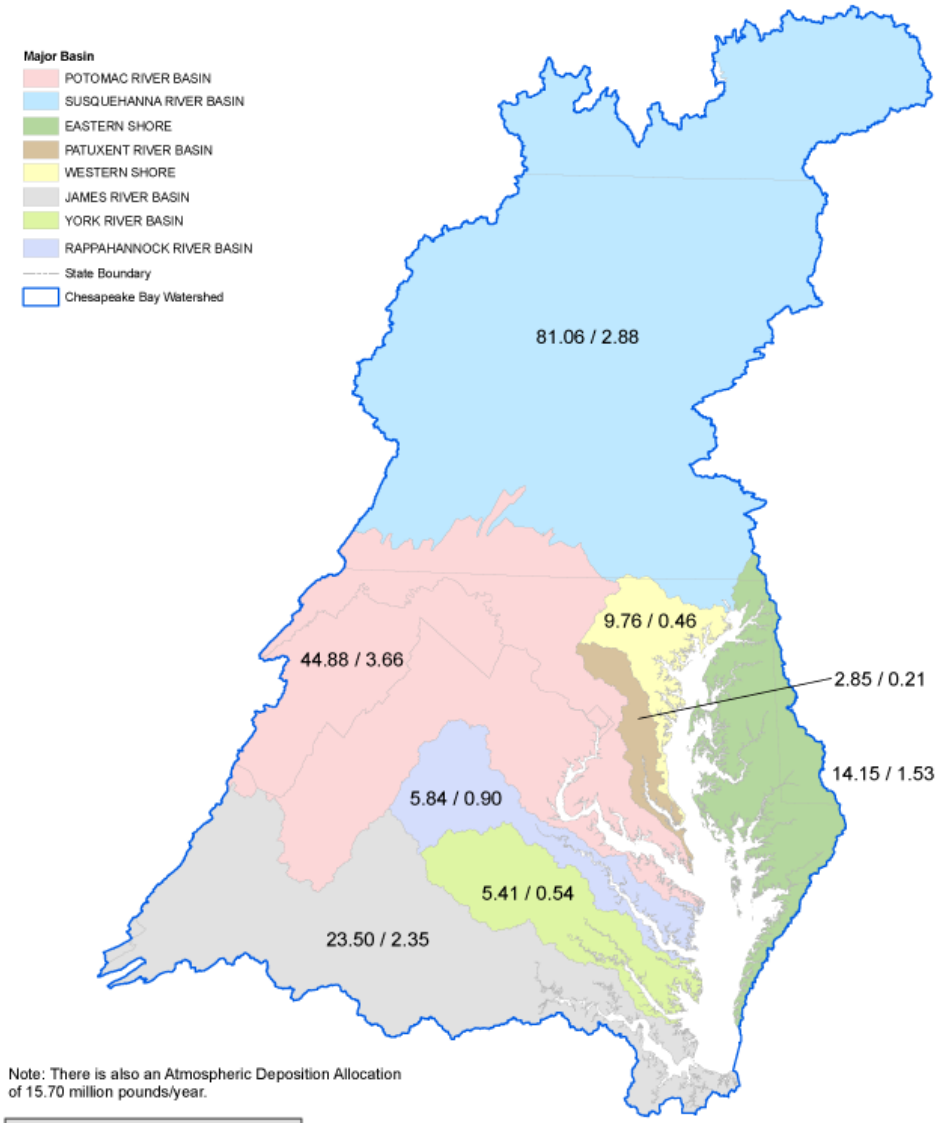


Major River Basin by Jurisdiction Relative Impact on Bay Water Quality

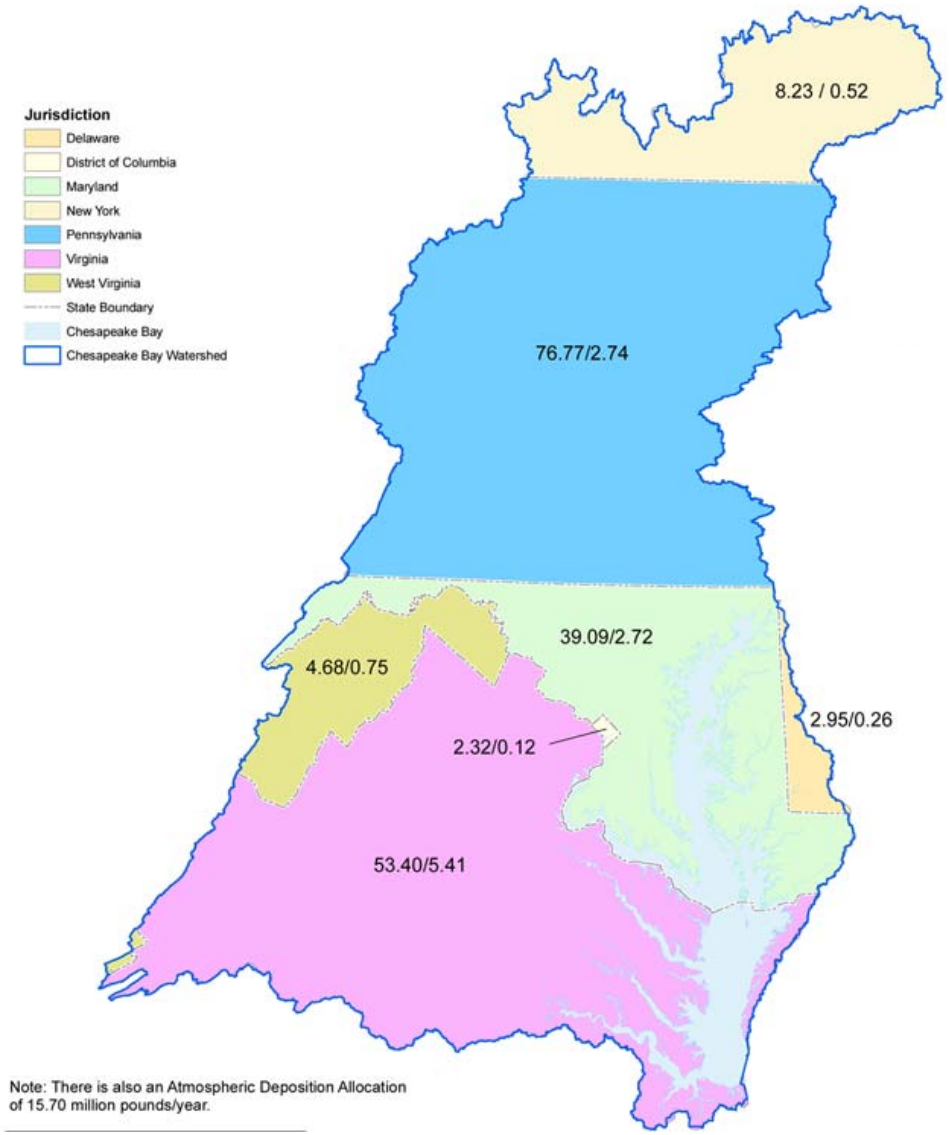



All Other
WWTP
TN, p5.3, goal=190, WWTP = 4.5-8 mg/l, other: max=min+20%
Percent reduction from 2010 noBMPs to E3
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
6
7
8
9
10
Relative Effectiveness
Wastewater Loads
4.5 mg/l
8 mg/l
All other sources
20 percent slope
Allocation Method Agreed to by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

Pollution Diet by River



Pollution Diet by State

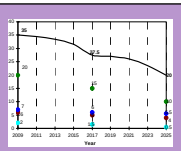


Accountability Framework

Components of Bay TMDL Accountability Framework

1. Watershed Implementation Plans identify nutrient and sediment targets that meet water quality standards.

2. 2-Year Milestones with programmatic and pollutant reduction commitments



3.Track and Assess Progress implementing WIPs and milestones

4. Federal Actions if insufficient Watershed Implementation Plans or 2-year milestones

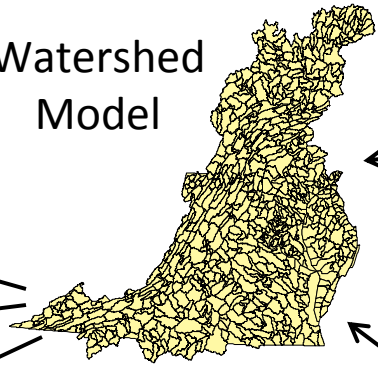
Source: Chesapeake Bay TMDL Section 7

Accountability Framework

1. Watershed Implementation Plans identify nutrient and sediment targets that meet water quality standards.

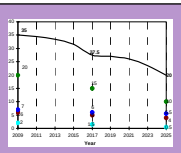
CAST

Watershed Model

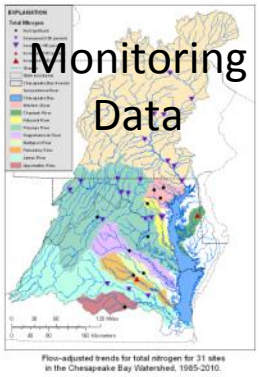


Land Change Model

2. 2-Year Milestones with programmatic and pollutant reduction commitments

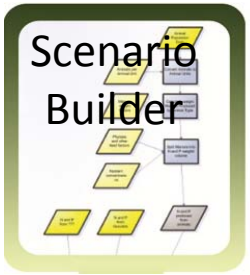


Monitoring Data



Flow-adjusted trends for total nitrogen for 31 sites in the Chesapeake Bay Watershed, 1985-2010.

Scenario Builder

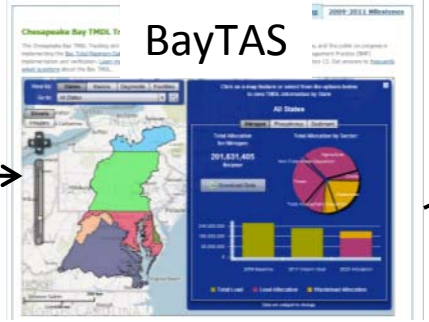


3.Track and Assess Progress implementing WIPs and milestones

NEIEN

Environmental Information eXchange Network

BayTAS



4. Federal Actions if insufficient Watershed Implementation Plans or 2-year milestones

Chesapeake Bay Program Partners

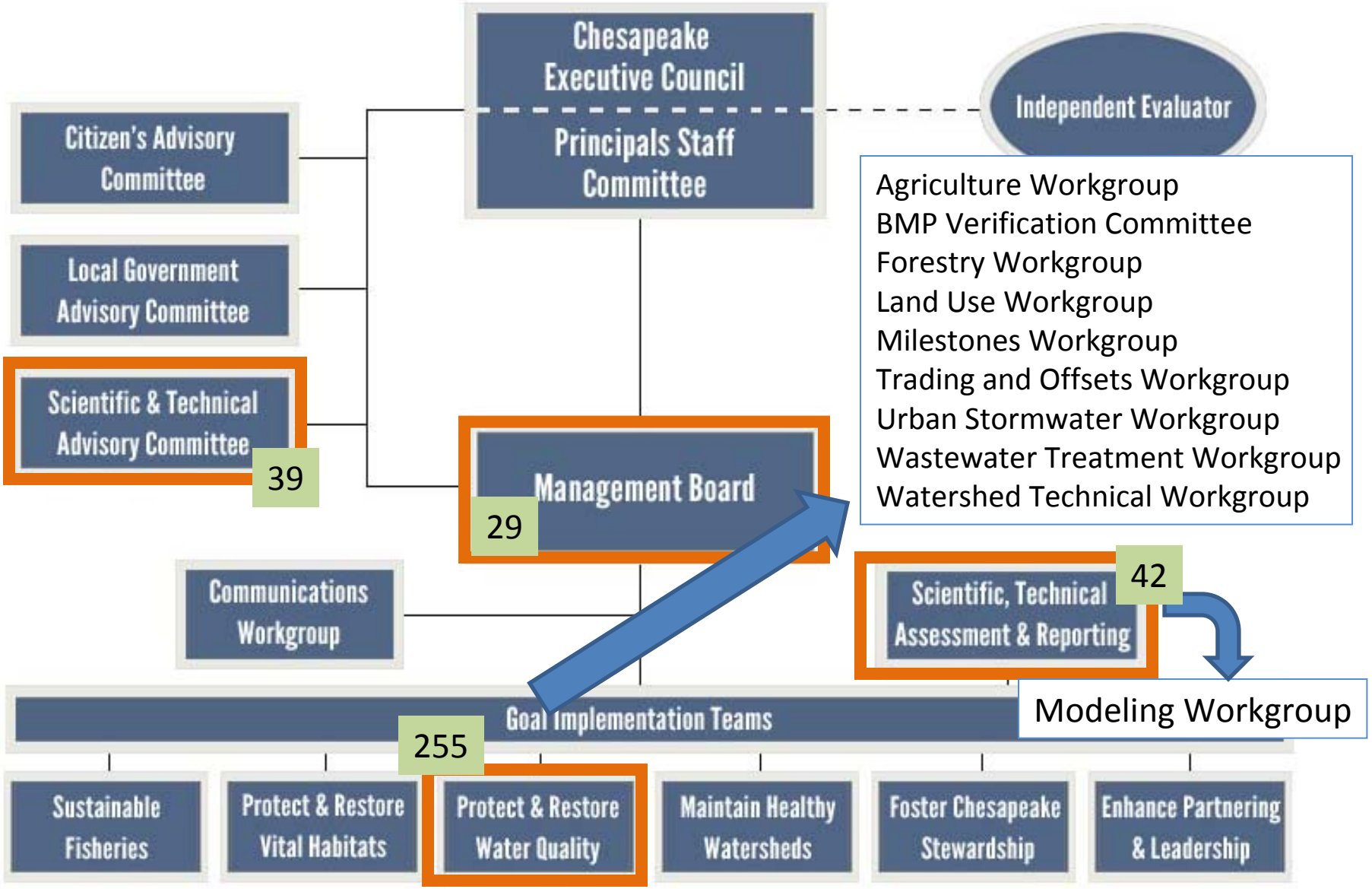
- Signatories to the Chesapeake Bay Agreement
  - PA, MD, VA, DC
  - CBC
  - EPA
- Headwater States
  - DE, NY, WV
- Federal Agencies
  - NOAA
  - USDA
  - USGS
  - NPS
  - USFW
  - DOD
  - NASA
  - NCPC
  - D.Ed.
  - USPS
  - GSA

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

Model related Membership as of 7/2013 – 365 individuals

Chesapeake Bay Program Partnership



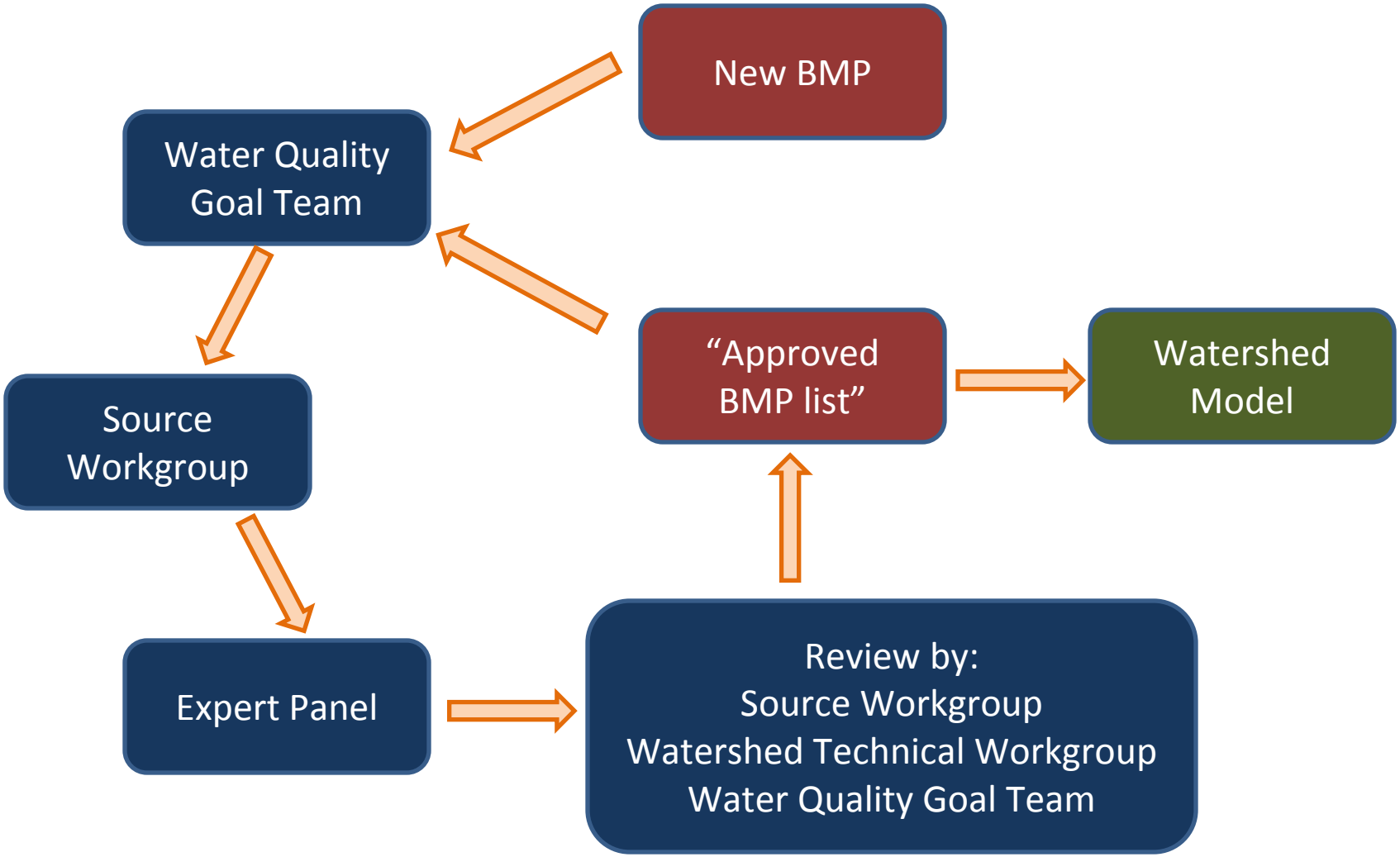
Agricultural Workgroup

- **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

BMP Effectiveness Estimation Process



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

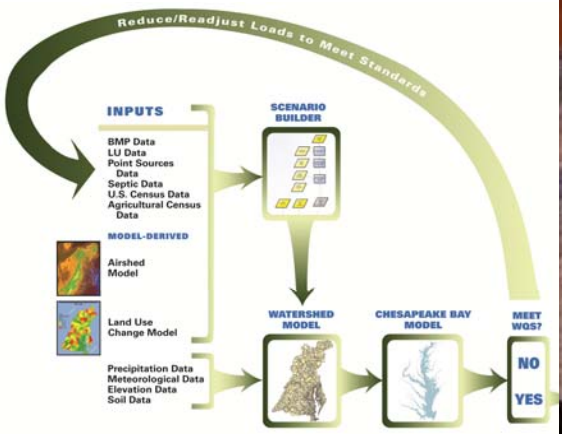
Urban

- 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

What's on the table for Phase 6?



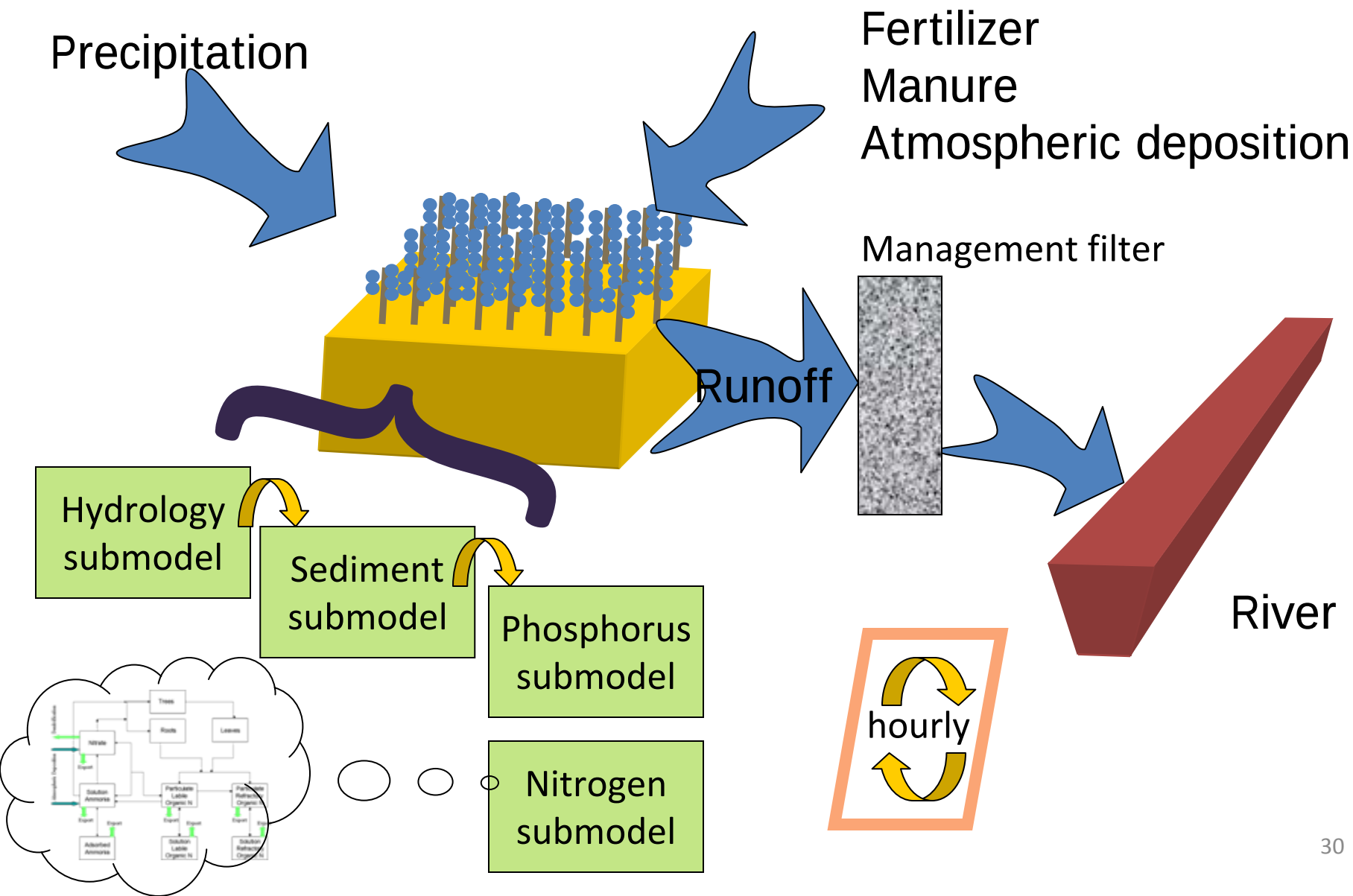
Lessons Learned through TMDL

- The CBP Partnership wants transparency:
  - Simplicity
  - Scalability
  - Ease of Use
  - Understandability

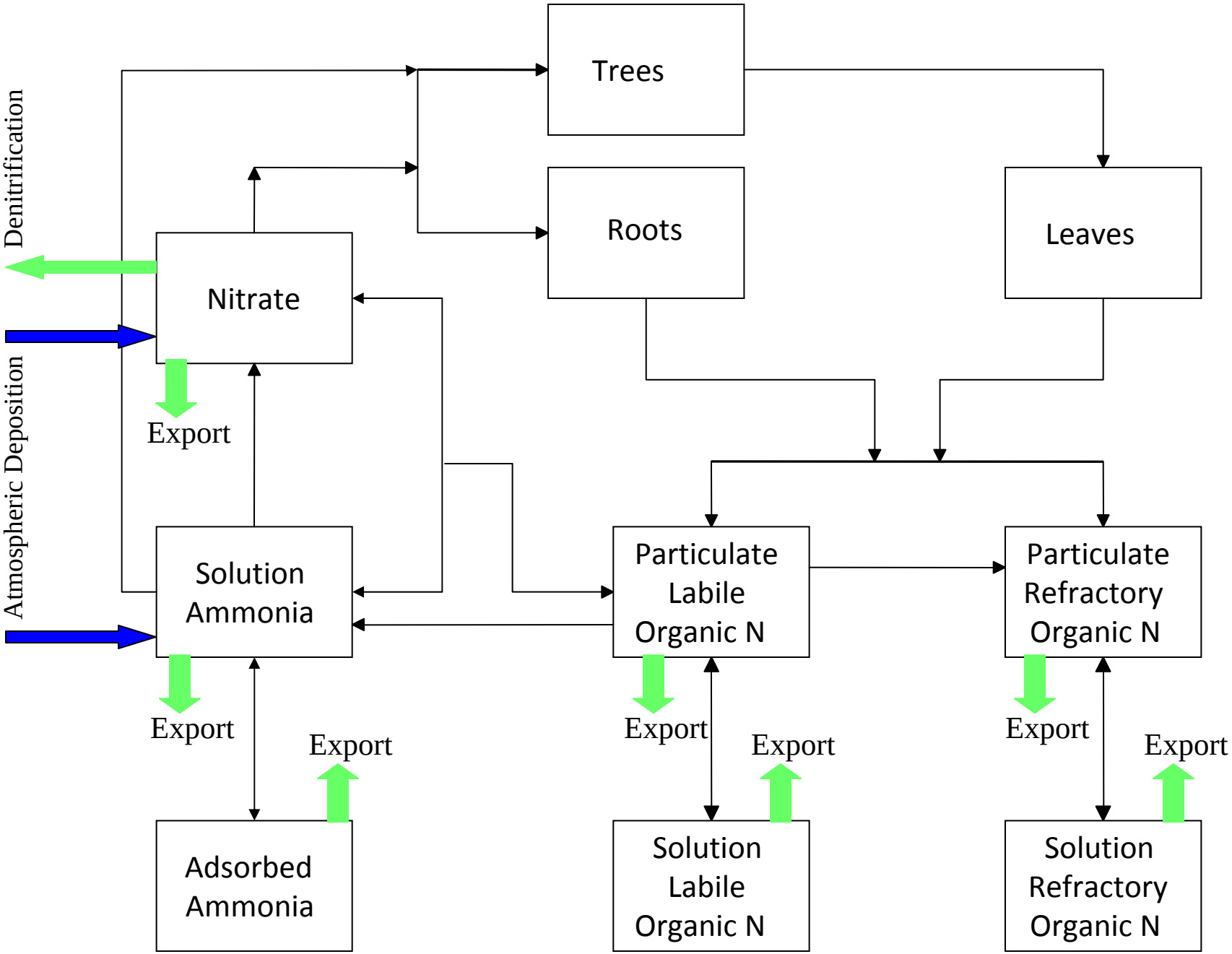
- Quote from State Government Representative:

"***We*** *want to be able to explain the models to our stakeholders and have them be* relevant *at the local scale*."

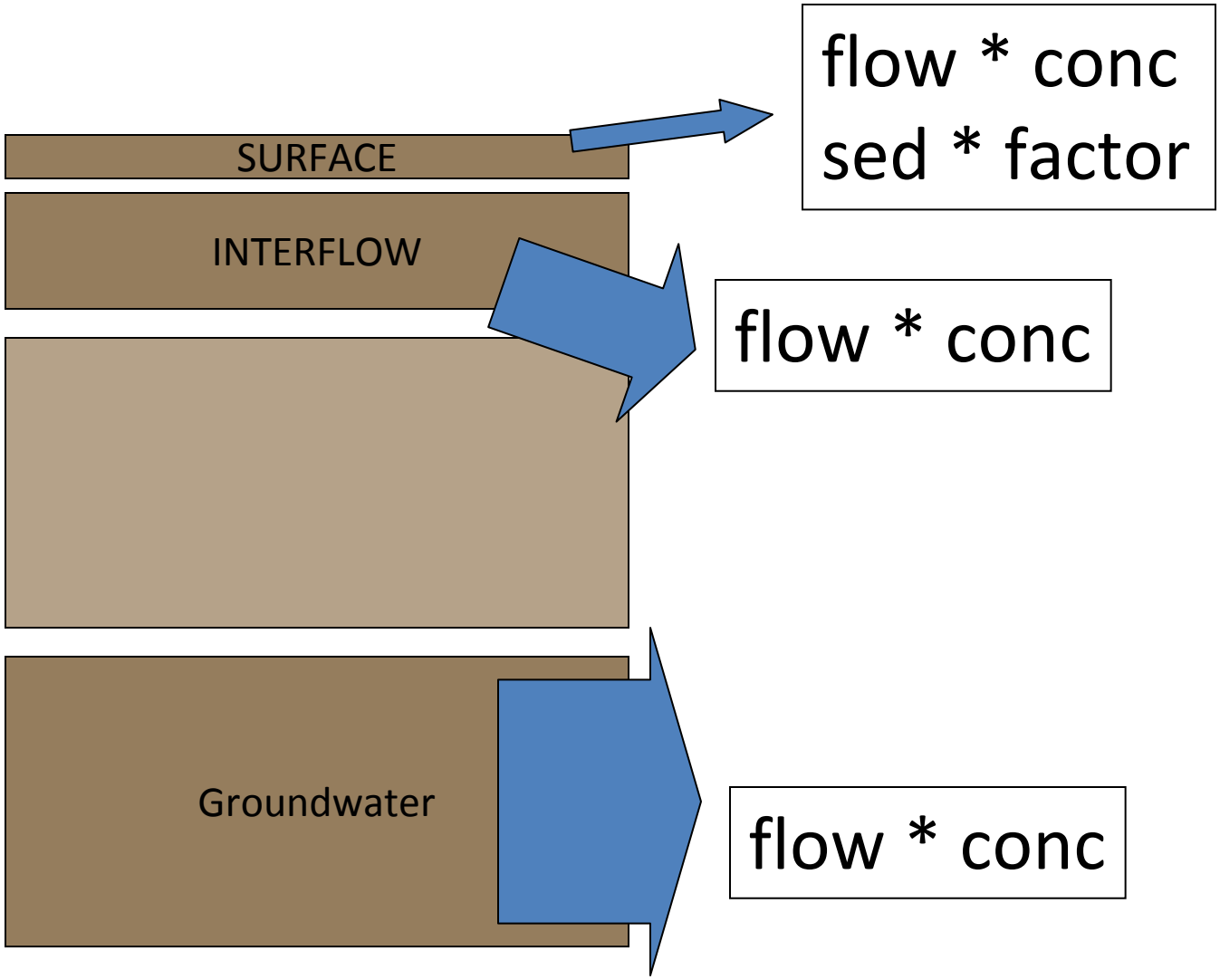
Changes in Phase 6



AGCHEM Loading Model - simulated separately in each soil layer



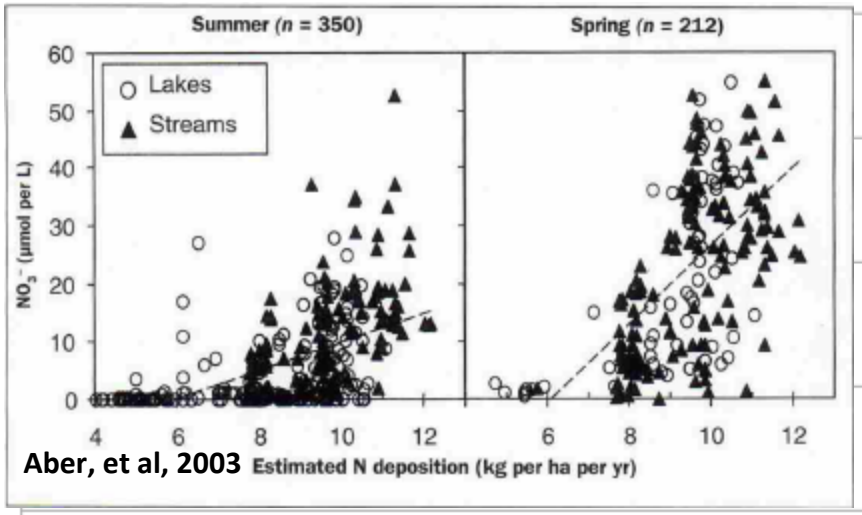
PQUAL loading model



Complex *vs* Simple

Complex	Simple
• Calibration is complex and time consuming	• Calibration is relatively simple and fast
• Calibration is imprecise	• Calibration is precise
• Longer run time	• Shorter run time
• Simulated sensitivity to inputs	• Sensitivity to inputs must be specified

Reduction in forest loads from 1985 to CAIR



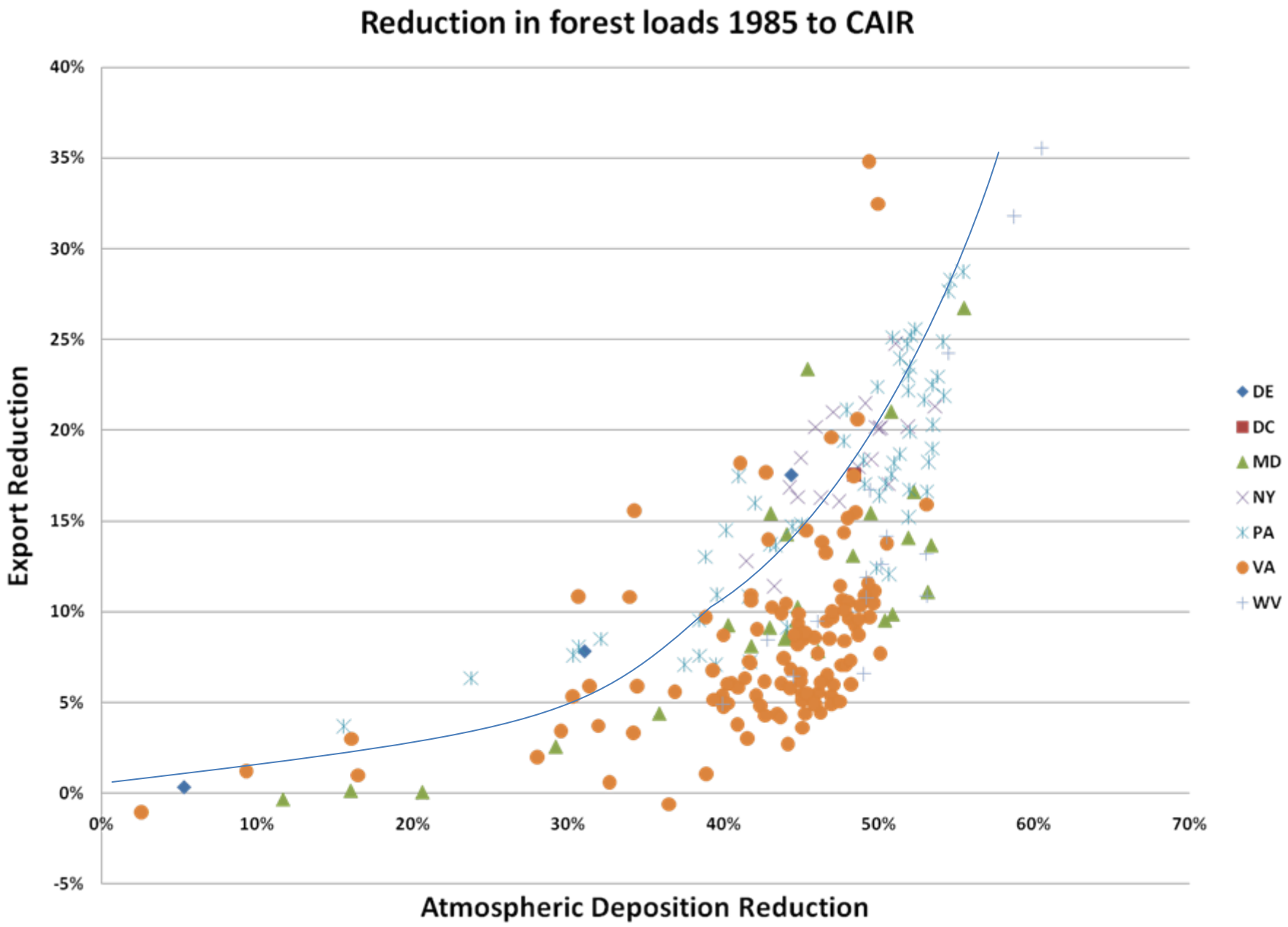
Aber, et al, 2003

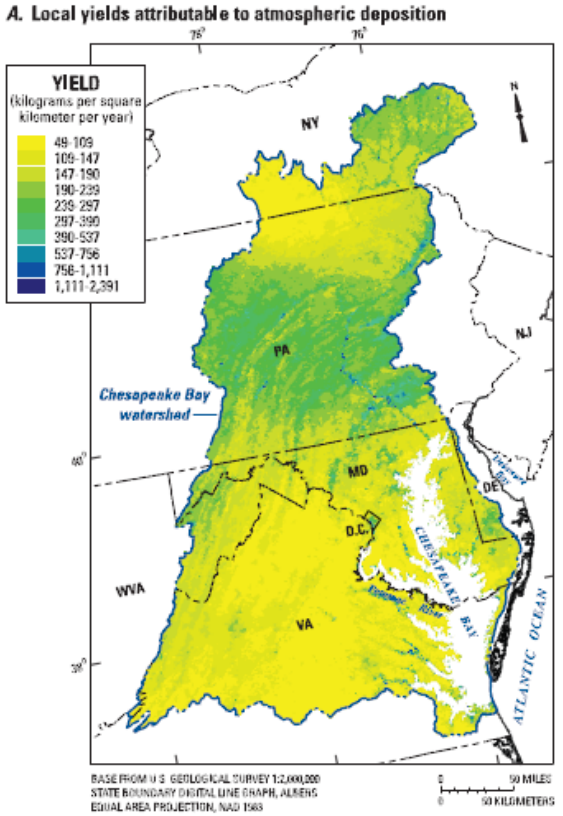
Export Reduction

40%
35%
30%
25%
20%
15%
10%
5%
0%
-5%

0%
10%
20%
30%
40%
50%
60%
70%

Atmospheric Deposition Reduction


Reduction in forest loads 1985 to CAIR
Export Reduction
Atmospheric Deposition Reduction
40%
35%
30%
25%
20%
15%
10%
5%
0%
-5%
0%
10%
20%
30%
40%
50%
60%
70%
DE
DC
MD
NY
PA
VA
WV

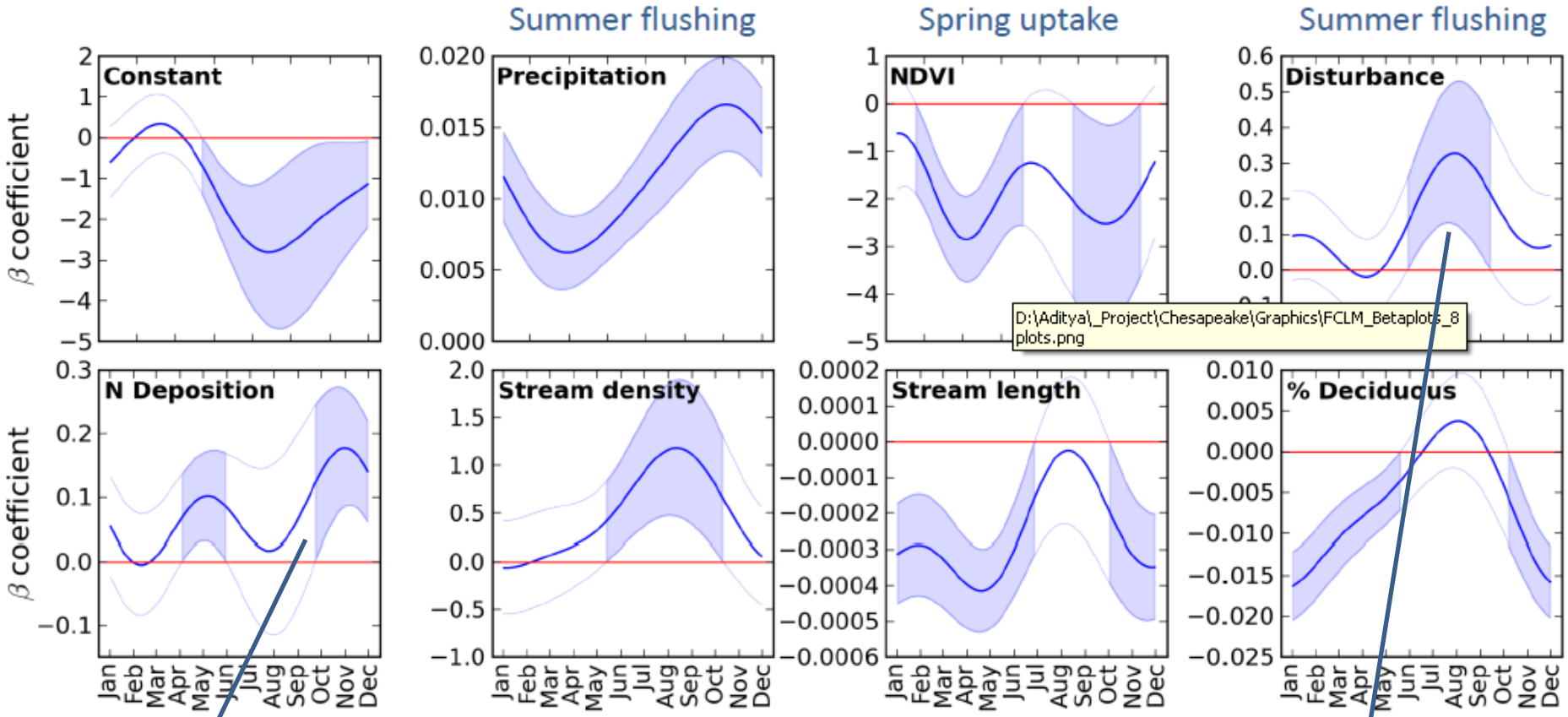


Total Nitrogen, 2002
(n = 181, MSE = 0.0836, RMSE = 0.289, flux R^2 = 0.978, yield R^2 = 0.858

Explanatory variables	Estimate	Units	90-percent confidence interval	Standard error	p[1]
Sources					
Point sources (kg yr^{-1})	0.774		0.375 – 1.17	0.242	0.0008
Crop fertilizer and fixation (kg yr^{-1})	0.237		0.177 – 0.297	0.0363	< 0.0001
Manure (kg yr^{-1})	0.0582		0.0138 – 0.103	0.0269	0.0157
Atmospheric deposition (kg yr^{-1})	0.267		0.179 – 0.355	0.0533	< 0.0001
Urban[2] (km^2)	1,090	kg km^{-2} yr^{-1}	707 – 1,480	234	< 0.0001
Land-to-water delivery					
ln[Mean EVI for WY02 (dimensionless)]	-1.70		-2.65 – -0.737	0.580	0.0039
ln[Mean soil AWC (fraction)]	-0.829		-1.26 – -0.401	0.260	0.0016
ln[Groundwater recharge (mm)]	0.707	mm^{-1}	0.499 – 0.916	0.126	< 0.0001
ln[Piedmont carbonate (percent of area)]	0.158		0.0755 – 0.241	0.0500	0.0018
Aquatic decay					

Results:

Regression of monthly nitrate yield – Preliminary Results



Estimating nitrate export from Chesapeake Bay watersheds using MODIS and climate data

Aditya Singh and Phil Townsend
Angélica Gutiérrez-Magness
Keith Eshleman
Brenden McNeil

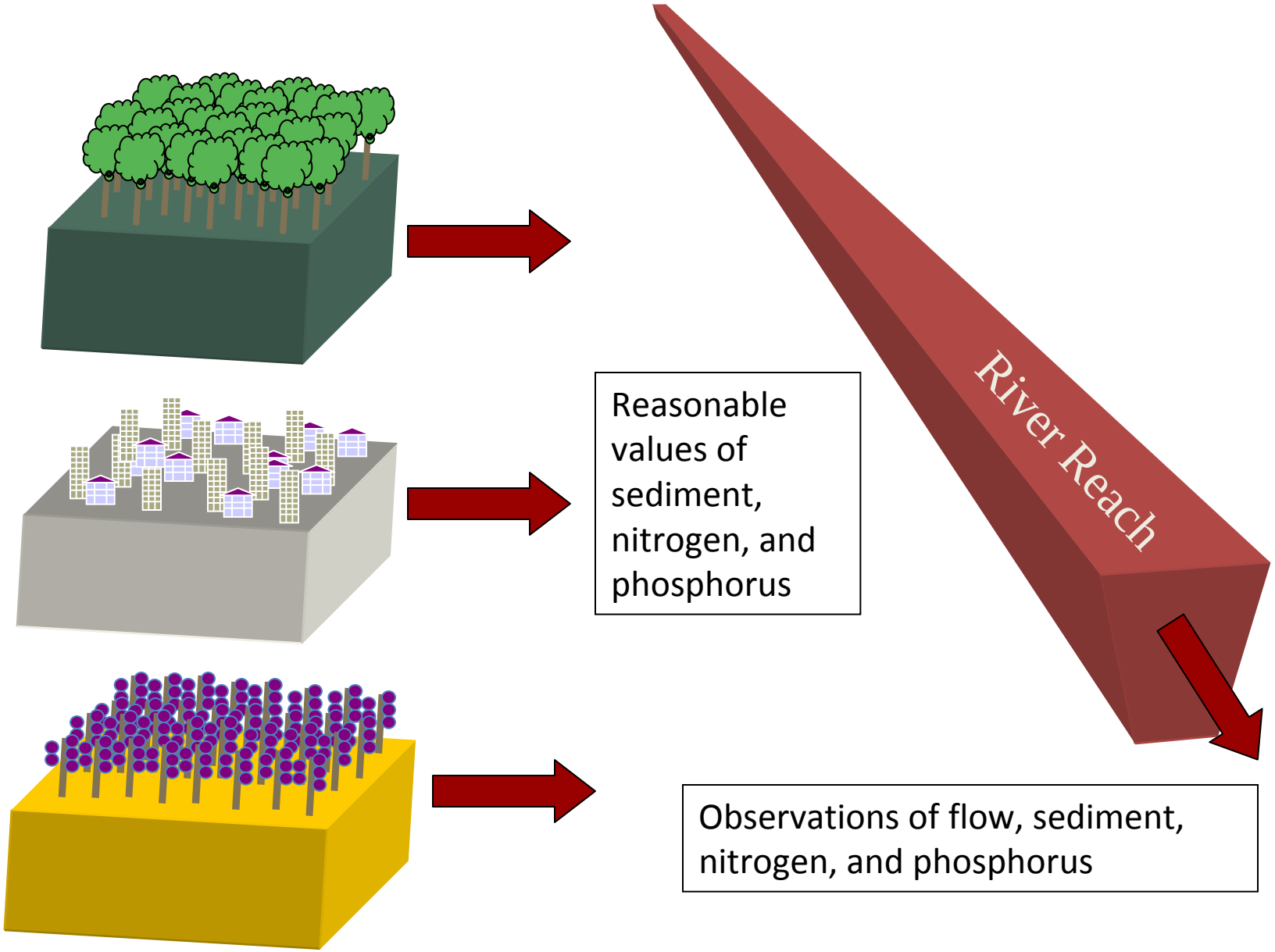
Deposition is Important in the spring and fall

Disturbance is Important in the summer

Specific Issues not addressed above

- Land use loading rates and Regional Factors
- Septic Systems
- CSO / SSO
- BMP flexibility

How do we calibrate?

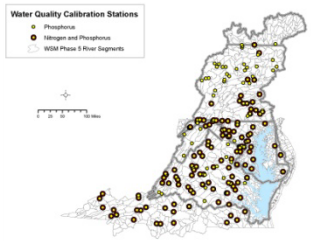


Land use Loads (a simplification)

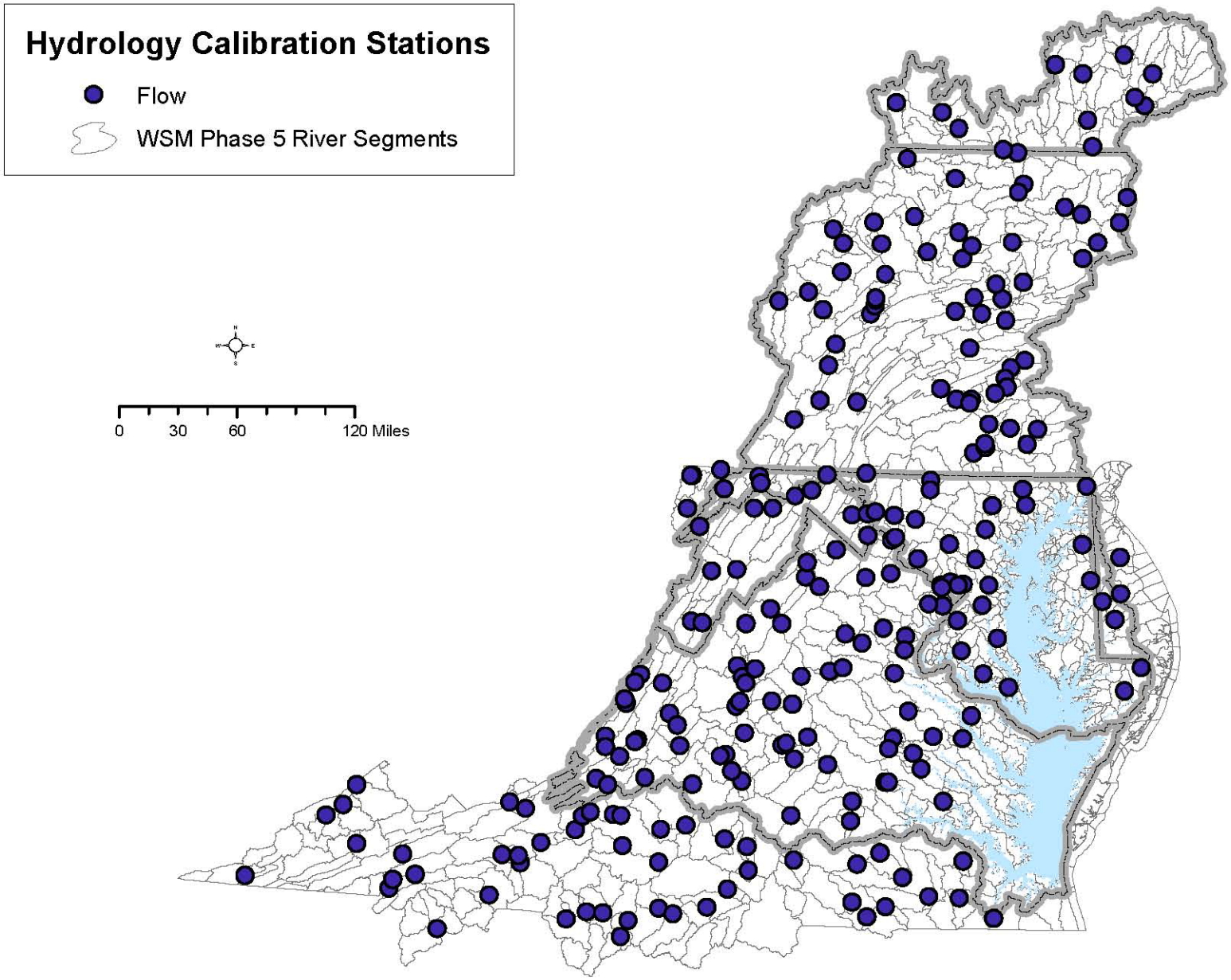
- Literature Surveys
- Additional Literature
- Other calibrated models
  - USGS Statistical Model
  - Earlier CBP WSMs

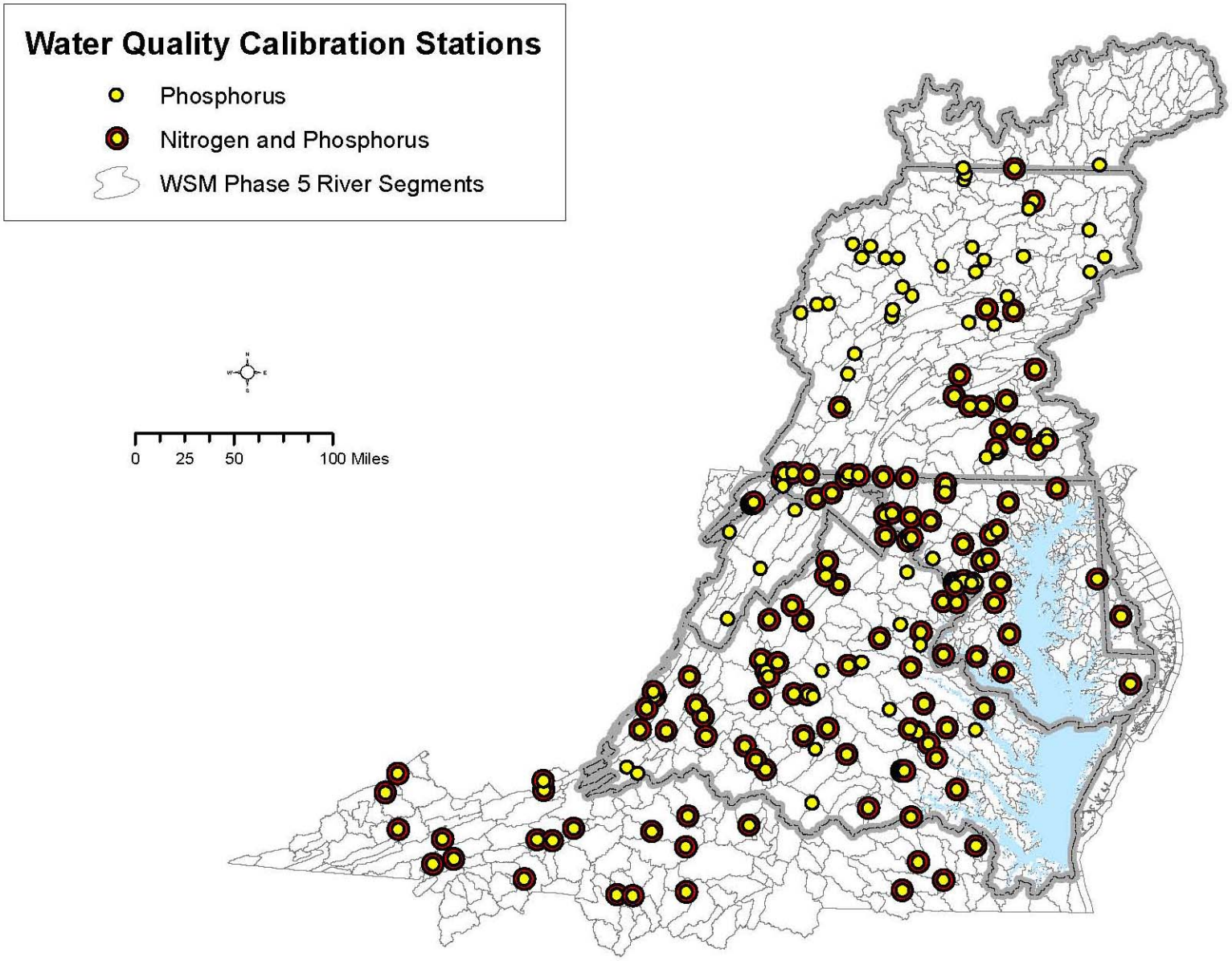
	N	P
• Forest	2	0.1
• Urban	10	1
• Ag	20	2

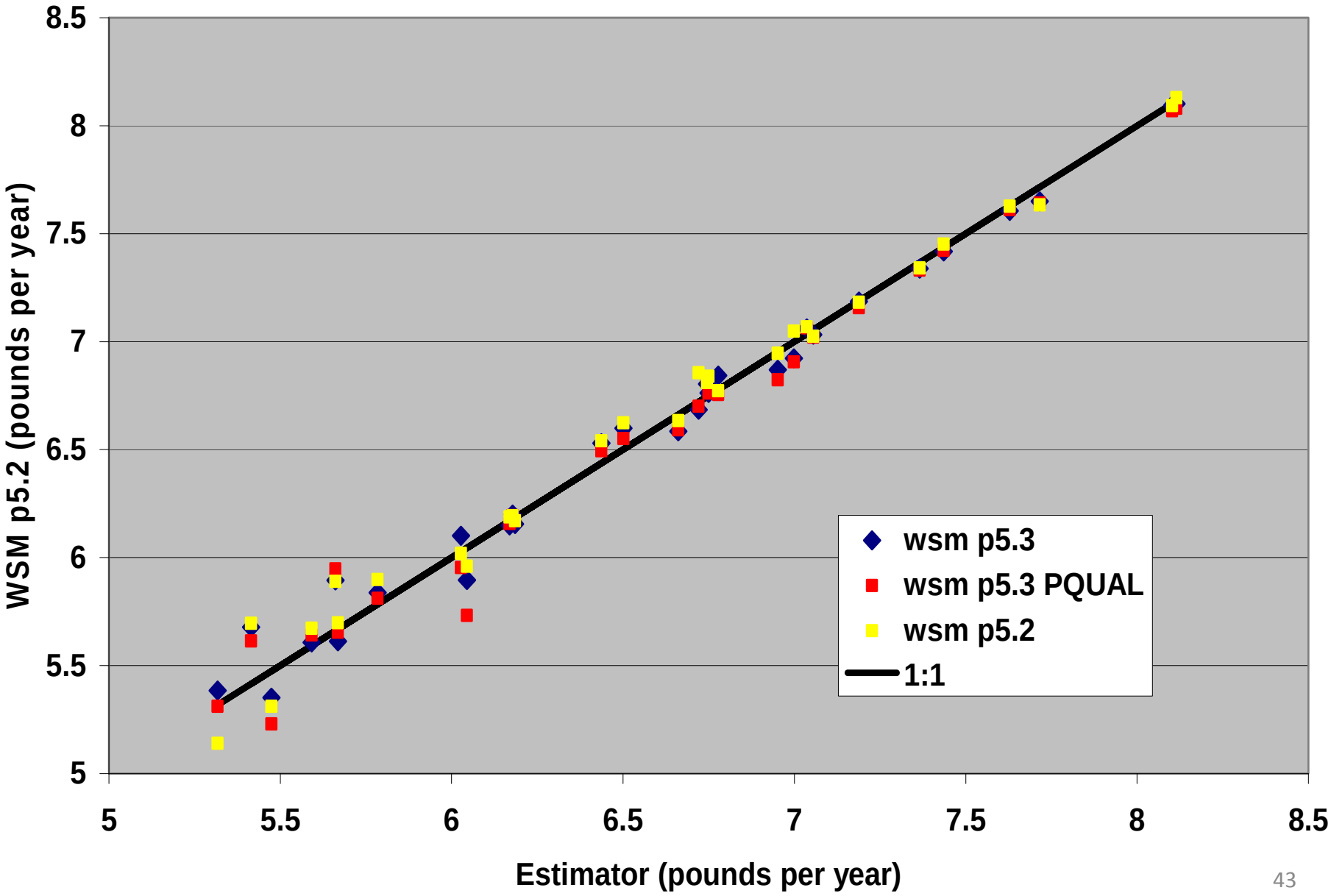
- Dependence on inputs
- More land use types



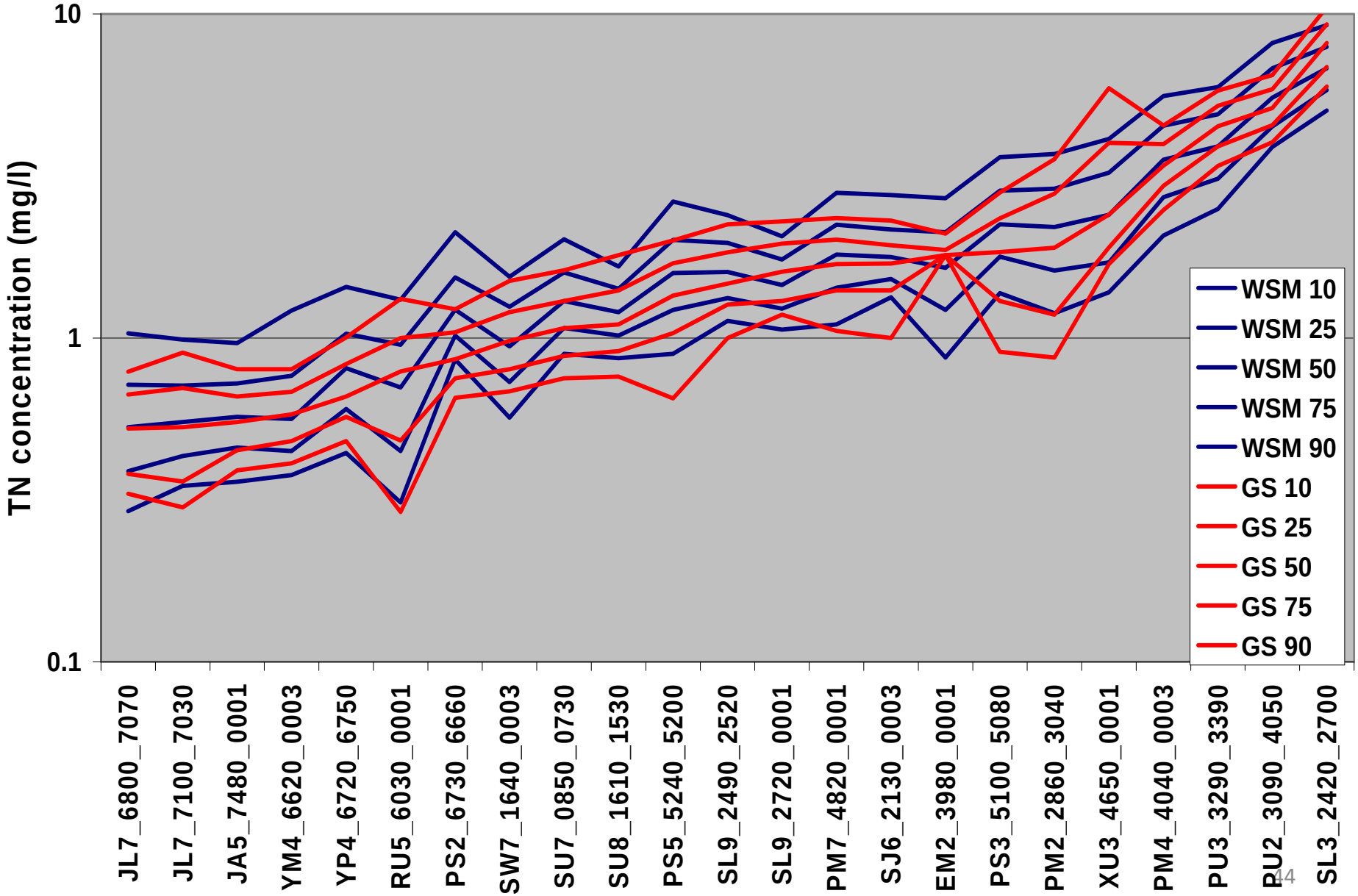
Edge-of-Stream Total Nitrogen (lb/a)	Mean	Median
forest, woodlots, and wooded	3.6	3.1
hay-unfertilized	6.8	6.2
nutrient management pasture	7.3	5.8
pasture	9.5	8.2
nutrient management hay	9.7	9.0
hay-fertilized	10.2	9.5
alfalfa	10.6	9.5
nutrient management alfalfa	10.9	11.6
high intensity impervious urban	11.8	9.9
low intensity impervious urban	11.9	10.4
high intensity pervious urban	12.8	10.9
low intensity pervious urban	13.2	11.2
extractive	14.0	13.1
harvested forest	24.3	21.4
bare-construction	29.5	26.4
nutrient management conservation till	37.1	39.6
conservation till receiving manures	38.1	39.6
nutrient management conventional till with manure	40.5	43.5
conventional till with manure	41.9	44.8
conventional till without manure	42.5	40.2
nutrient management conventional till without manure	42.9	42.4
degraded riparian pasture	52.4	45.9
nursery	286.7	253.8
animal feeding operations	1087.1	1045.7


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


Log of WSM and Estimator TN Loads
WSM p5.2 (pounds per year)
Estimator (pounds per year)
8.5
8
7.5
7
6.5
6
5.5
5
5
5.5
6
6.5
7
7.5
8
8.5
wsm p5.3
wsm p5.3 PQUAL
wsm p5.2
1:1

'Unbiased' USGS samples vs WSM Population TN p5.3



ftp://ftp.chesapeakebay.net/Modeling/P5Documentation/SECTION_10.pdf

Nitrogen Loading Rates*

*These Loading rates are Bay-wide averages with zero management practices (No BMPs) applied.

Edge-of-Stream Total Nitrogen (lb/a)	Mean	Median
forest, woodlots, and wooded	3.6	3.1
hay-unfertilized	6.8	6.2
nutrient management pasture	7.3	5.8
pasture	9.5	8.2
nutrient management hay	9.7	9.0
hay-fertilized	10.2	9.5
alfalfa	10.6	9.5
nutrient management alfalfa	10.9	11.6
high intensity impervious urban	11.8	9.9
low intensity impervious urban	11.9	10.4
high intensity pervious urban	12.8	10.9
low intensity pervious urban	13.2	11.2
extractive	14.0	13.1
harvested forest	24.3	21.4
bare-construction	29.5	26.4
nutrient management conservation till	37.1	39.6
conservation till receiving manures	38.1	39.6
nutrient management conventional till with manure	40.5	43.5
conventional till with manure	41.9	44.8
conventional till without manure	42.5	40.2
nutrient management conventional till without manure	42.9	42.4
degraded riparian pasture	52.4	45.9
nursery	286.7	253.8
animal feeding operations	1087.1	1045.7

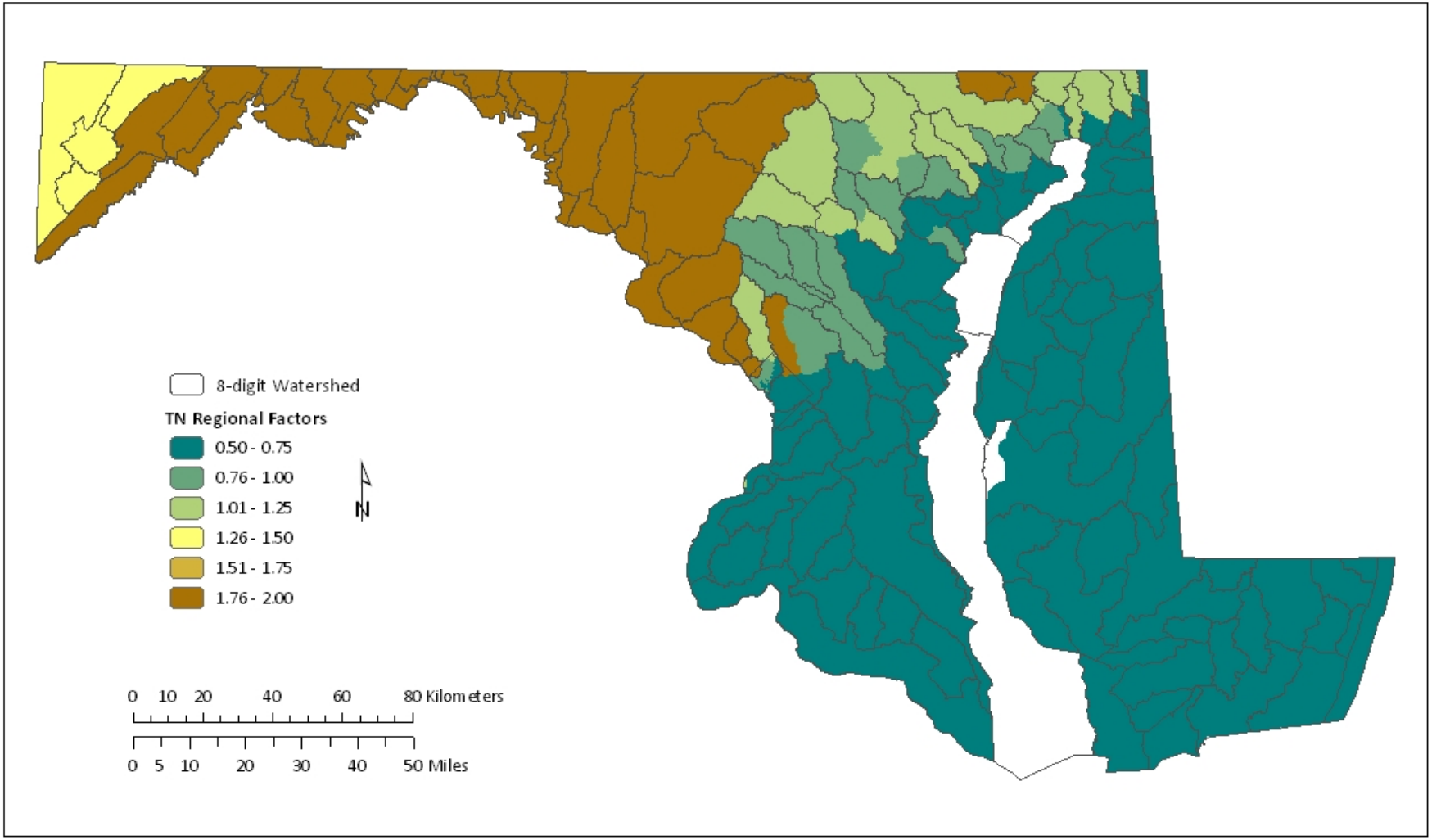
ftp://ftp.chesapeakebay.net/Modeling/P5Documentation/SECTION_10.pdf

Phosphorus Loading Rates*

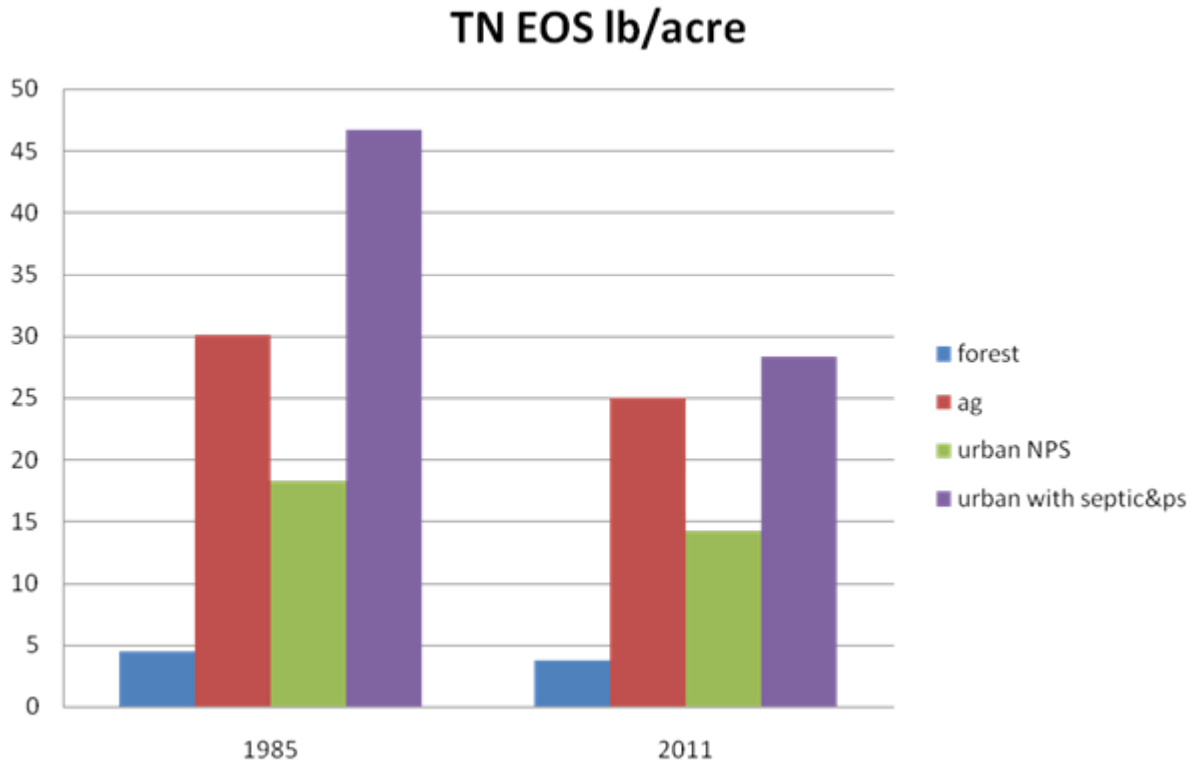
*These Loading rates are Bay-wide averages with zero management practices (No BMPs) applied.

Edge-of-Stream Total Phosphorus (lb/a)	Mean	Median
hay-unfertilized	0.03	0.03
hay-fertilized	0.06	0.05
forest, woodlots, and wooded	0.14	0.13
nutrient management hay	0.16	0.15
nutrient management alfalfa	0.82	0.83
high intensity pervious urban	0.88	0.89
low intensity pervious urban	0.90	0.90
alfalfa	0.92	0.87
nutrient management pasture	0.94	0.83
pasture	0.99	0.92
harvested forest	1.14	1.02
nutrient management conservation till	1.88	1.56
conservation till with manures	2.00	1.73
nutrient management conventional till with manures	2.39	1.98
conventional till with manures	2.51	2.05
high intensity impervious urban	2.62	2.49
low intensity impervious urban	2.63	2.50
nutrient management high till without manures	3.07	2.92
conventional till without manures	3.09	3.08
extractive	4.83	4.42
bare-construction	9.67	8.81
degraded riparian pasture	11.77	10.97
animal feeding operations	59.97	56.45
nursery	118.51	111.98

P532 TN Regional Factors In MD



Land use Loads - Nitrogen

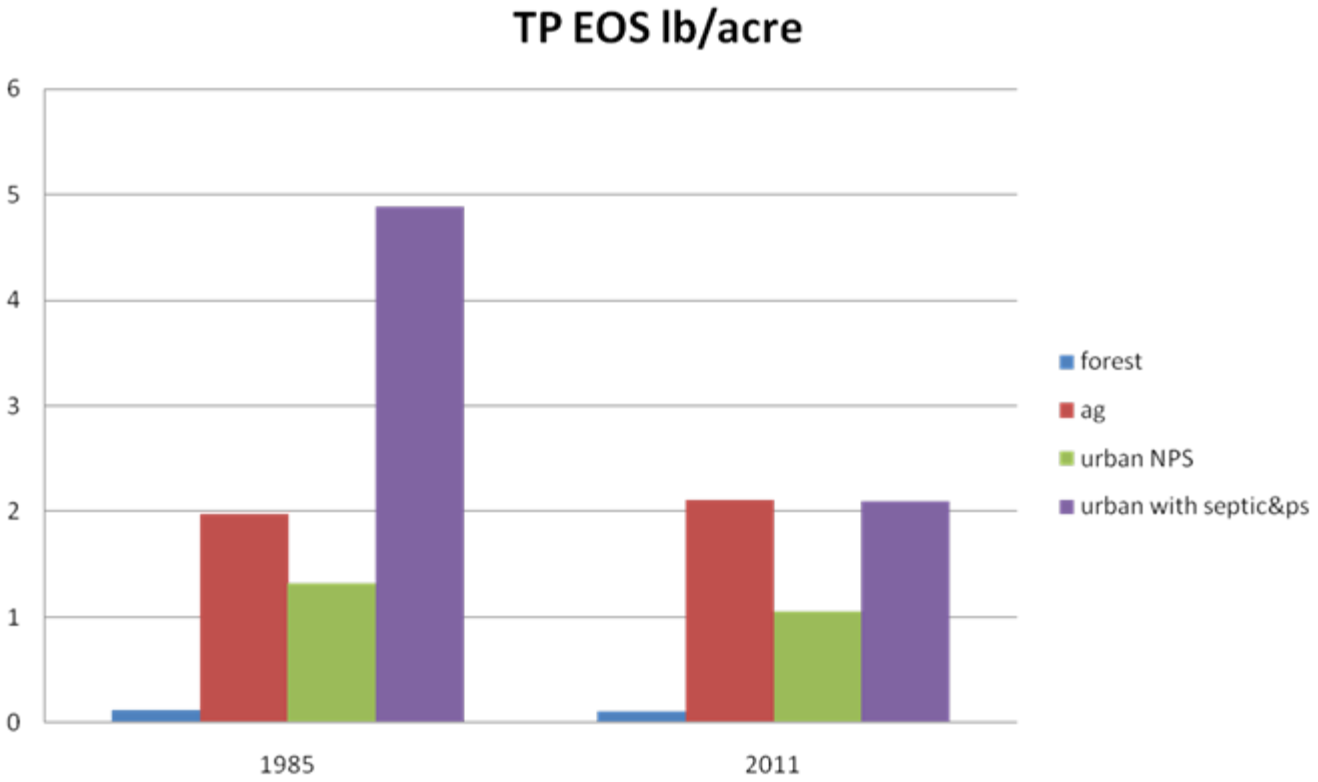


Source: Phase 5.3.2 Watershed model

Originally based on:

Literature Surveys
Additional Primary Literature
USGS Statistical Model (Sparrow)

Land use Loads - Phosphorus



Source: Phase 5.3.2 Watershed model

Originally based on:

Literature Surveys
Additional Primary Literature
USGS Statistical Model (Sparrow)

Estimating Population on Sewer and On-site Septic Systems Phase 5.3.2

# of Septic Systems in 2010 =

(Total Housing Units – Total Housing Units in Sewer Service Areas)

* (ratio of Total Households to Total Housing Units)

* (ratio of Single-detached to Total Housing Units)

# of Septic Systems in 2020 =

(# of Septic Systems in 2010)

\+ ((Change in Total Housing Units 2010 – 2020)

* (potential growth† on sewer))

* (ratio of Total Households to Total Housing Units)

* (ratio of Single-detached to Total Housing Units)

† **Potential growth on sewer considers:**

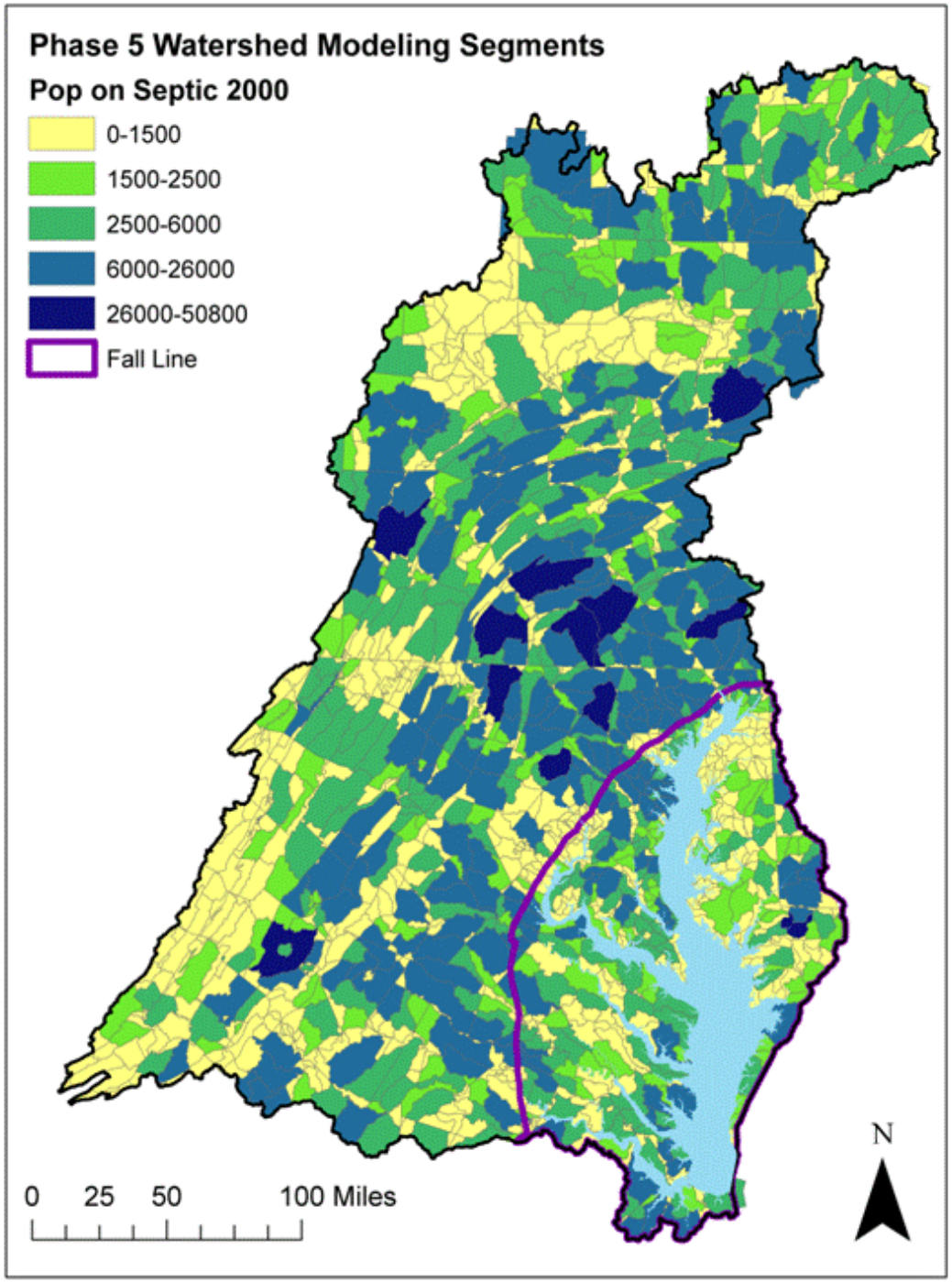
proportion of historical growth (1984 – 2006) on sewer

proportion of change in total housing units on sewer (2000 – 2010)

proportion of remaining land available for development within sewer service area

Septic Nitrogen Pass-Through Rate

State	Pass-Through Rate	2011_# Systems
DE	40%	21,735
DC	40%	-
MD	30%	241,893
MD	50%	159,783
MD	80%	48,630
NY	40%	96,810
PA	40%	526,721
VA	40%	535,351
WV	40%	62,695


Phase 5 Watershed Modeling Segments
Pop on Septic 2000
0-1500
1500-2500
2500-6000
6000-26000
26000-50800
Fall Line
0 25 50 100 Miles
N

Wastewater and Septic
Phase 5.3.2 vs. Phase 6

Phase 5.3.2

- Population on sewer
- Households on septic

Phase 6

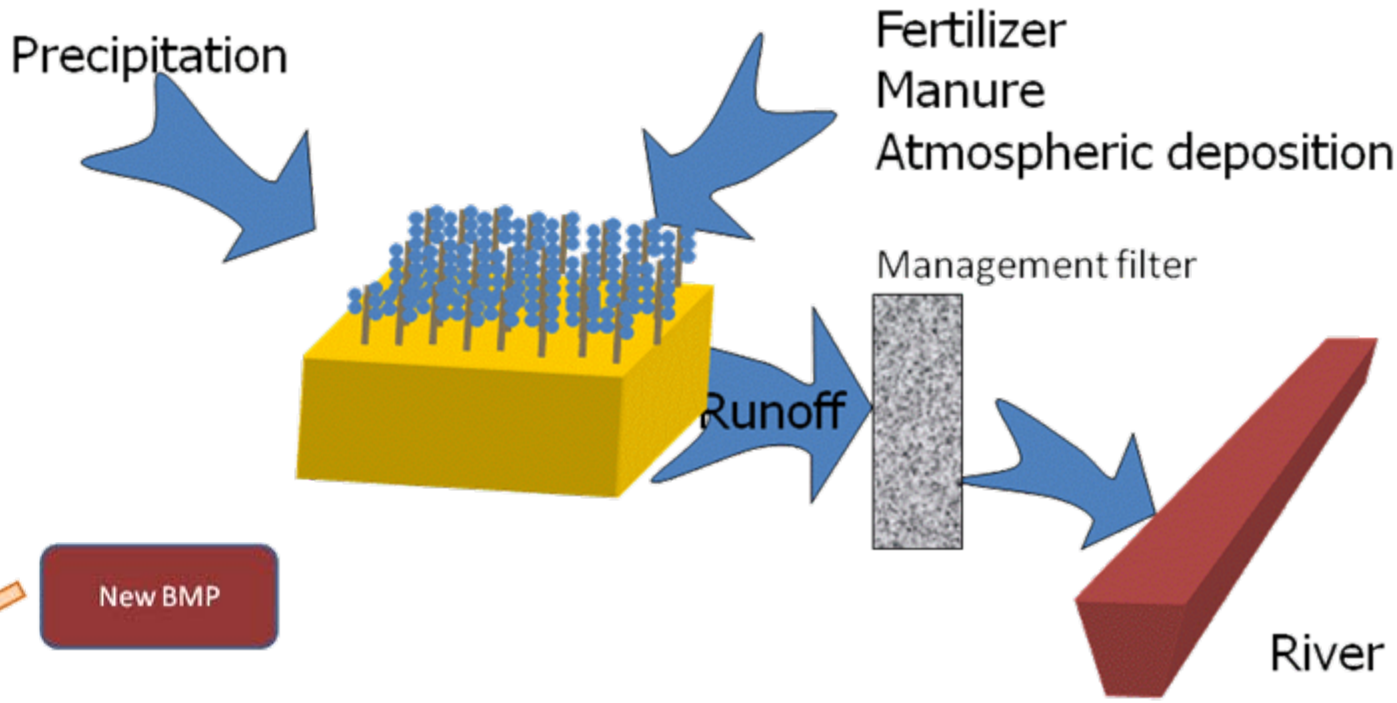
- Population on sewer
  - Improve maps of areas served by sewer and relate areas to individual plants and their efficiencies;
  - Forecast growth on sewer using Chesapeake Bay Land Change Model v3.

- Households on septic
  - Distinguish different types of systems: commercial/retail, mass drain fields, shallow drain fields, failing systems, and direct discharges;
  - Adjust soil attenuation rates based on distance to waterways (1:24K or 1:100K streams);
  - Forecast growth on septic using Chesapeake Bay Land Change Model v3.

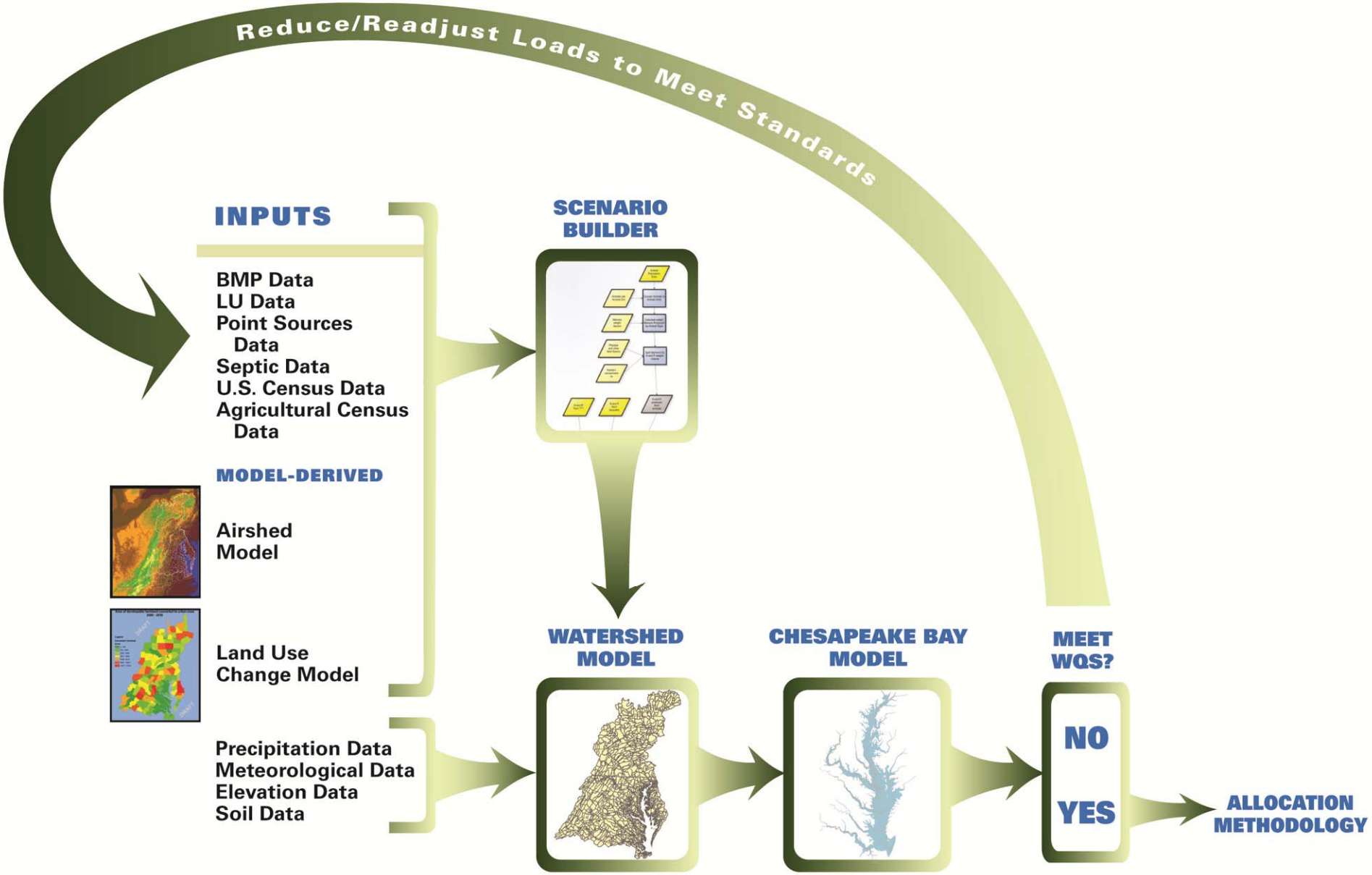
CSO / SSO

- Combined Sewer area loads are picked up through WWTP and CSO loads.
  - Implementation of BMPs within CS watershed have no effect
  - Implementation of CS disconnect and capacity increase have an effect
- Sanitary Sewer Overflows are not currently counted in the watershed model

BMP Flexibility



Questions?


Reduce/Readjust Loads to Meet Standards
INPUTS
BMP Data
LU Data
Point Sources Data
Septic Data
U.S. Census Data
Agricultural Census Data
MODEL-DERIVED
Airshed Model
Land Use Change Model
Precipitation Data
Meteorological Data
Elevation Data
Soil Data
SCENARIO BUILDER
WATERSHED MODEL
CHESAPEAKE BAY MODEL
MEET WQS?
NO
YES
ALLOCATION METHODOLOGY