Chesapeake Bay Program Watershed Modeling

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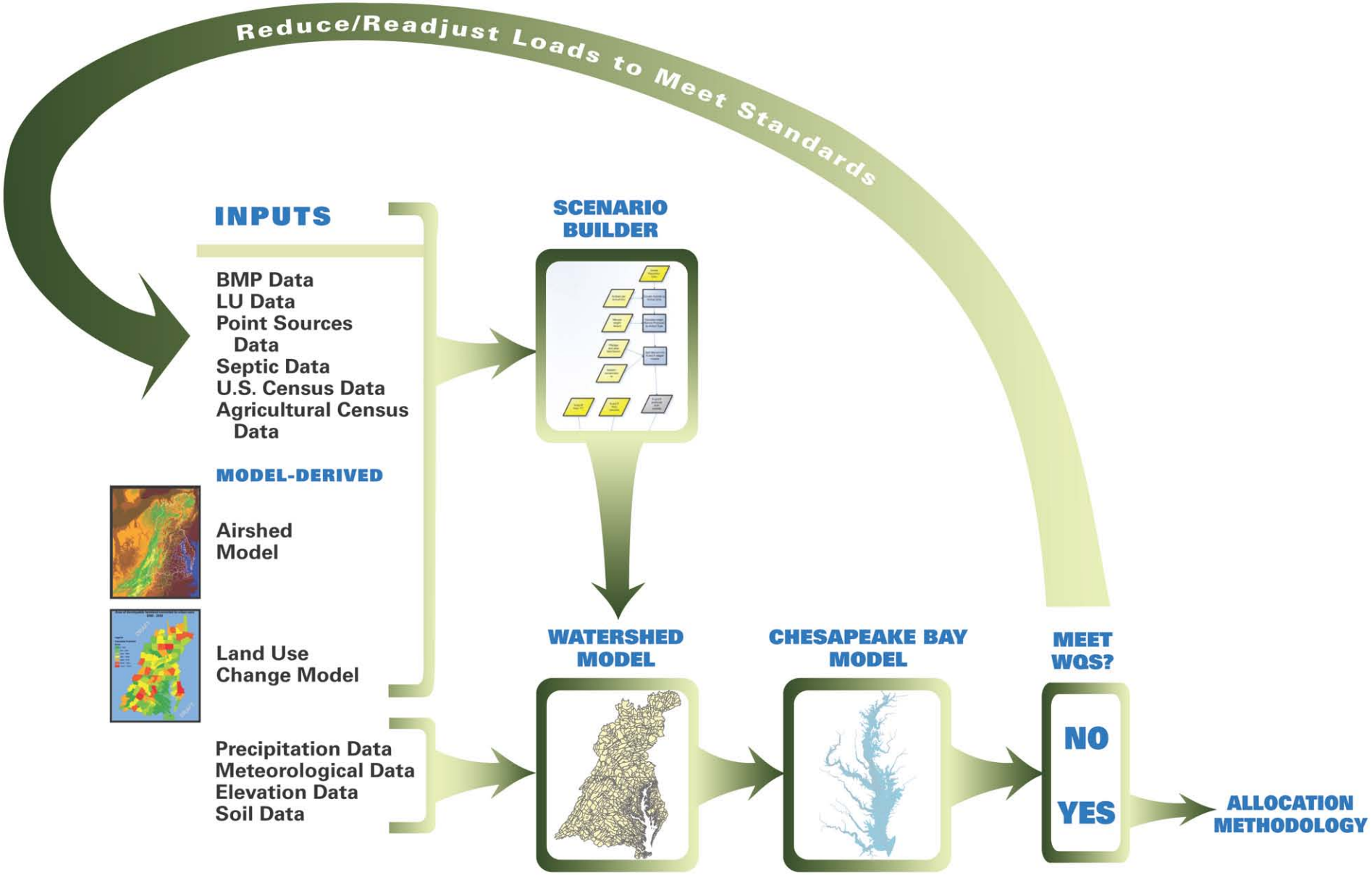
Presentation to STAC

3/22/2011

Chesapeake Bay Partnership Models



Recent History of the Chesapeake Bay Program's Watershed Model

- Phase 4.3 – (2002 – 2010) - C2K
- Phase 5.3.0 – (2010) – TMDL
  - Segmentation Input data
  - Calibration Functionality
  - Accessability
- Phase 5.3.2 – (2011-2017) – WIP2
  - Land use
  - Nutrient Management

Watershed Model Supervision

- Water Quality Goal Implementation Team
  - Watershed Technical Workgroup
  - Agriculture Workgroup
  - Urban Stormwater Workgroup
  - Forestry Workgroup
  - Sediment Workgroup
- Modeling Workgroup (STAR)
- PSC

STAC involvement in WSM

- Formal review in 2005 and 2008 of watershed model
- Workshops in the past 10 years
  - Modeling in the CBP: 2010 and beyond
  - Pasture Management
  - Atmospheric Deposition
  - Wetlands
  - Fertilizer Sales Data
  - Shoreline Modification
  - Innovative Ag BMPs

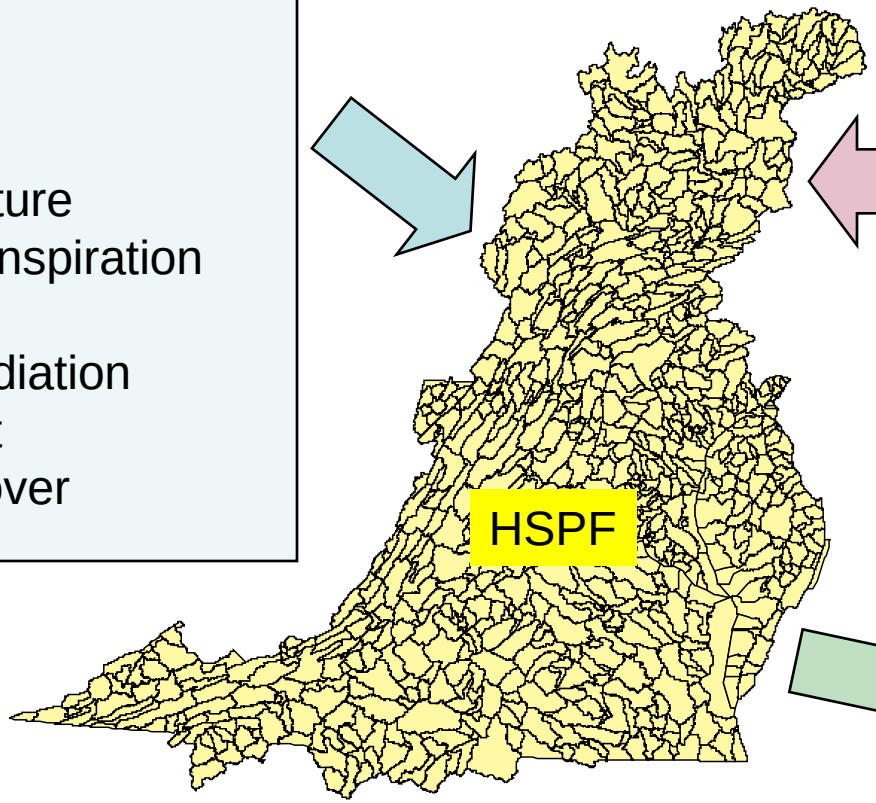
How the Watershed Model Works

Hourly Values:

Rainfall
Snowfall
Temperature
Evapotranspiration
Wind
Solar Radiation
Dewpoint
Cloud Cover

Annual or Monthly:

Land Use Acreage
BMPs
Fertilizer
Manure
Atmospheric Deposition
Point Sources
Septic Loads

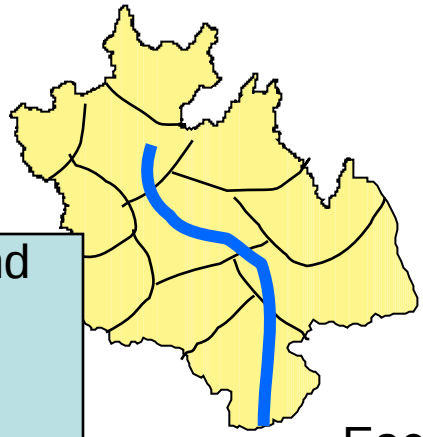


Daily output compared
To observations

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

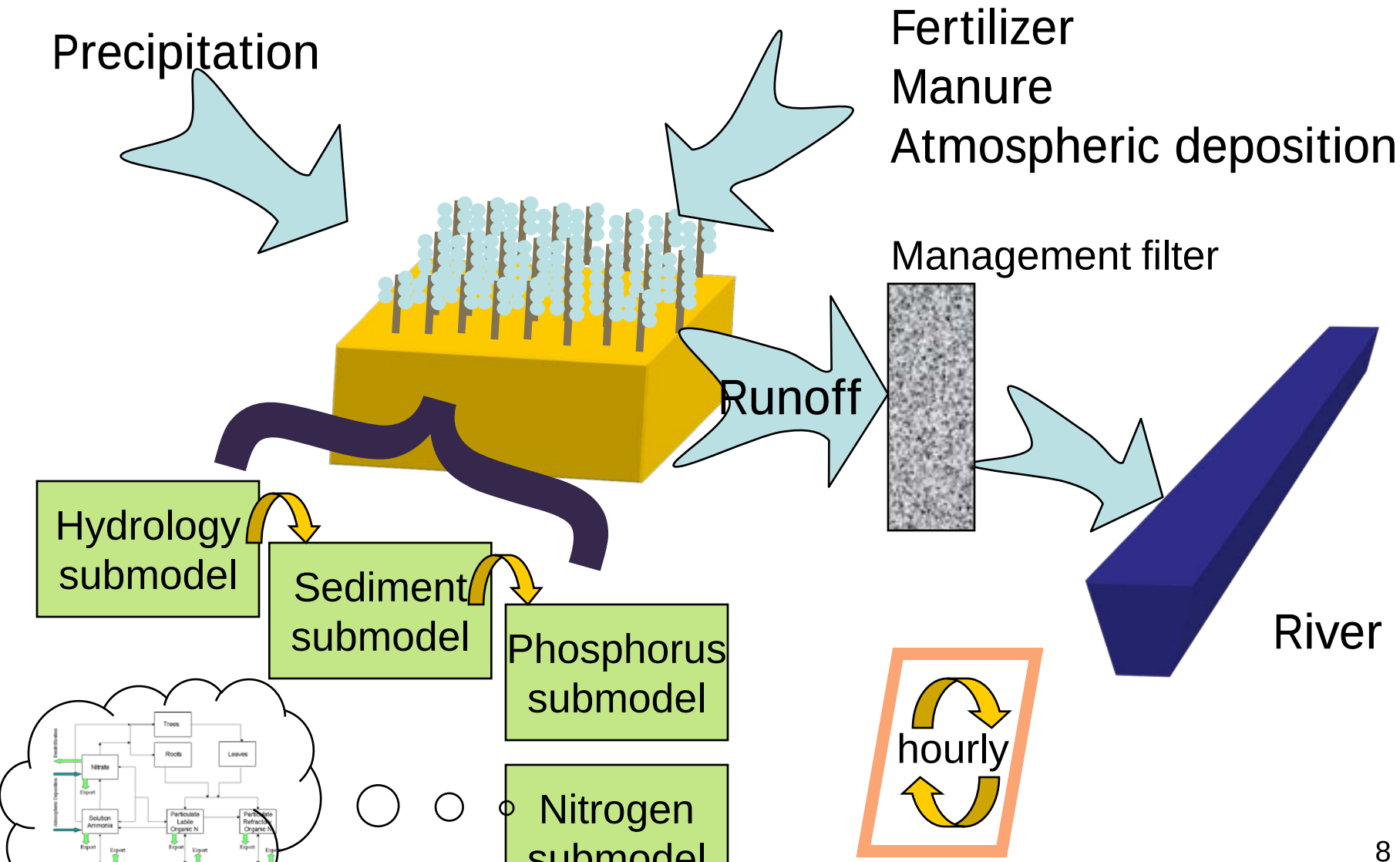


- Corn/Soy/Wheat rotation (high till)
- Corn/Soy/Wheat rotation (low till)
- Other Row Crops
- Alfalfa
- Nursery
- Pasture
- Degraded Riparian Pasture
- Afo / Cafo
- Fertilized Hay
- Unfertilized Hay
  - Nutrient management versions of the above

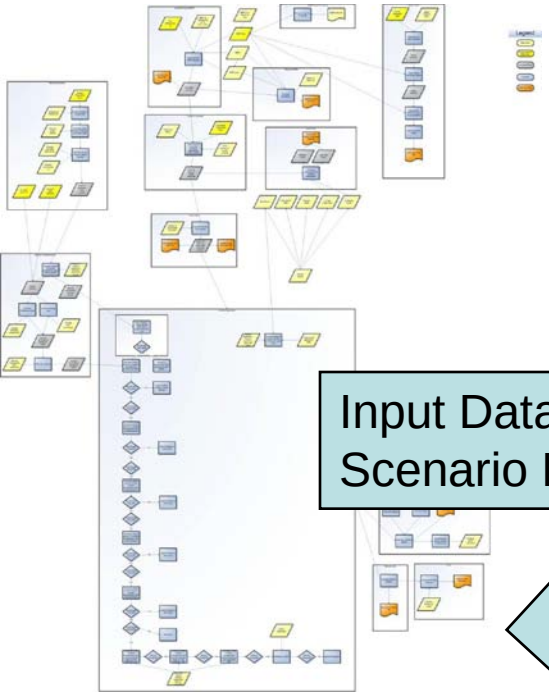
Plus: Point Source and Septic Loads, and Atmospheric Deposition Loads

Each calibrated to nutrient and Sediment targets

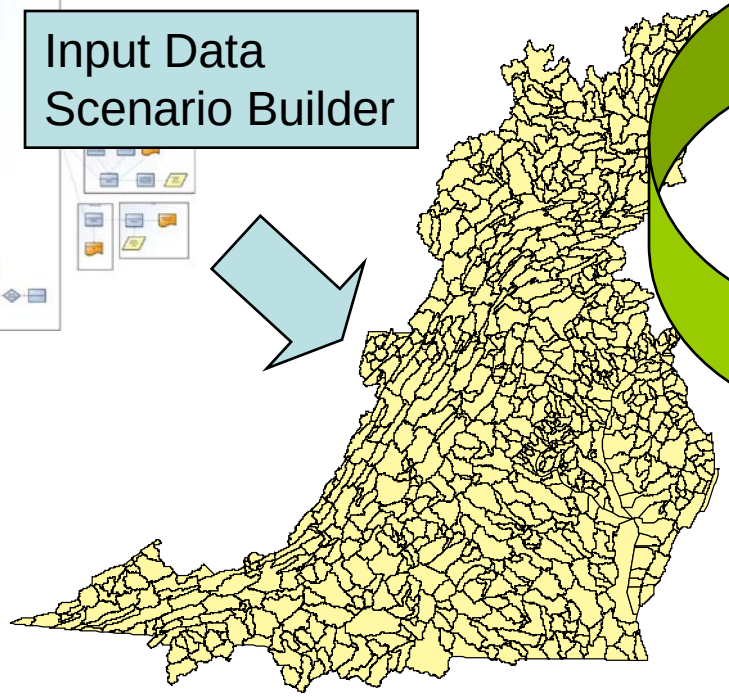
How the Watershed Model Works



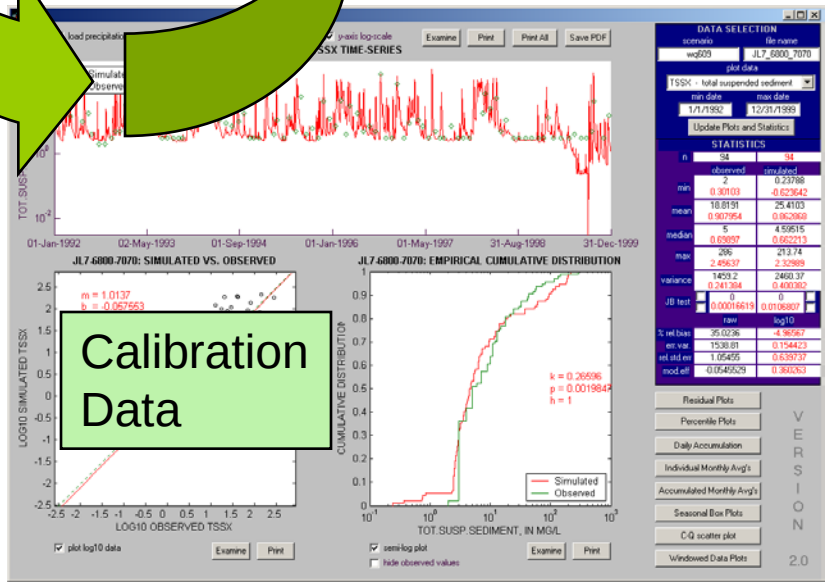
Automated Calibration



Input Data
Scenario Builder



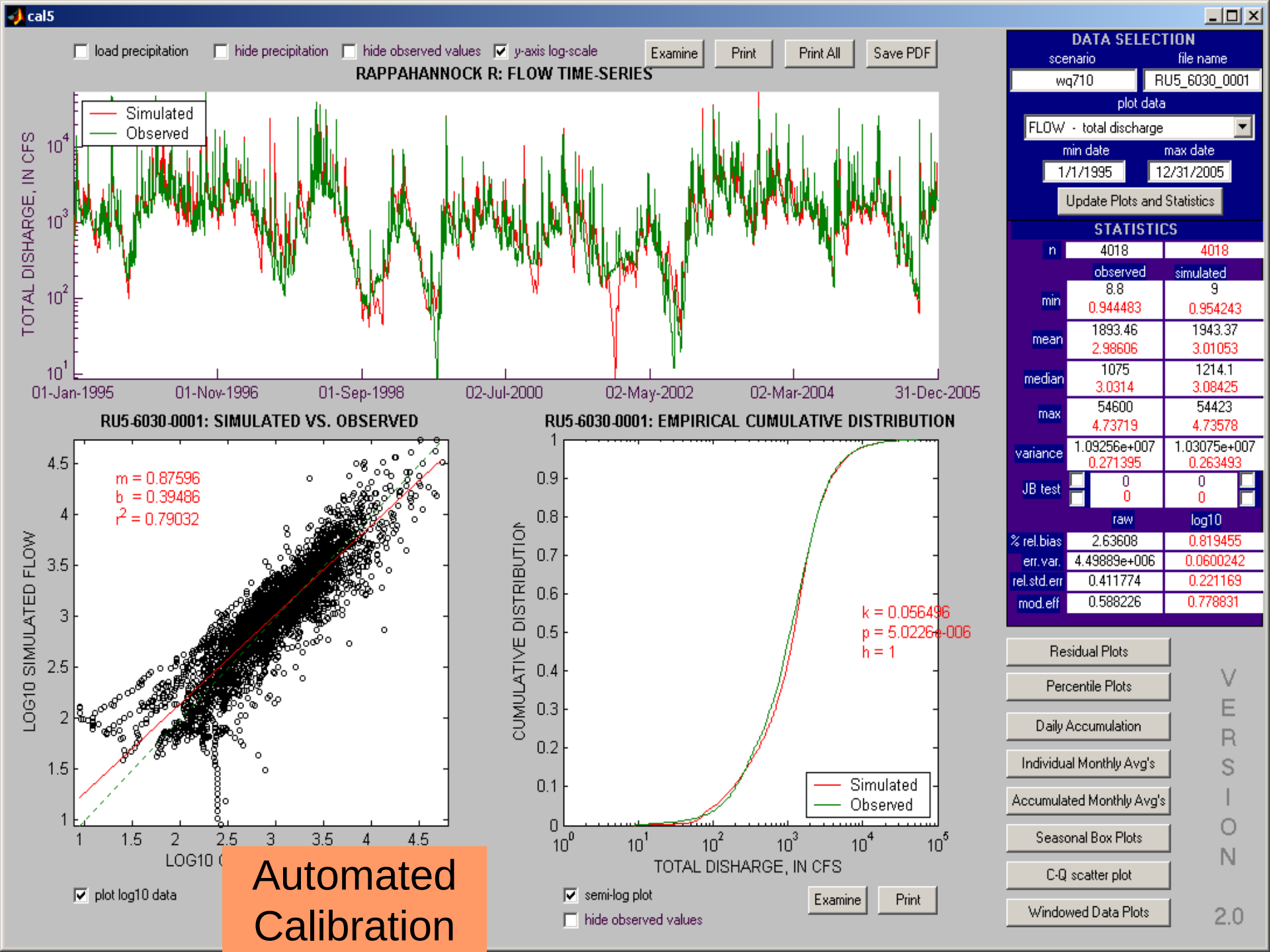
Calibration
Procedures

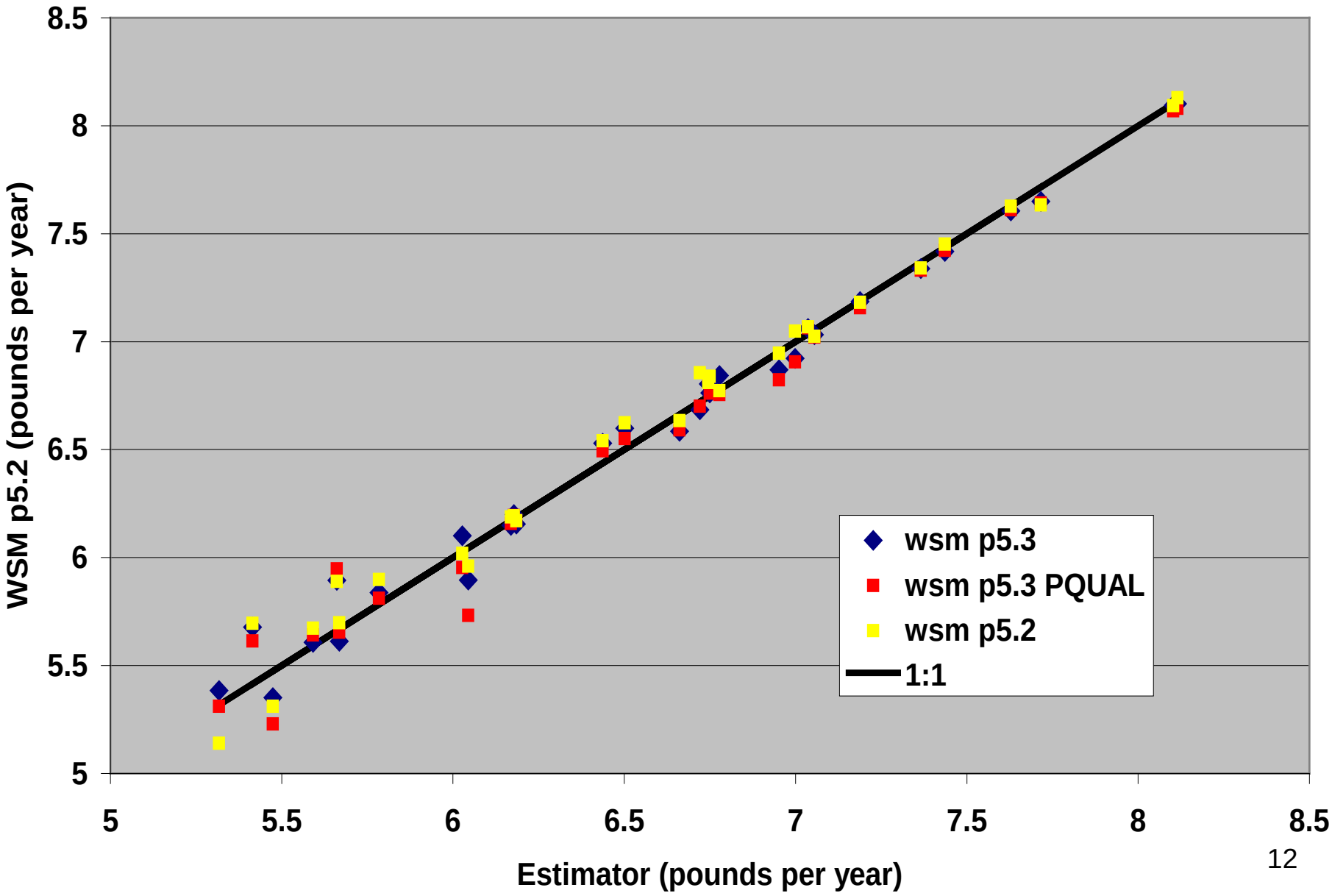


Calibration
Data

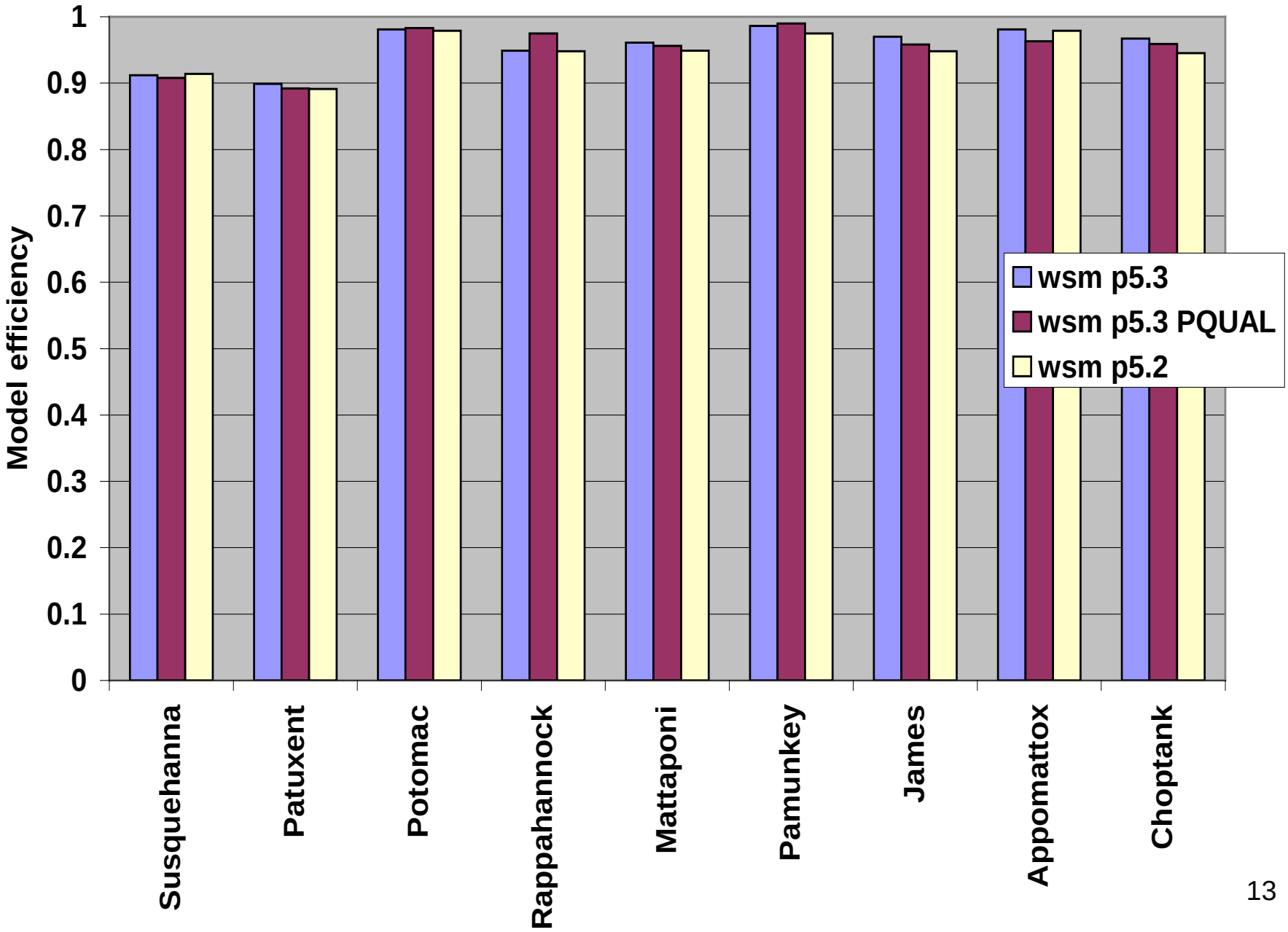
Calibration Strategy

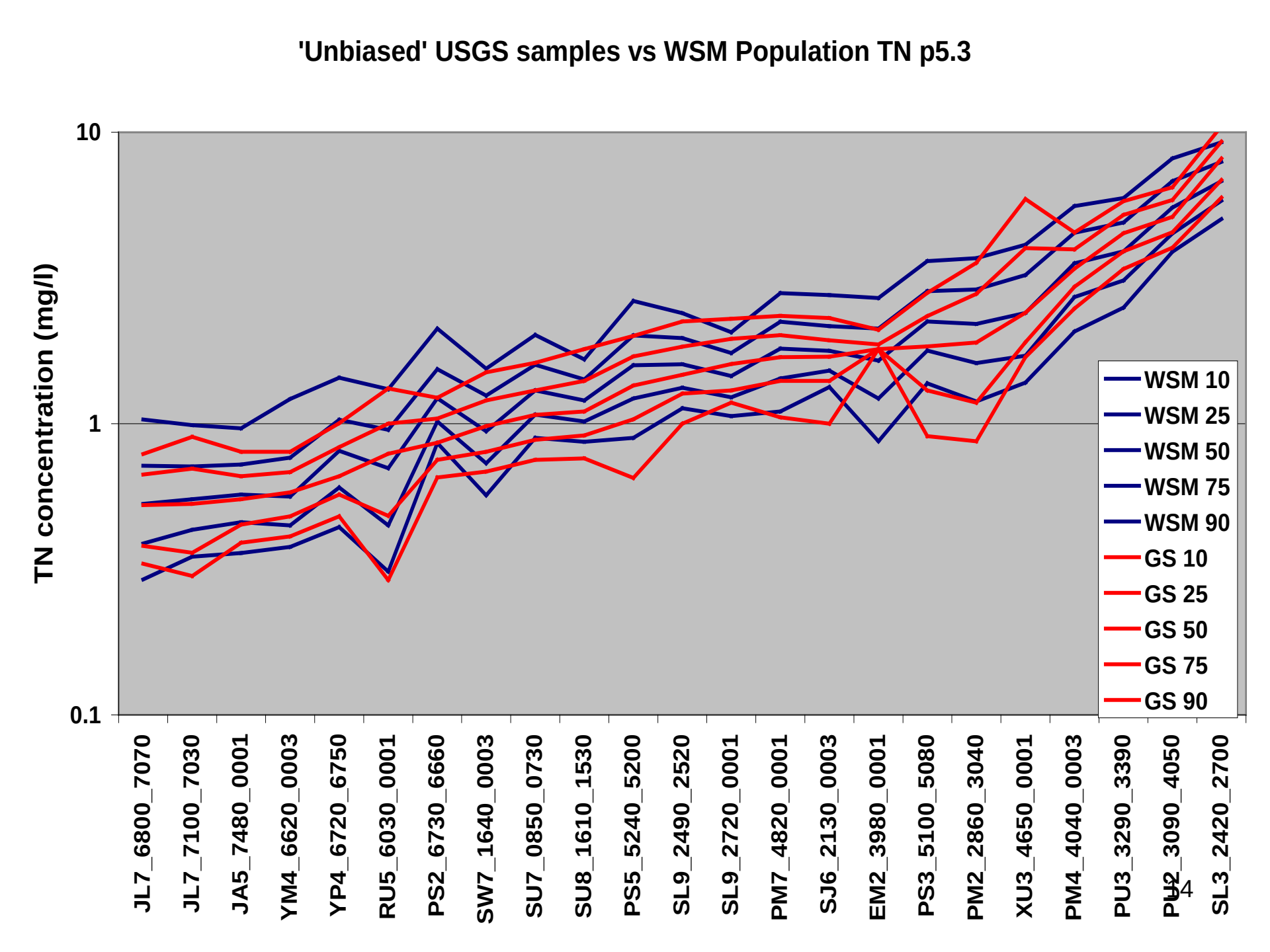
- Match observations in rivers
- Match properties and trends
  - Groundwater recession curve
  - Crop uptake of Nitrogen
- Match literature and other models
  - Reasonable rates of nutrient export
  - USGS estimator and sparrow empirical models

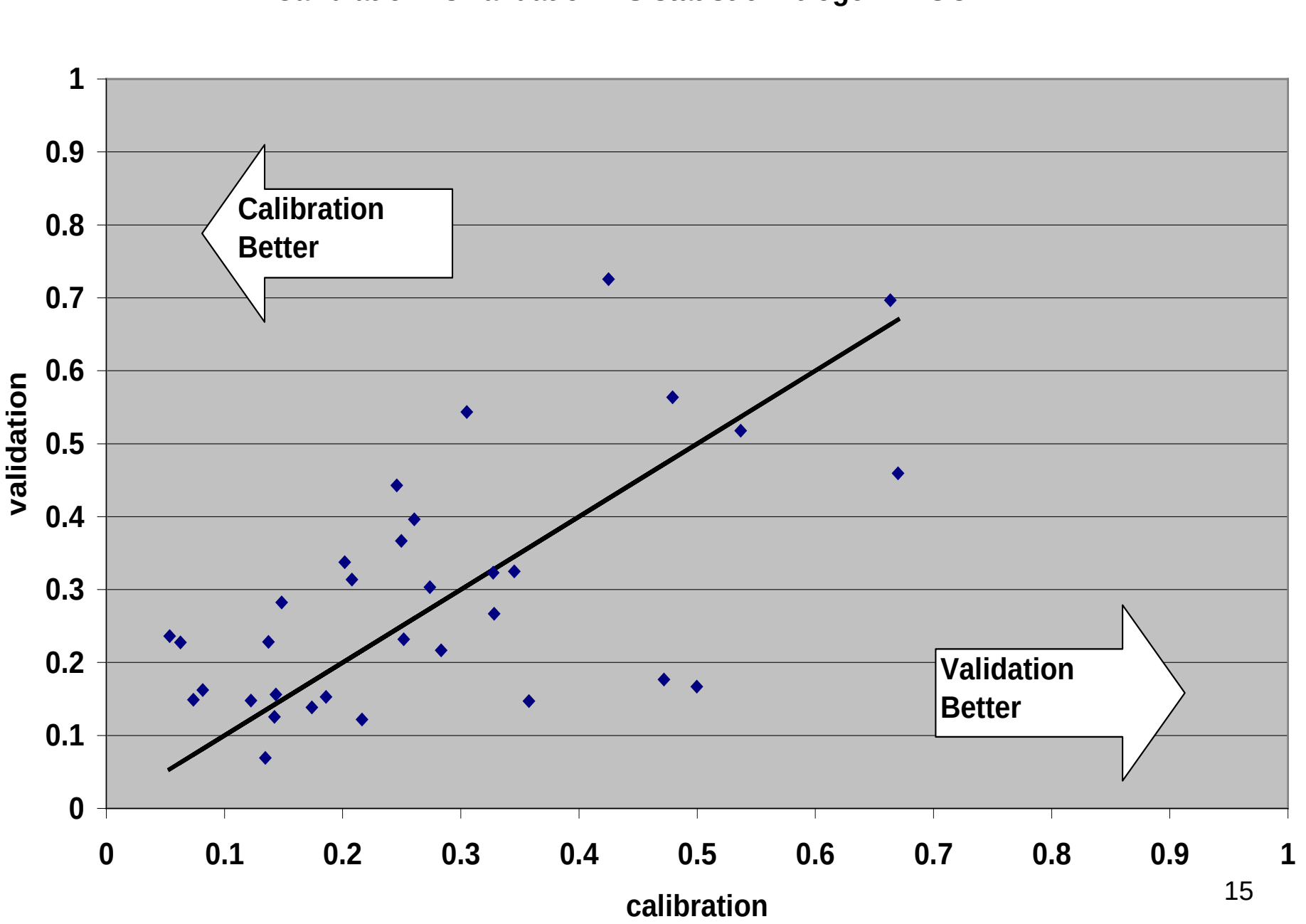

cal5
load precipitation
hide precipitation
hide observed values
y-axis log-scale
Examine
Print
Print All
Save PDF
RAPPAHANNOCK R: FLOW TIME-SERIES
Simulated
Observed
TOTAL DISHARGE, IN CFS
01-Jan-1995
01-Nov-1996
01-Sep-1998
02-Jul-2000
02-May-2002
02-Mar-2004
31-Dec-2005
RU5-6030-0001: SIMULATED VS. OBSERVED
m = 0.87596
b = 0.39486
r2 = 0.79032
LOG10 SIMULATED FLOW
plot log10 data
RU5-6030-0001: EMPIRICAL CUMULATIVE DISTRIBUTION
CUMULATIVE DISTRIBUTION
k = 0.056496
p = 5.0226e-006
h = 1
TOTAL DISHARGE, IN CFS
semi-log plot
hide observed values
DATA SELECTION
scenario
wq710
file name
RU5_6030_0001
plot data
FLOW - total discharge
min date
1/1/1995
max date
12/31/2005
Update Plots and Statistics
STATISTICS
n 4018 4018
observed simulated
min 8.8 9
0.944483 0.954243
mean 1893.46 1943.37
2.98606 3.01053
median 1075 1214.1
3.0314 3.08425
max 54600 54423
4.73719 4.73578
variance 1.09256e+007 1.03075e+007
0.271395 0.263493
JB test 0 0
0 0
raw log10
% rel.bias 2.63608 0.819455
err.var. 4.49889e+006 0.0600242
rel.std.err 0.411774 0.221169
mod.eff 0.588226 0.778831
Residual Plots
Percentile Plots
Daily Accumulation
Individual Monthly Avg's
Accumulated Monthly Avg's
Seasonal Box Plots
C-Q scatter plot
Windowed Data Plots
VERSION 2.0
Automated Calibration


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

Correlation of Fall Line Stations vs Estimator Annual Loads TN




'Unbiased' USGS samples vs WSM Population TN p5.3
TN concentration (mg/l)
10
1
0.1
WSM 10
WSM 25
WSM 50
WSM 75
WSM 90
GS 10
GS 25
GS 50
GS 75
GS 90
JL7_6800_7070
JL7_7100_7030
JA5_7480_0001
YM4_6620_0003
YP4_6720_6750
RU5_6030_0001
PS2_6730_6660
SW7_1640_0003
SU7_0850_0730
SU8_1610_1530
PS5_5240_5200
SL9_2490_2520
SL9_2720_0001
PM7_4820_0001
SJ6_2130_0003
EM2_3980_0001
PS3_5100_5080
PM2_2860_3040
XU3_4650_0001
PM4_4040_0003
PU3_3290_3390
PU2_3090_4050
SL3_2420_2700


Calibration vs validation KS statistic Nitrogen - AGCHEM
validation
calibration
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Calibration
Better
Validation
Better

Quick Overview of Watershed Model Scenarios

Hourly output is summed over 10 years of hydrology to compare against other management scenarios

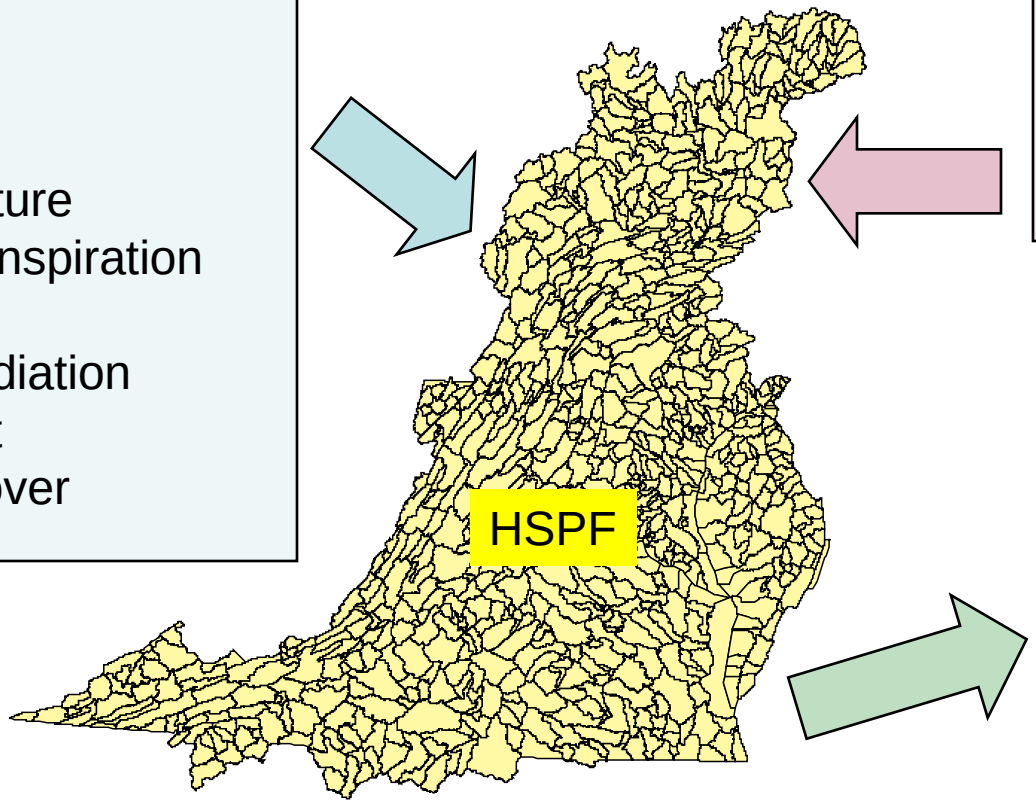
Scenario Builder

Snapshot:

Land Use Acreage
BMPs
Fertilizer
Manure
Atmospheric Deposition
Point Sources
Septic Loads

Hourly Values:

Rainfall
Snowfall
Temperature
Evapotranspiration
Wind
Solar Radiation
Dewpoint
Cloud Cover



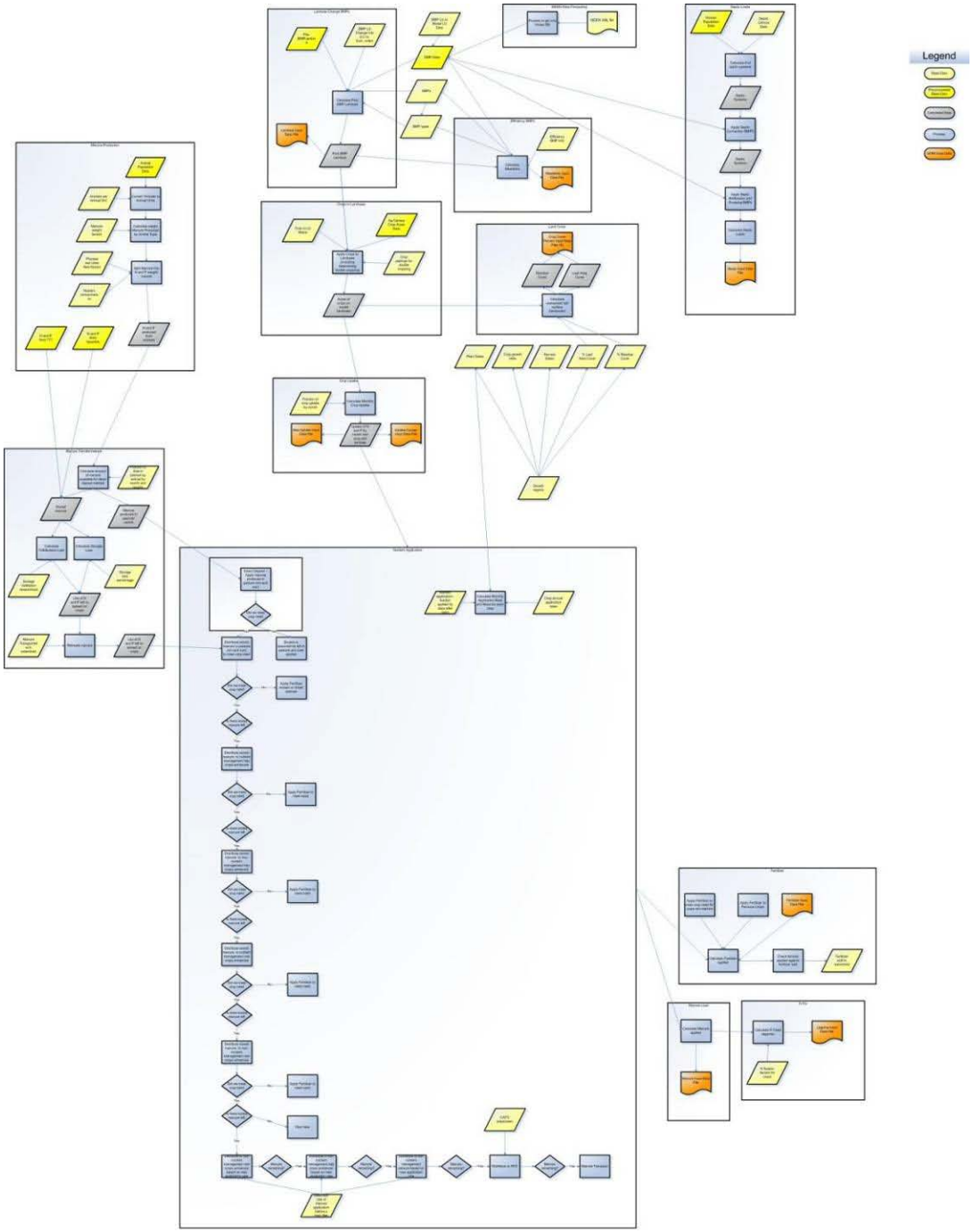
1991-2000

"Average Annual Flow-Adjusted Loads"

Number of Scenarios

- Mid 1980s – 0
- Early 1990s – phase 2 – fewer than 10
- Late 1990s phase 4.1 – 37
- Early 2000s – phase 4.3 – 400-500
- 2009-2010 – phase 5.3.0 more than 300
- 2011 - 2017 - phase 5.3.2 - ?????

Scenario Builder

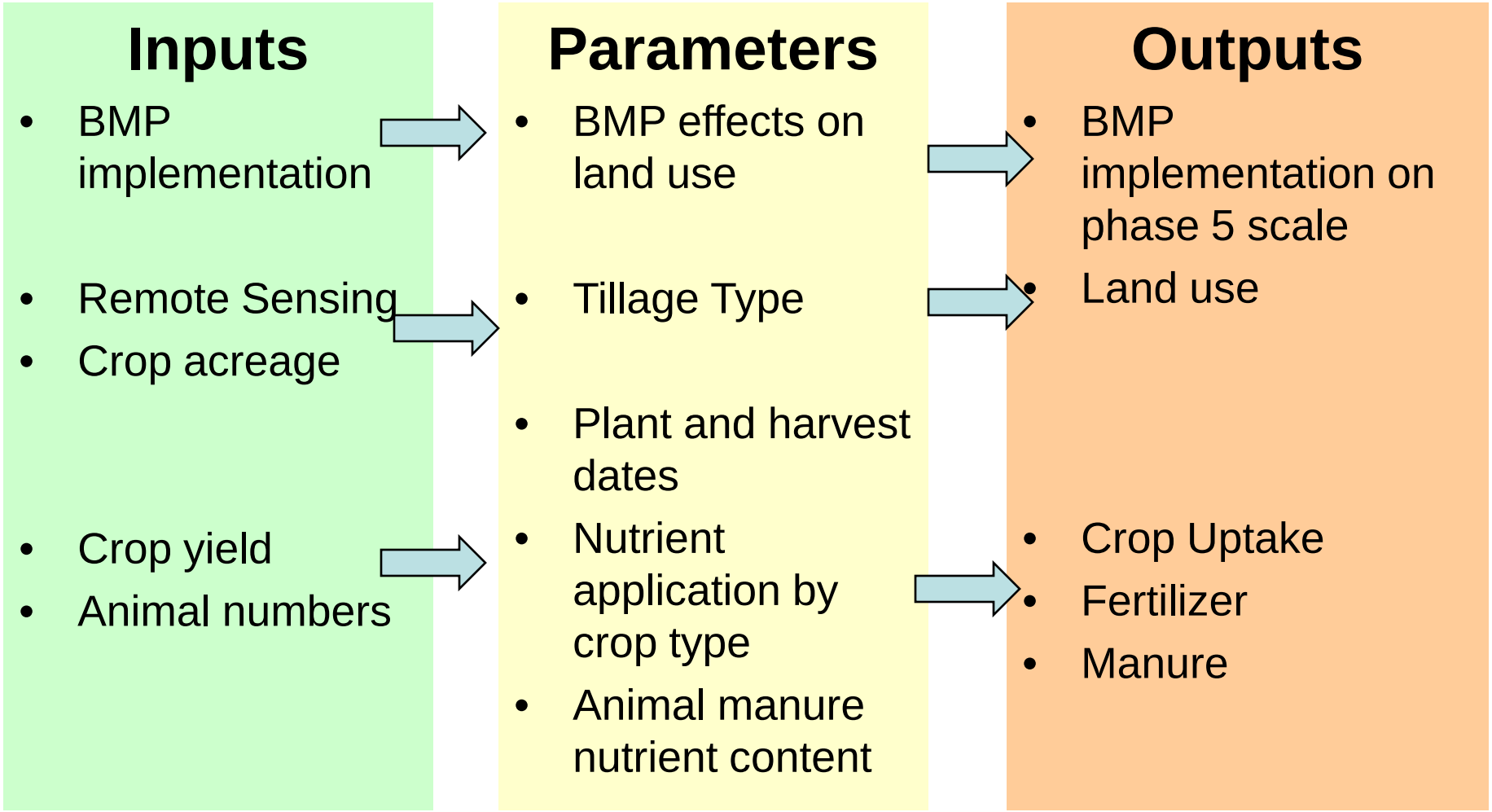


Input processor for the watershed model

Generates past, present, or future state of the watershed

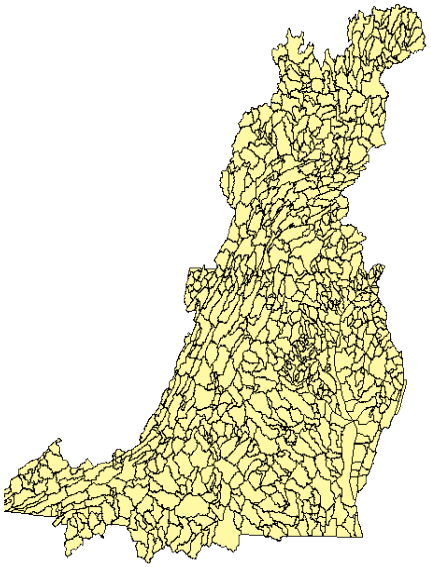
Land use, management practices, fertilizer and manure applications, crop growth

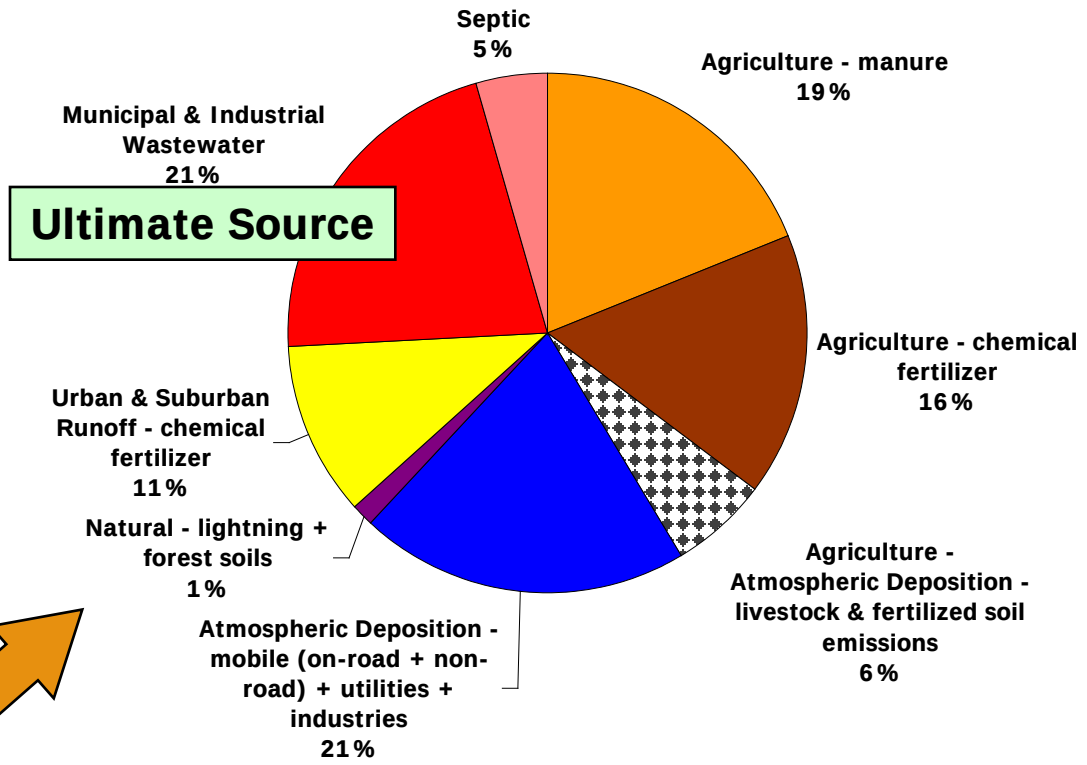
Sample Input and Output

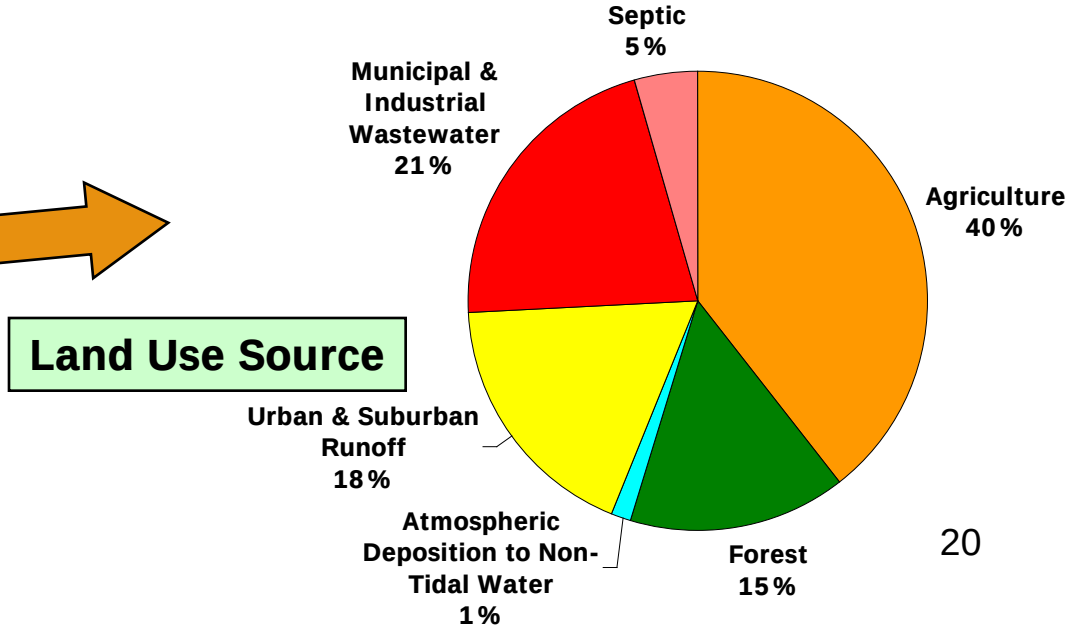


WSM Uses:

Divide Load into contributing areas and sources

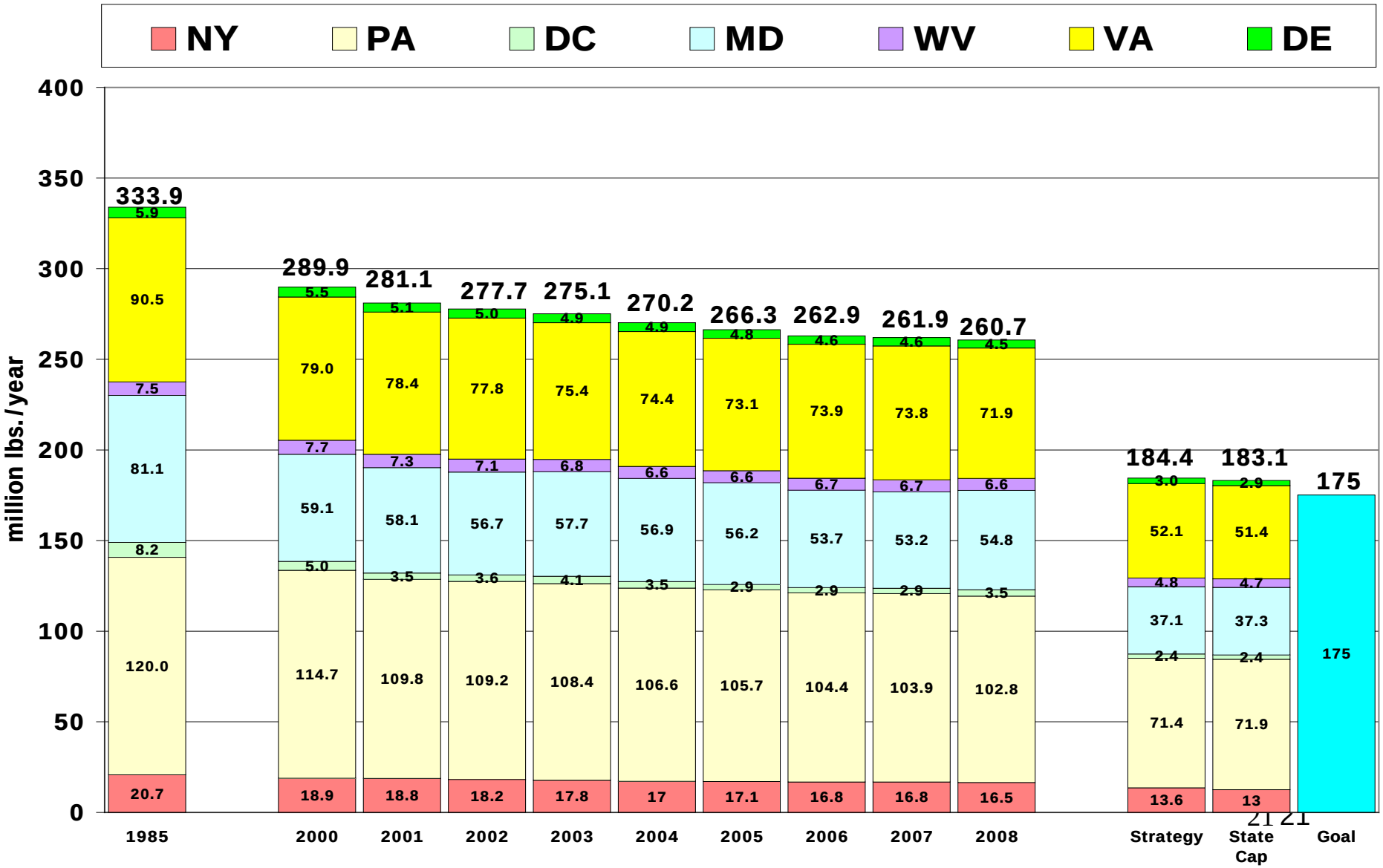






Nitrogen Loads Delivered to the Chesapeake Bay By Jurisdiction

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



How is the Bay Watershed Model Applies Practices and Programs

- **BMPs that alter nutrient applications to cropland**
  - Diet and feed changes
  - Manure transport
  - Nutrient management applications
- **BMPs involving landuse conversions**
- **BMPs with nutrient and sediment reduction efficiencies**
- **BMPs with both landuse conversions and reduction efficiencies**
  - Riparian forest buffers and wetland restoration
  - Riparian grass buffers

Non-Point Source Practices and Programs

Agricultural BMPs	Developed Lands BMPs
Riparian Forest Buffers	Riparian Forest Buffers
Riparian Grass Buffers	Riparian Grass Buffers
Wetland Restoration	Wetland Restoration
Land Retirement	Tree Planting
Tree Planting	Forest Conservation
Conservation-Tillage	Urban Growth Reduction
Continuous No-Till	Wet Ponds & Wetlands
Carbon Sequestration/Alternative Crops	Dry Detention Ponds & Hydrodynamic Structures
Poultry and Swine Phytase	Dry Extended Detention Ponds
Poultry Litter Transport	Infiltration Practices
Ammonia Emission Reductions	Filtering Practices
Animal Waste Management Systems: Livestock & Poultry	Stream Restoration
Barnyard Runoff Control/Loafing Lot Management	Erosion & Sediment Control
Dairy Precision Feeding /and Forage Management	Nutrient Management
Nutrient Management Applications	Abandoned Mine Reclamation
Precision Agriculture	Dirt & Gravel Road Erosion & Sediment Control
Enhanced Nutrient Management	Street Sweeping
Conservation Plans/SCWQP	Septic Connections
Cover Crops (Early- and Late-Planting)	Septic Pumping
Small Grain Enhancement (Early- and Late-Planting)	Septic Denitrification
Off-Stream Watering with and without Fencing	Structural Shoreline Erosion Control
Off-Stream Watering w/ Fencing & Rotational Grazing	Non-Structural Shoreline Erosion Control
Precision Grazing	
Horse Pasture Management	**Forestry BMPs**
Water Control Structures	Forest Harvesting Practices
Stream Restoration	

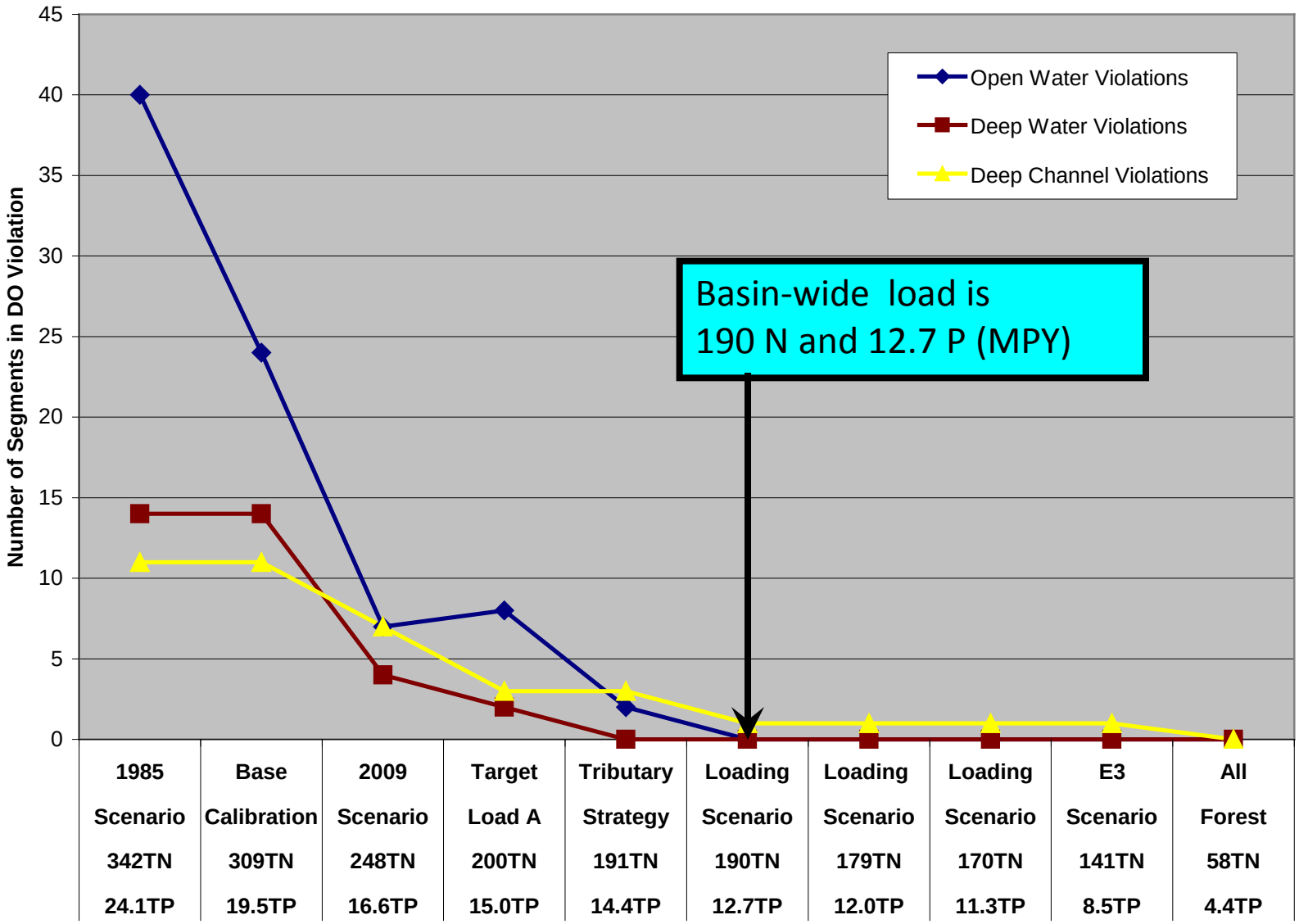
http://archive.chesapeakebay.net/pubs/NPS_BMP_Table1.8.pdf (8 pages)

Process for new BMPs

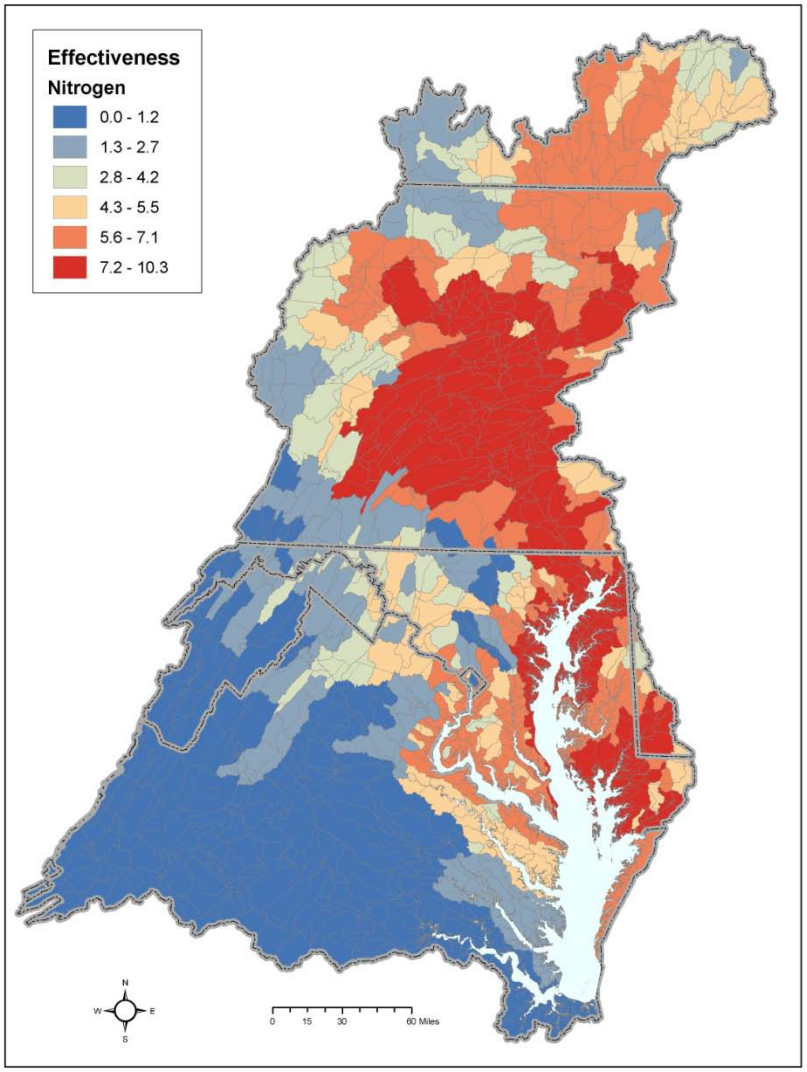
- Generate request from Sector Workgroup
- Convene a review panel
  - Gather research
  - Characterize as to applicability, location, variability, amount of research, and scientific support
- Review by Source Sector Workgroup, Watershed Technical Workgroup, and WQGIT

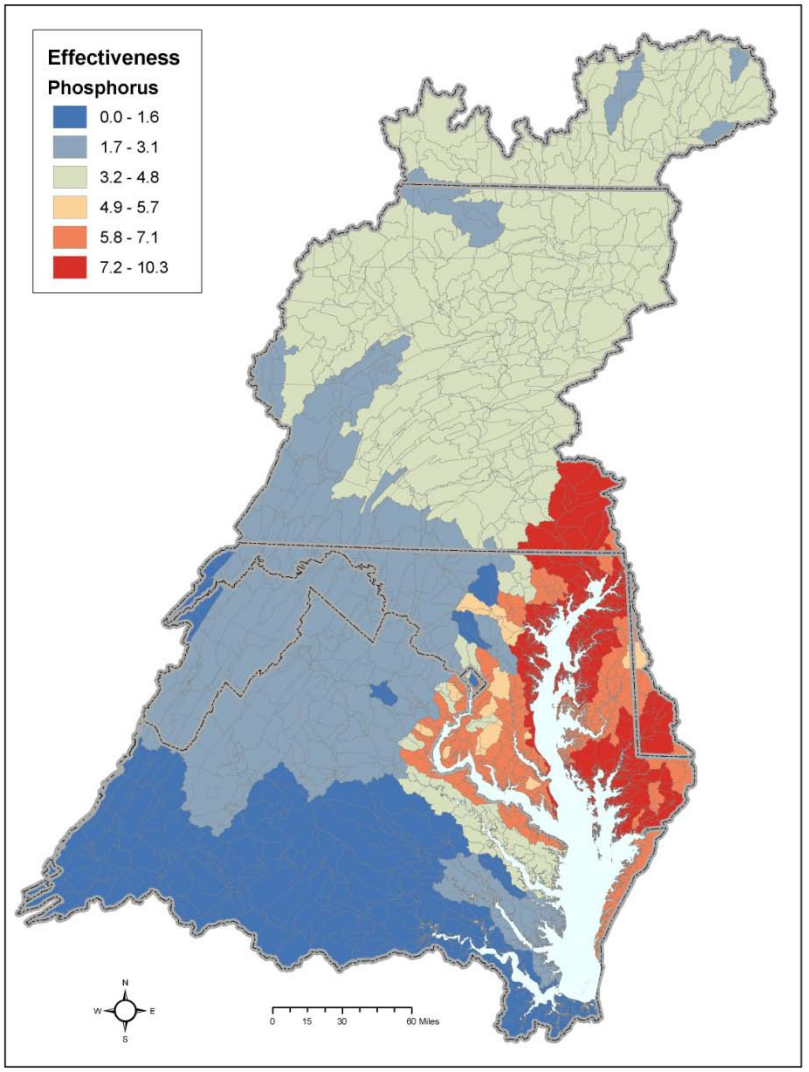
http://archive.chesapeakebay.net/pubs/Nutrient-Sediment_Control_Review_Protocol.pdf

Dissolved Oxygen Criteria Attainment

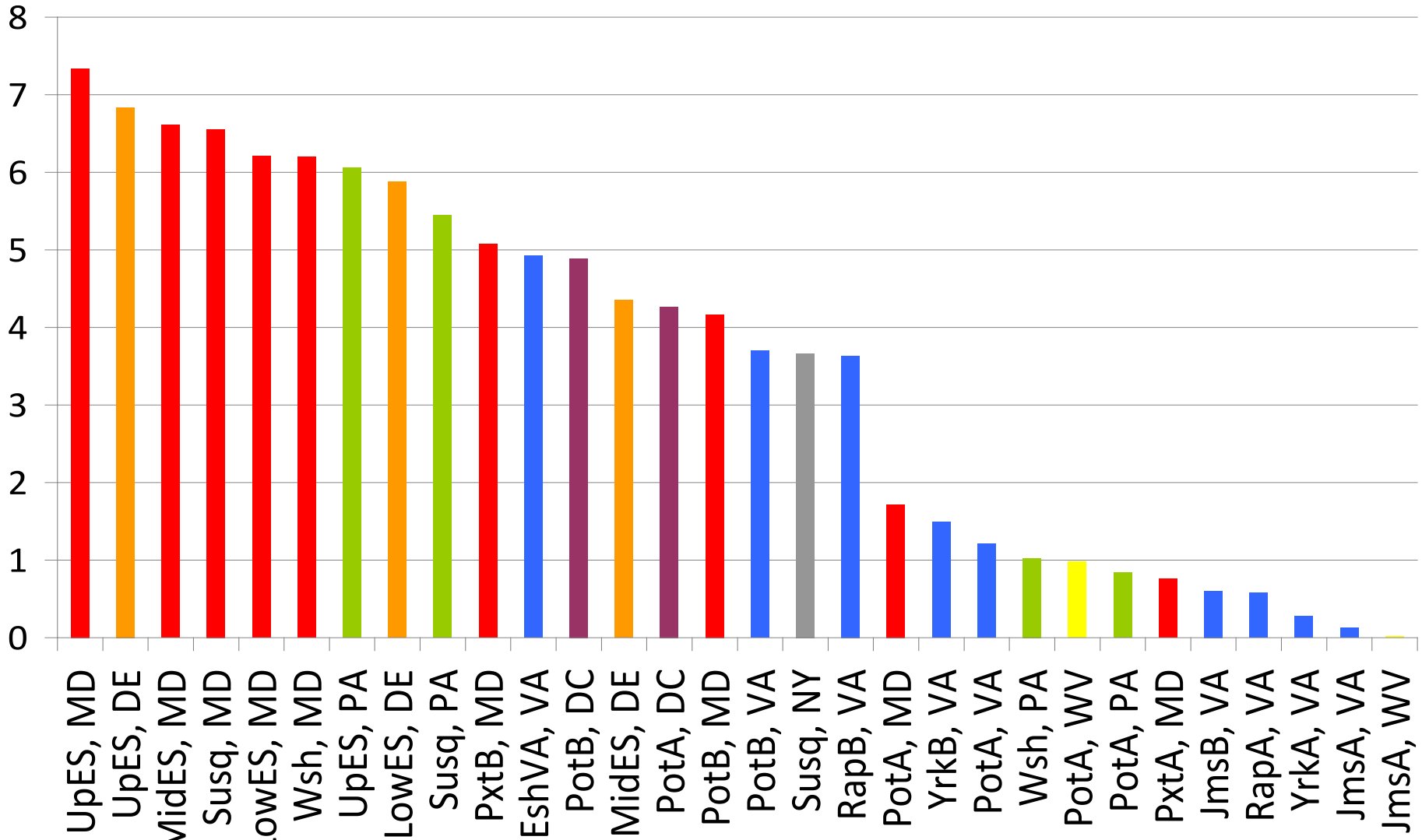


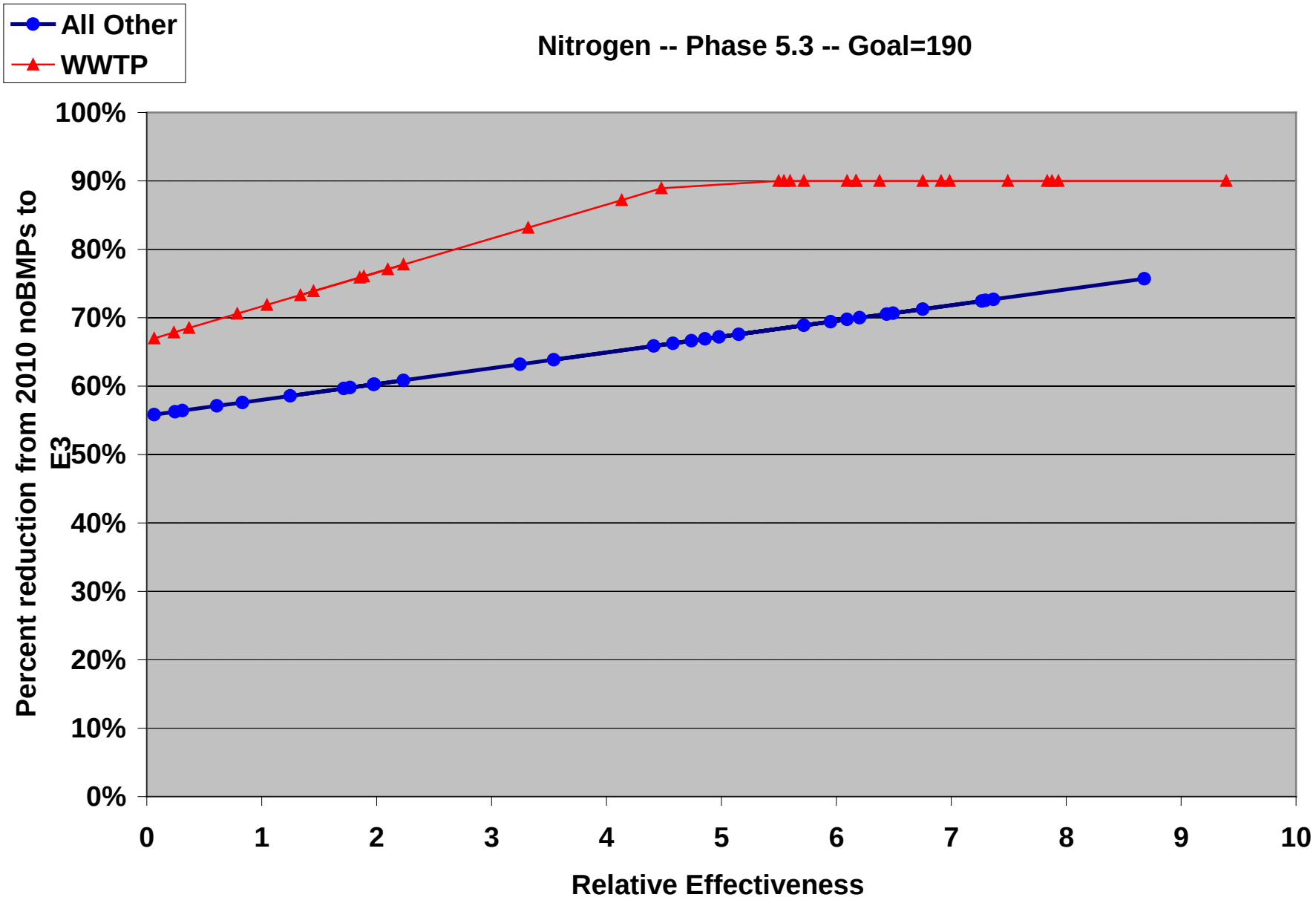
Relative Effect of a Pound of Pollution on Bay Water Quality



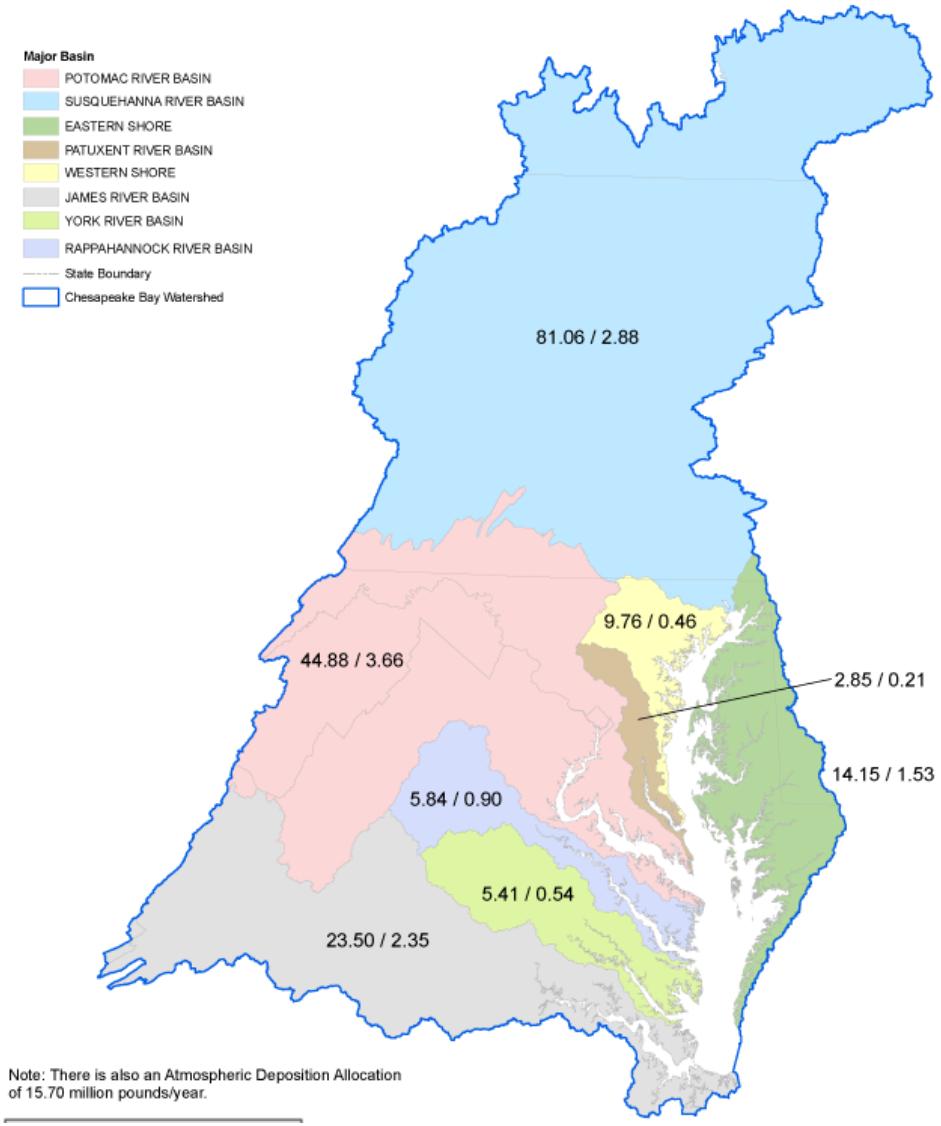


Major River Basin by Jurisdiction Relative Impact on Bay Water Quality



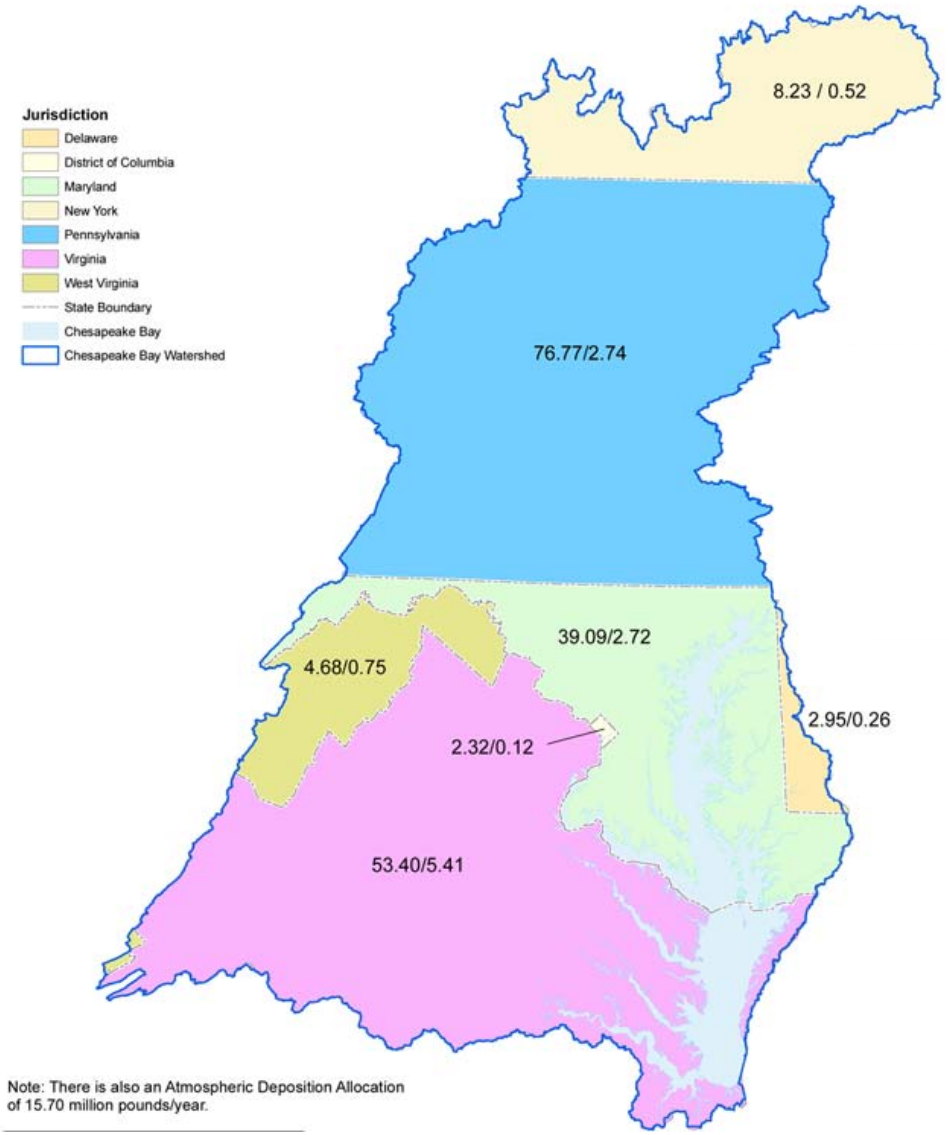

All Other
WWTP
Nitrogen -- Phase 5.3 -- Goal=190
Percent reduction from 2010 noBMPs to E3
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
6
7
8
9
10
Relative Effectiveness

Pollution Diet
by River



Note: There is also an Atmospheric Deposition Allocation of 15.70 million pounds/year.

Pollution Diet
by State



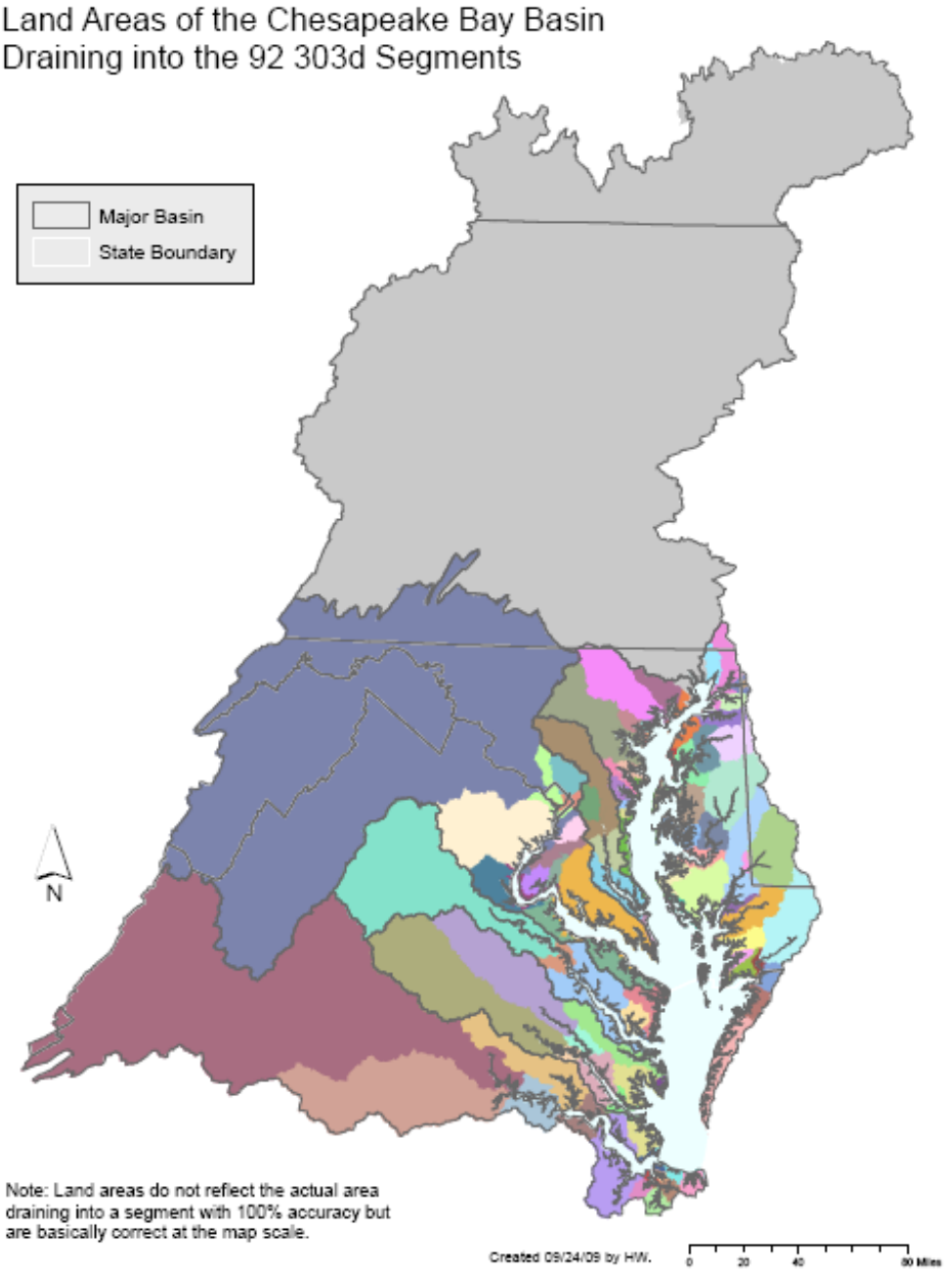
Note: There is also an Atmospheric Deposition Allocation of 15.70 million pounds/year.

Jurisdictions' Watershed Implementation Plans

92 Individual TMDLs

Table B2. Format for Submitting Phase I Watershed Implementation Plan Outputs t

St.	Maj. Basin	Impaired Segment Drainage	Unique Code	Source Sector [b]	Type [c]	NPDES Permit
MD	W. Shore	PAXTF	MWPTF	Agriculture-CAFO	Agg. WLA	
				Agriculture-CAFO	Ind. WLA	MD356913
				Agriculture	LA	
				Subtotal: Agriculture		
				Wastewater: POTW#1	Ind. WLA	MD012452
				Wastewater: POTW#2	Ind. WLA	MD013943
				Wastewater: Indus #1	Ind. WLA	MD821672
				Wastewater: Indus #2	Ind. WLA	MD853653
				Subtotal: Wastewater		
				Onsite	LA	
				Urb/Suburb Runoff: MS4	Agg. WLA	MD546195
				Urb/Suburb Runoff: Non-MS4	LA	
				Urb/Suburb Runoff: MS4	Ind. WLA	MD892645
				Industrial Stormwater	Agg. WLA	
				Industrial Stormwater	Ind. WLA	MD246139
				Construction	Agg WLA	
				Subtotal: Urb/Suburb		
				Forest	LA	
MD	W. Shore	SEVMH	MWSeM	Agriculture-CAFO	Agg. WLA	MD382614
				Agriculture	LA	
				Subtotal: Agriculture		
				Wastewater: POTW#1	Ind. WLA	MD083699
				Wastewater: POTW#2	Ind. WLA	MD054732
				Wastewater: Indus #1	Ind. WLA	MD836679
				Wastewater: Indus #2	Ind. WLA	MD854469
				Subtotal: Wastewater		
				Onsite	LA	
				Urb/Suburb Runoff: MS4	Agg. WLA	MD588578
				Urb/Suburb Runoff: Non-MS4	LA	
				Subtotal: Urb/Suburb		
				Forest	LA	
	…					
MD	W. Shore			Reserve for Growth	WLA/LA	
MD	**W Shore**		**MW**	**Total**		



System Configuration and Flows

Final TMDL, Baseline Progress, Other data.

Feds, States and DC submit Non-Point Source Load, Practices/Verification using NEIEN

Wastewater Point Source /Data Direct Reporting

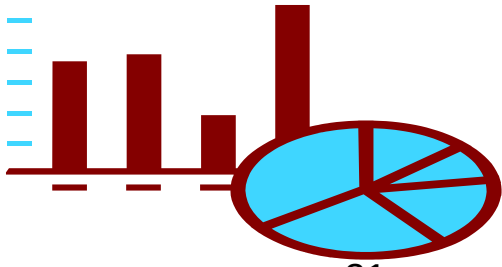
Practices

Scenario Builder

Watershed Model runs measure loadings progress.

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

BayTAS (In CBPO IT Infrastructure)



To Chesapeake Stat for Presentation

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