Application of the SPARROW Methodology for Multi-Scale Modeling of Nutrient Loading in the Chesapeake Bay Watershed

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WHAT IS SPARROW ?

* SPAtially Referenced Regression Modeling
  On Watershed Attributes

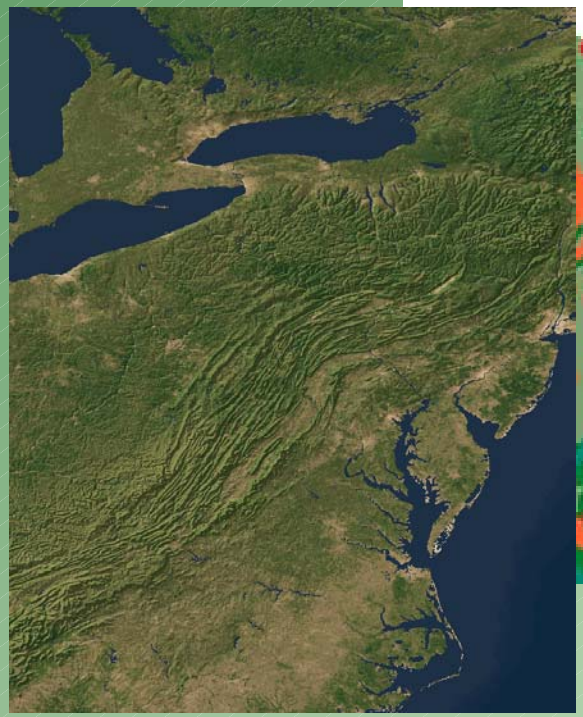
* Statistical Model for Relating
  Watershed Nutrient Sources to Stream Nutrient Loads

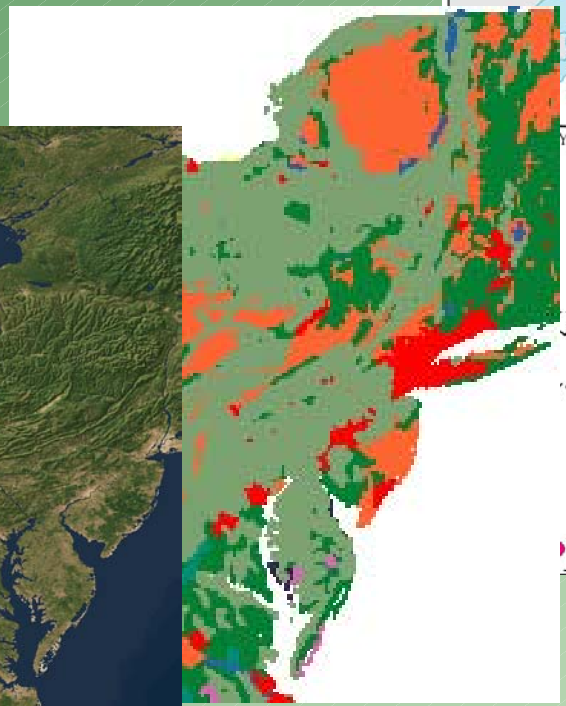
* Spatial Analysis Tool for Evaluating
  Geographical Distribution of Factors Affecting Loads

Integrates watershed data over multiple spatial scales to predict origin & fate of contaminants

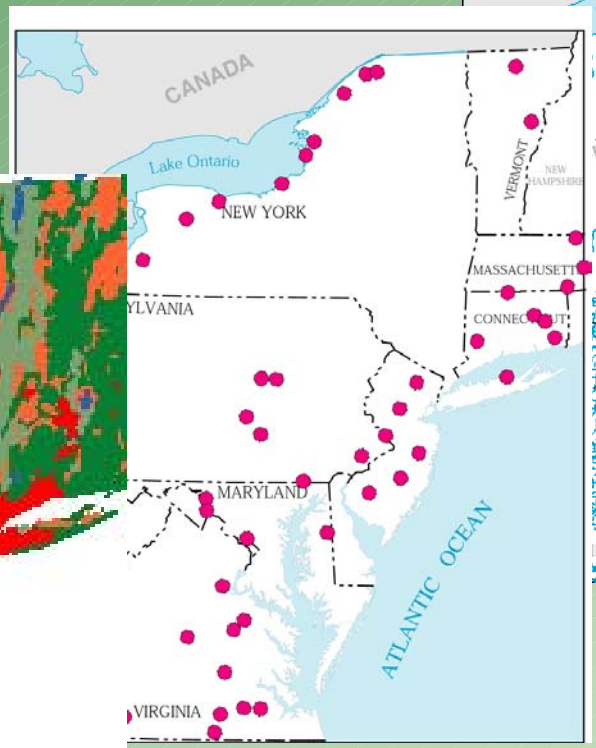
SPARROW (SPAtially Referenced Regression on Watershed Attributes)

Landscape Features

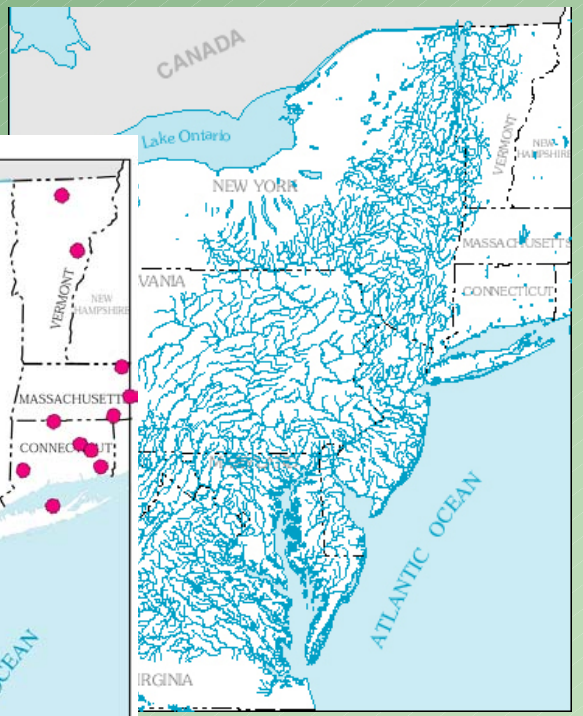




Land Use & Sources

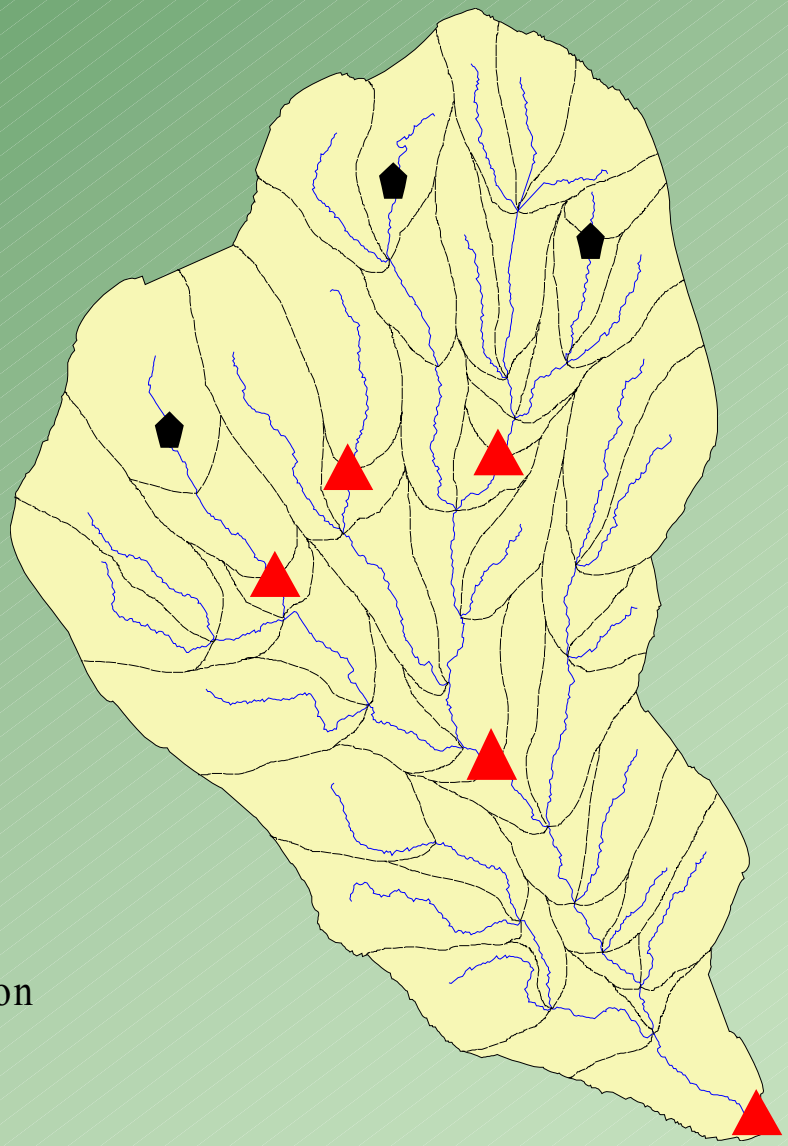


Monitoring Data



Drainage & Impoundments

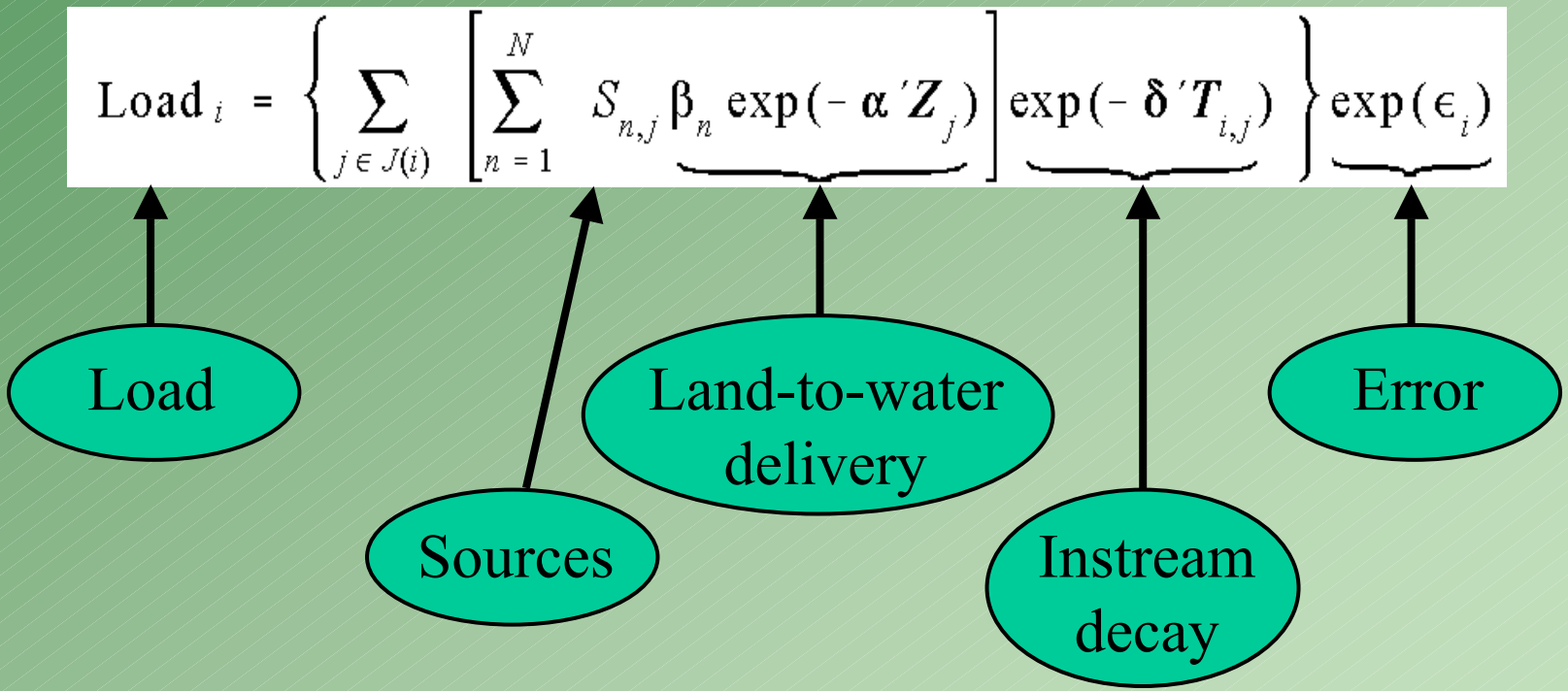
SPARROW Approach for Interpretation of Watershed Water-Quality Data



Sewage Treatment Plant

Water-Quality Monitoring Station

SPARROW
Estimated Equation



SPARROW'S DATA COMPONENTS

* Network - Including Stream Network and Basin Segmentation

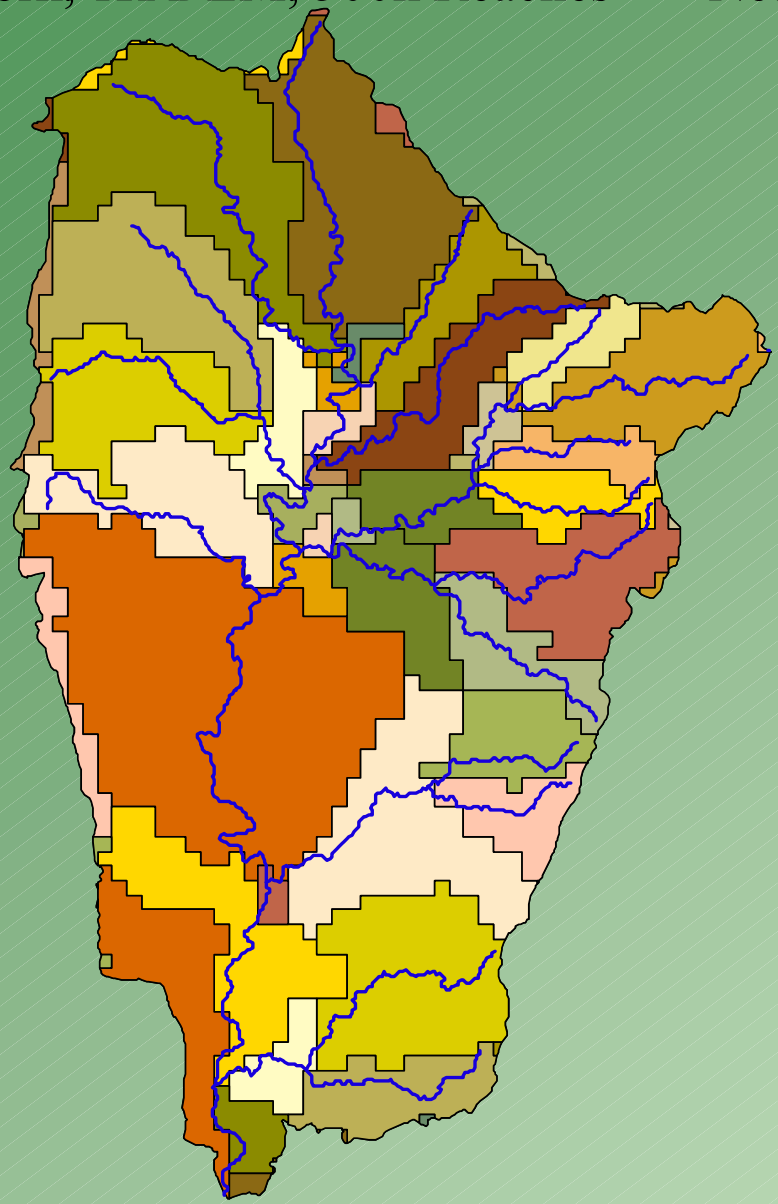
* Dependent Variable - Stream Loading Information

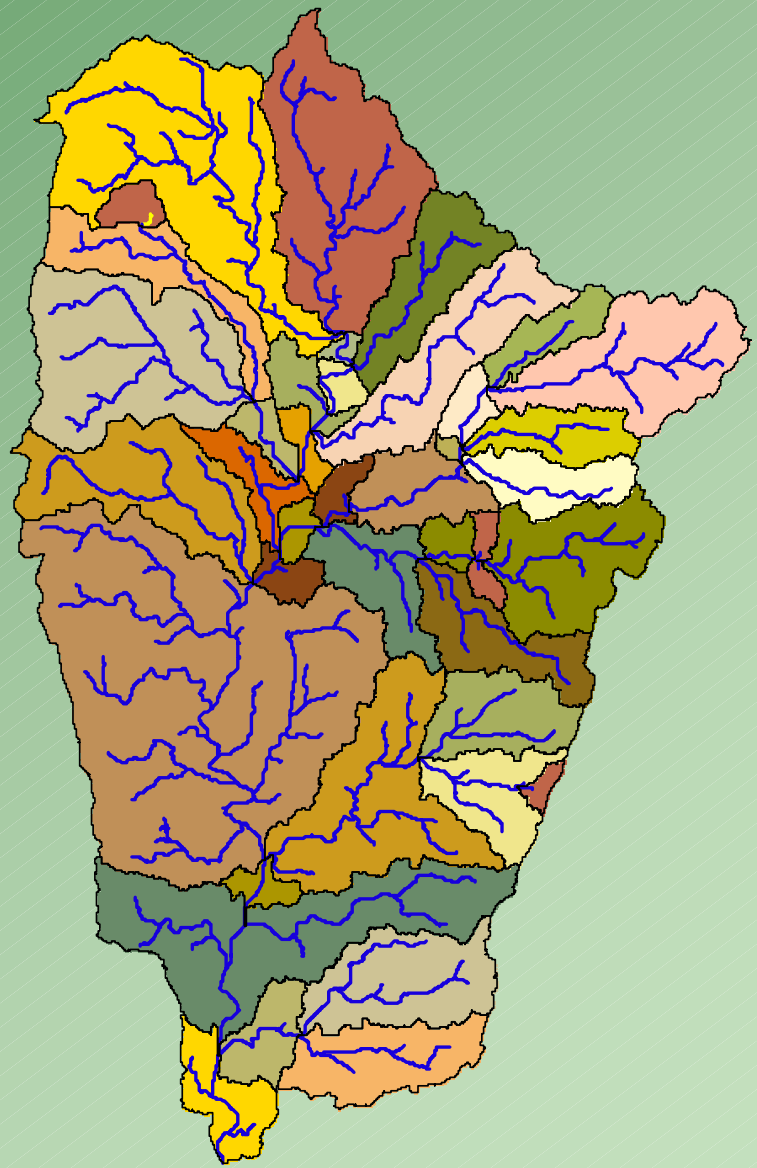
* Nutrient Sources - Point Source, Nonpoint Source, Atmospheric Deposition, Others

* Delivery Factors - Soils, Slope, Physiography, Geology, Meteorology, Others

Network, 1K DEM, 500k Reaches

Network, 30m DEM, >5000 cells per Reach





3 0 3 6 9 12 15 Miles

Monocacy River Basin

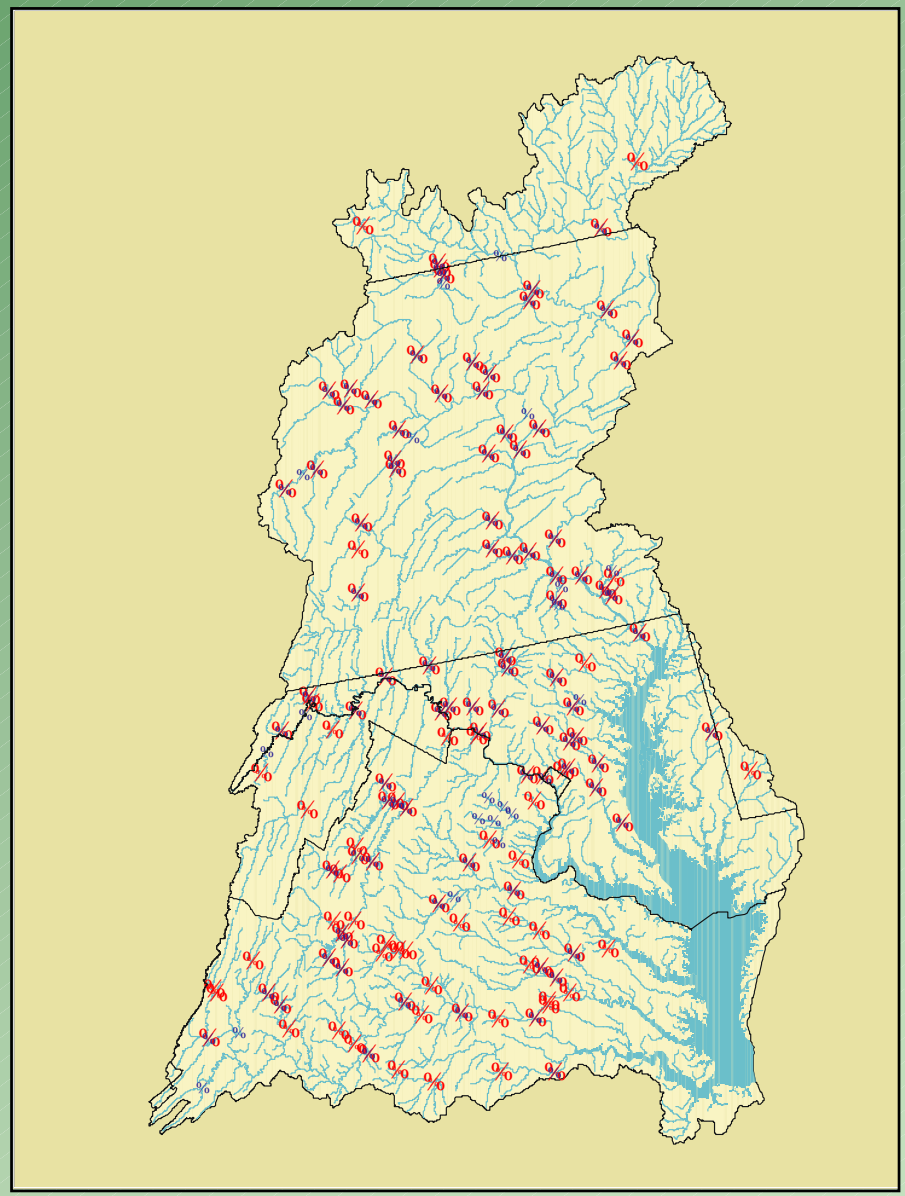
Chesapeake Bay SPARROW

Version II

Enhanced Stream-Load Data Base

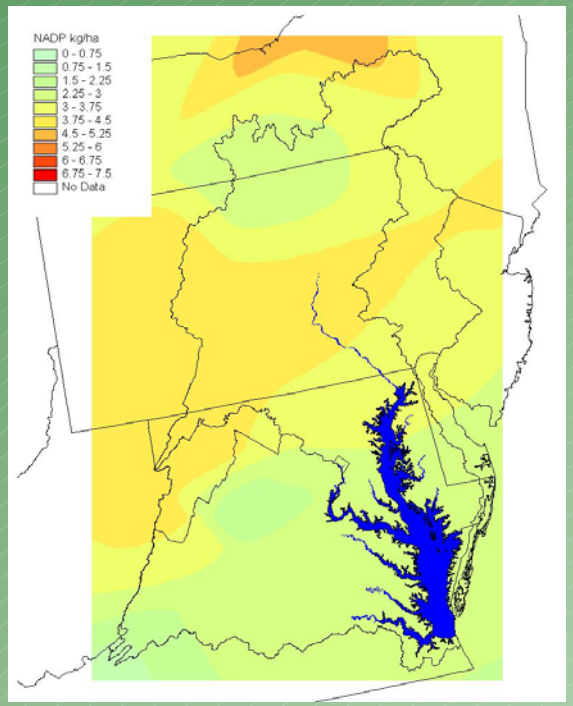
▲ Version I - 1987

▲ Version II - 1992

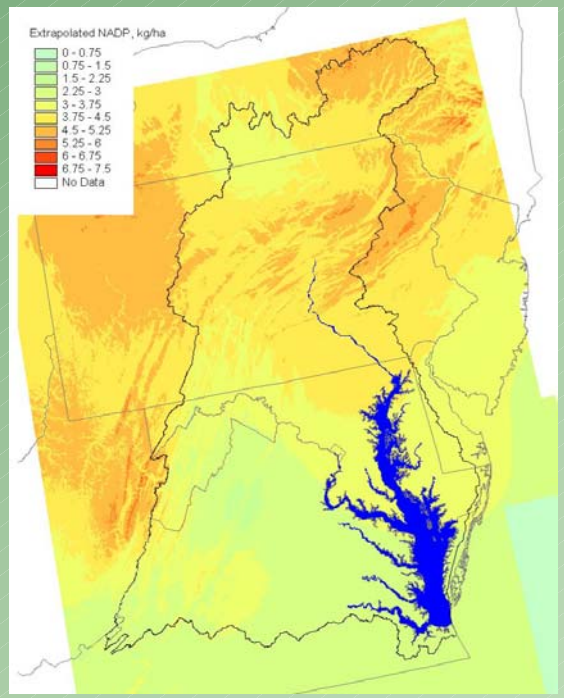


Nitrate Wet-Deposition Data Sets Chesapeake Bay Region

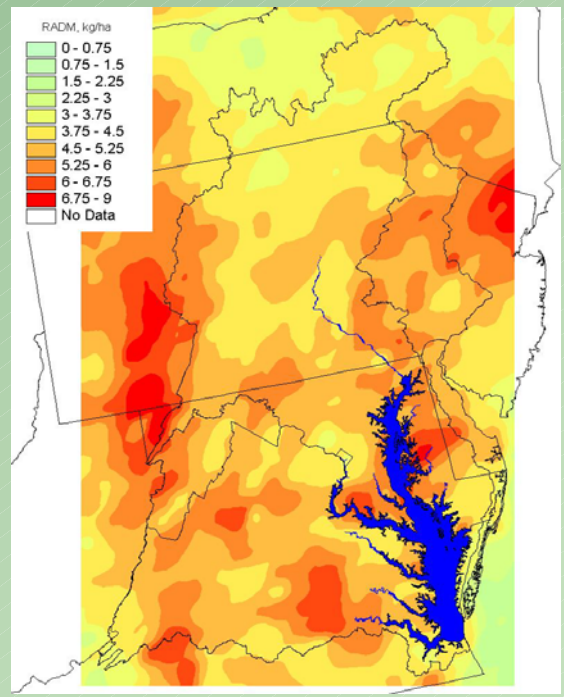
Interpolated NADP Data



Penn State Modeled NADP Data



RADM Model



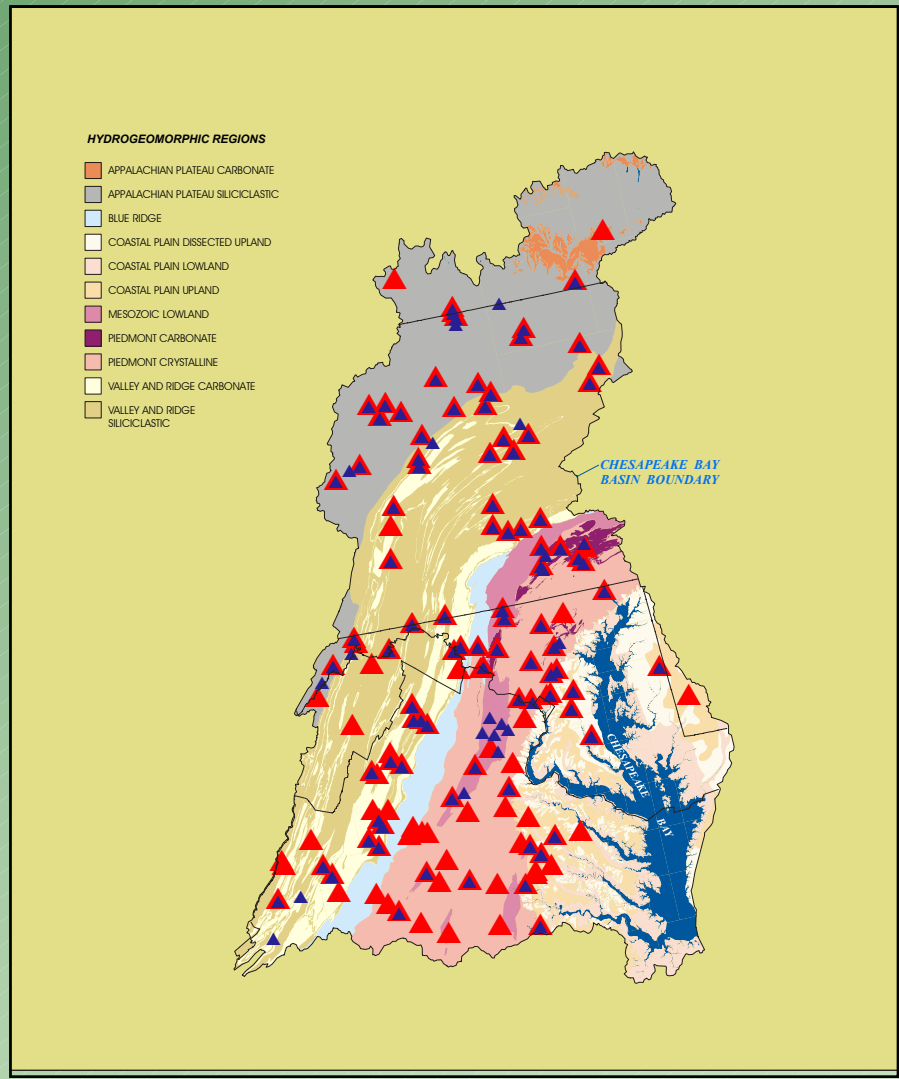
Chesapeake Bay SPARROW

Version II

HGMR / Load Site Distribution

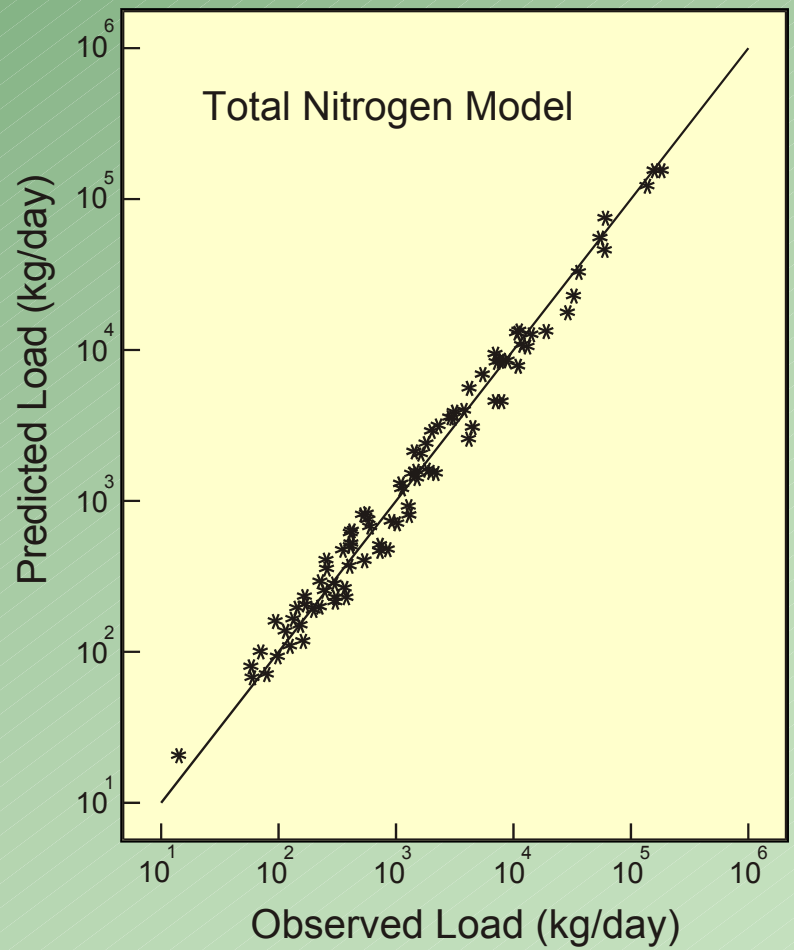
▲ Version I - 1987

▲ Version II - 1992



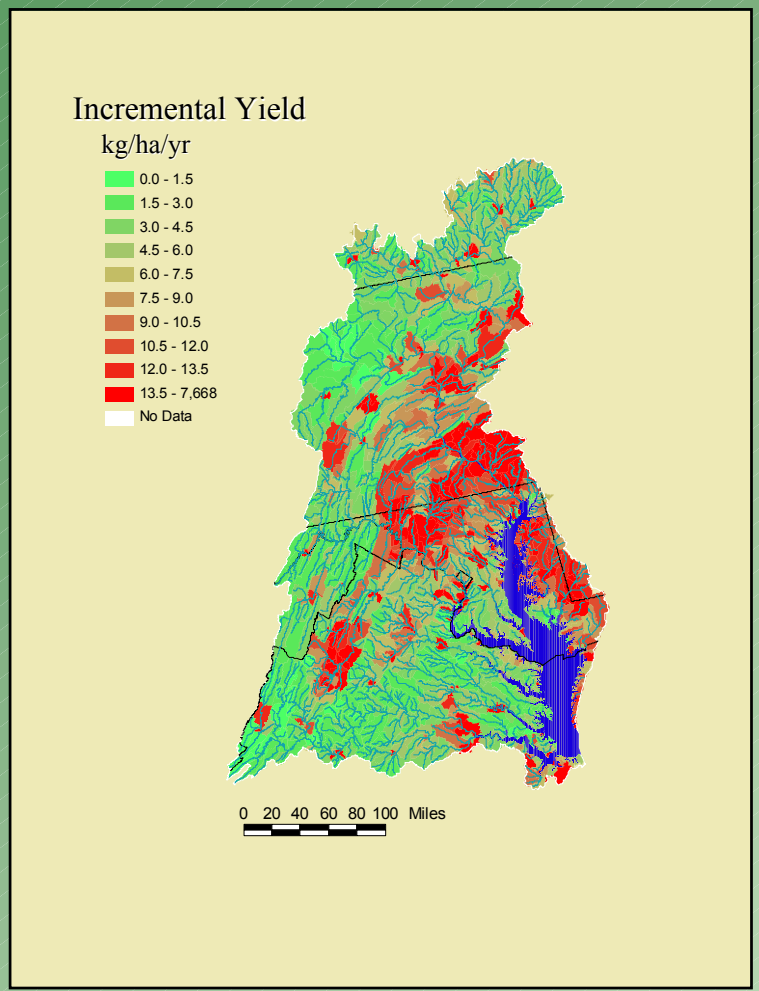
Chesapeake Bay SPARROW
Total Nitrogen Model - Calibration Results

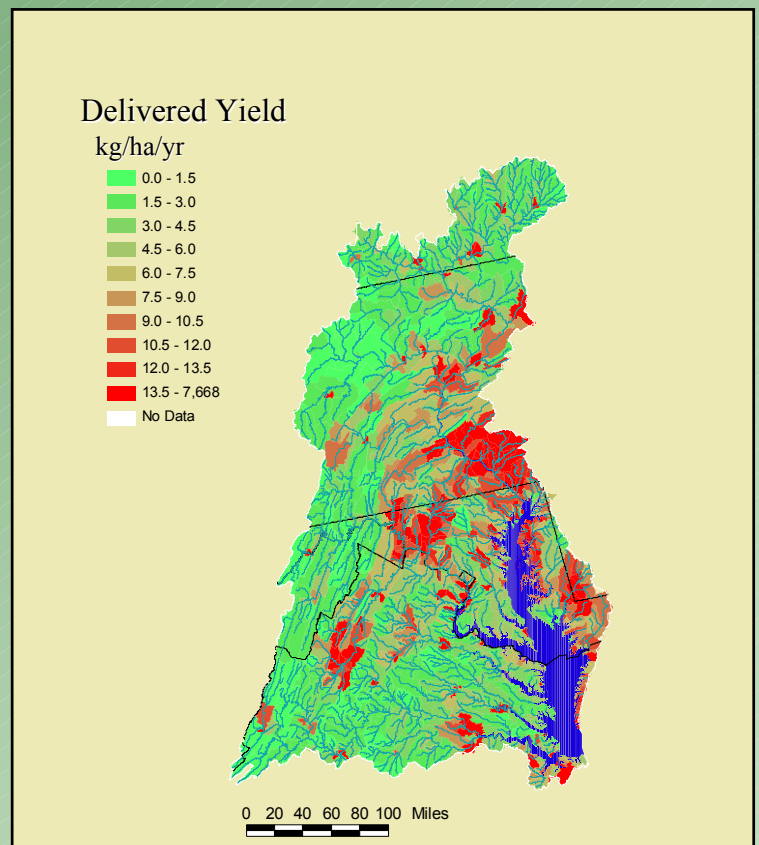
Explanatory Variables	Parameter Estimates	Prob > |T|
Nitrogen Sources (β)		
Point sources (kg/yr)	2.04	<0.005
Septic Tank (kg/yr)	0.598	0.083
Urban area (ha)	14.9	<0.005
Fertilizer application (kg/yr)	0.373	<0.005
Manure application (kg/yr)	0.287	<0.005
Atmospheric deposition (kg/yr)	0.317	<0.005
Land to water delivery (α)		
Temperature (°F)		
Precipitation (in)		
Average slope (%)		
Coastal Plain Area (%)	0.454	0.002
Soil permeability (in/hr)		
Stream density (1/mi)		
Wetland (%)		
Instream loss (δ)		
T_1 (Q < 200 ft^3/s)	0.640	<0.005
T_2 (200 ft^3/s < Q < 1,000 ft^3/s)	0.201	0.104
T_3 (Q > 1,000 ft^3/s)	0.004	0.940
T_3 (reservoir retention)	0.463	0.043
R-squared	0.977	
Root mean square error	0.308	
Number of observations	88	



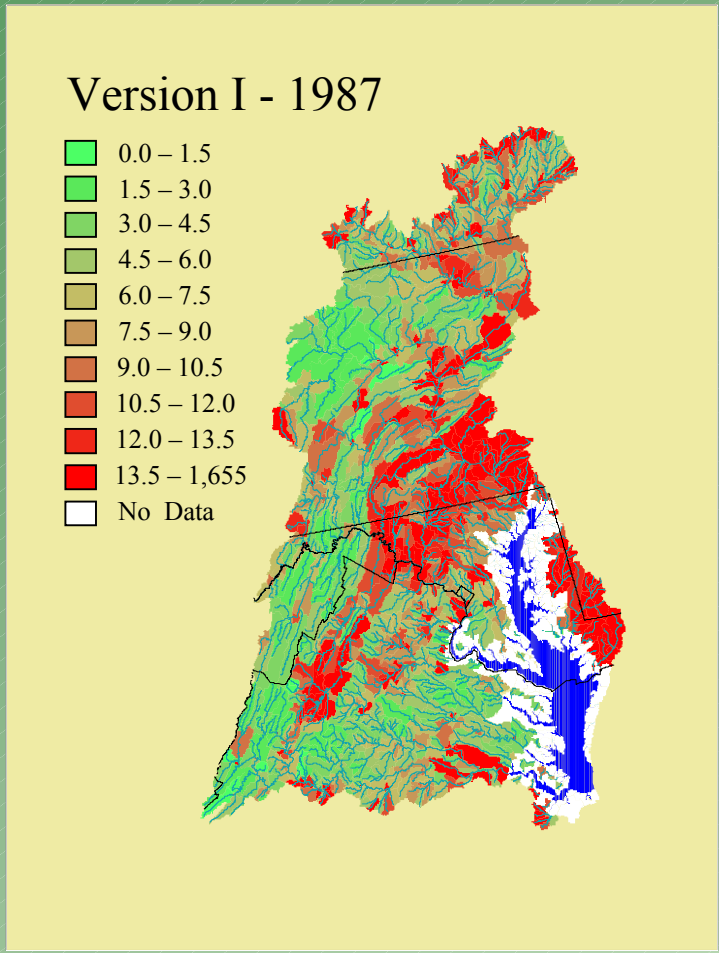
Chesapeake Bay SPARROW

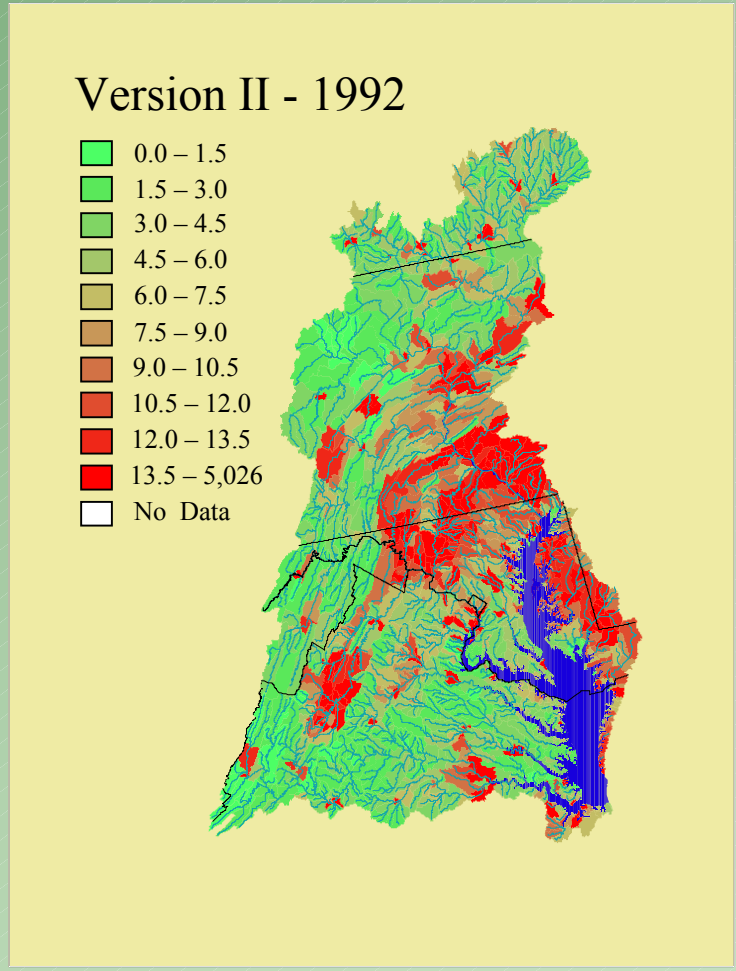
Predicted Total Nitrogen Yield





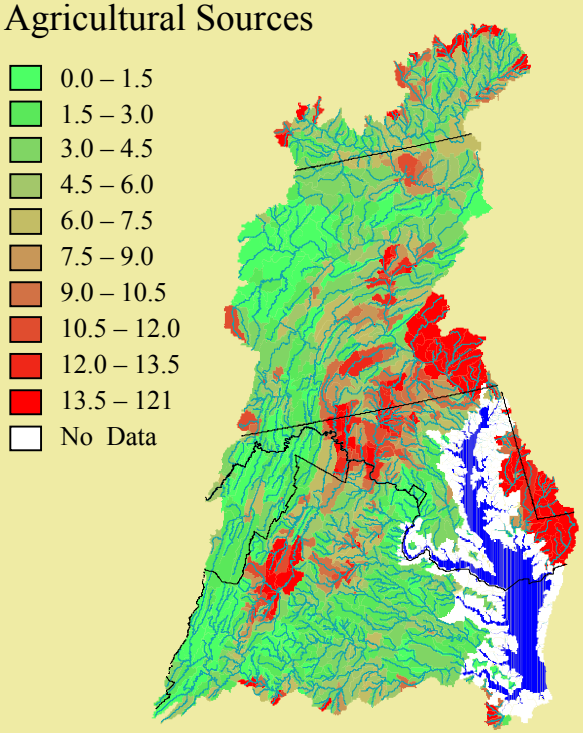
Chesapeake Bay Watershed
Total Nitrogen – Incremental Yield (kg/ha-yr)



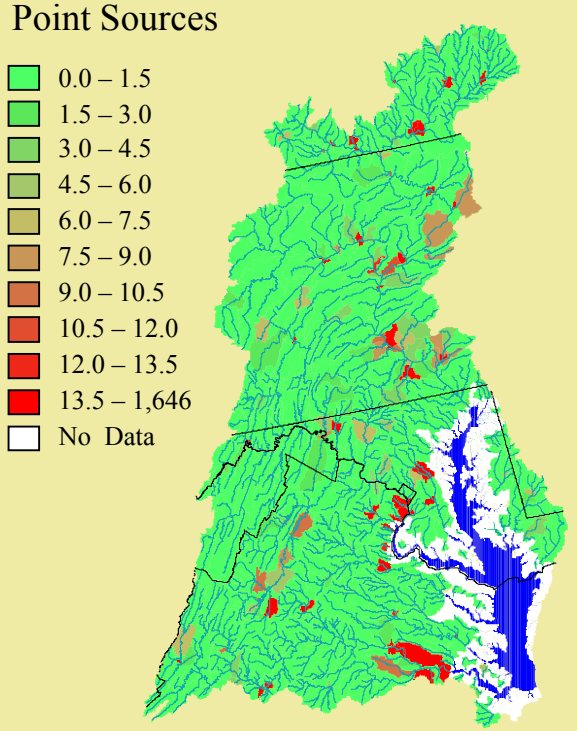


Chesapeake Bay Watershed
Nitrogen Yield (kg/ha-yr)

Incremental Yield Due to Agricultural Sources

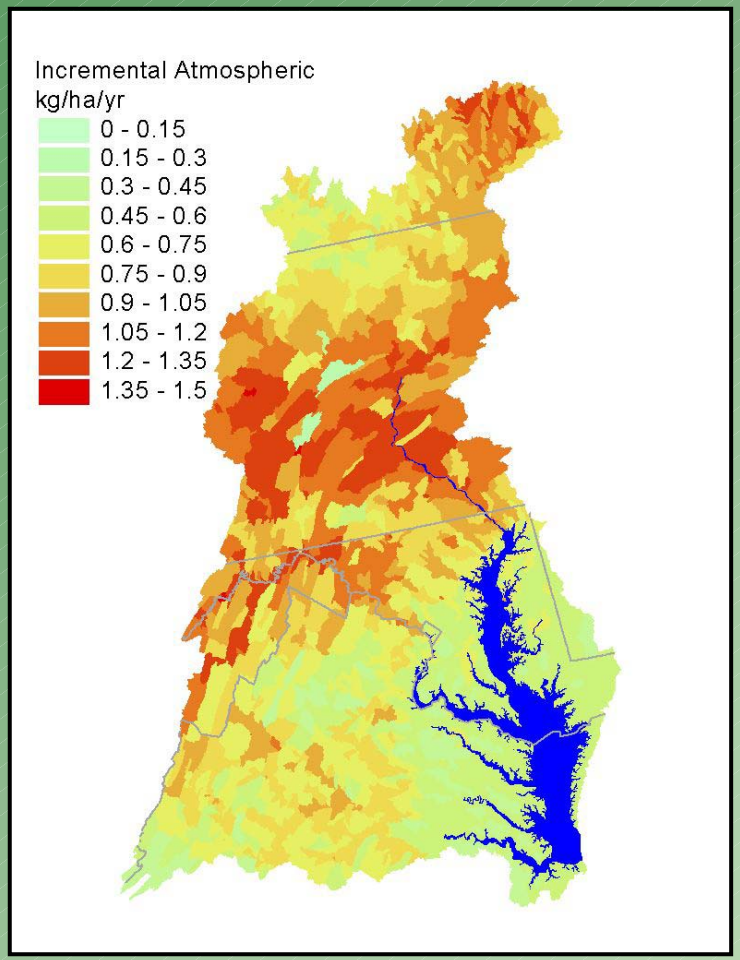


Incremental Yield Due to Point Sources

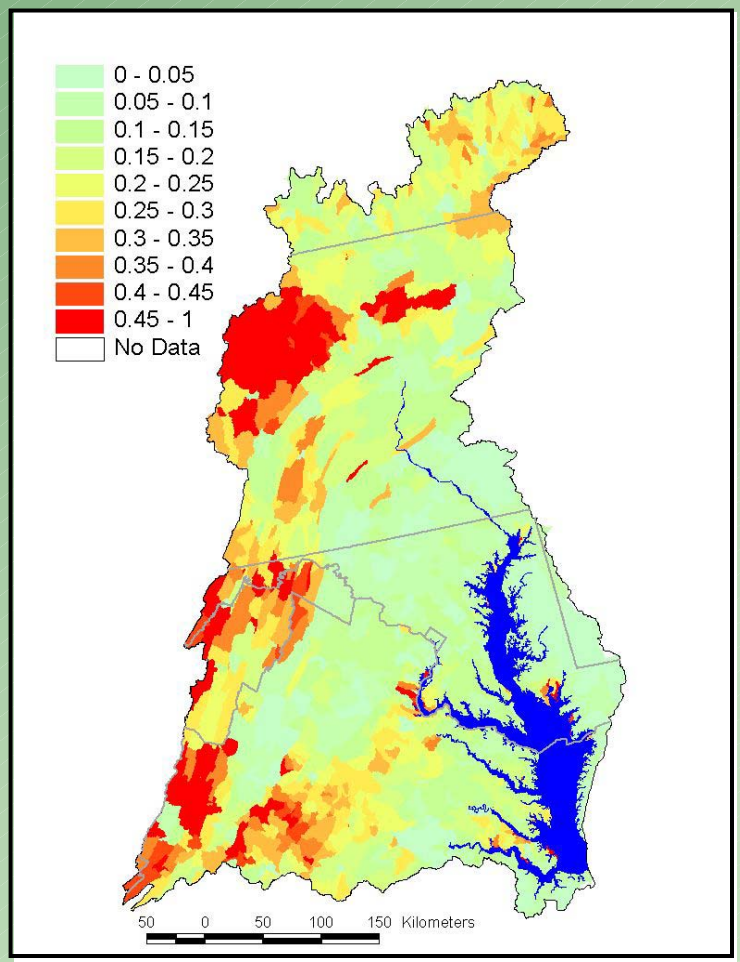


CB SPARROW Atmospheric Contributions Exported from Reach Catchments

TN Yield

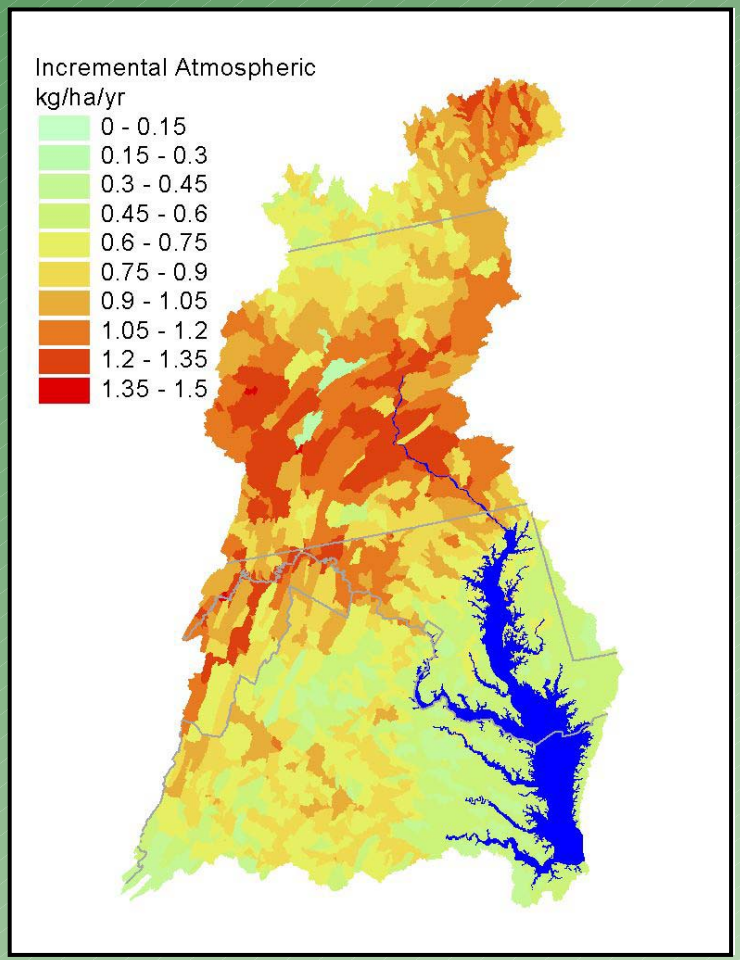


Fraction of All Sources

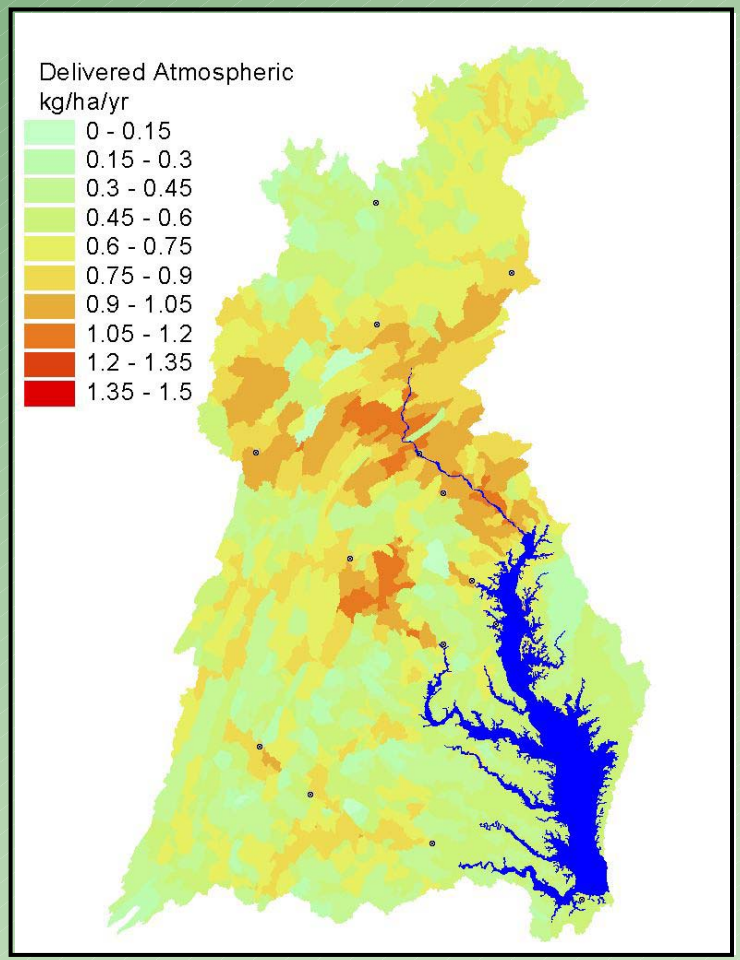


CB SPARROW Atmospheric Contributions Exported from Catchments & Delivered to Bay

TN Yield

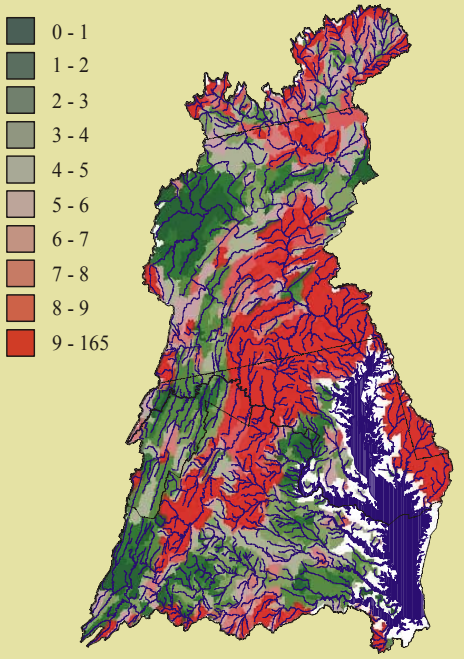


Delivered TN Yield

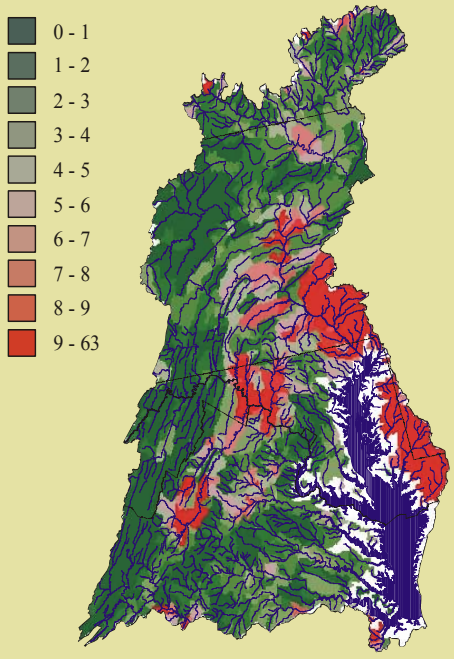


Chesapeake Bay - Instream Delivery of Nitrogen

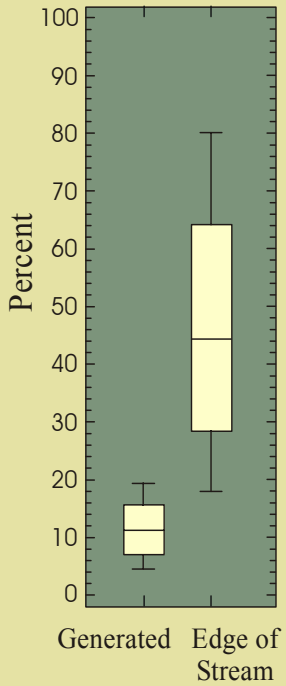
Agricultural Nitrogen Yield
Edge of Stream (kg/ha-yr)



Agricultural Nitrogen Yield
Delivery to Bay (kg/ha-yr)



Instream Delivery
Percentage



Aspects of the Approach for "Delisting" Chesapeake Bay

Establish Tidal Water-Quality Criteria

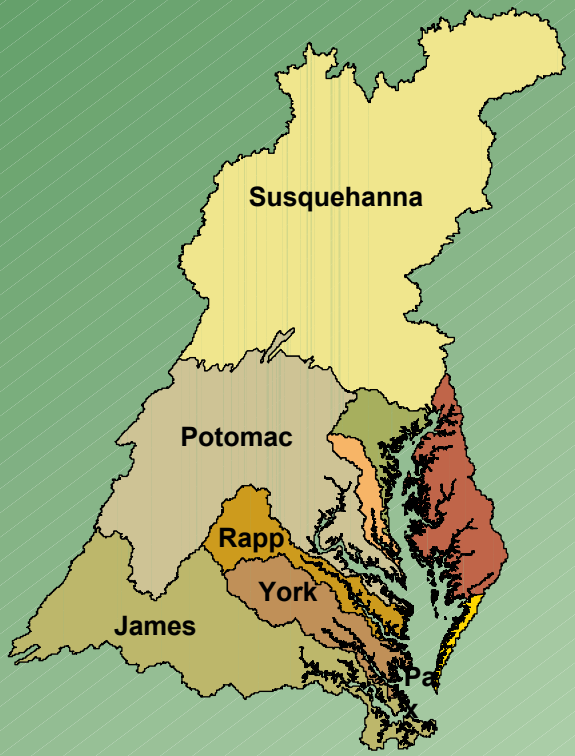
- Dissolved Oxygen
- Chlorophyll a
- Clarity

Apply Tidal Water-Quality Model to Set Allocations for Major Drainages

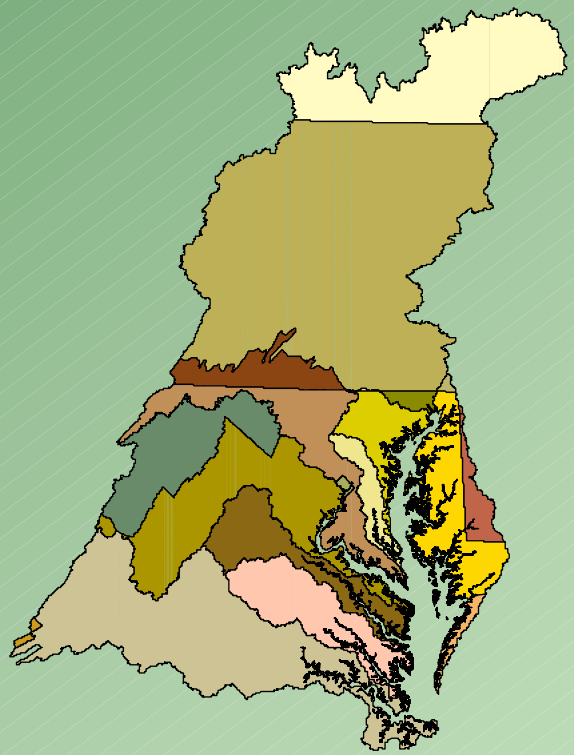
Apply Watershed Model to Set Allocations Within Major Drainages

Setting Load Allocations

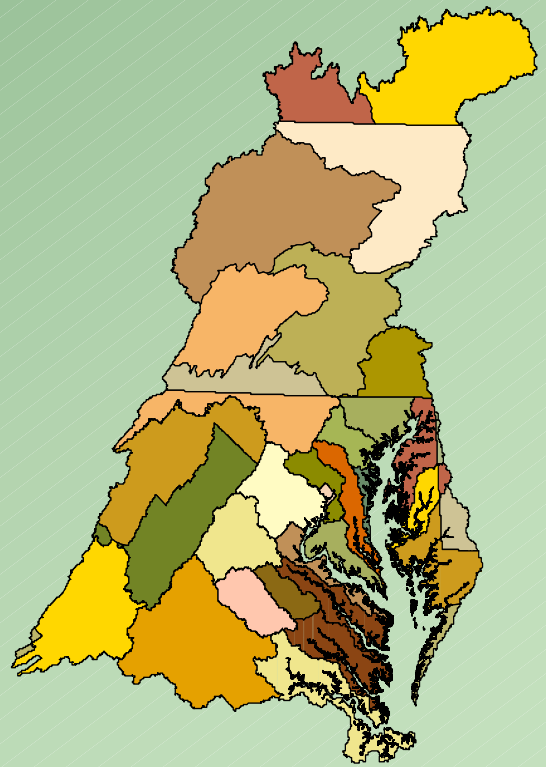
Allocate Loading Caps to the 9 Major Basins



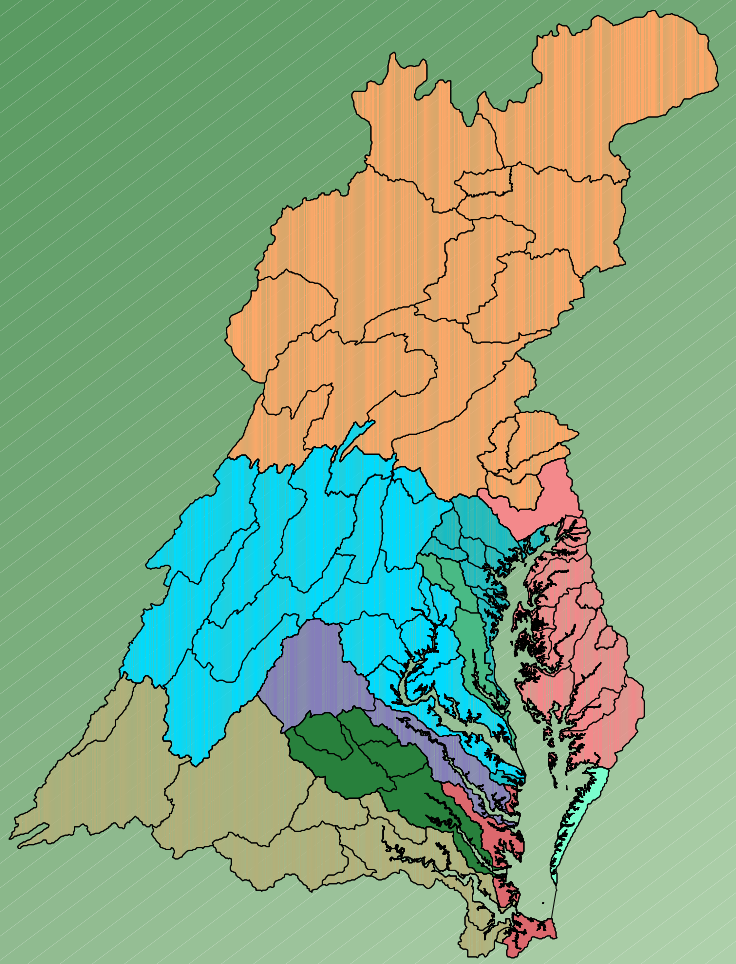
Further allocate cap load responsibilities to each state



Further allocate major tributary basin load caps to 37 state defined sub-basins



Chesapeake Bay Program Watershed Model - HSPF



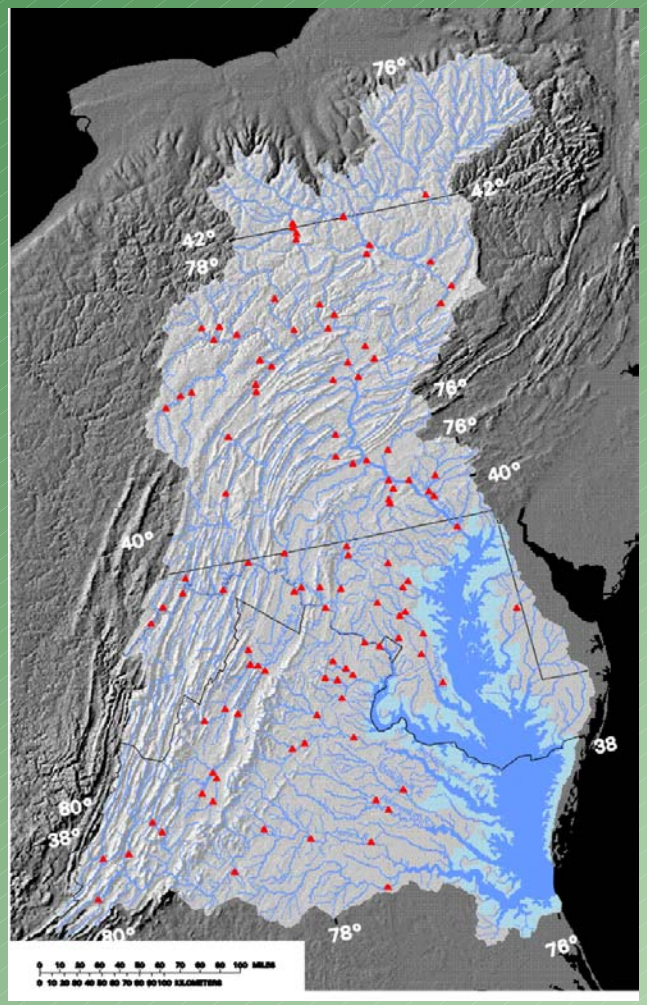
Limitations of Modeling Framework

- Over-Parameterized
- Labor-Intensive Manual Calibration
- Spatial Coarseness
- No Systematic Method of Assessing Error

Why is HSPF Necessary?

- Designed for Studying the Relations of Human Activities on the Landscape to Nutrient and Sediment Loads of Streams
- Allows Simulation of "ALL" Human Activities that Affect Stream Loads
- Allows the Simulation of Management-Practices to Assess Their Effectiveness and Optimize the Efficient Use of Resources

U.S. Geological Survey - SPARROW



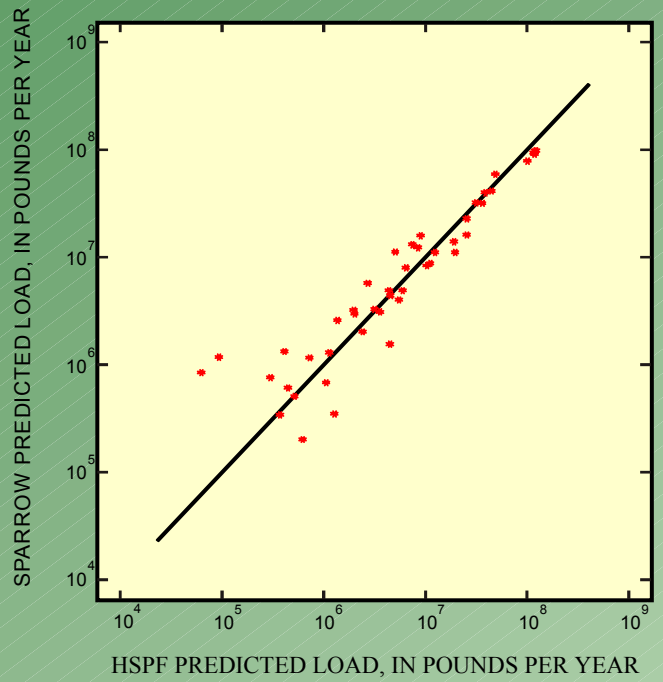
Description of Modeling Framework

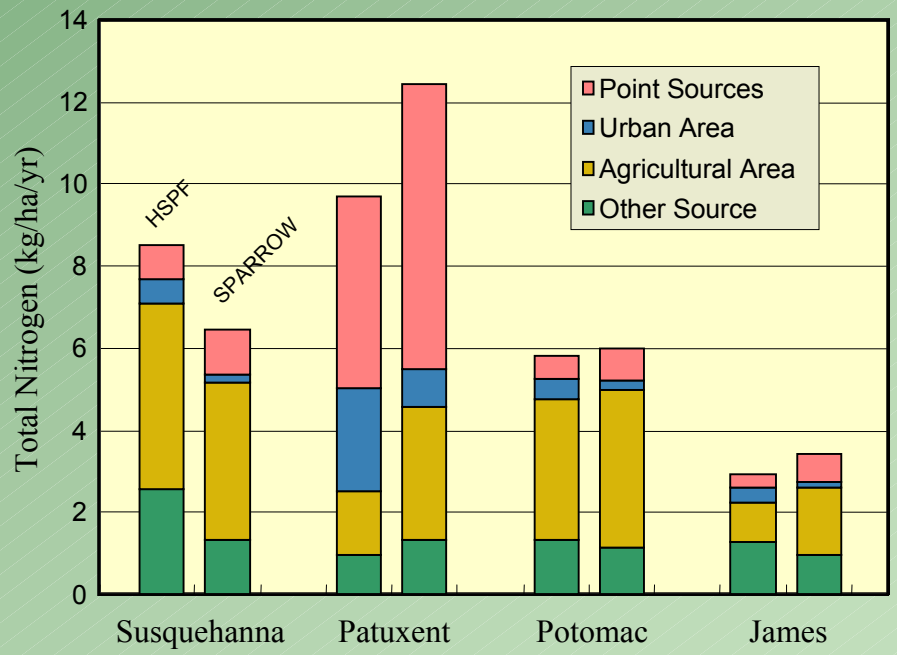
- Statistical
- Designed to Define Spatial Relations Between Contaminant Sources and Stream Loads
- Spatially Defined Only
- Spatially Detailed

Chesapeake Bay Application

- Provide Framework for Relating Various Types of Detailed Geographic Data to Stream Nutrient Loads
- Statistically Identify the Environmental Factors that are Most Closely Related to Stream Loads
- Provide Spatially Detailed Estimates of Stream Load for Targeting and Other Uses

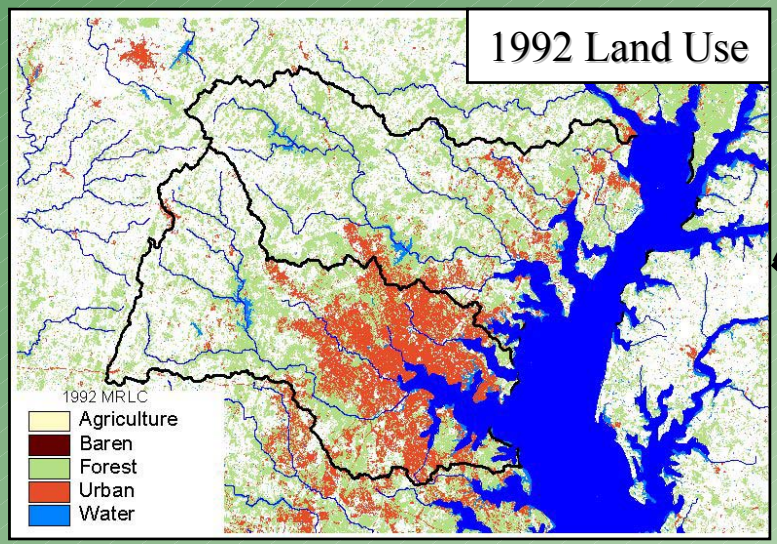
Chesapeake Bay Watershed
SPARROW / HSPF Comparison

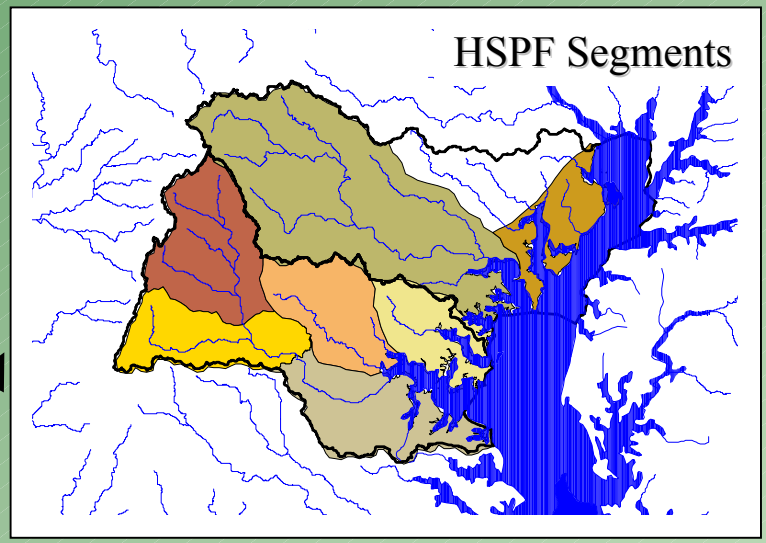


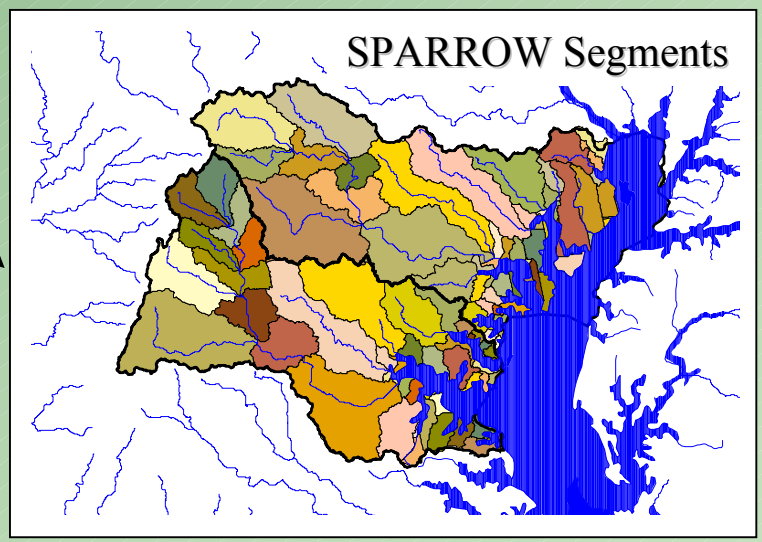


Joint Application of HSPF and SPARROW

Targeting – Area Specific Management Plans

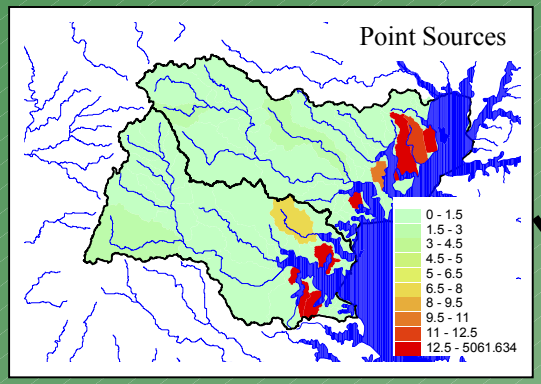


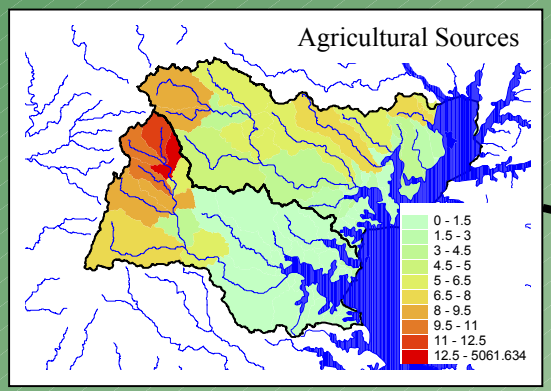


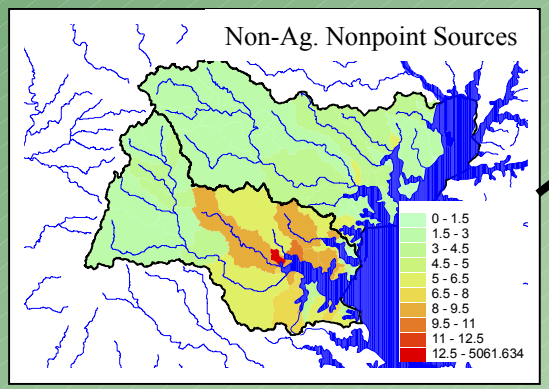


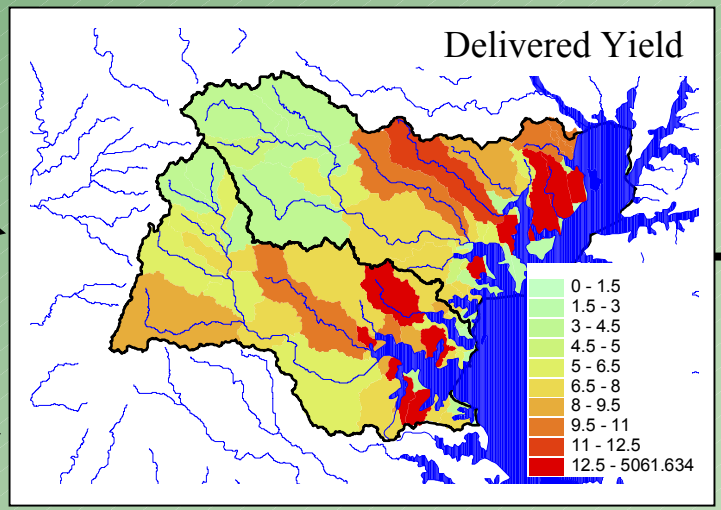
Joint Application of SPARROW and HSPF

Targeting – Area Specific Management Plans







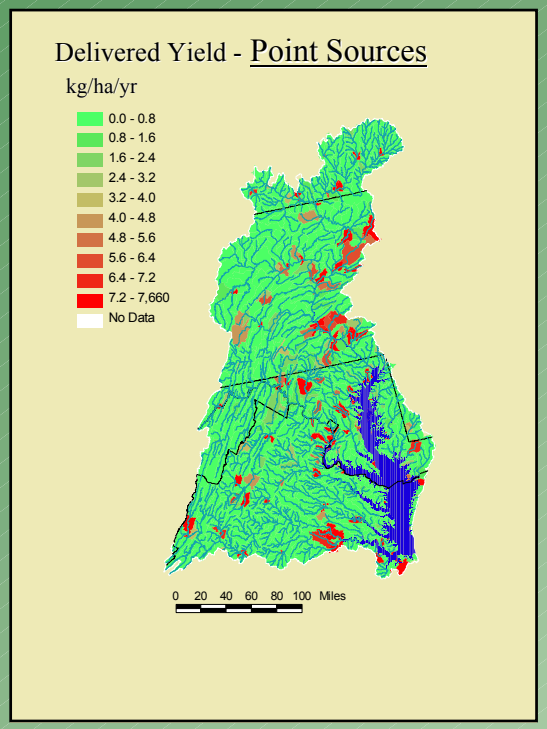


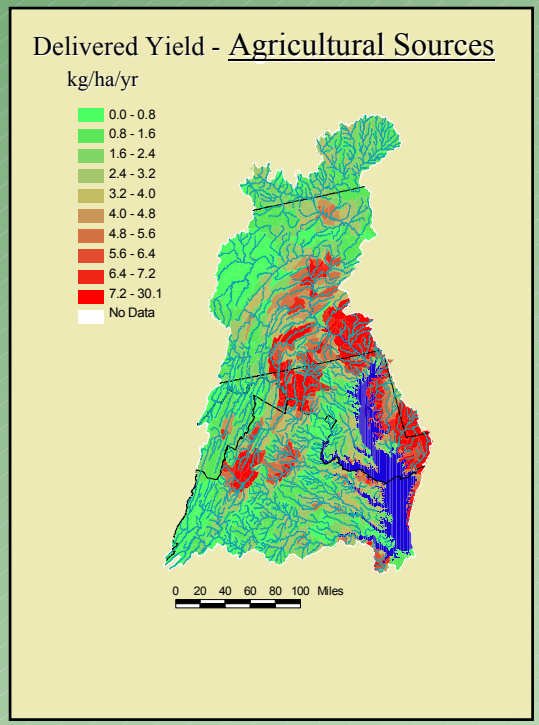
Management Scenario

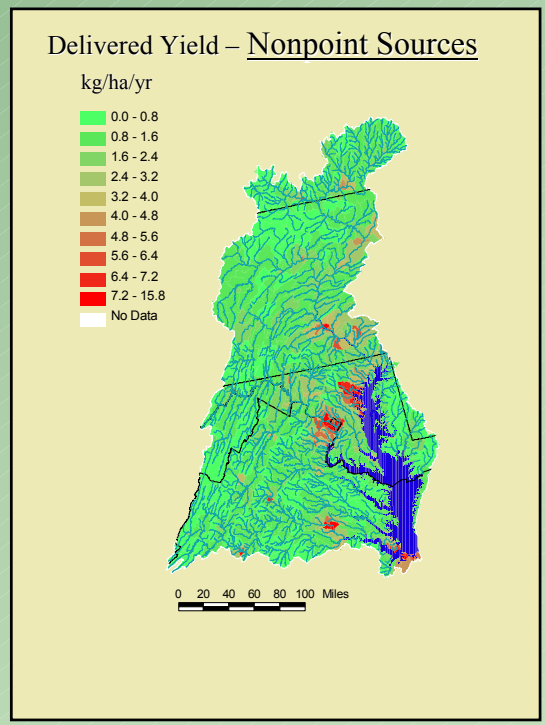
Test With HSPF

Joint Application of SPARROW and HSPF

Targeting – Basin-wide Allocation Process







“All models are wrong…some models are useful.”

- ***-G.E.P. Box***