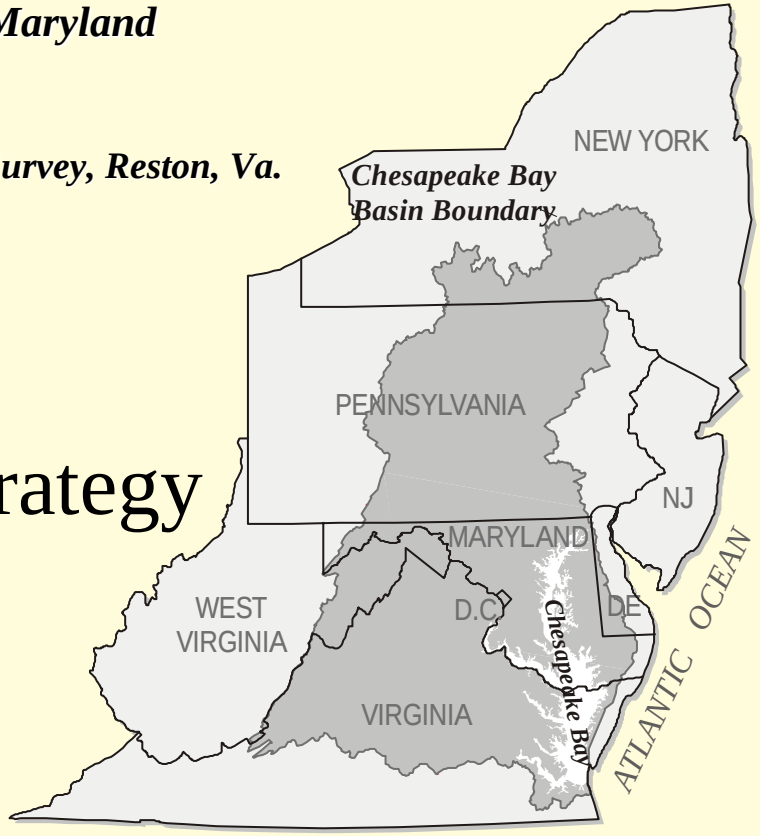
Application of a Spatially Referenced Regression Model (SPARROW) in the Chesapeake Bay Watershed

John W. Brakebill U.S. Geological Survey, jwbrakeb@usgs.gov, 410-238-4257
Water Science Center, Baltimore, Maryland
Stephen D. Preston, U.S. Geological Survey spreston@usgs.gov 410-267-9875
Chesapeake Bay Program, Annapolis, Maryland

Acknowledge: Richard Smith, Greg Schwarz ,Richard Alexander
National SPARROW team, U.S. Geological Survey, Reston, Va.



Overview of SPARROW

Northern Virginia Tributary Strategy

02-22-2006

SPARROW

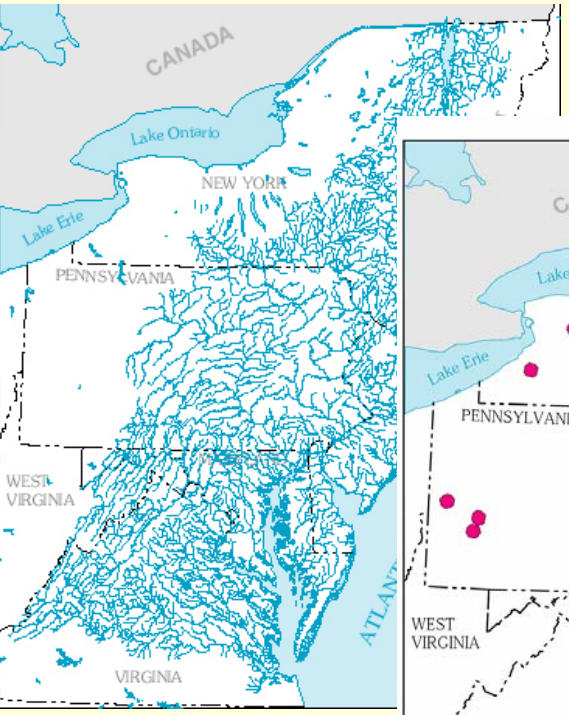
SPAtially **R**eferenced **R**egressions **O**n **W**atershed Attributes

- Spatial Statistical Approach that Empirically Relates Contaminant Sources to Measured Stream Loads
- Tool Provides Spatially Detailed Estimates:
  - Contaminant Sources
  - Regional Importance of Individual Sources
  - How Sources Relate to Loads Entering the Chesapeake Bay
- Spatial Framework Provides:
  - Potential Targeting Management Practices
  - Evaluating Distribution of Factors Affecting Loads

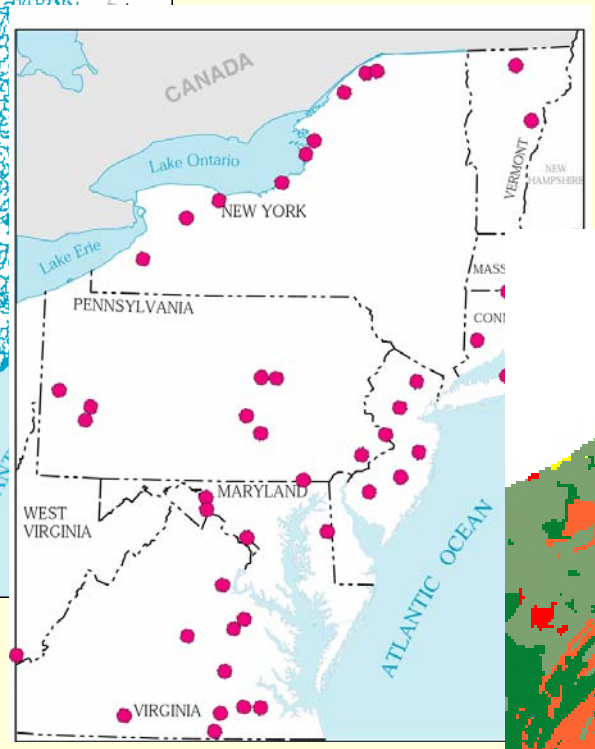
USGS

SPARROW Spatially Designed

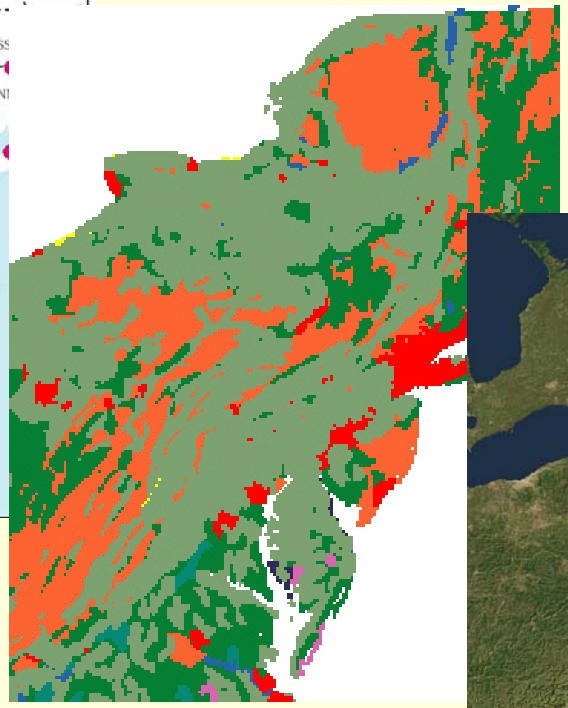
Integrates watershed data over multiple spatial scales to predict origin & fate of contaminants



Network of connected and attributed streams and watersheds

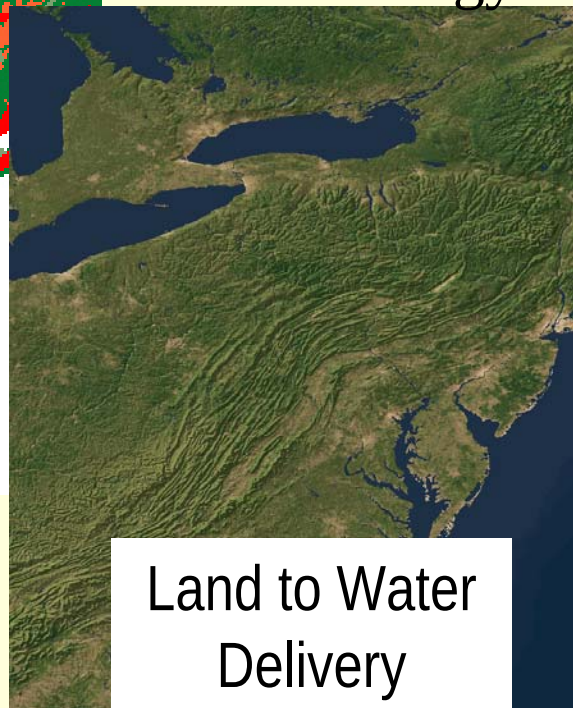


Monitoring Data (Dependent Variable)



Source data

Soils, Slope, Physiography, Geology, Meteorology

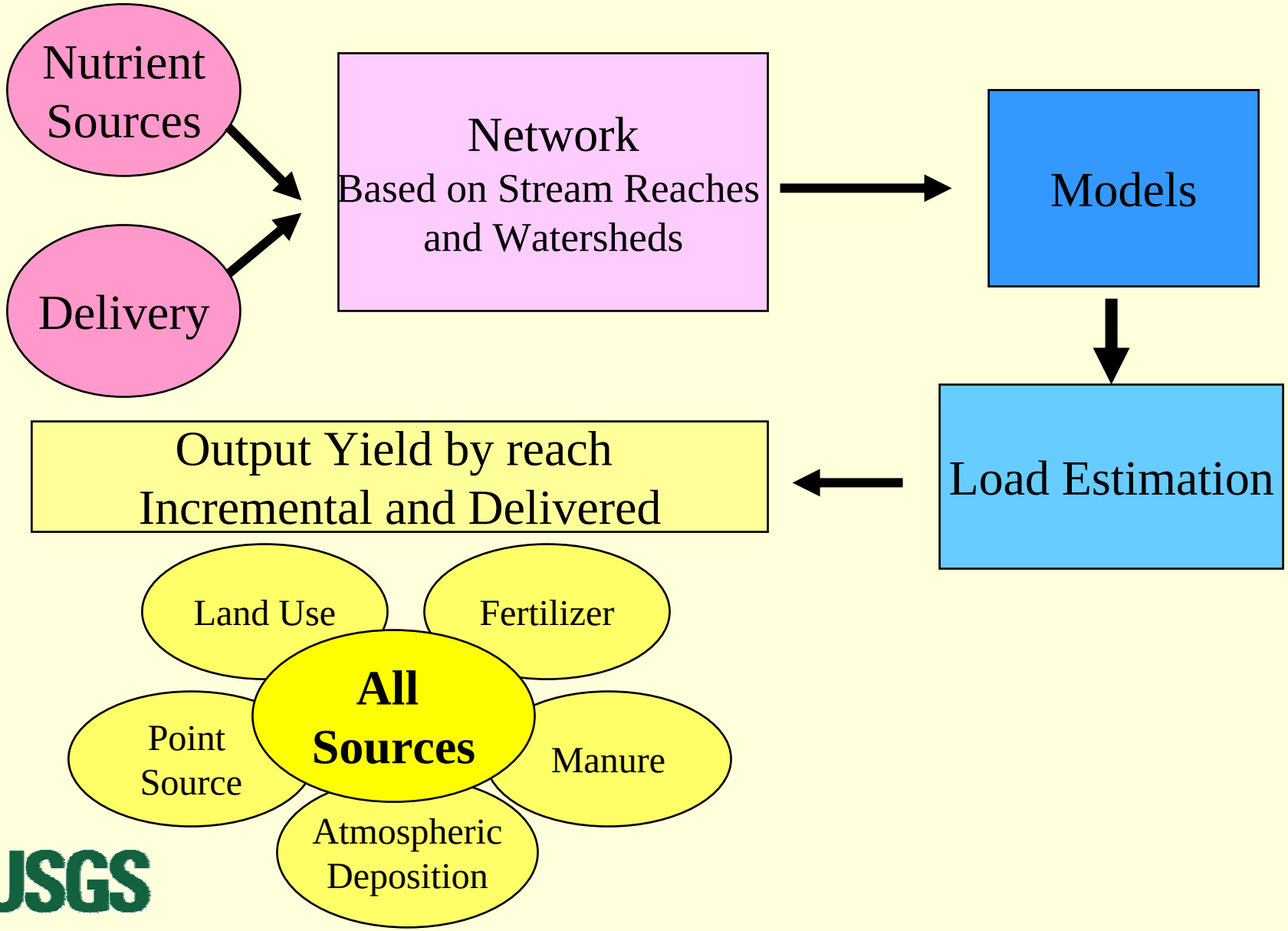


Land to Water Delivery

USGS

GIS

SPARROW


Nutrient Sources
Delivery
Network
Based on Stream Reaches and Watersheds
Models
Load Estimation
Output Yield by reach
Incremental and Delivered
Land Use
Fertilizer
All Sources
Point Source
Manure
Atmospheric Deposition

SPARROW
Estimated Equation

$$\text{Load}_i = \left\{ \sum_{j \in J(i)} \left[\sum_{n=1}^{N} S_{n,j} \underbrace{\beta_n \exp(-\boldsymbol{\alpha}' Z_j)} \right] \underbrace{\exp(-\boldsymbol{\delta}' T_{i,j})} \right\} \underbrace{\exp(\epsilon_i)}$$

Load

Sources

Land-to-water delivery

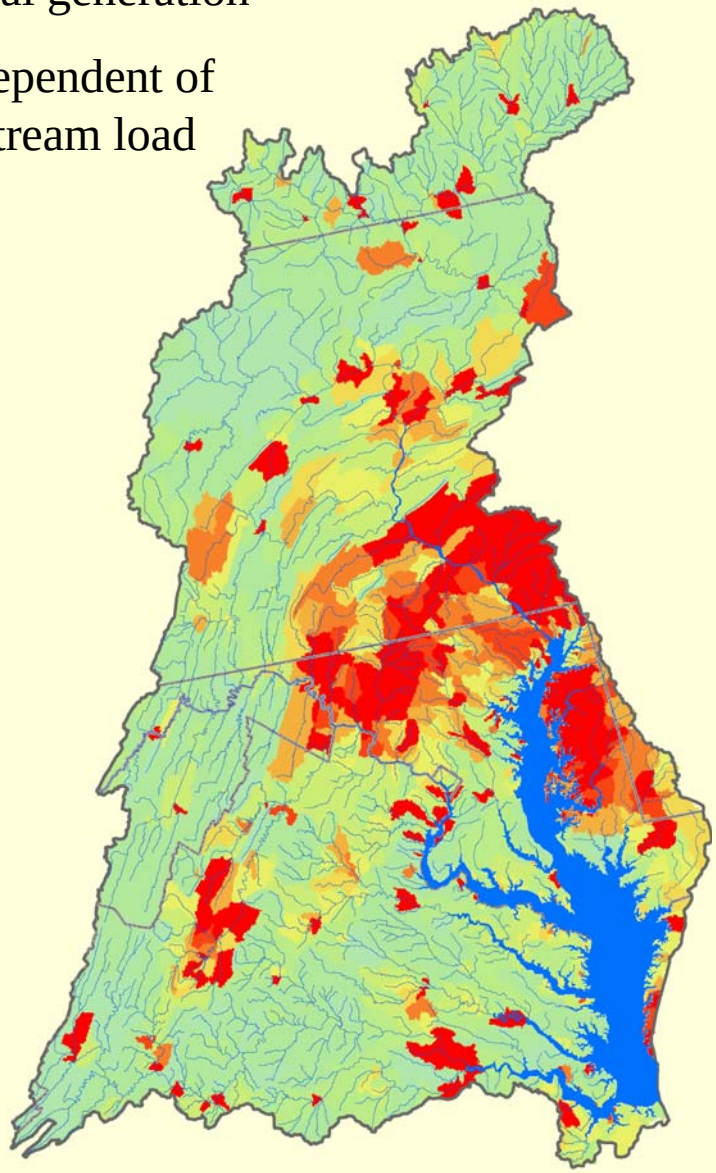
Instream decay

Error

USGS

Local generation

Independent of upstream load

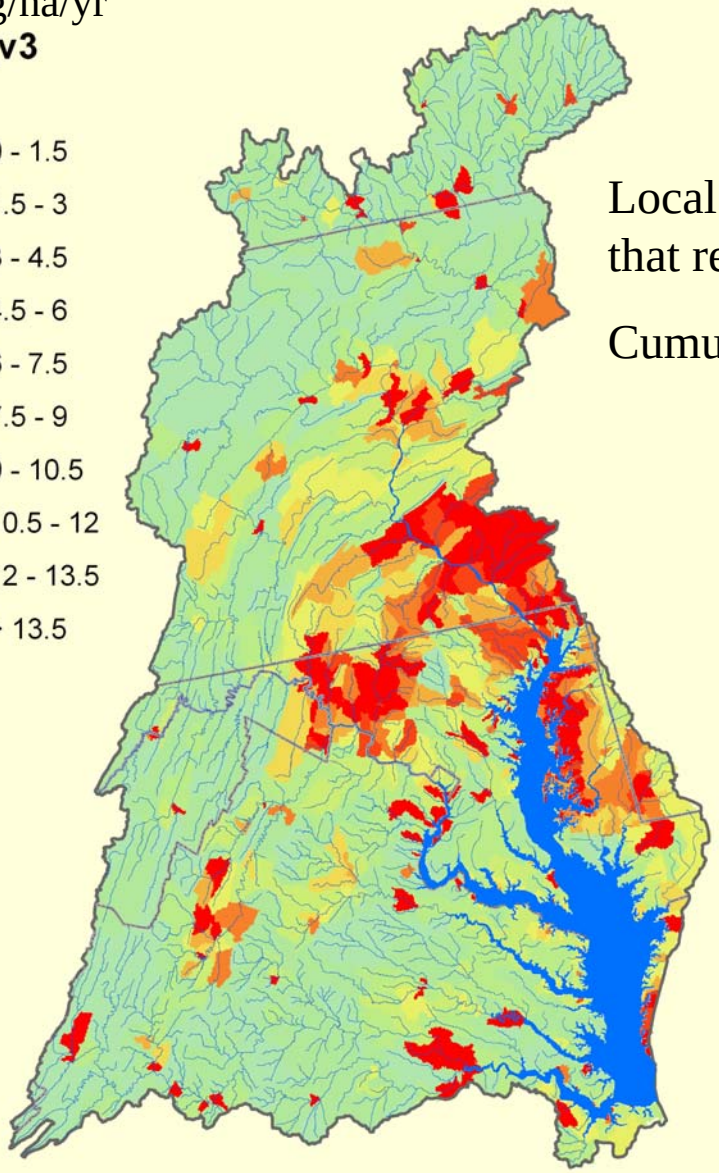


TN Kg/ha/yr

tnws_v3

dytot

- 0 - 1.5
- 1.5 - 3
- 3 - 4.5
- 4.5 - 6
- 6 - 7.5
- 7.5 - 9
- 9 - 10.5
- 10.5 - 12
- 12 - 13.5
- > 13.5



Local generation that reaches bay

Cumulative loss

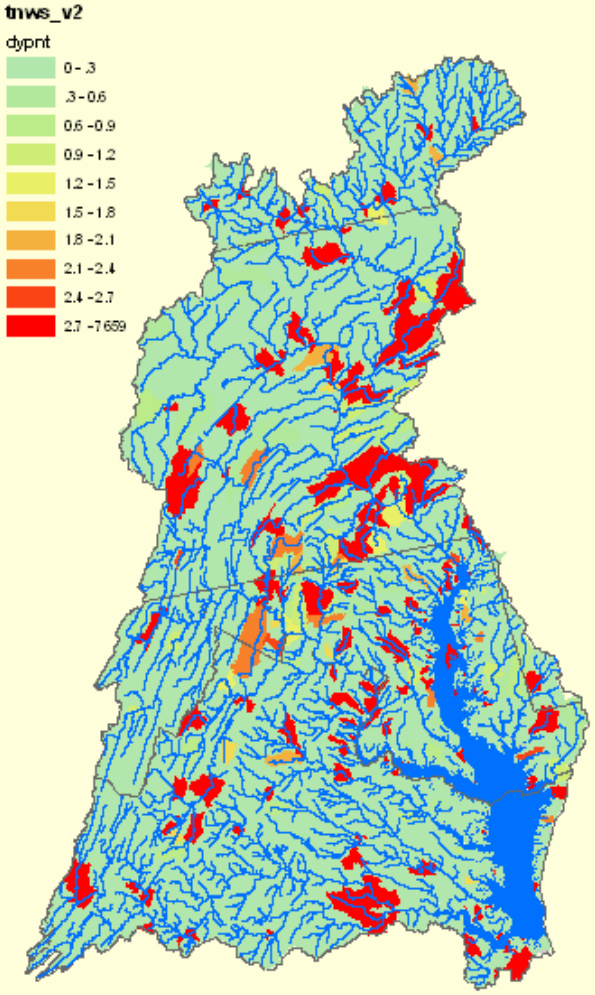
Incremental Yield

Delivered Yield

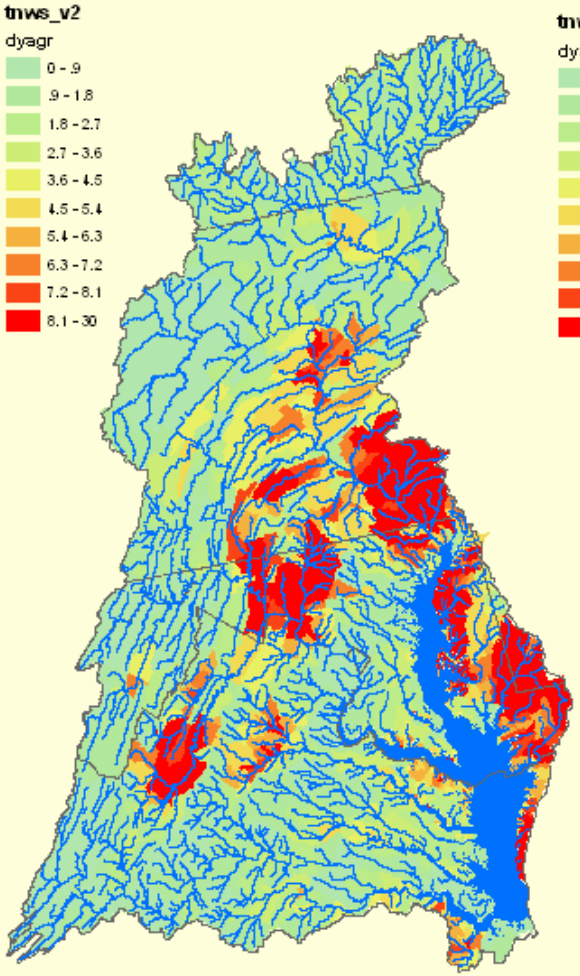
USGS

SPARROW Estimates of Total Nitrogen for all Sources, Late 1990's

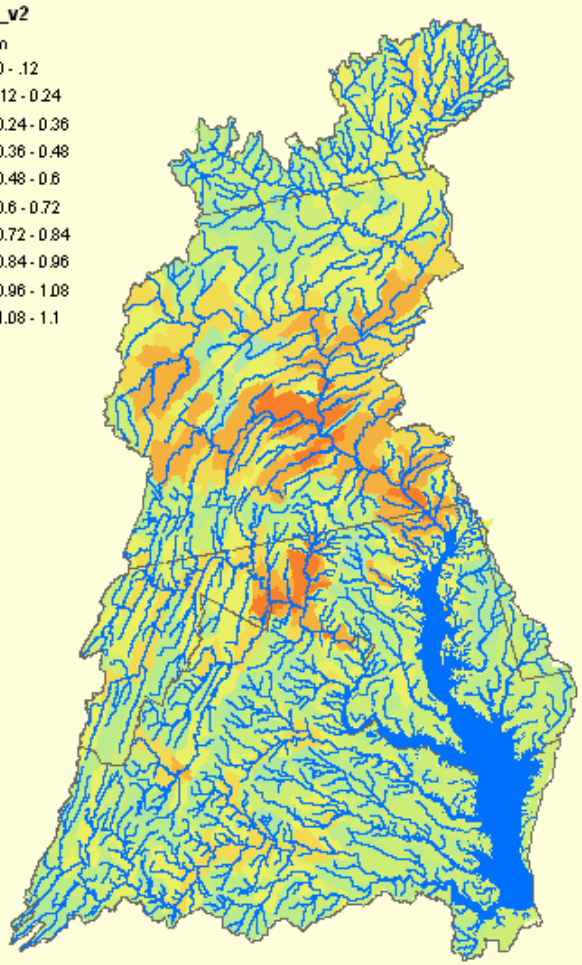
Delivered Yield from Individual Sources



Point Sources



Agriculture



Atmospheric

Comparing relative importance from one time period

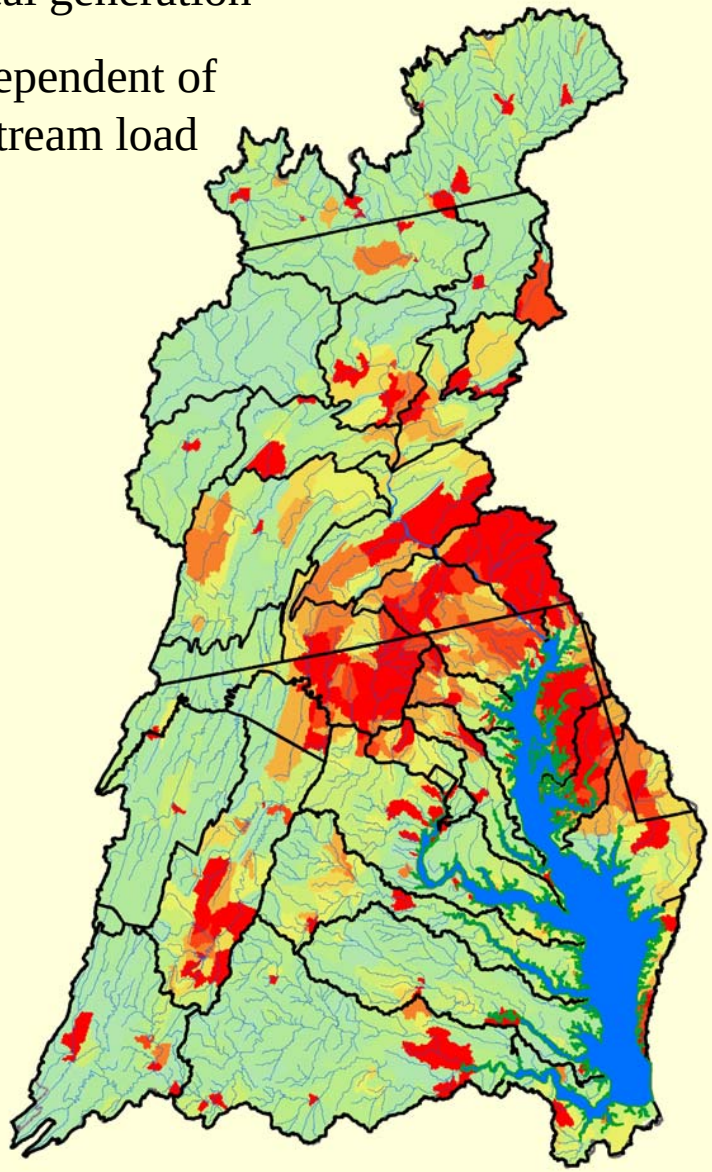
Chesapeake Bay Restoration

- Providing Maps of SPARROW Model Estimates
  - Target audiences Tributary Strategy Groups
    - Watershed and jurisdiction
    - Revising nutrient management plans
    - Static images of individual TSB basins
  - Provides spatial detail within management area
  - Local and Delivered TN and TP for late 1990's
  - Potential for Delivery of All Sources
  - Fraction of single sources contribution
- Provide GIS data sets

USGS

Local generation

Independent of upstream load



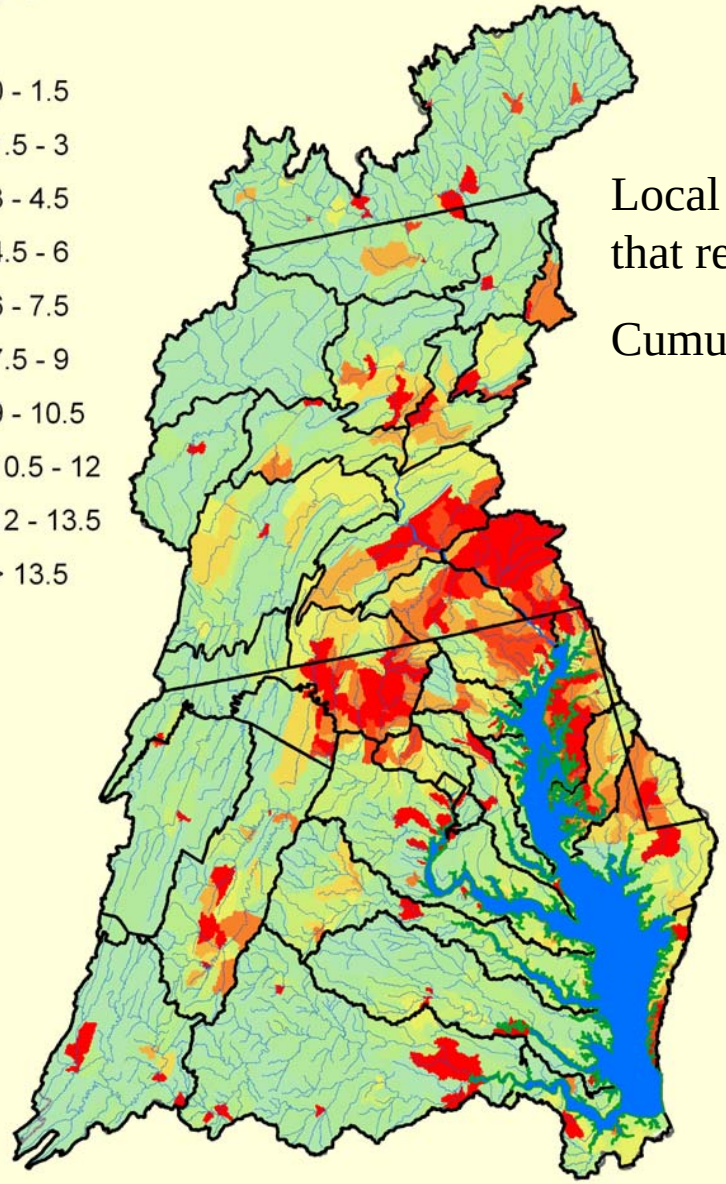
tnws_v3

iytot

- 0 - 1.5
- 1.5 - 3
- 3 - 4.5
- 4.5 - 6
- 6 - 7.5
- 7.5 - 9
- 9 - 10.5
- 10.5 - 12
- 12 - 13.5
- > 13.5

Local generation that reaches bay

Cumulative loss



Incremental Yield

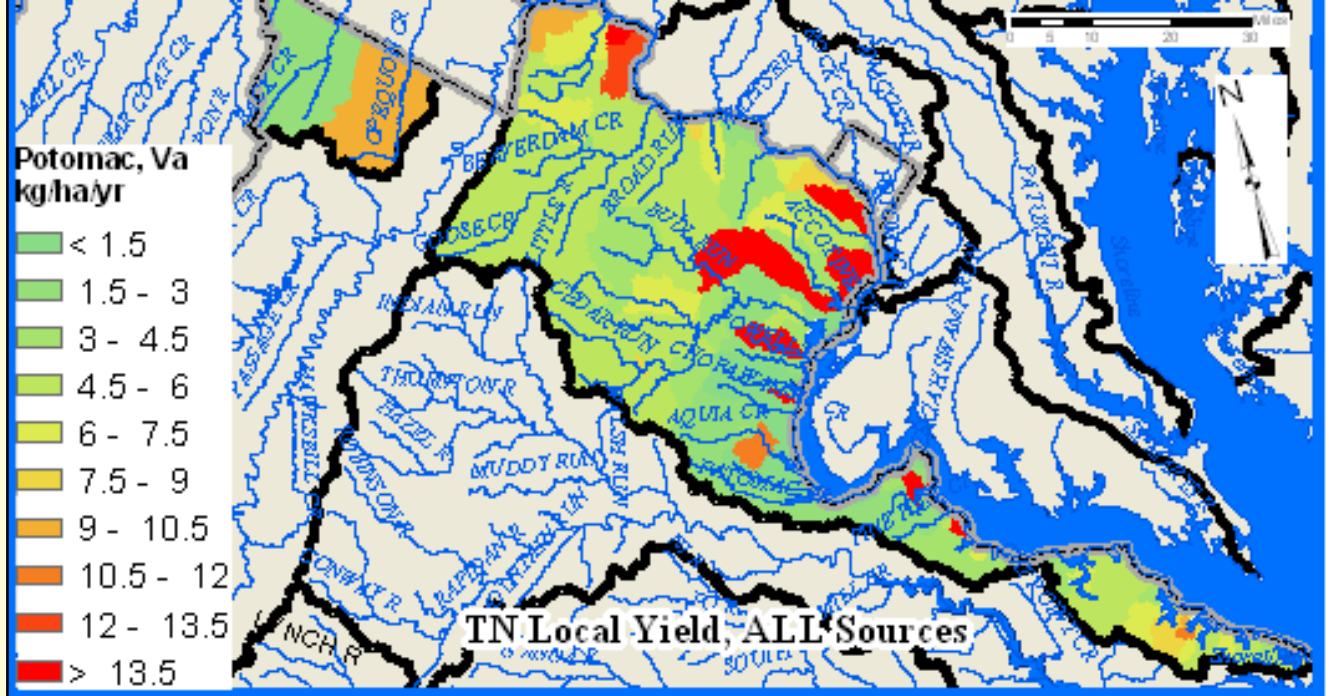
Delivered Yield

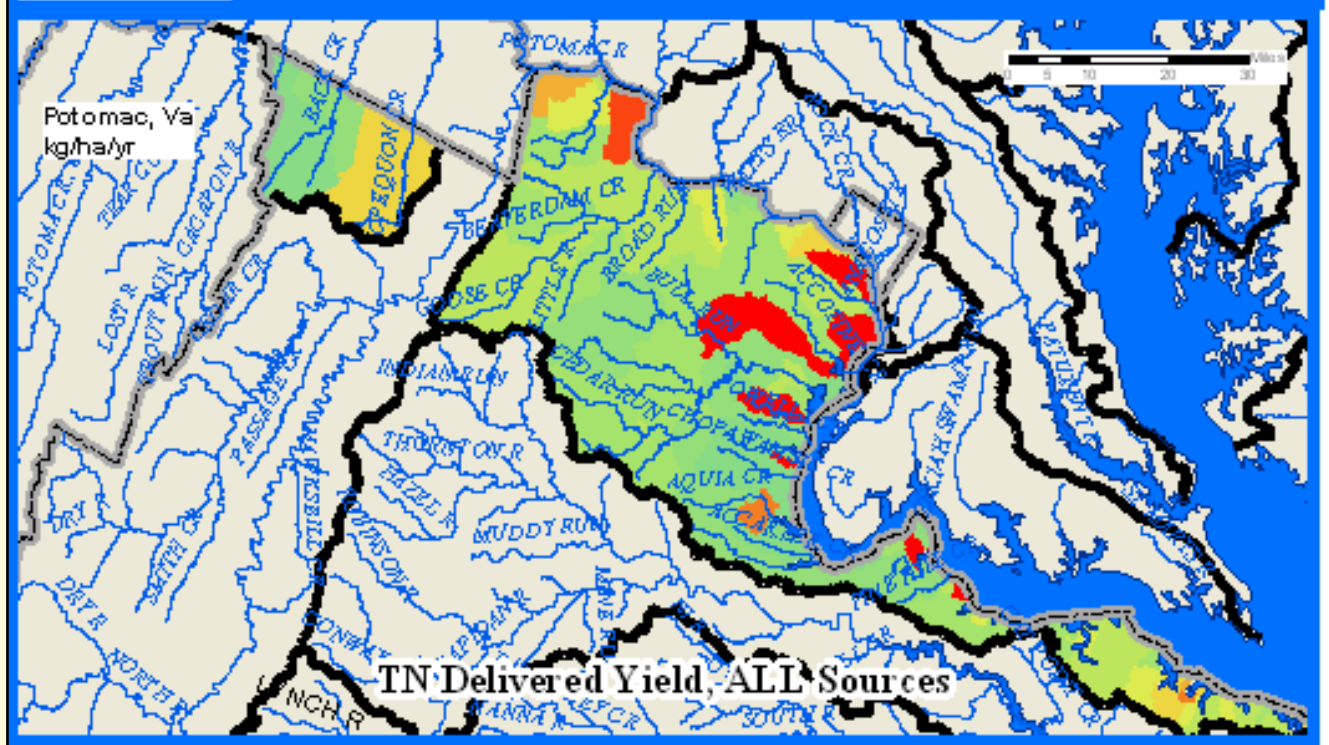
USGS

SPARROW Estimates of Total Nitrogen for all Sources, Late 1990's

TN

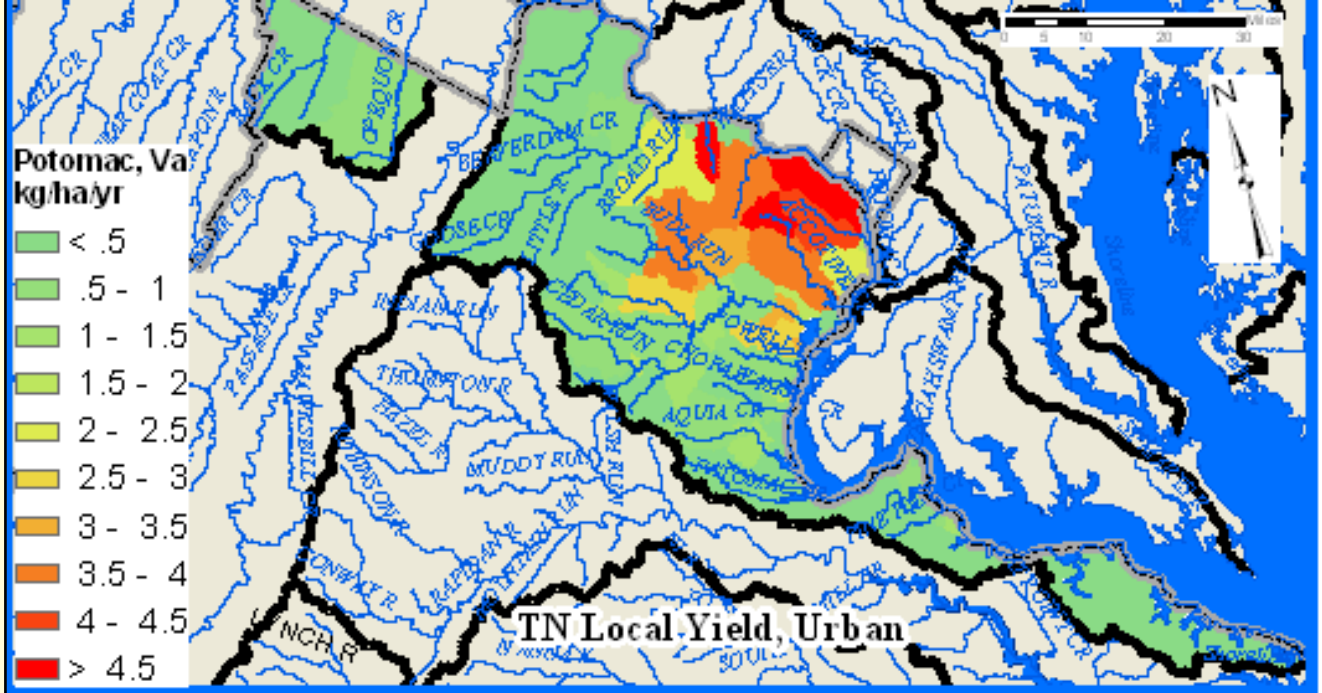
- Local Generation
- Delivery to Bay
- All Sources
- Sources Individually

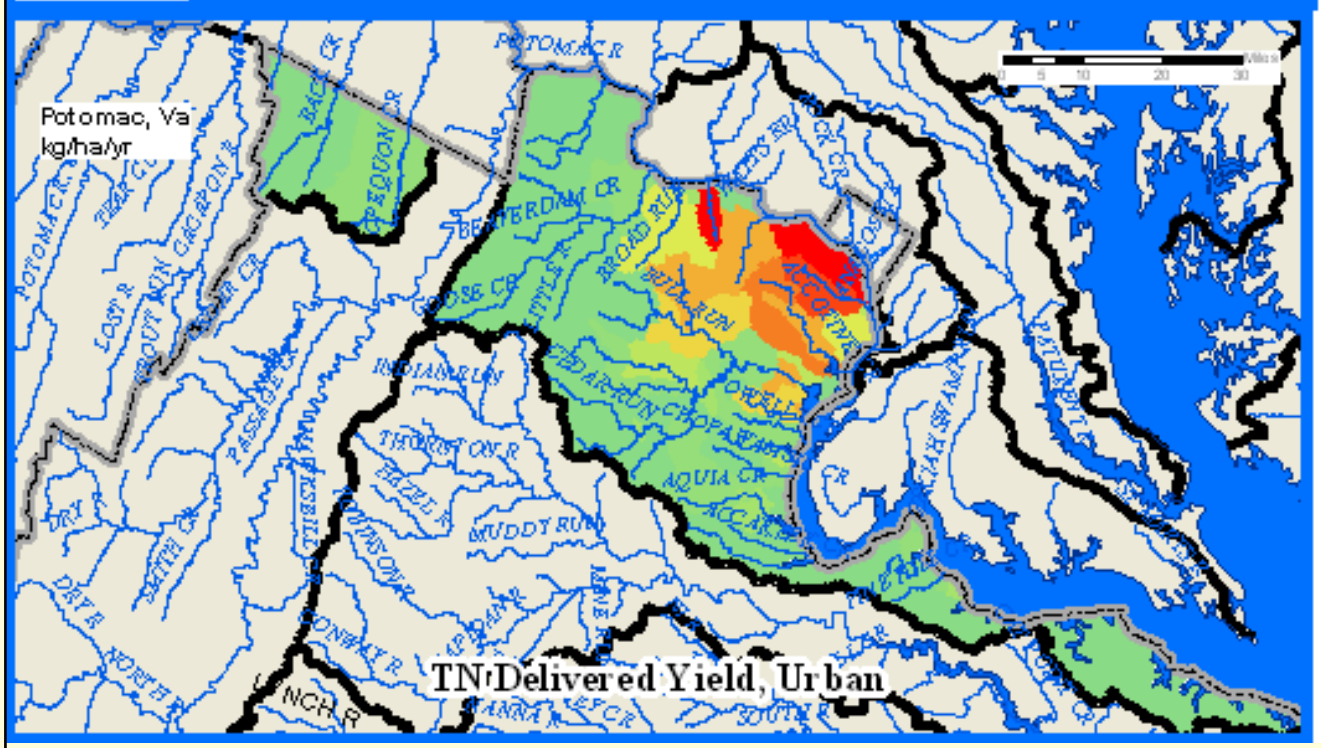




TN

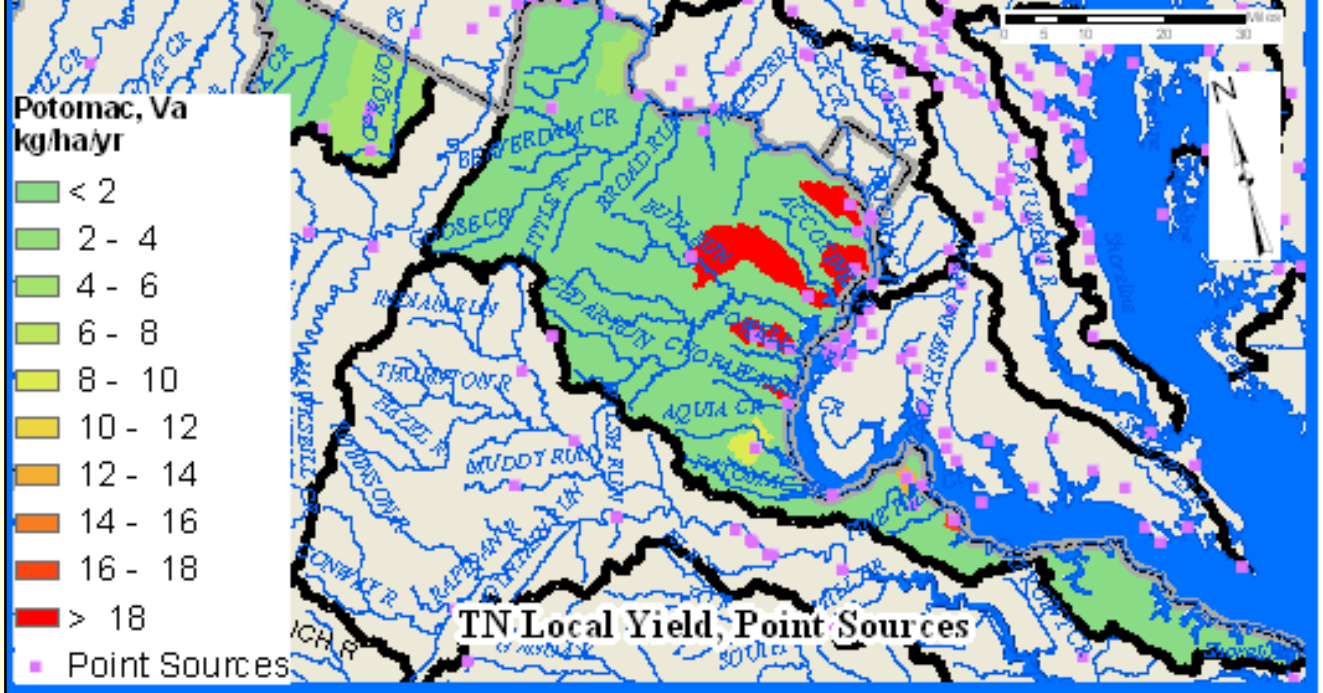
- Urban

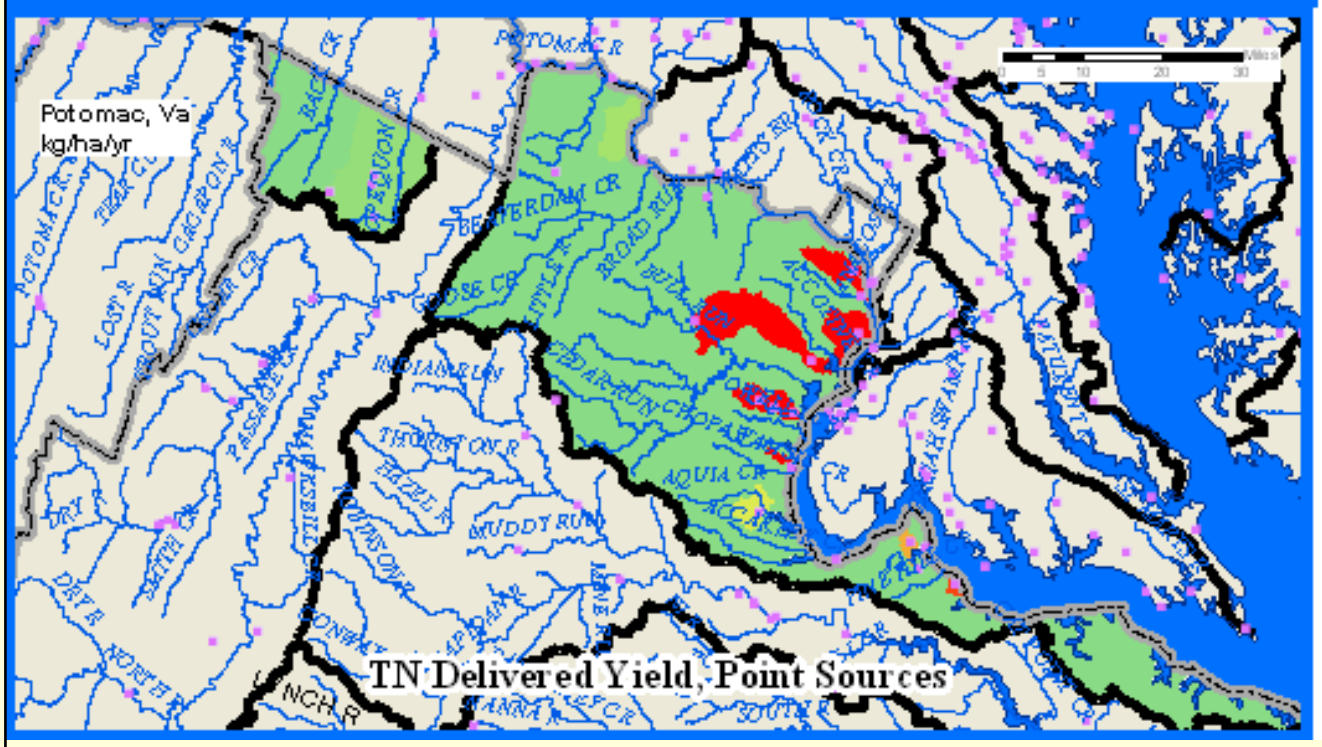

Potomac, Va
kg/ha/yr
< .5
.5 - 1
1 - 1.5
1.5 - 2
2 - 2.5
2.5 - 3
3 - 3.5
3.5 - 4
4 - 4.5
> 4.5
TN Local Yield, Urban


Potomac, Va
kg/ha/yr
TN Delivered Yield, Urban

TN

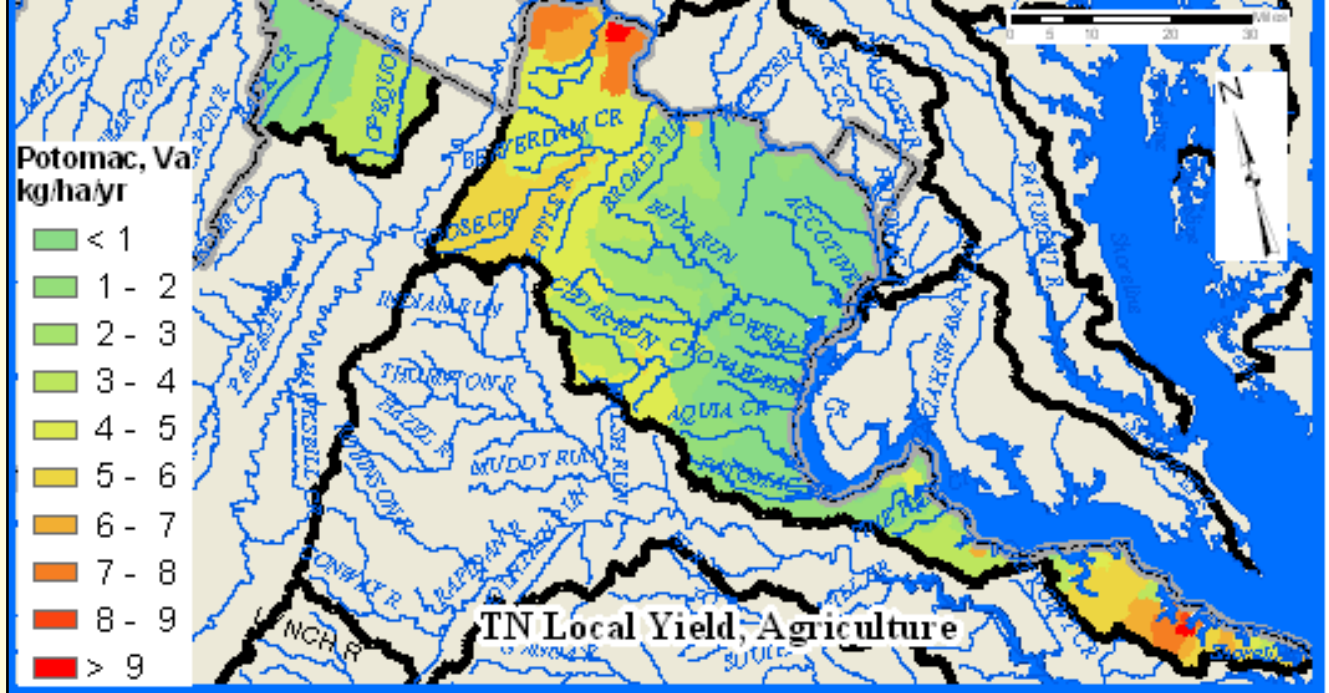
- Point Sources

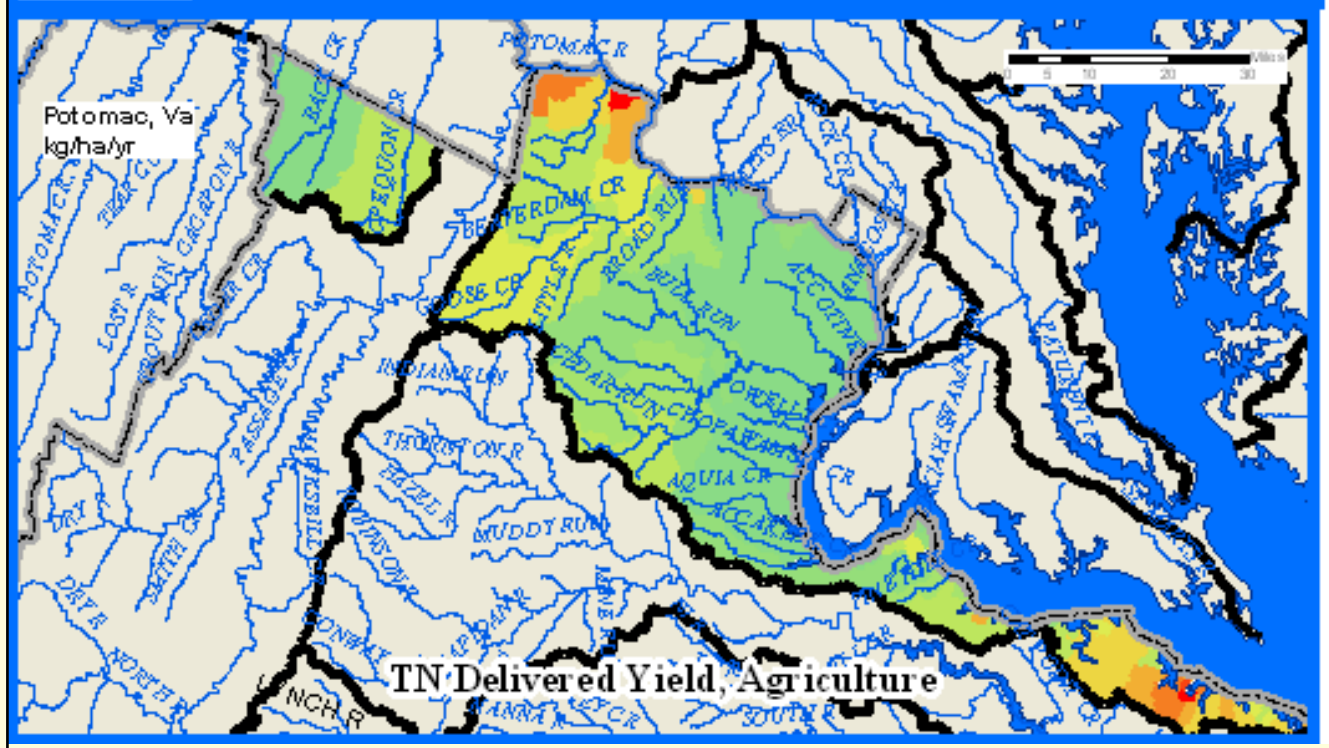




TN

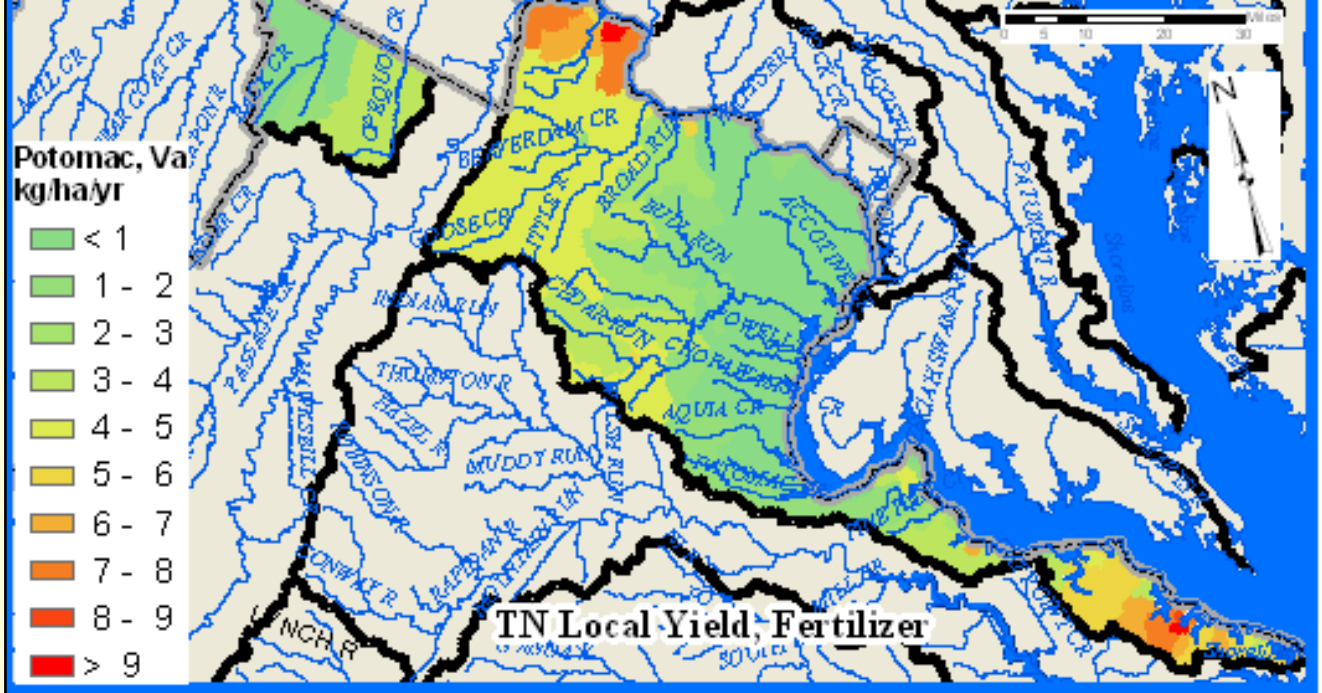
- Agriculture

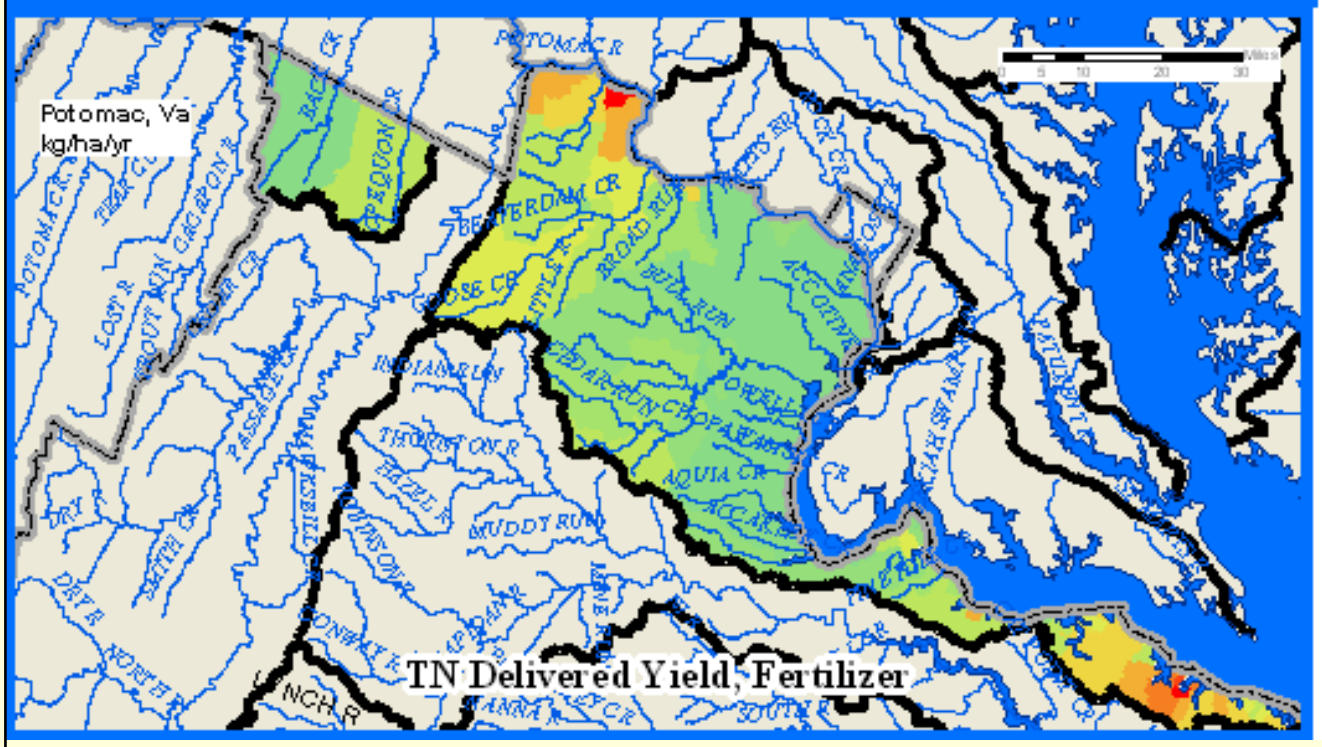




TN

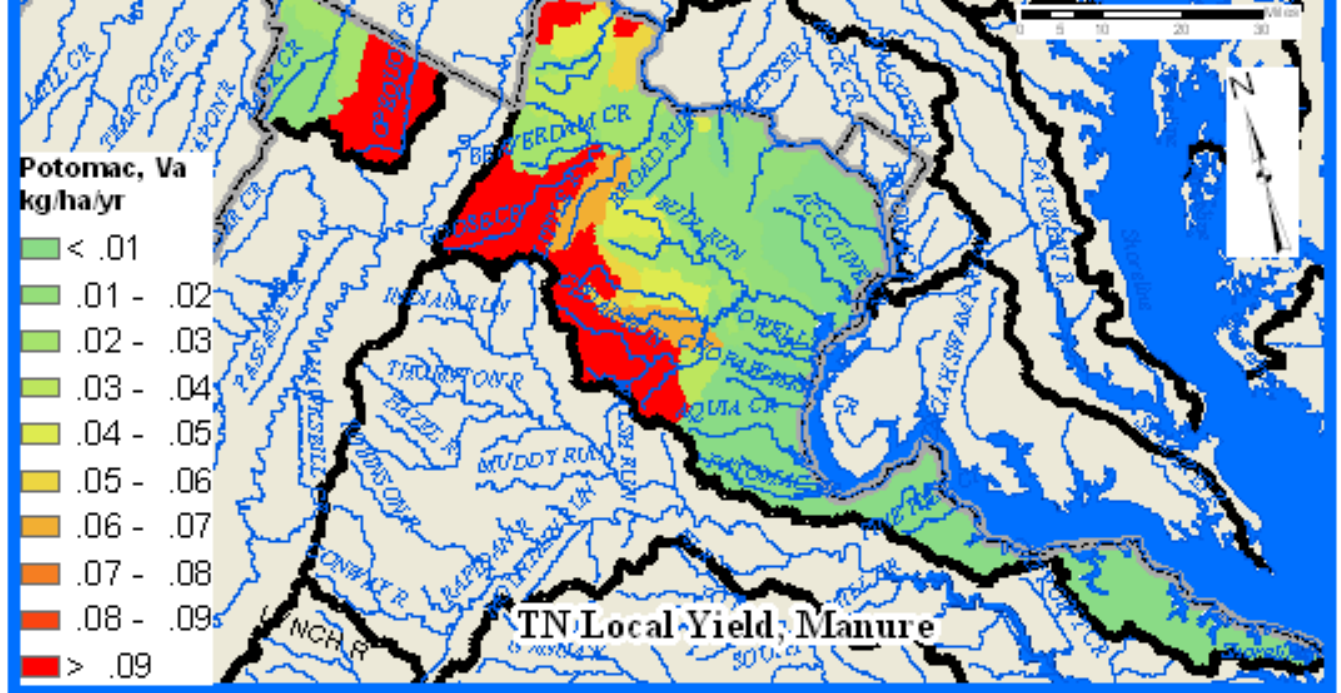
- Fertilizer

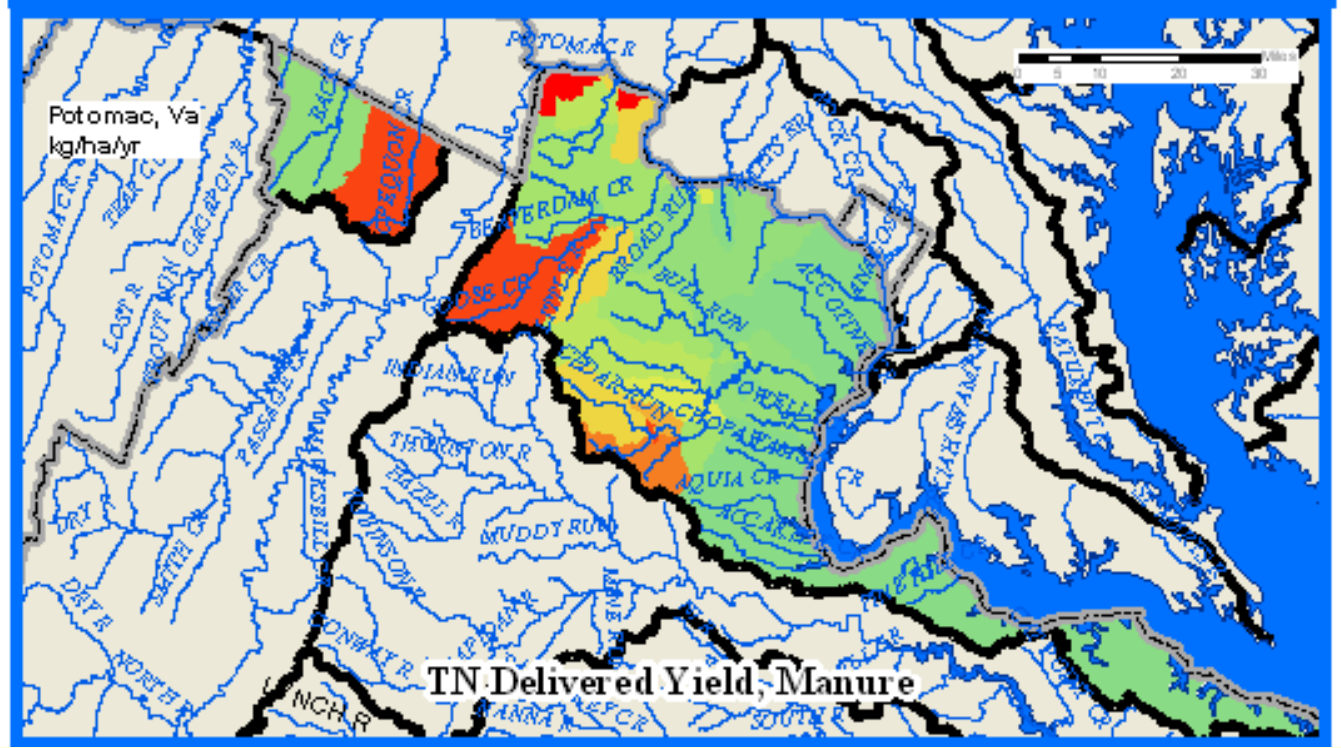




TN

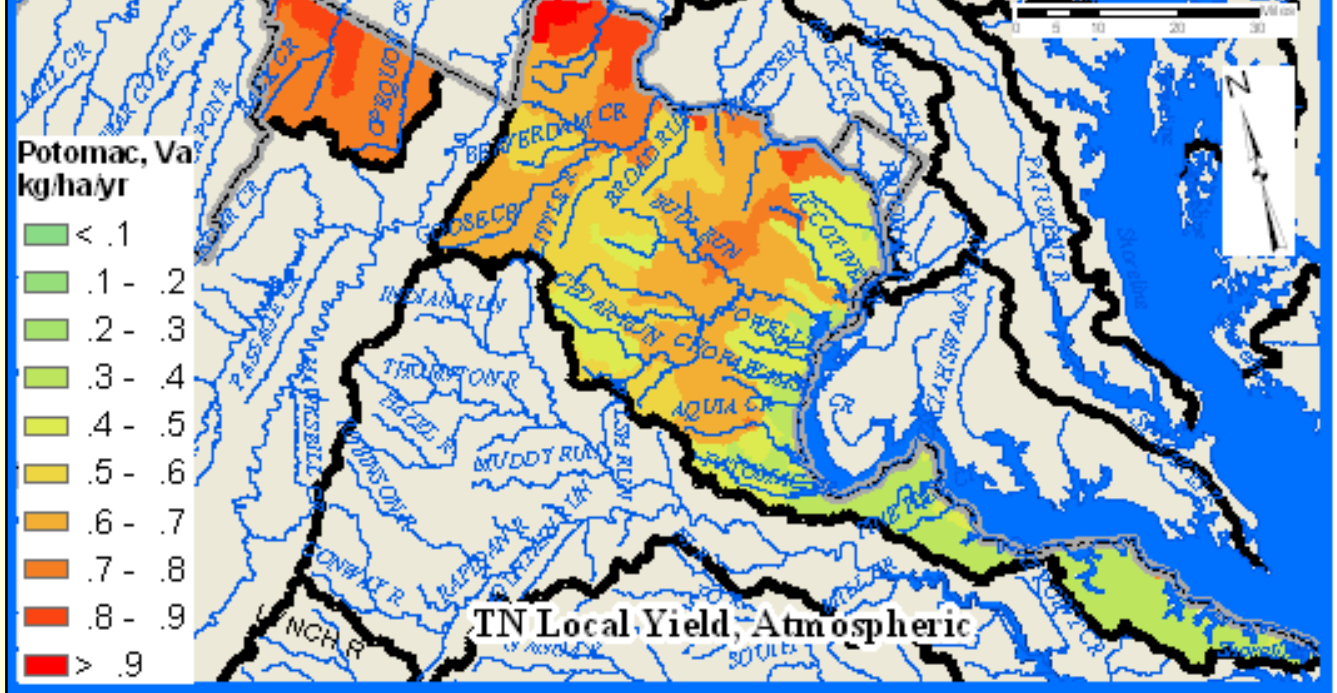
- Manure

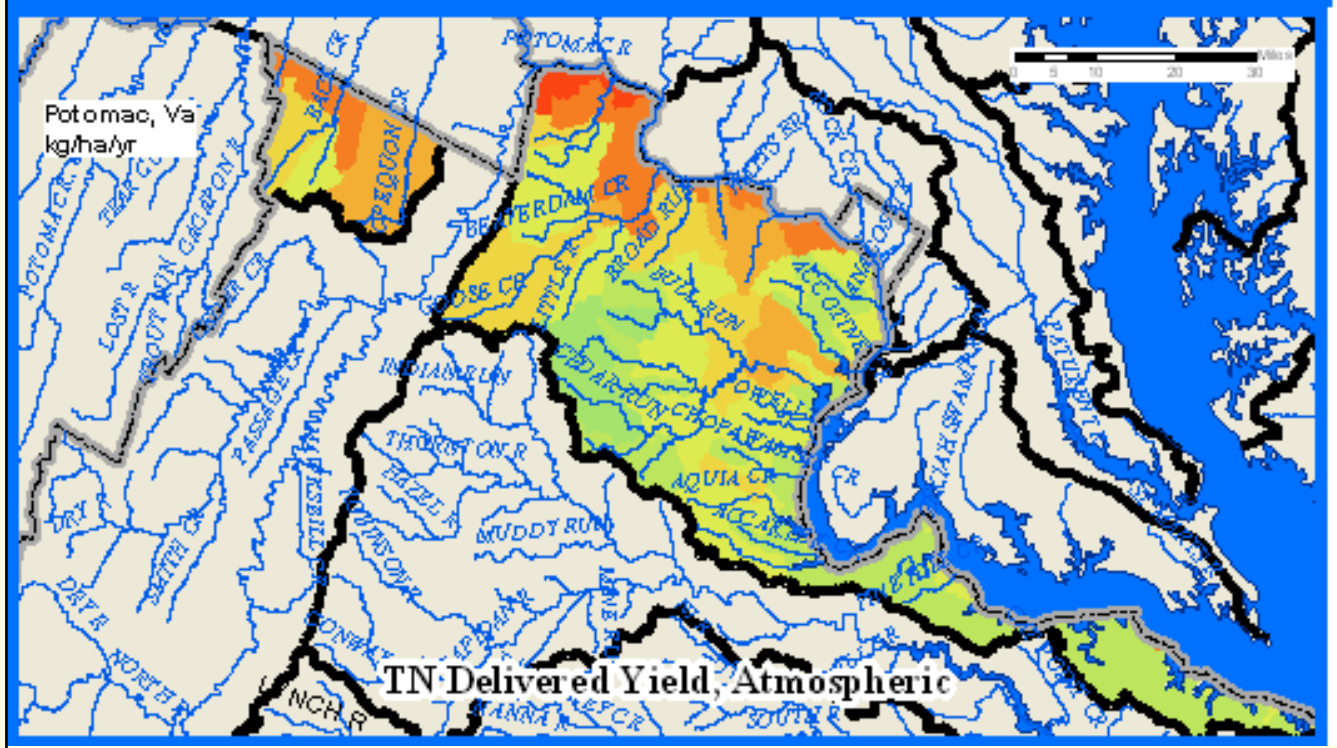

Potomac, Va
kg/ha/yr
< .01
.01 - .02
.02 - .03
.03 - .04
.04 - .05
.05 - .06
.06 - .07
.07 - .08
.08 - .09
> .09
TN Local Yield, Manure


Potomac, Va
kg/ha/yr
TN Delivered Yield, Manure

TN

- Atmospheric

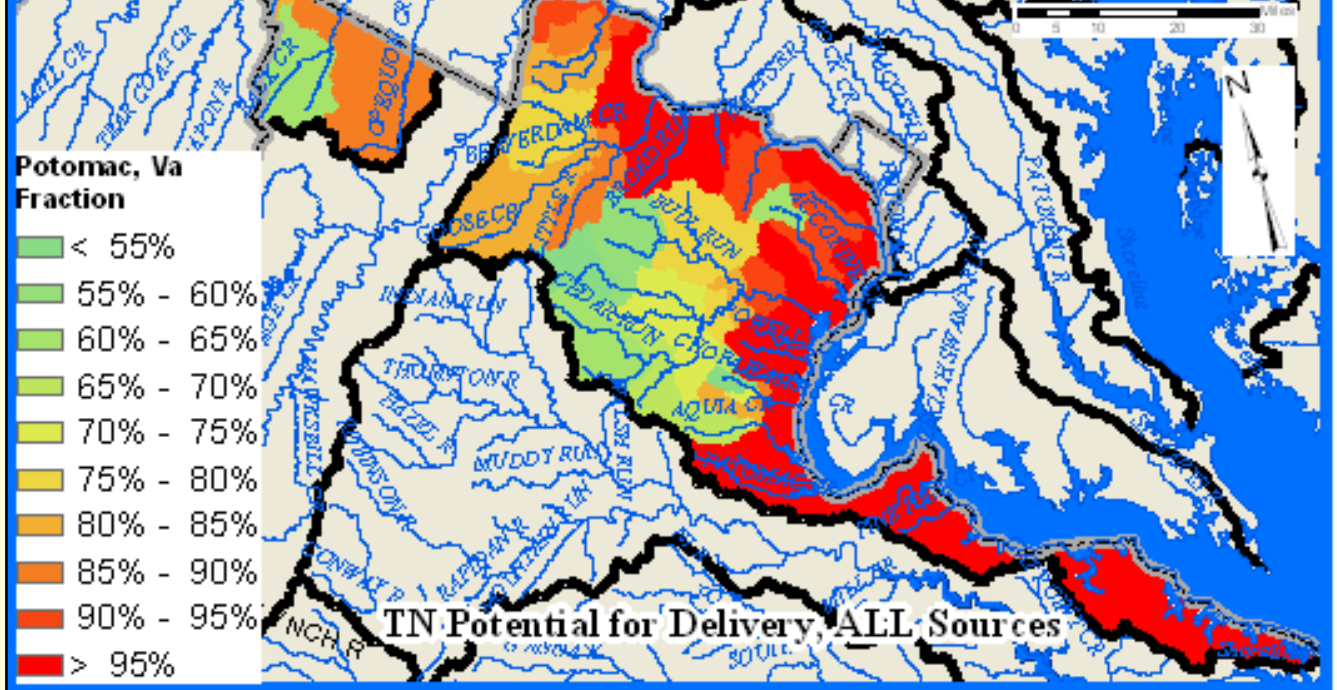


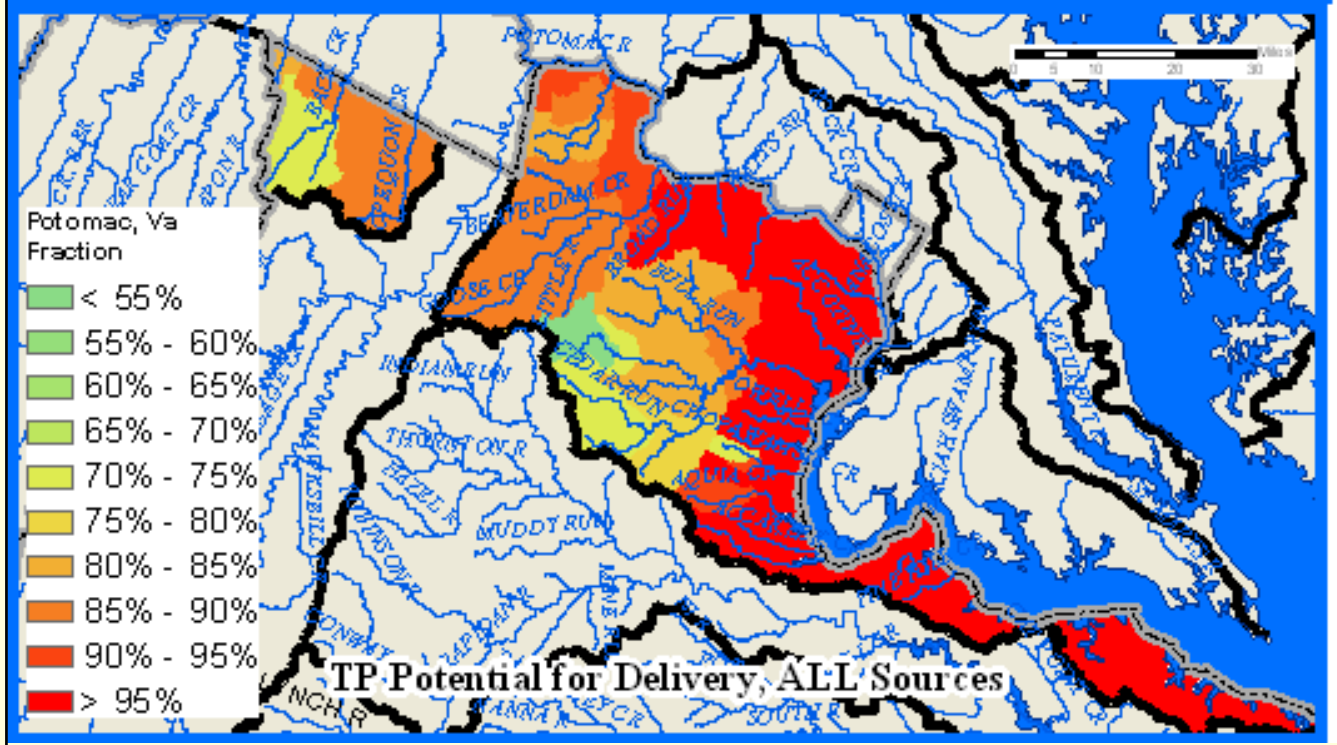


TN

- Potential for Delivery
- How much reaches Bay once in stream?
- Fraction of all sources

TP

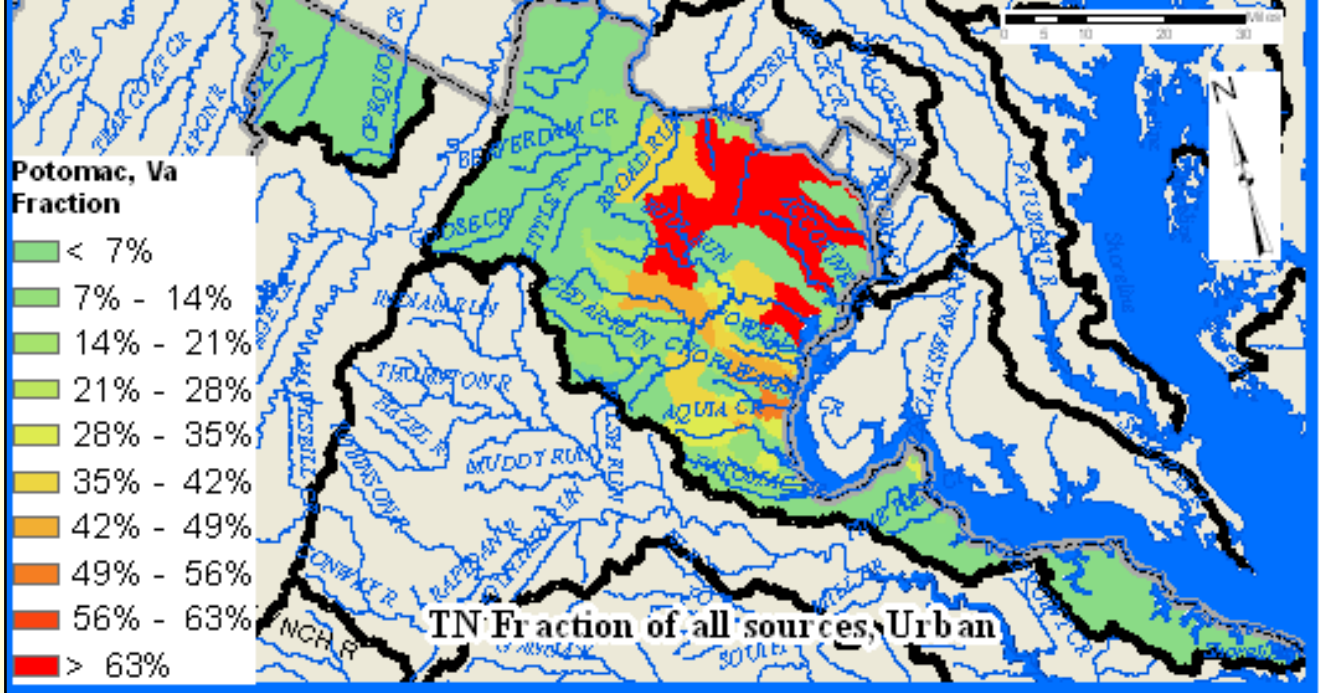


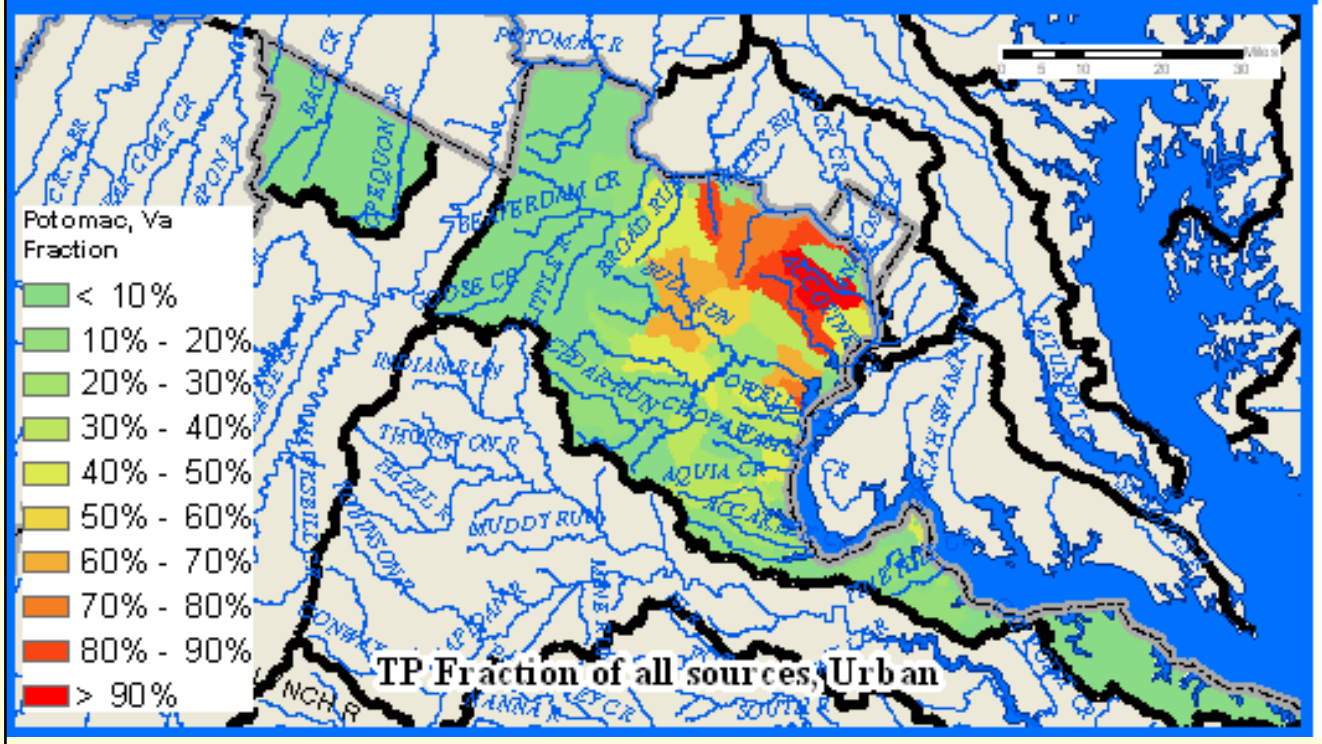


TN

- Fraction of All sources, Urban

TP

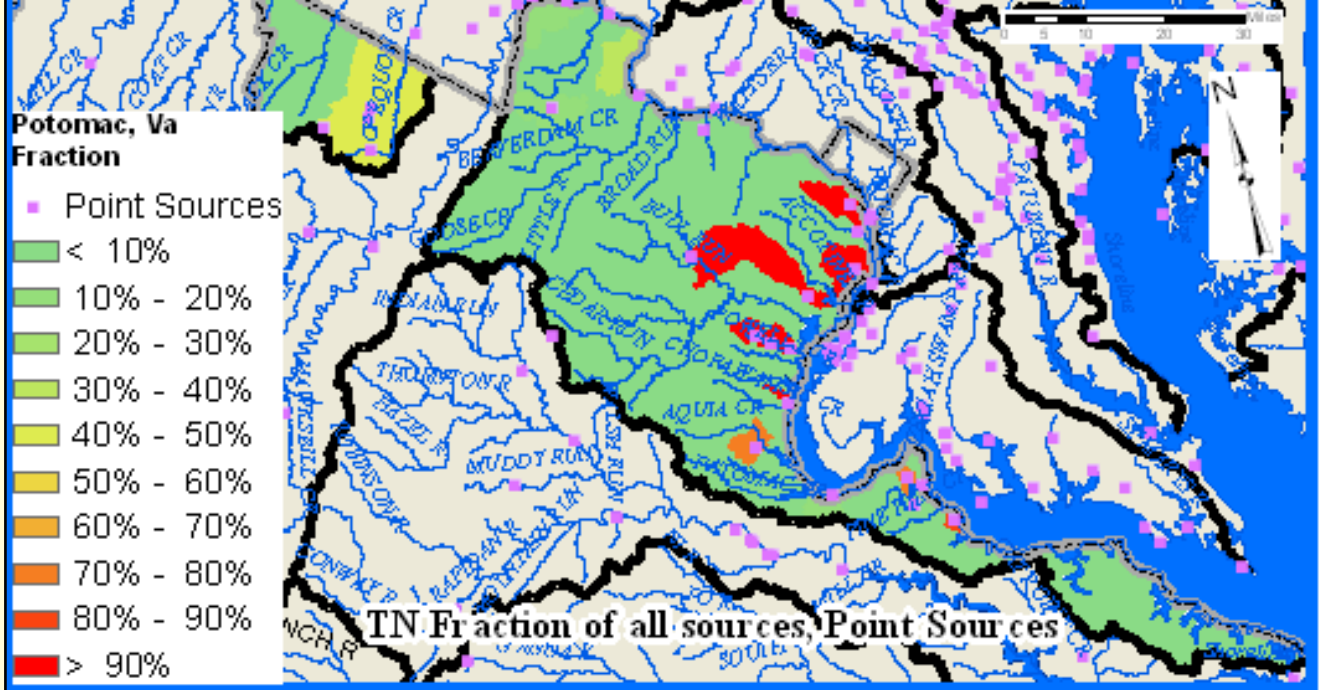


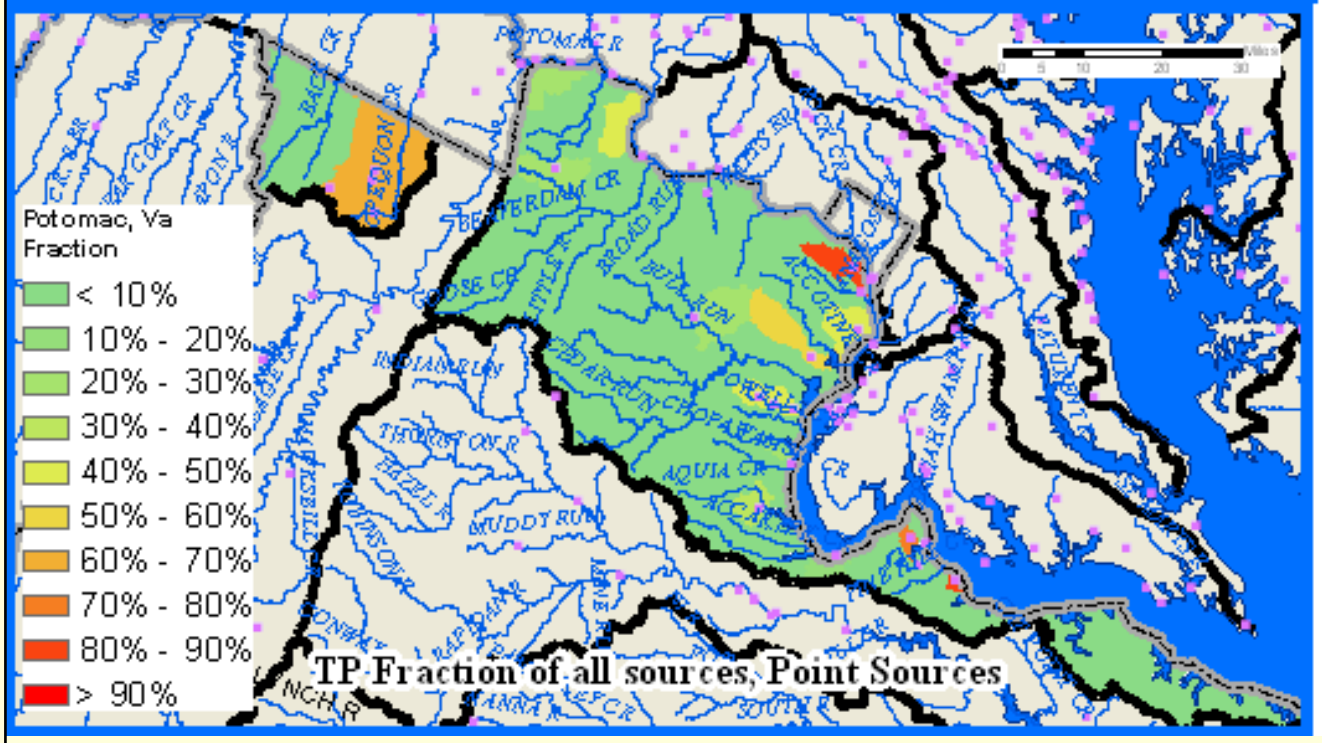


TN

- Fraction of All sources, Point Sources

TP

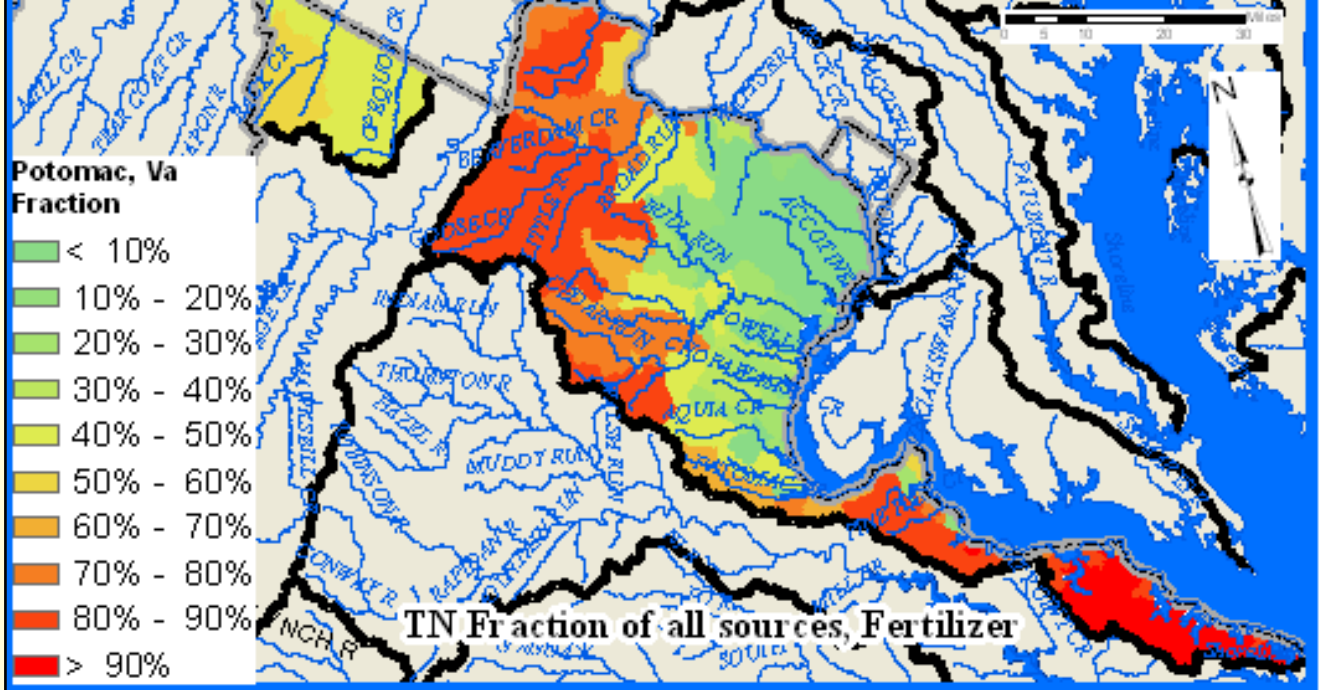


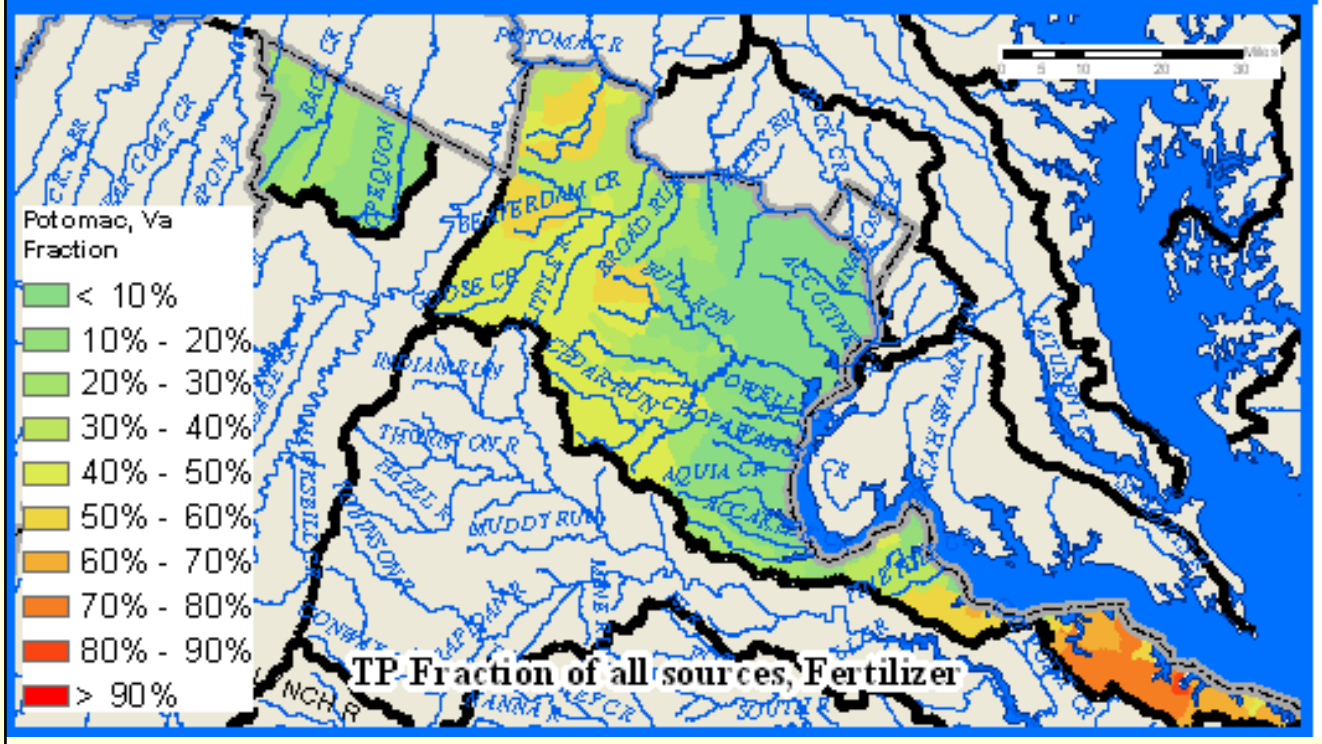


TN

- Fraction of all sources, Fertilizer

TP

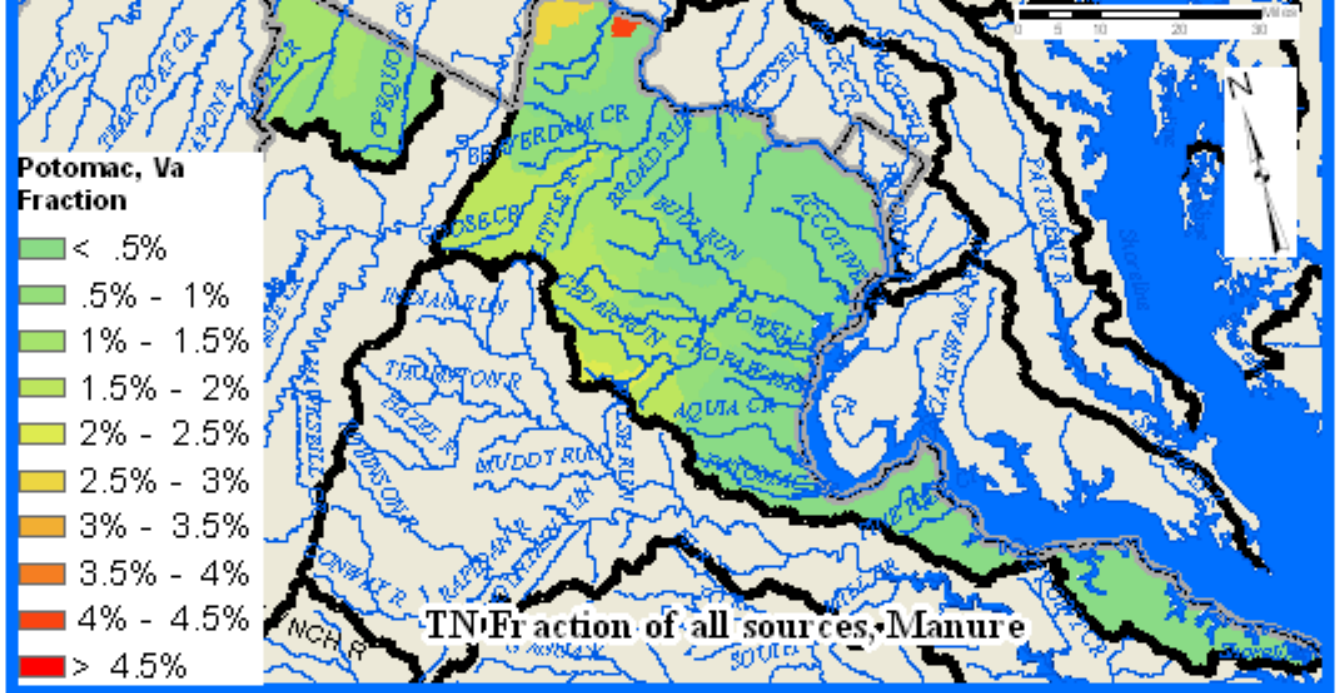


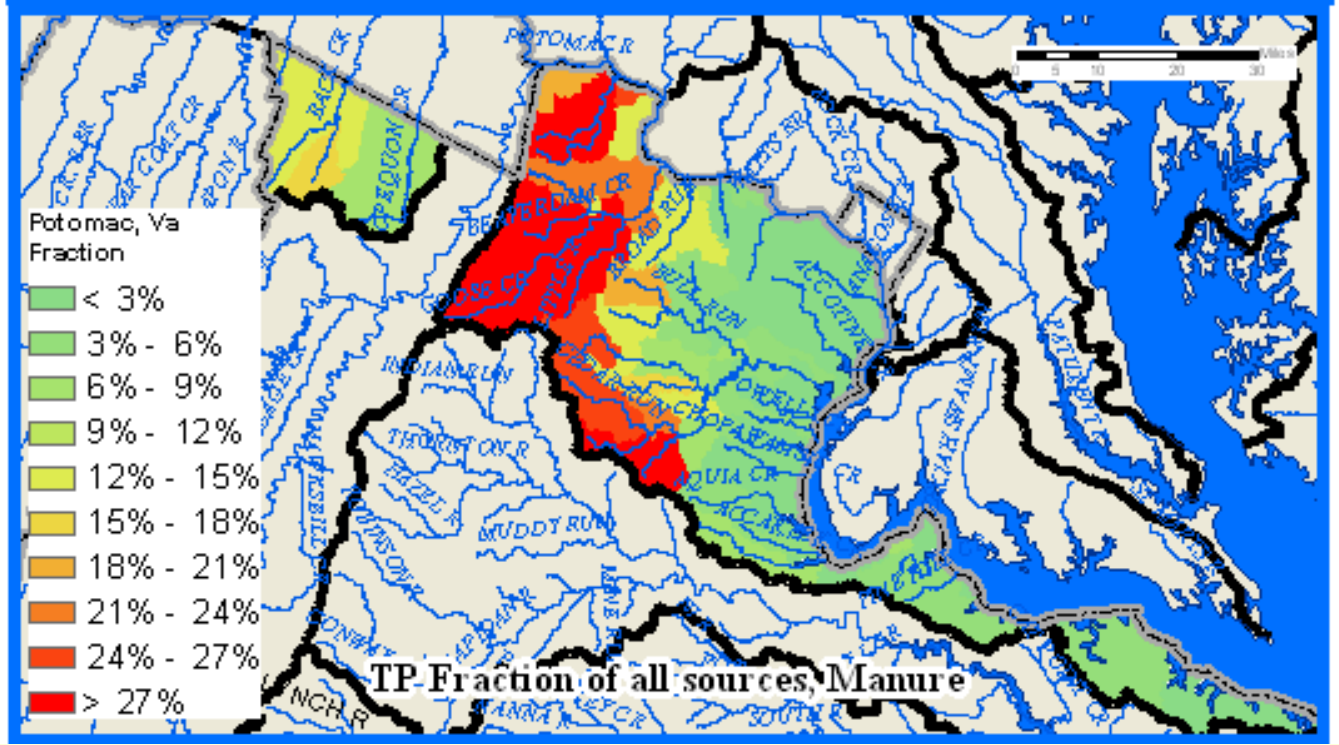


TN

- Fraction of all sources, Manure

TP

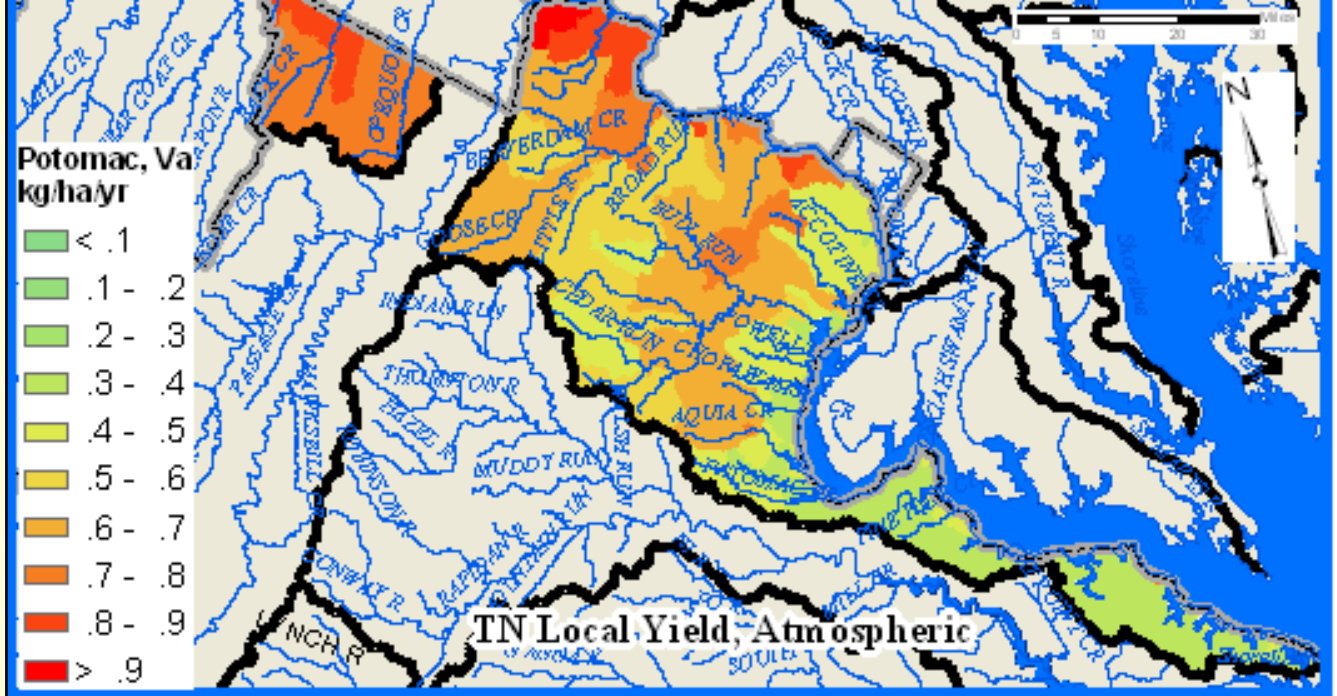


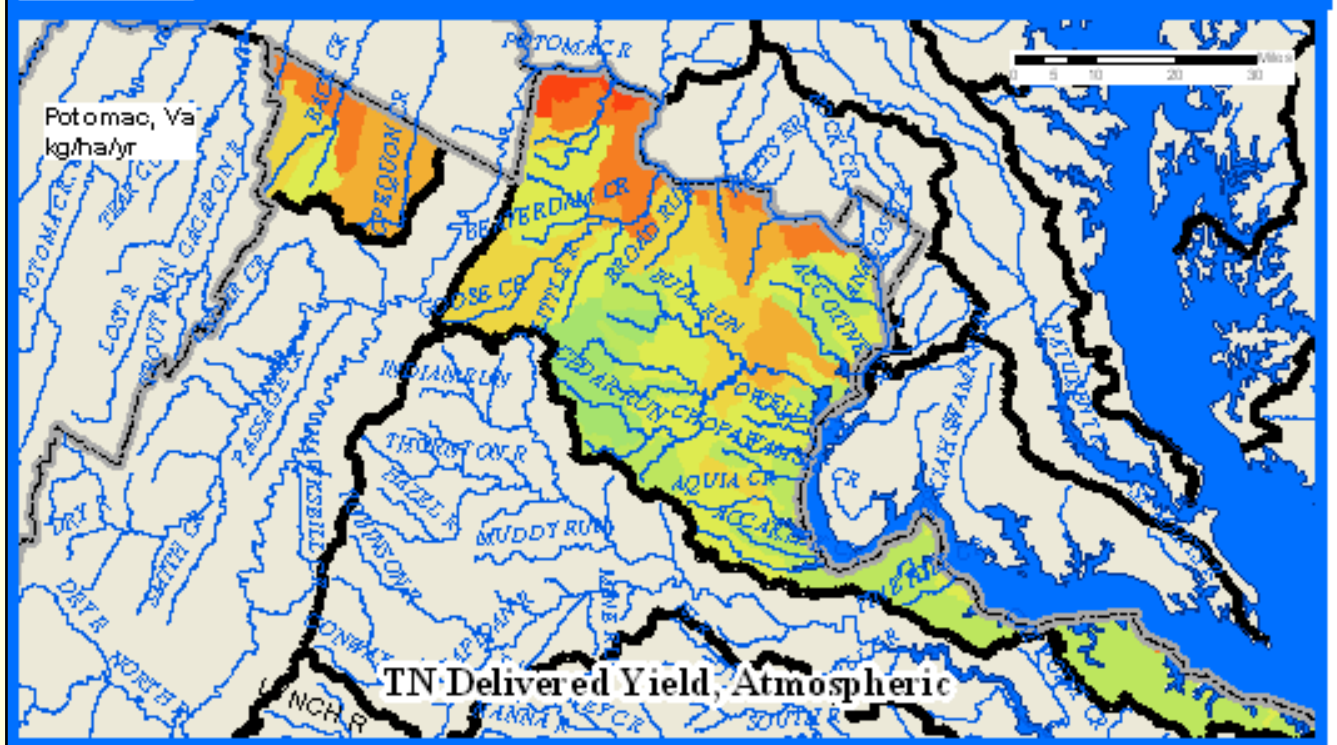


TN

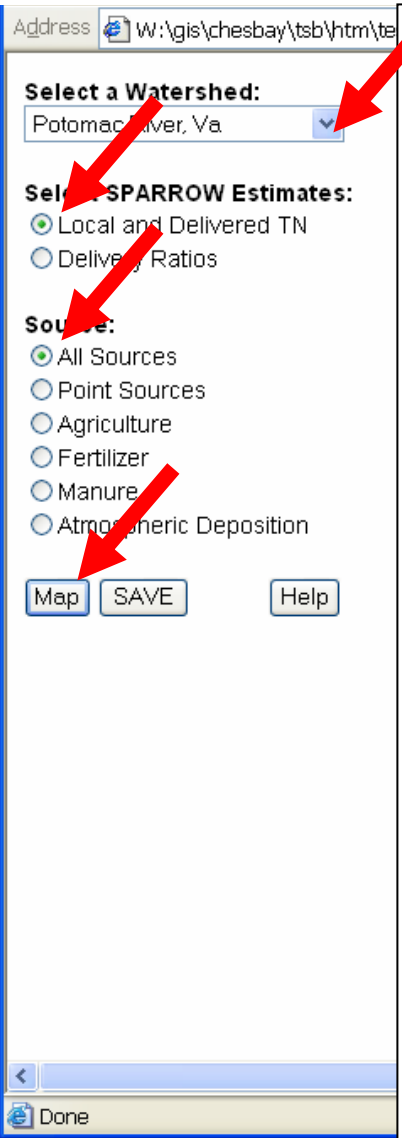
- Fraction of all sources, Atmospheric

TP





IMPROVING a Web based data delivery system



- Static maps for **EACH** Tributary Basin Boundary.
- Displays .gif files based on user selection.
- Limitation is data is static nature

1) In this example, user selects Potomac River, Va. Watershed
2) SPARROW Local and Delivered Estimates for ALL sources
3) Then Map.
4) Static Image displays Local and delivered yield estimates

W:\gis\chesbay\tsb\htm\testhtm\tnform.html - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites

Address W:\gis\chesbay\tsb\htm\testhtm\tnform.html Go Links

Select a Watershed:

Potomac River, Va

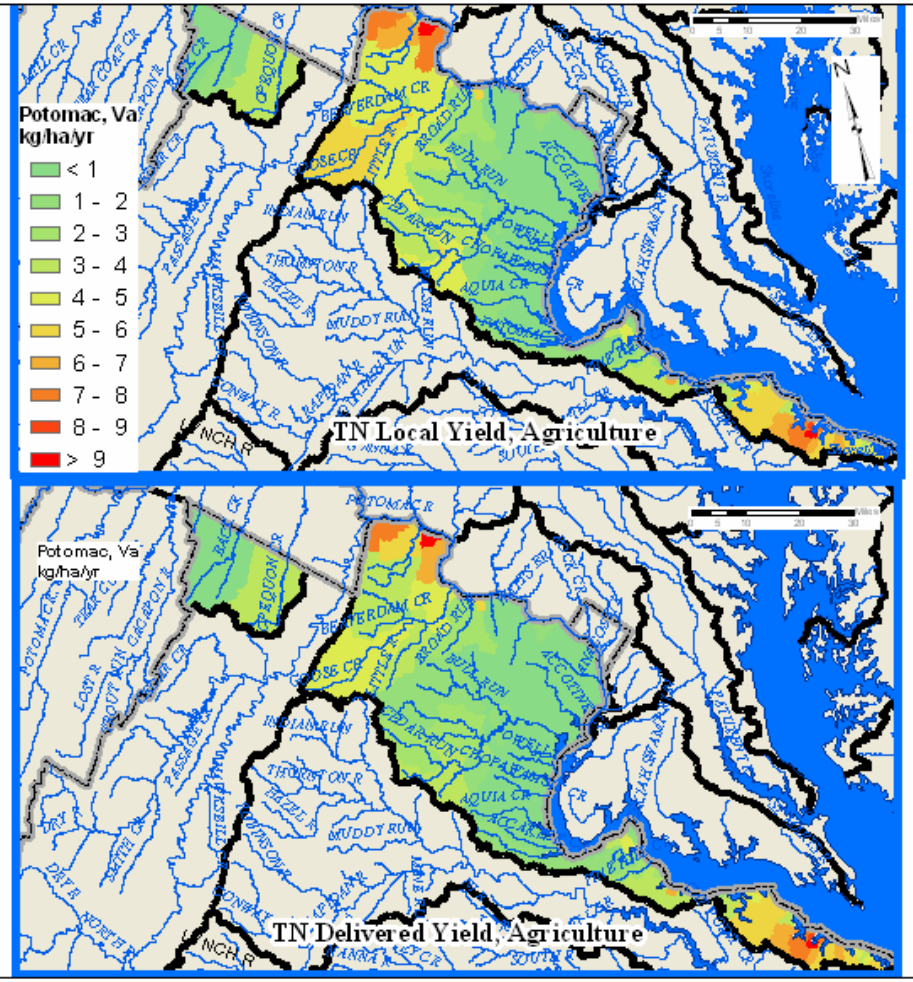
Select SPARROW Estimates:

- Local and Delivered TN
- Delivery Ratios

Source:

- All Sources
- Point Sources
- Agriculture
- Fertilizer
- Manure
- Atmospheric Deposition

Map SAVE Help

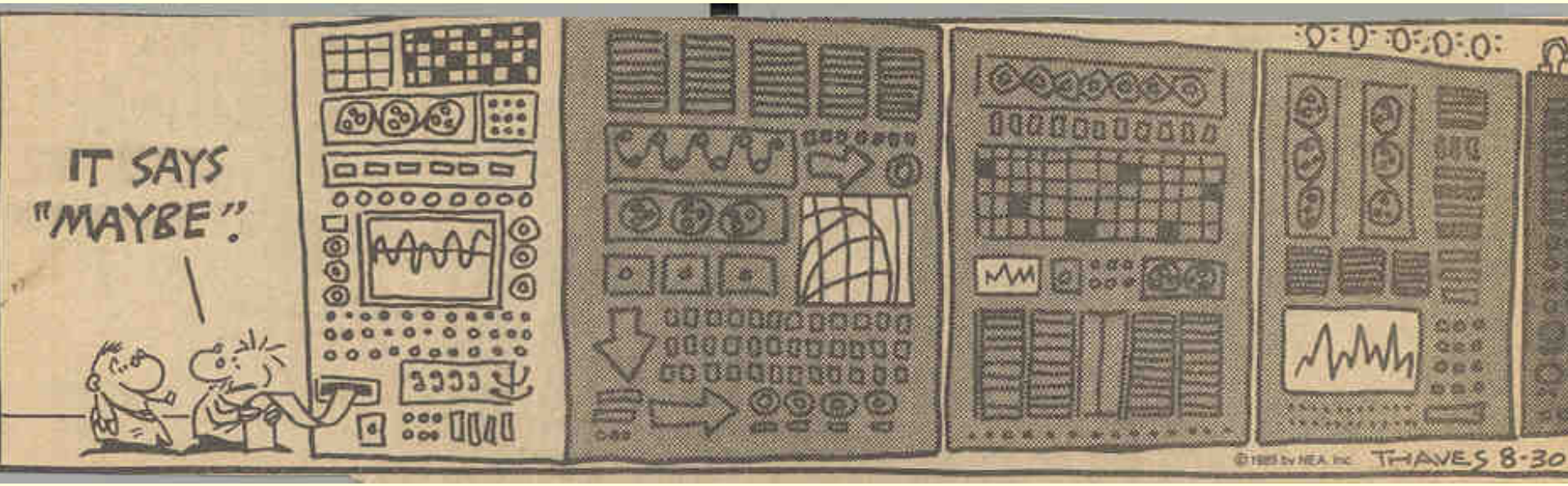


Done Local intranet

SUMMARY

- SPARROW provides a methodology to spatially relate contaminate loads to sources.
- In terms of nutrient delivery to the Bay,
  - less nutrient loss is likely to occur in large streams, and close proximity to those large streams.
  - N loss is more likely to occur in headwaters of non-urban watersheds.
  - Soil Permeability (and coastal plain), Stream time of travel affect loss rates.
- Information Delivery
  - Tributary Strategy Workgroups to help revise nutrient management
  - Individual images, GIS data, or web site
- http://md.water.usgs.gov/gis/chesbay/SPARROW.htm
- jwbrakeb@usgs.gov 410-238-4257

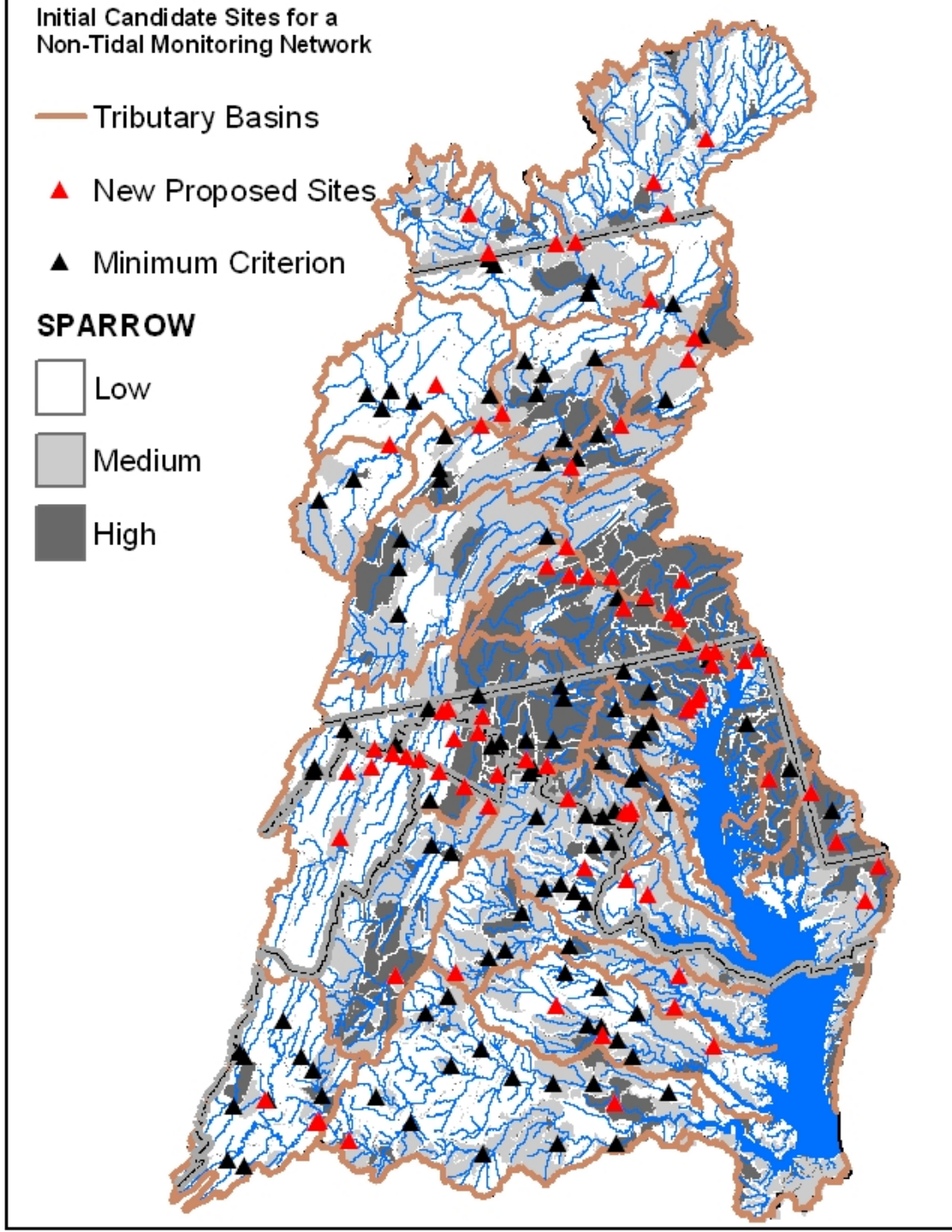
USGS



jwbrakeb@usgs.gov 410-238-4257

Designing a Monitoring Network

- High Load area identified
- Monitoring expanded



USGS