Potomac Trends Workshop
Explaining Change

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Based on contributions from dozens of incredibly smart and dedicated scientists

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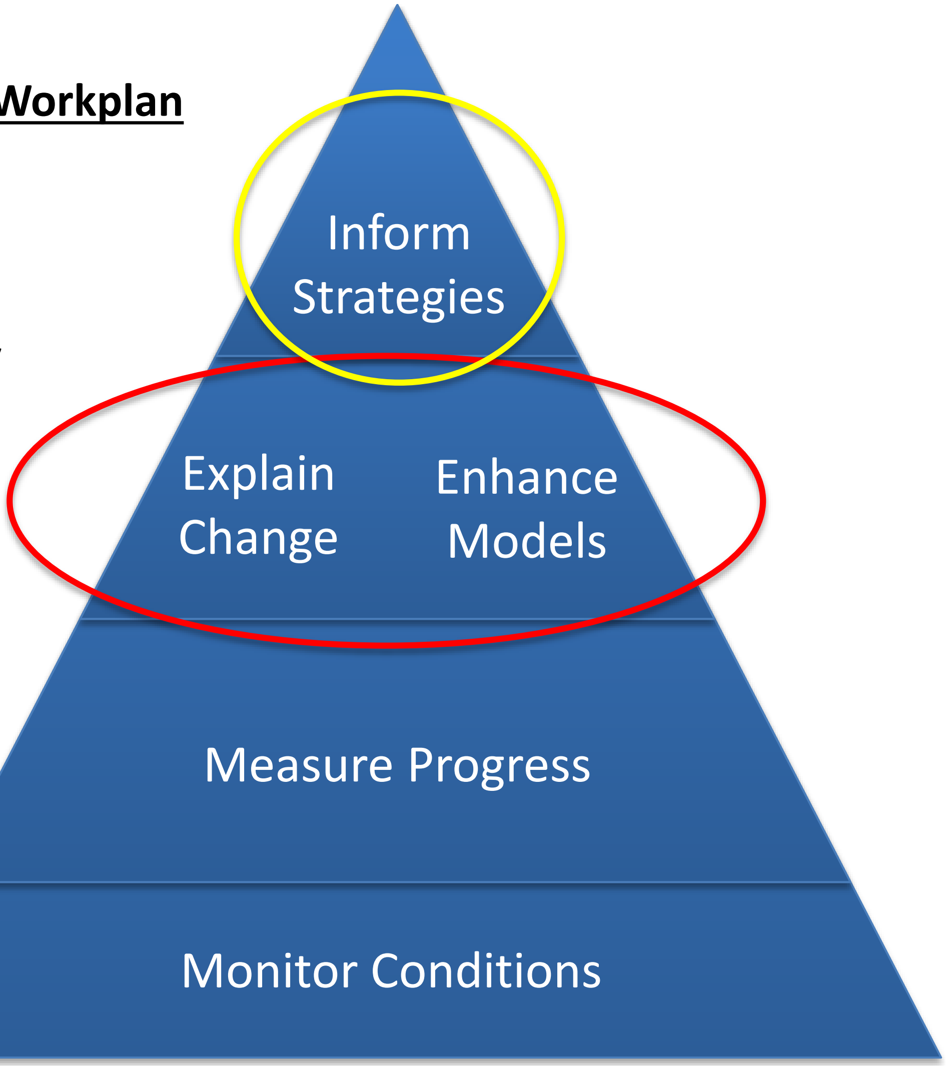
Using Monitoring Data To Measure Progress and Explain Change

Overview: STAR Workplan Elements

<u>Elements of STAR Mid-Point Assessment Workplan</u>

1. Measure progress
   - Trends of nitrogen, phosphorus and sediment in the watershed.
   - Trends of water quality in the estuary
2. Explain water-quality changes
   - Response to management practices
3. Enhance CBP models
4. Inform management strategies
   - WIPs
   - Water-quality benefits



Outline

- Overview
- Source Changes and BMP effects
- Statistically modeling Change
- Small-Watershed studies
- Engage Workshop Attendees

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STAC Recommendations

For the 2017 Midpoint Assessment:

- GAMS estuary
- Report Uncertainty
- Use findings from current projects
- Apply selected analytical approaches In pilot watersheds
- SPARROW to inform WSM
- Make WSM data accessible

Longer-Term Enhancements for Explaining Trends by 2025:

- Improve BMP data
- Implement continuous monitoring
- additional parameters to link landscape to water quality;
- apply statistical techniques

Explaining Change Process

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Changes in Land use, Nutrient Inputs, and BMPs

Land Use, Nutrient Inputs

- Description of spatial and temporal changes in
- Primary reference for all regional analyses

BMP implementation

- Description of spatial and temporal patterns in reported BMP across the watershed.
- Identification of expected mass reduction

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Sources and Inputs of Nutrients to the Chesapeake Bay Watershed, 1950-2012

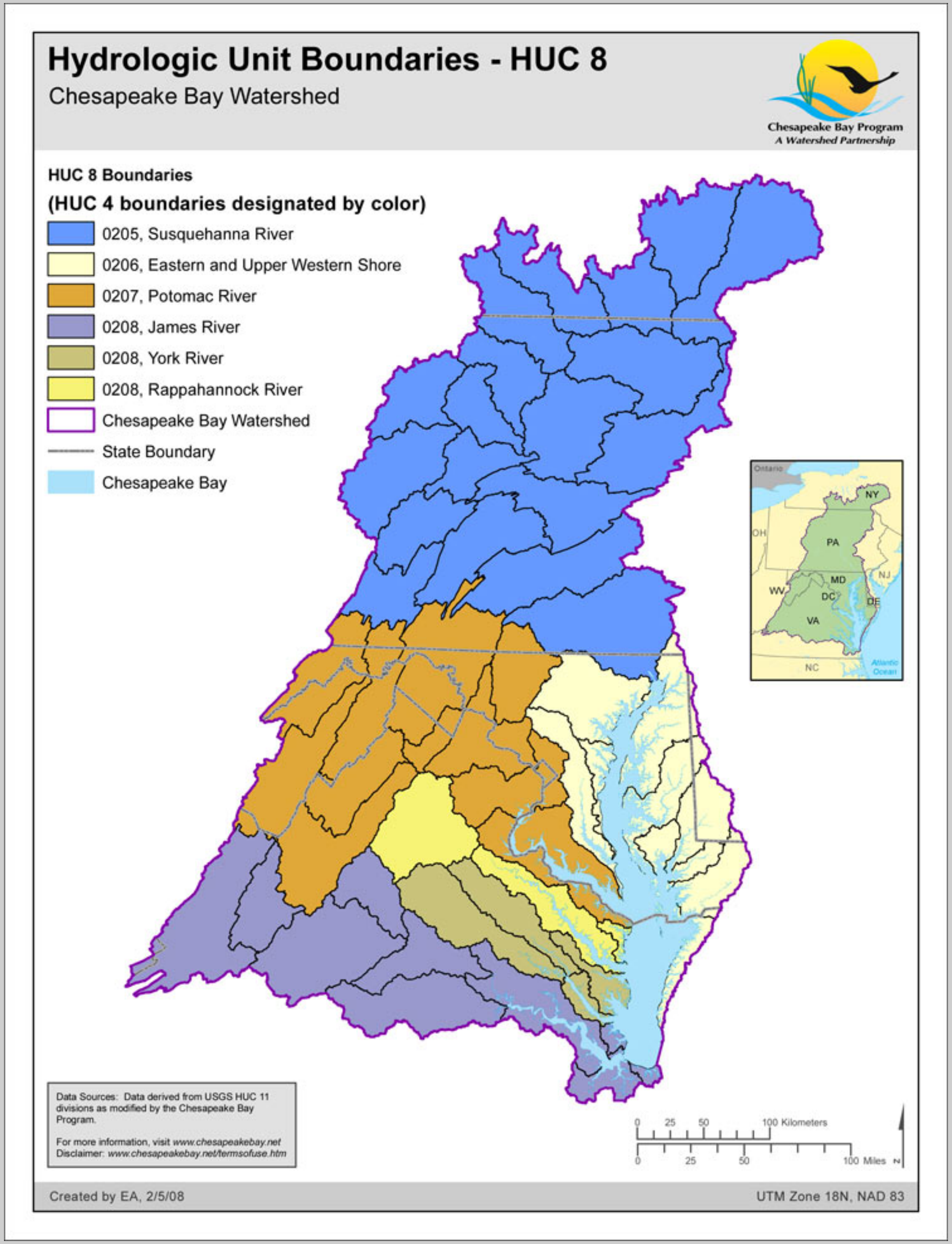
Jeni Keisman[1], Andrew Sekellick[1], Andrew LaMotte[1], Olivia Devereux[2], Lily Gorman-Sanisaca[1]

National Conference on Ecosystem Restoration

April 21, 2016

1. US Geological Survey (USGS) MD-DE-DC Water Science Center, 2. Devereux Consulting

Relating Nutrient Inputs, Sources, and BMPs

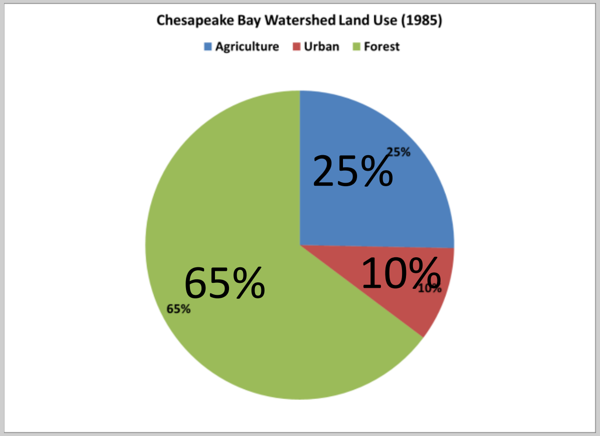


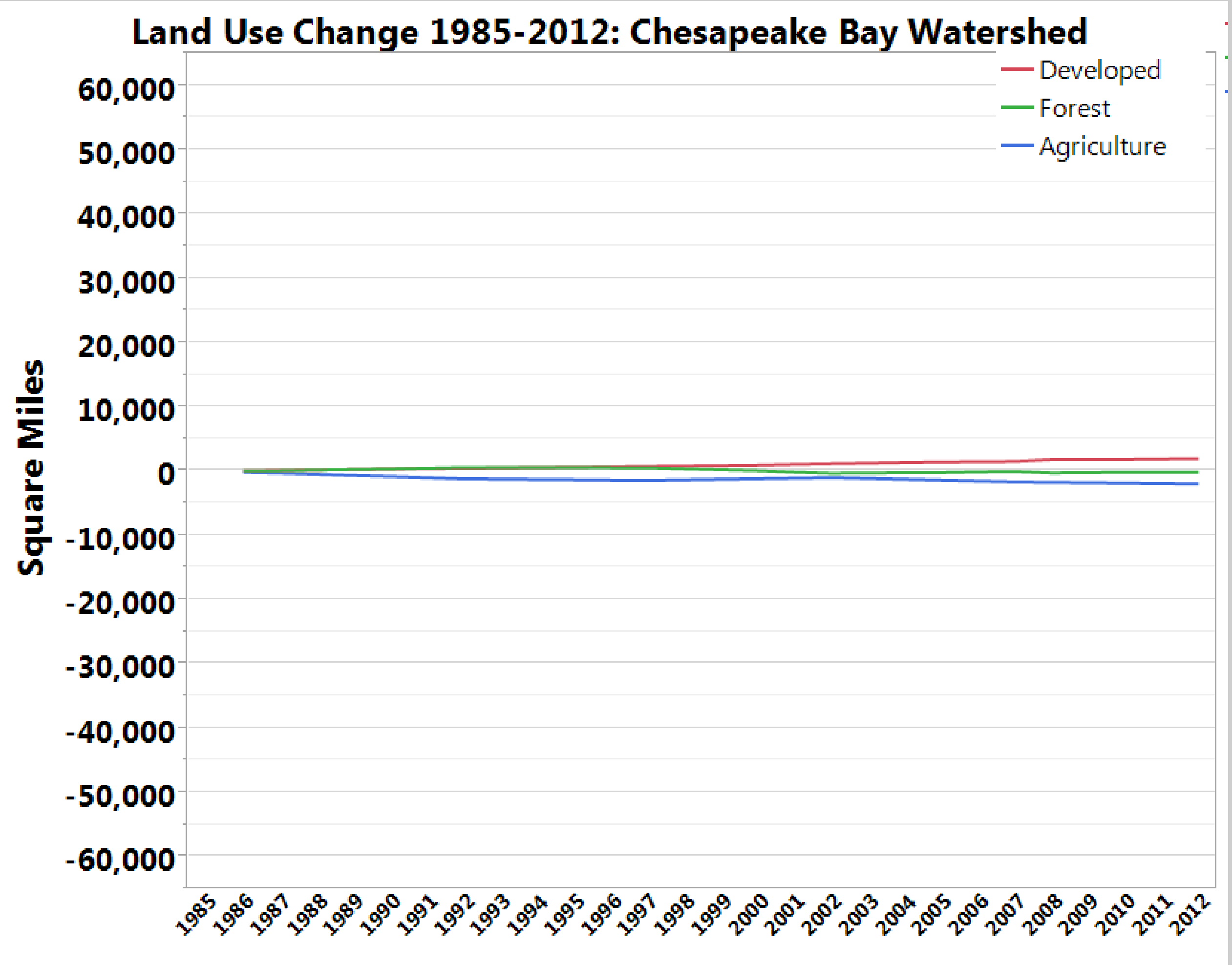
Questions

- How have nitrogen and phosphorus inputs and their sources changed over time in the Chesapeake Bay Watershed?
- What has driven observed changes?
- How are inputs and their sources distributed across the watershed?
- What is the expected effect of best management practices (BMPs) on nutrient inputs?

Preliminary Information-Subject to Revision.
Not for Citation or Distribution

The Chesapeake Bay Watershed covers about 64,000 square miles across 7 jurisdictions from New York to Virginia





Date Source: Chesapeake Bay Program

- **About 2000 square miles (3%) of the watershed was developed from 1985-2012*.**

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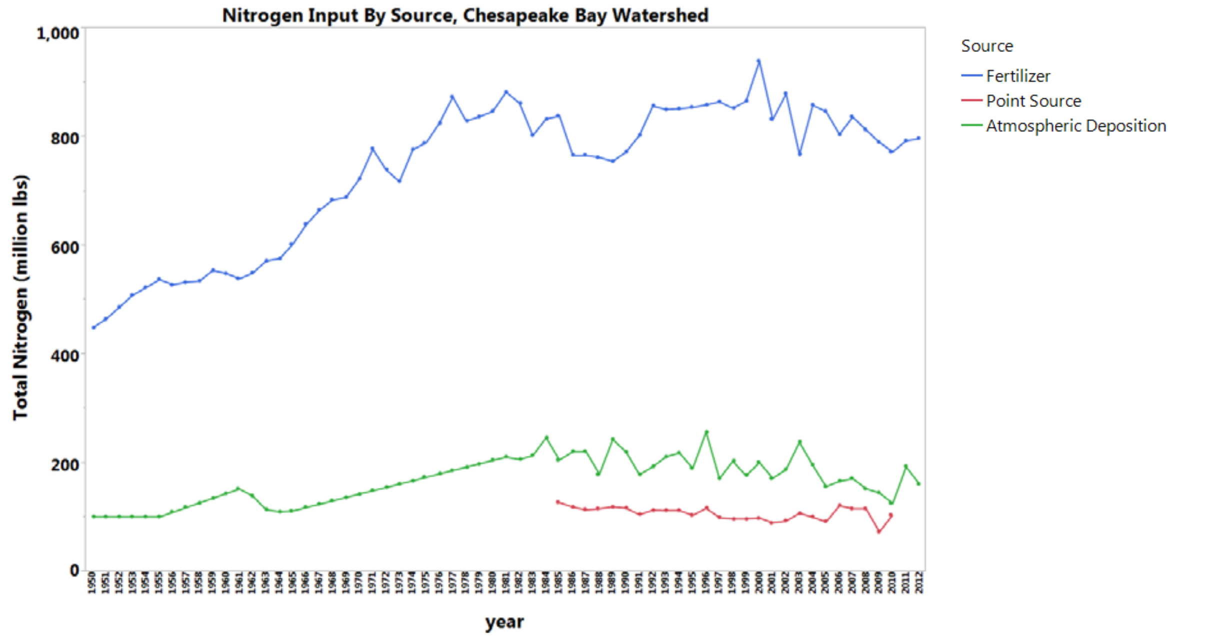
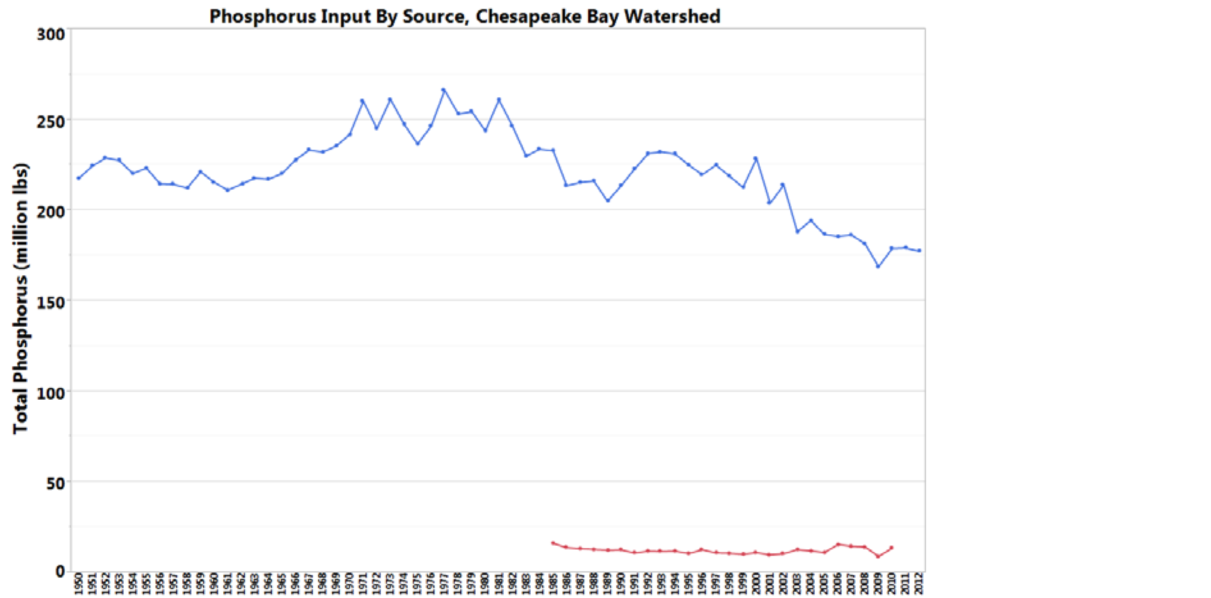
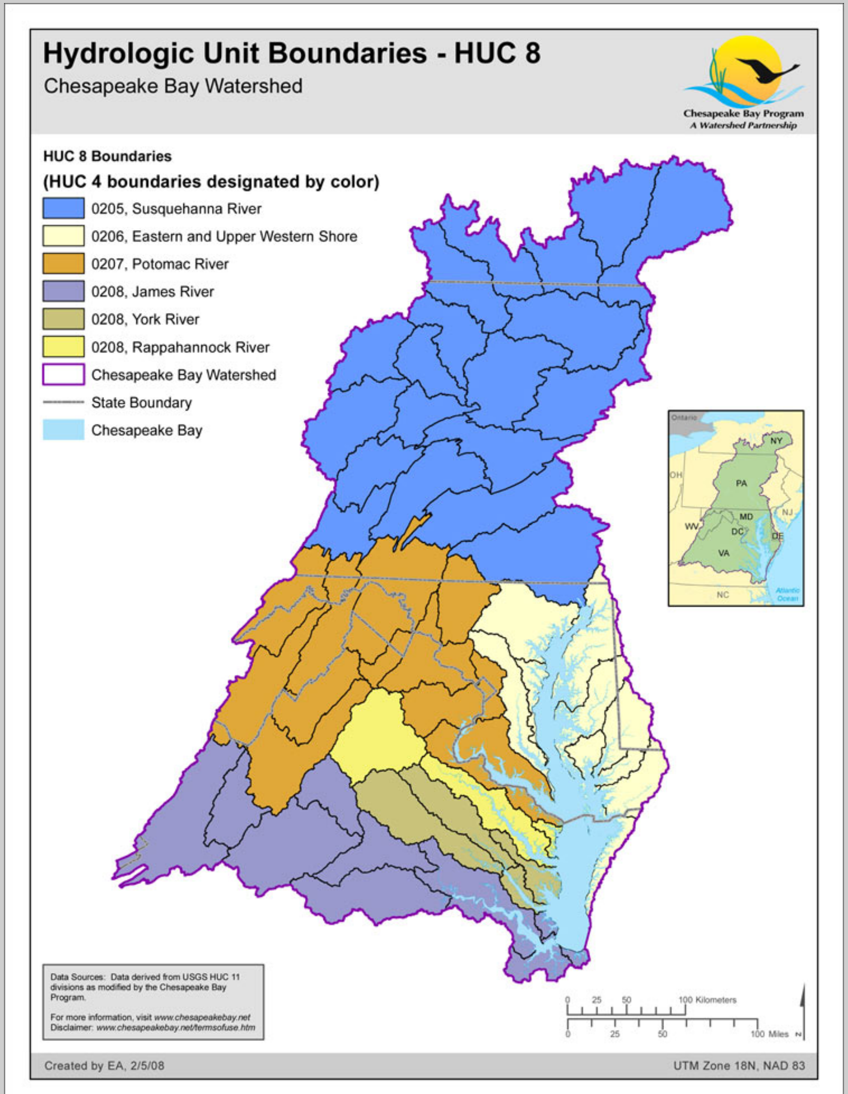
Nutrient Inputs To Watershed By Source





- **Fertilizer (both manure and commercial fertilizers) is the dominant source of N and P inputs watershed-wide**
- **The remainder of this presentation focuses on manure and inorganic fertilizer inputs from agriculture**

Relating Nutrient Inputs, Sources, and BMPs



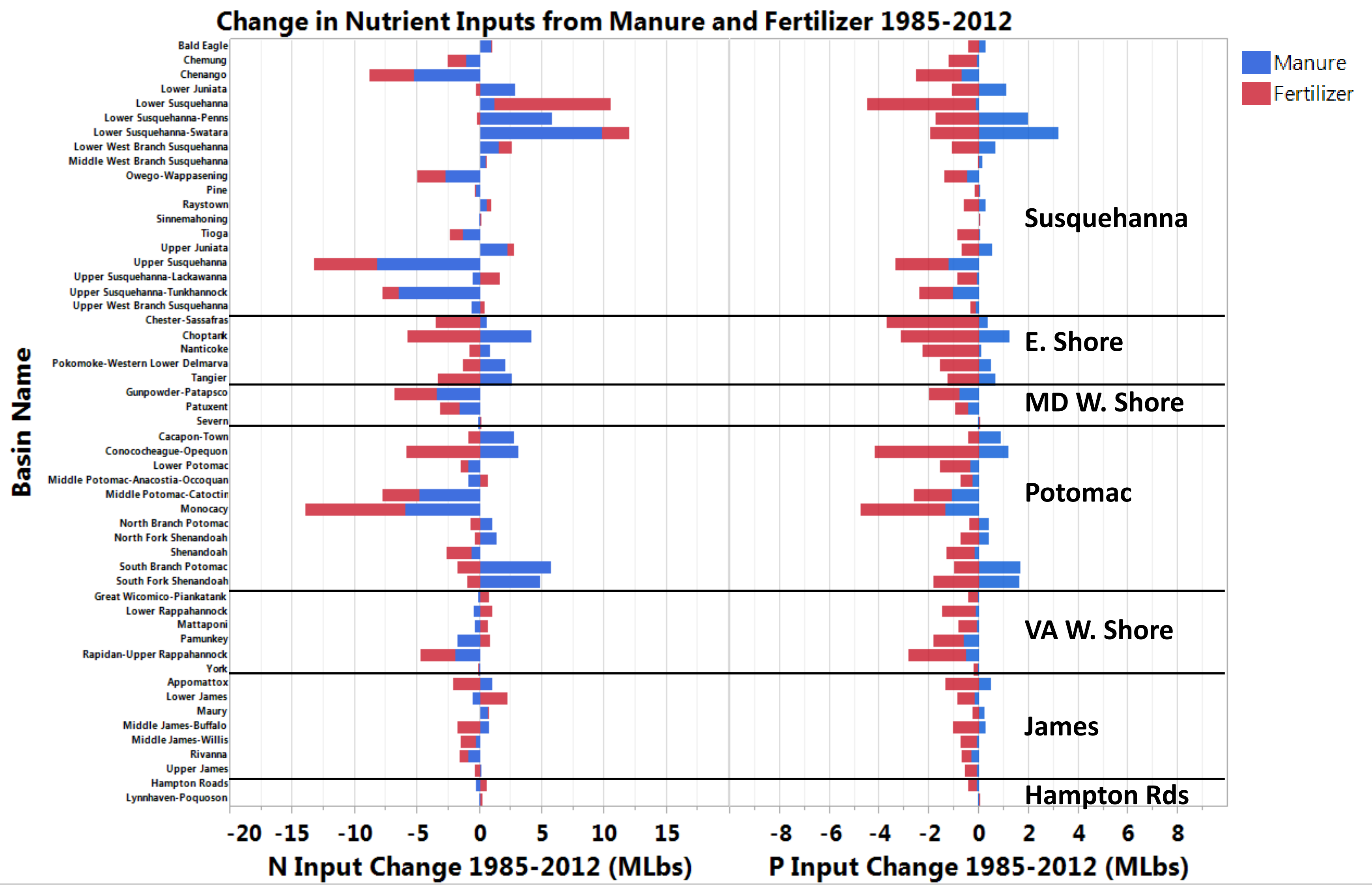
There are 53 8-digit HUC basins in the Chesapeake Bay Watershed

HUC 8 basins were grouped into 7 regions:

- **Susquehanna**
- **Eastern Shore**
- **Maryland Western Shore**
- **Potomac**
- **Virginia Western Shore**
- **James**
- **Hampton Roads**

Nitrogen and phosphorus inputs varied within and across these regions

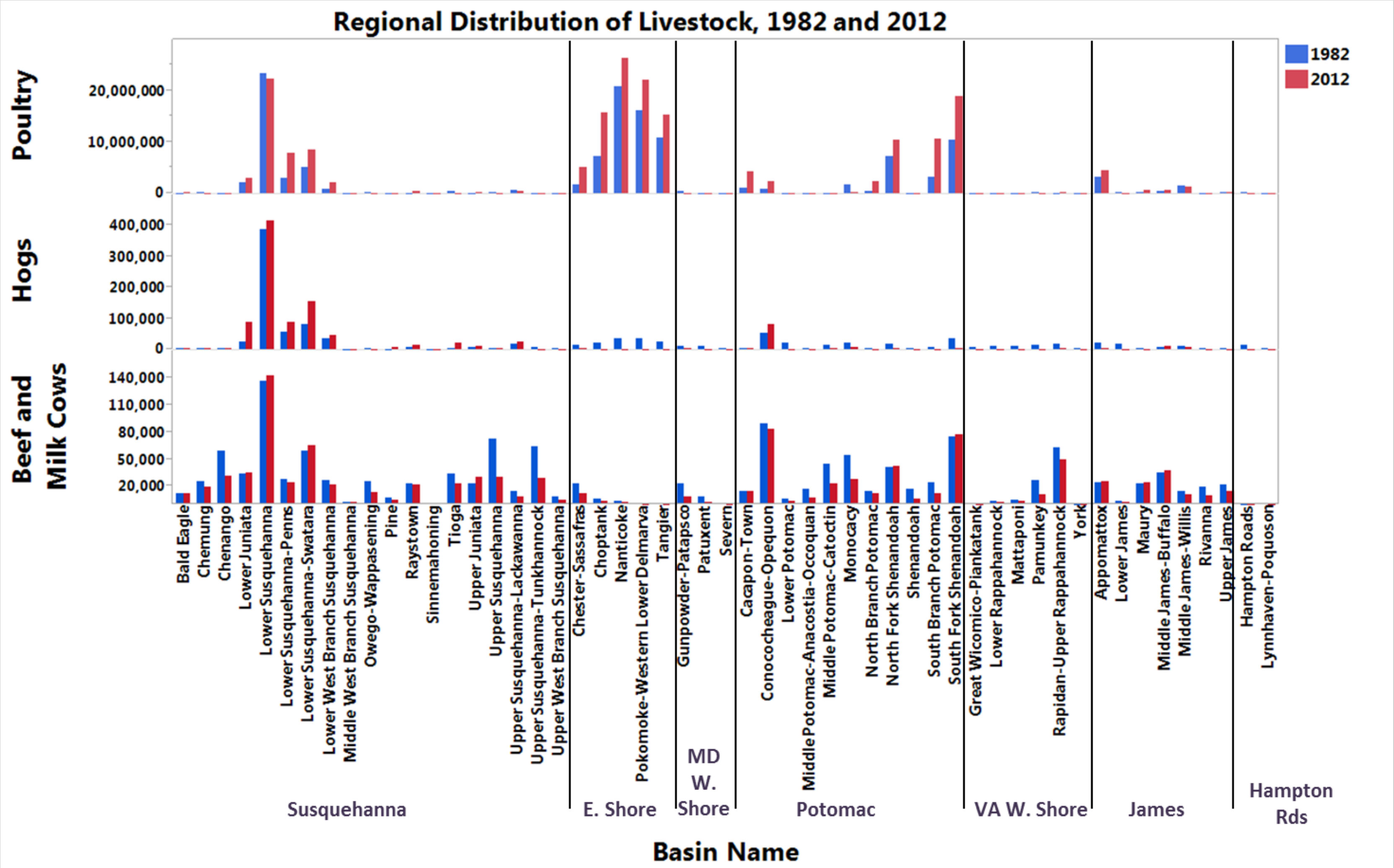
Regional Changes in Manure and Fertilizer Inputs



- The majority of N increases were in manure, although fertilizer increased in some basins.
- Net change for P was generally negative; all P increases were in manure

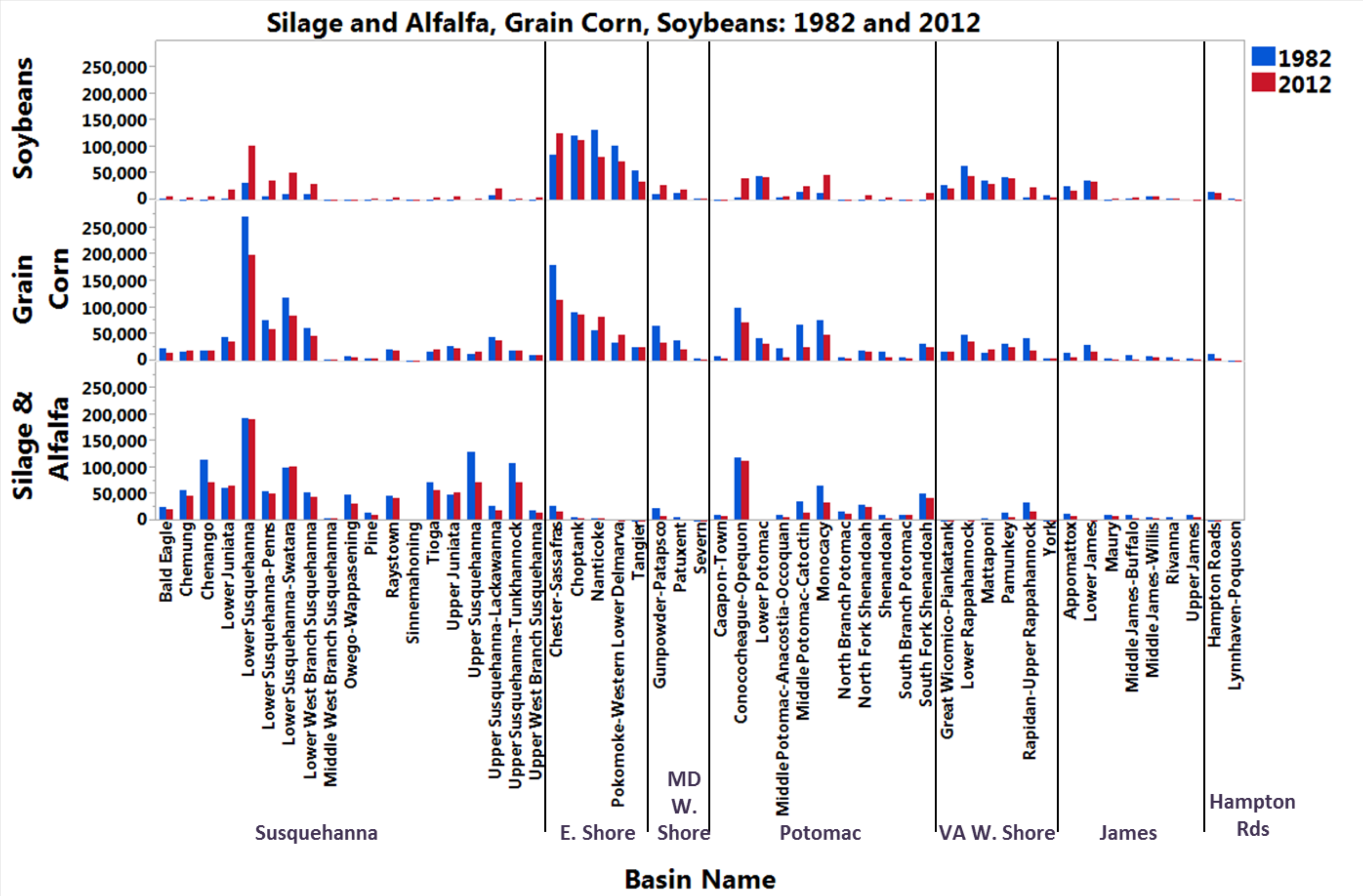
Preliminary Information-Subject to Revision. Not for Citation or Distribution

Regional Distribution of Livestock



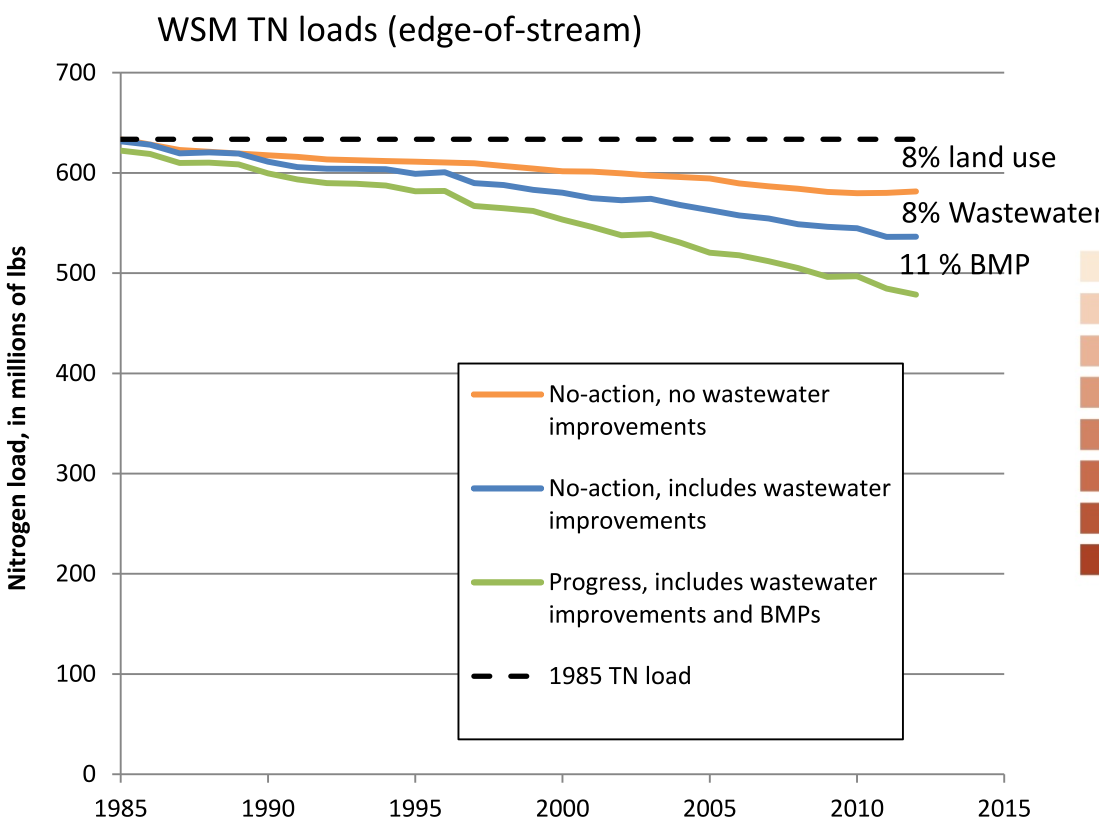
- **The Eastern Shore was dominated by poultry populations; additional hotspots in the Susquehanna and Potomac**
- **Hogs were concentrated in the Lower Susquehanna**
- **Cows were distributed across the watershed; there were local hotspots in the Lower Susquehanna and Potomac regions**

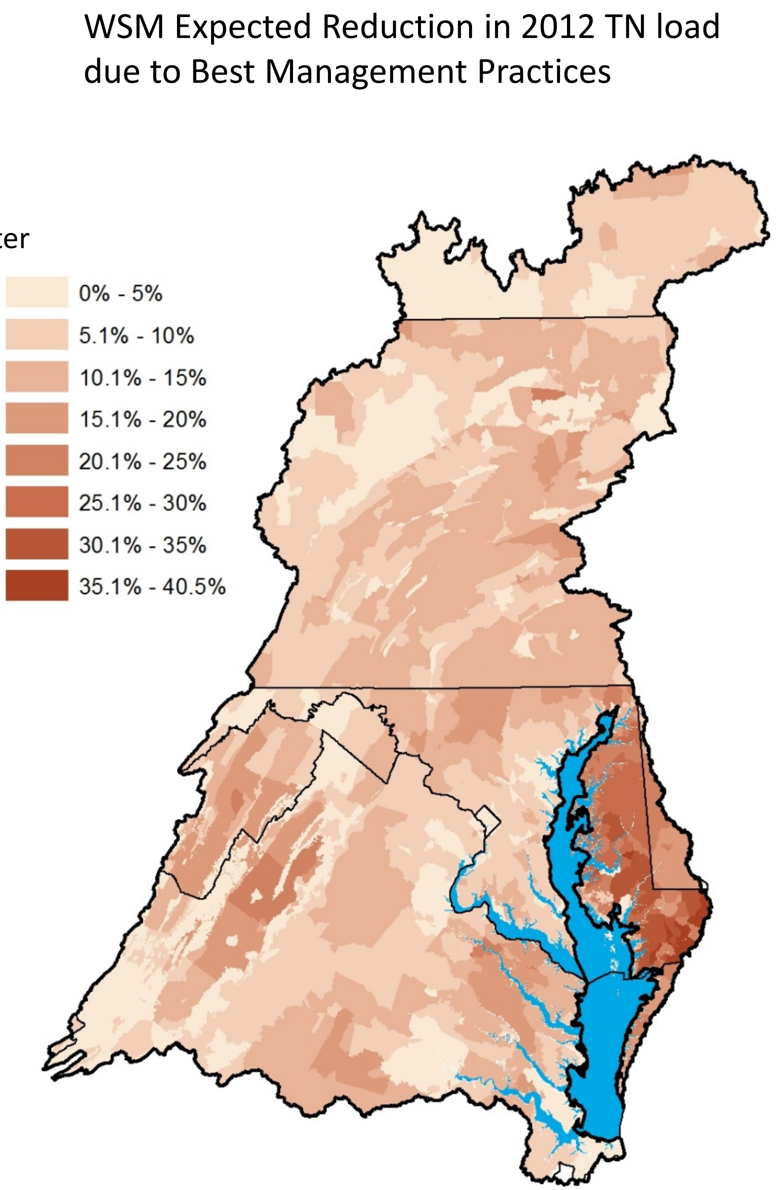
Regional Distribution of Major Crops



- Silage and alfalfa crops were concentrated in the Susquehanna region
- About 50% of soybean acres were concentrated on the Eastern Shore in 1982; Susquehanna and Potomac gained soybean acres in 2012
- The lower Susquehanna region and the Eastern Shore stand out for crops as well as for livestock

SPATIAL AND TEMPORAL PATTERNS IN BMP IMPLEMENTATION: Changes in Delivered Nutrient Loads due to Best Management Practices Using the CBP Watershed Model





SPARROW TO EXPLAIN CHANGE

- Decadal Land Use SPARROW model
- SPARROW with BMP effects
- Dynamic nitrogen model including groundwater lags
- Dynamic phosphorus model including storage.
- Delta SPARROW

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Application of SPARROW Modeling to Understanding Water-Quality Trends in the Chesapeake Bay Watershed

Scott W. Ator, Ana Maria Garcia

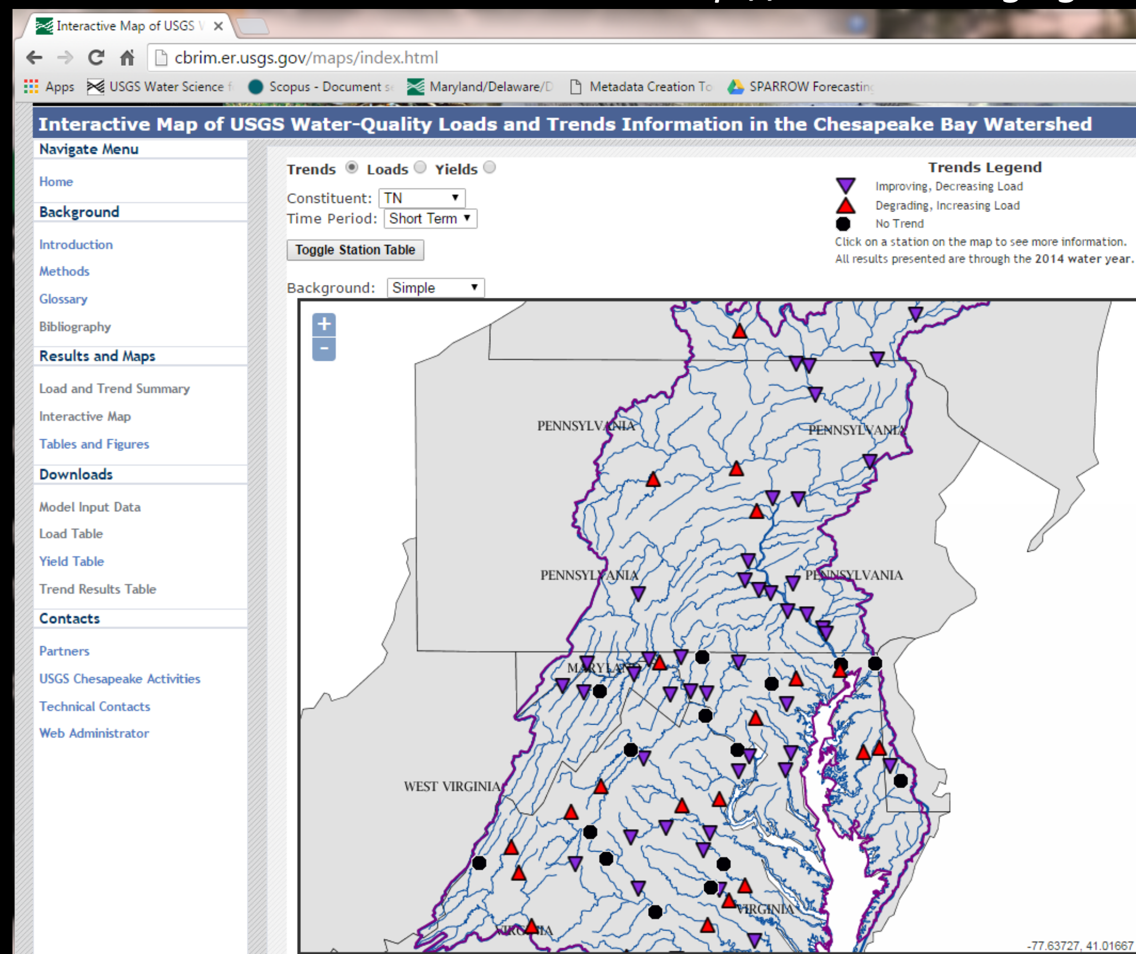
Thanks to:

Silvia Terziotti, Greg Schwarz, Doug Moyer, Joel Blomquist, Jeff Chanat, Andy Sekellick

Nitrogen and Phosphorus in Chesapeake Bay

http://cbrim.er.usgs.gov

- Sources and transport of N and P to Chesapeake Bay have been studied at multiple scales.
- Water-quality trends in selected tributaries are well documented.
- Less clear are the **causes** of different trends in different areas.



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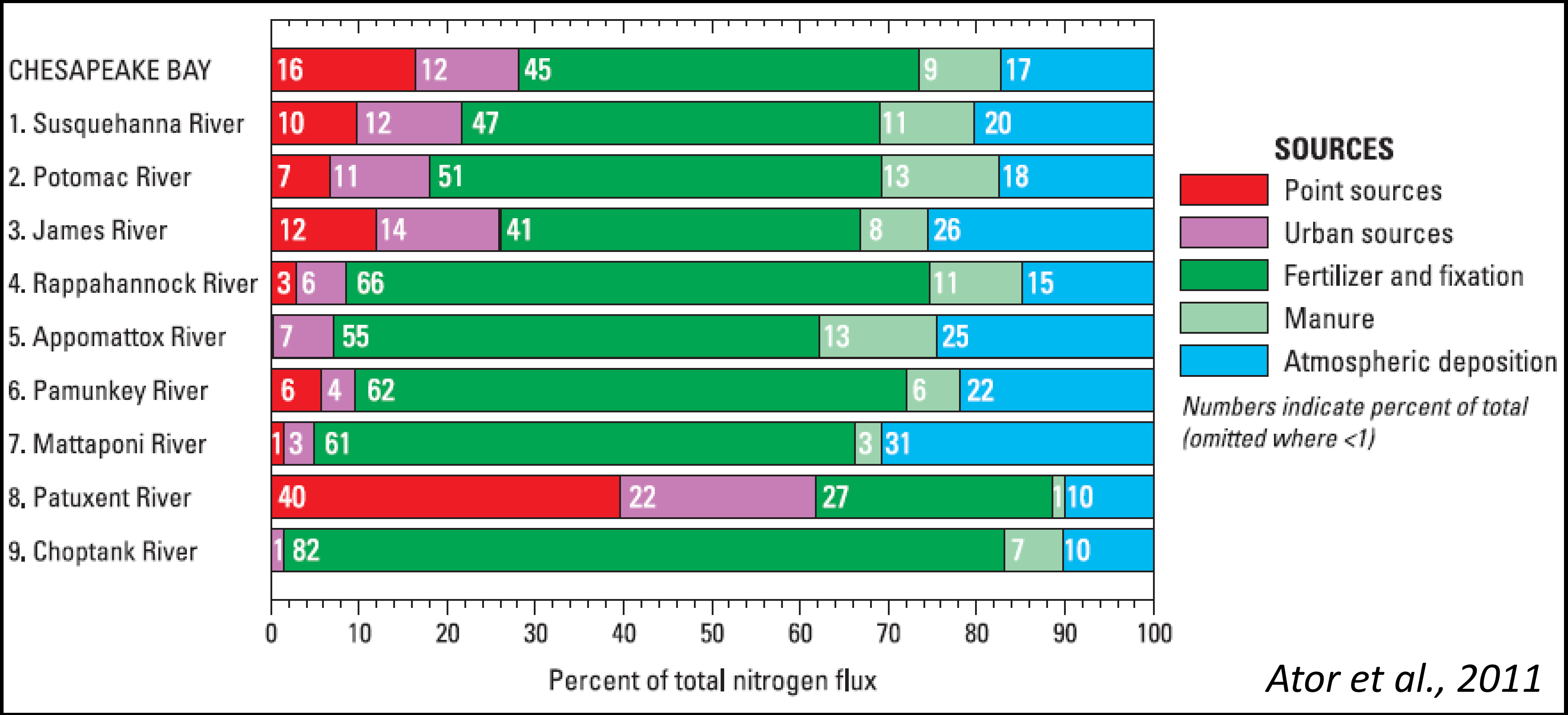
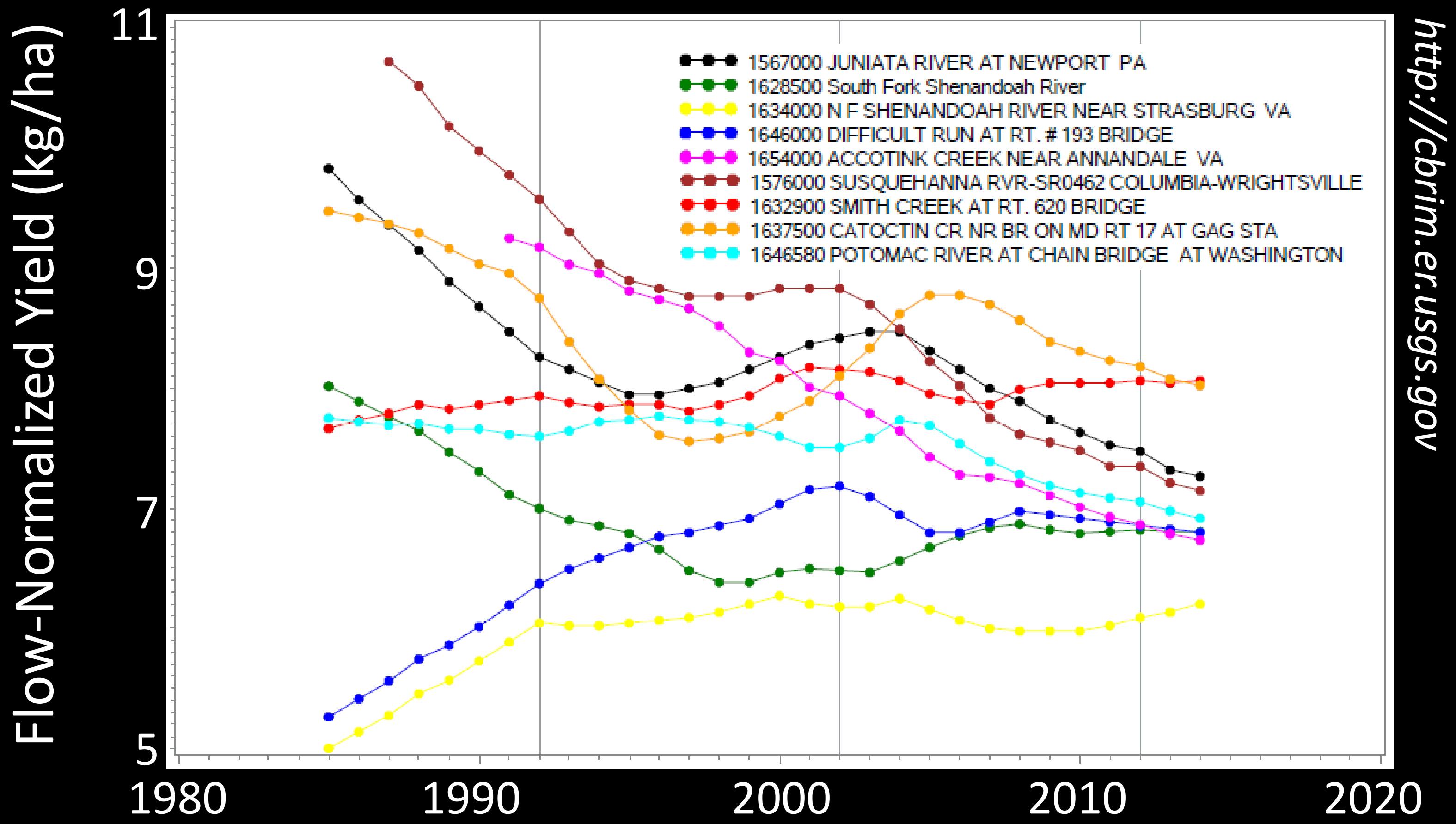
Sources of Nitrogen



- Agriculture provides the majority of nitrogen inputs to Chesapeake Bay and most major tributaries.

Nitrogen in Streams

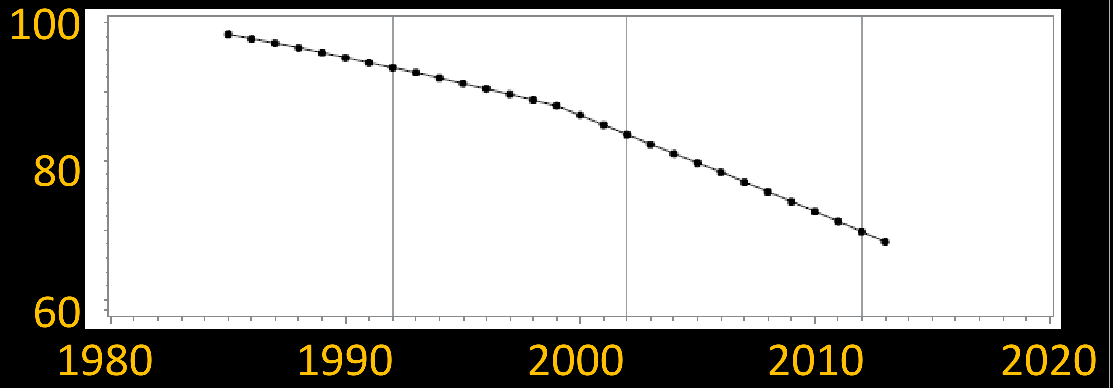


- Nitrogen concentrations have generally decreased in recent years in many tributaries, but increased in others.

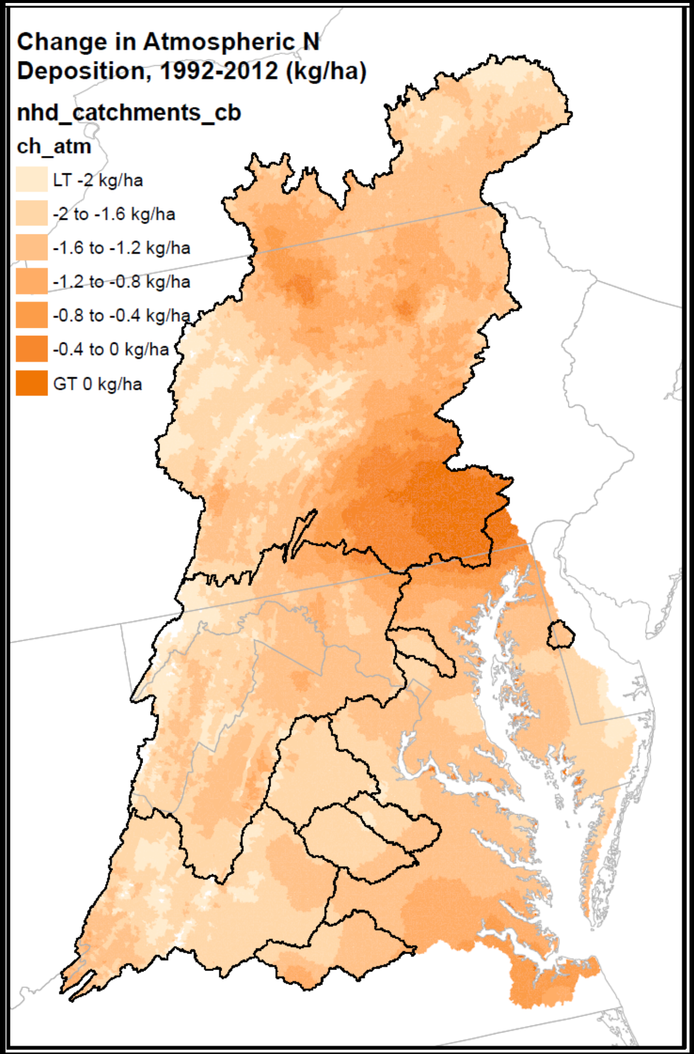
Nitrogen Sources

- Atmospheric deposition has generally decreased over time, but varies spatially.

Atmospheric Nitrogen Deposition
in 1000's of Metric Tons (LOESS smooth).

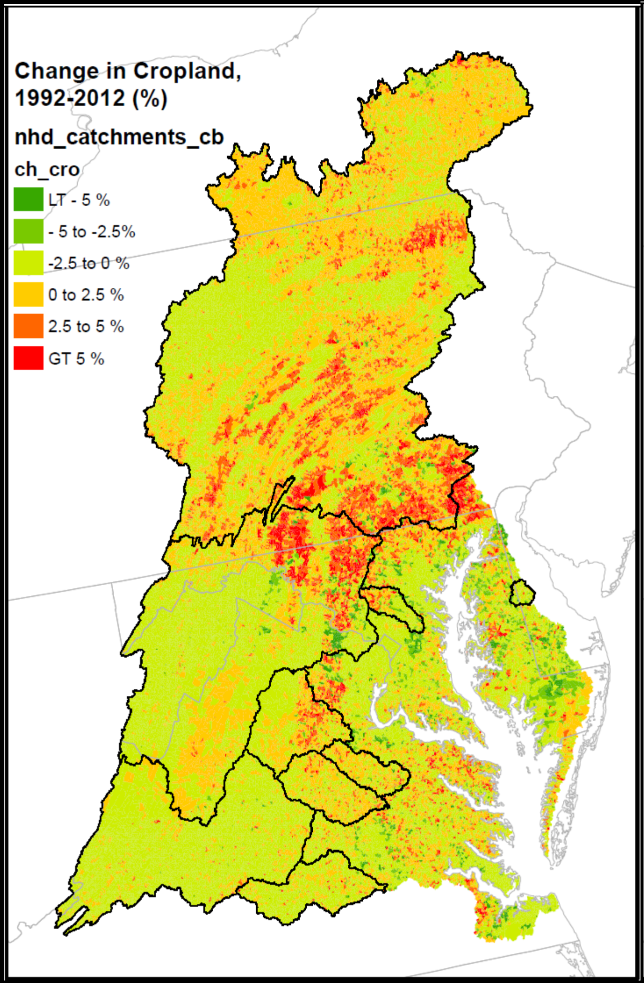


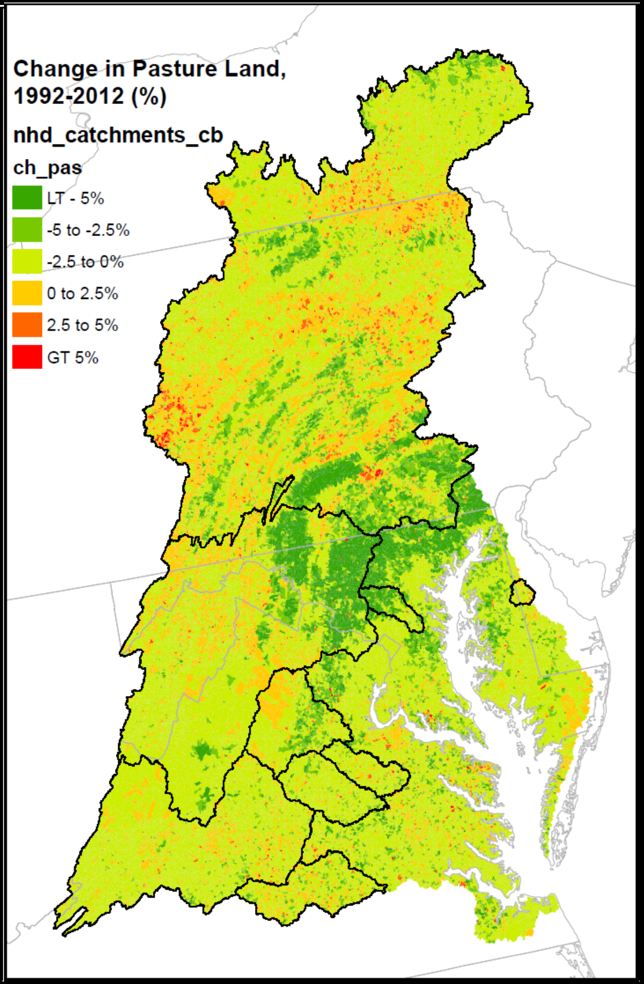
Data from Chesapeake Bay Program



Nitrogen Sources

- Land-use change, 1992 – 2012.





Falcone, 2015

Research Questions

- How do changes in stream chemistry relate to:
  - changing land use patterns?
  - changing practices within certain land-use settings?
  - changing atmospheric deposition or point sources?
- How can multiple steady-state SPARROW models calibrated for decadal time steps help to improve our understanding of landscape factors driving changes in stream chemistry?

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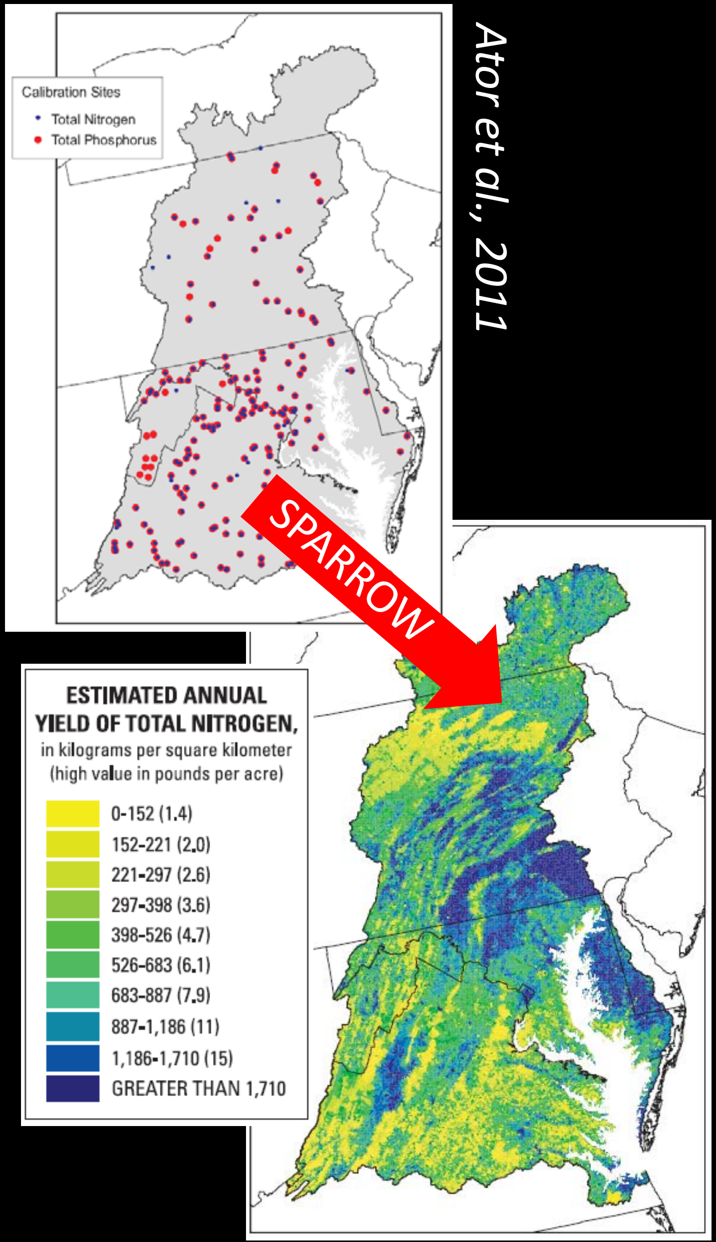
The SPARROW Model

- SPAtially-Referenced Regression On Watershed attributes
- Developed in the 1990s by USGS (Smith et al., 1997)
- Regression (NLLS) approach to extrapolate estimated mean-annual flux (load) at monitored streams to unmonitored streams on the basis of watershed attributes
- Includes mass-balance and flow-routing
- Steady-state model of mean-annual conditions*



Ator et al., 2011

Approach

- Calibrate individual SPARROW models for 1992, 2002, and 2012 using:
  - A common stream network, land-to-water specification, and aquatic decay specification
  - Flow-normalized annual loads for 1992, 2002, and 2012 at the same group of sites (for calibration)
  - Consistent and comparable land-use and atmospheric and point sources (as source terms)
- Evaluate estimated source coefficients (α_n) to understand trends

$Flux_i$ = Flux delivered from upstream + Flux generated in local catchment

$$F_i^* = \left(\sum_{j \in J(i)} F_j'\right) \delta_i A\left(\mathbf{Z}_i^S, \mathbf{Z}_i^R; \boldsymbol{\theta}_S, \boldsymbol{\theta}_R\right) + \left(\sum_{n=1}^{N_S} S_{n,i}\alpha_n D_n\left(\mathbf{Z}_i^D; \boldsymbol{\theta}_D\right)\right) A'\left(\mathbf{Z}_i^S, \mathbf{Z}_i^R; \boldsymbol{\theta}_S, \boldsymbol{\theta}_R\right).$$

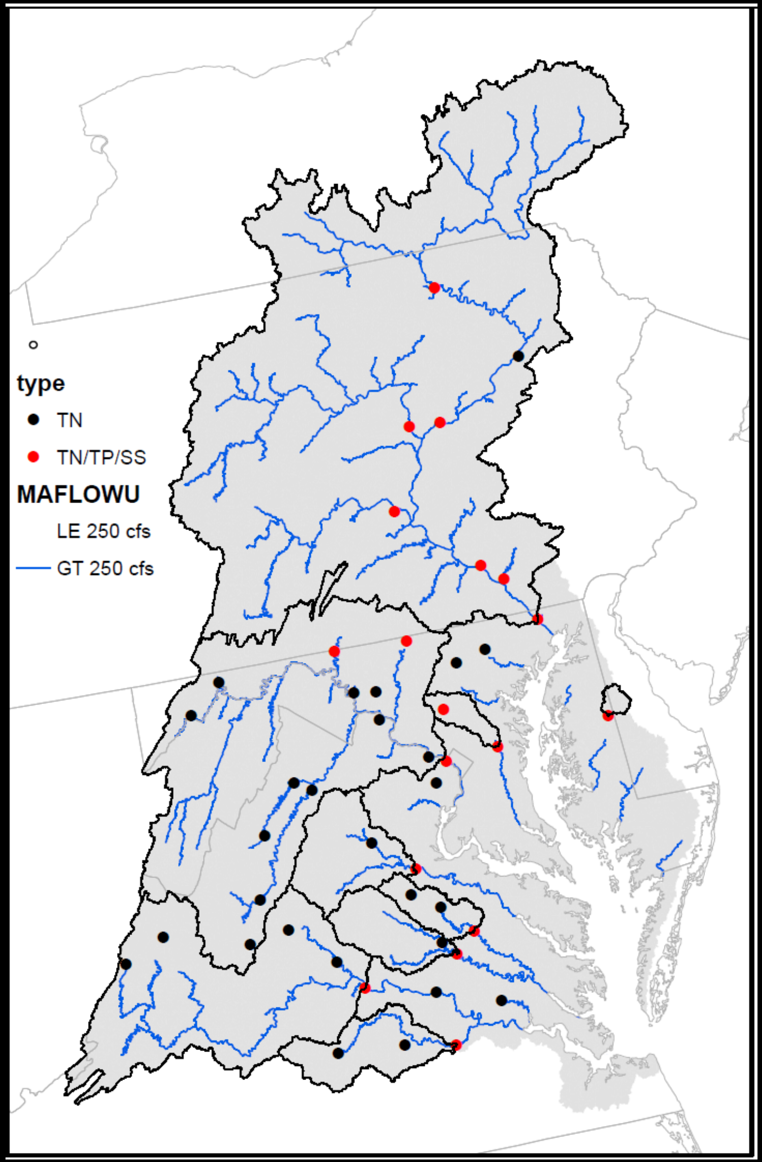
Schwarz et al., 2006

i = stream reach
j = upstream reach(es)
n= sources

D = overland delivery function (DVF_i)
A = fluvial delivery function
α, θ = estimated coefficients

Inputs: Calibration Data

- Flow-normalized annual loads are estimated and published for sites in the Chesapeake non-tidal monitoring network (NTN)
- With loads for 1992, 2002, and 2012:
  - TN (n=45 sites)
  - TP and SS (n=18 sites)



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Preliminary Nitrogen Models

	Explanatory Variable	1992		2002		2012	
		Coef	p	Coef	p	Ceof	p
Sources	Point sources (kg)	1.78	0.0213	1.38	0.0533	0.687	0.1416
Sources	Developed (ha)	17.3	0.0003	13.1	0.0018	11.8	0.0016
Sources	Forest (ha)	0.37	0.3170	0.68	0.2166	0.47	0.3006
Sources	Cropland (ha)	24.5	0.0070	32.2	0.0055	30.3	0.0047
Sources	Pasture (ha)	23.0	0.0001	19.3	0.0008	22.5	0.0004
L2W	GW recharge	0.924	0.0226	0.631	0.1671	0.783	0.0516
L2W	Soil AWC	-1.43	0.0326	-1.15	0.1106	-1.22	0.0401
L2W	Pied. carbonate	0.247	0.0505	0.279	0.0257	0.232	0.0483
Aquatic	Res Decay (d)	0.004	0.0526	0.004	0.0760	0.006	0.0543
Aquatic	Small Str Decay (d)	0.539	0.0102	0.574	0.0165	0.559	0.0177
Aquatic	Large Str Decay (d)	0.085	0.0999	0.067	0.1708	0.069	0.1738

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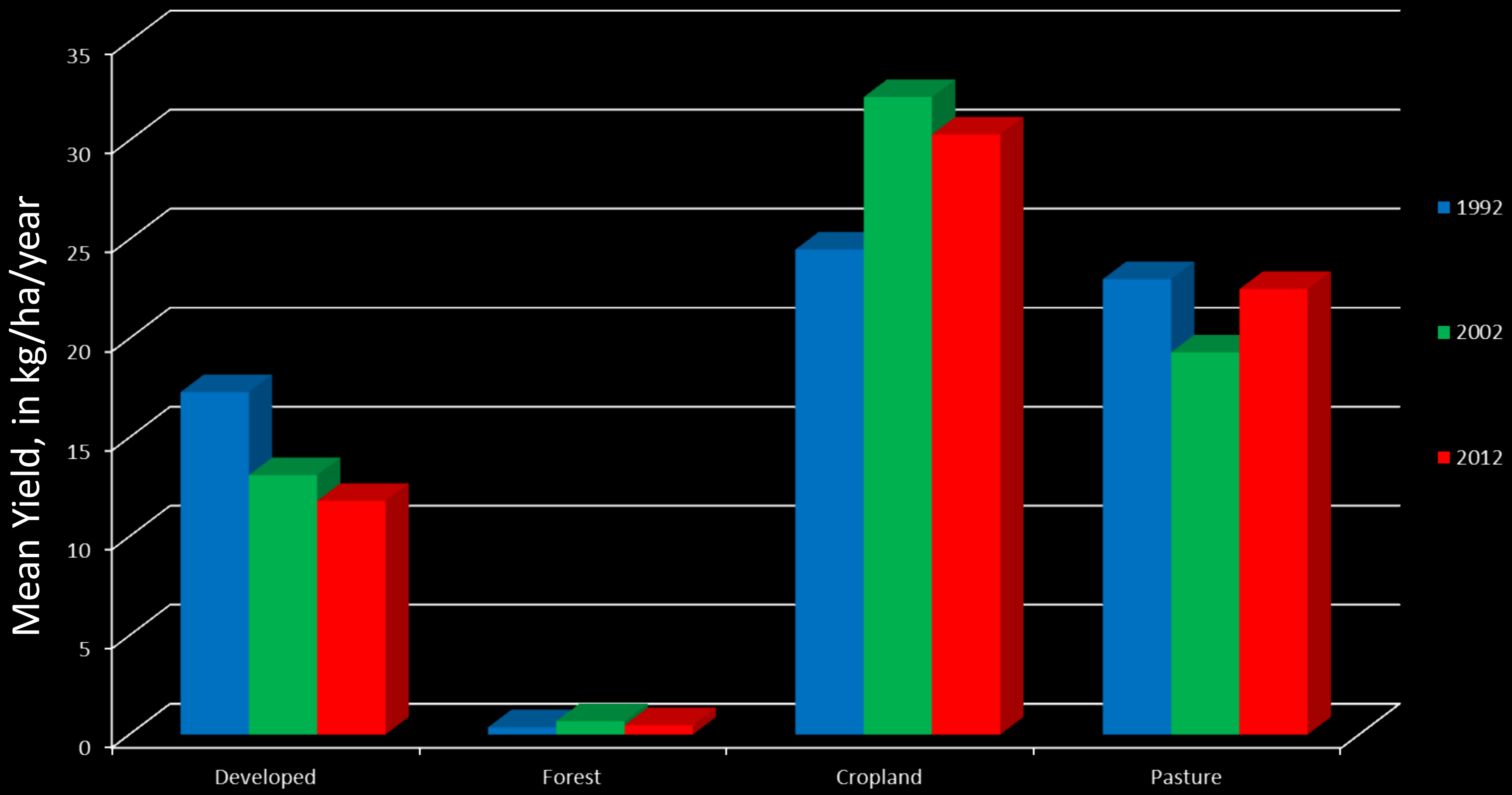
Preliminary Nitrogen Models



Next Steps

- Post-processor to:
  - Test H_0: source coefficients are not significantly different among time steps
  - Evaluate relative importance of changing sources (ie. land-uses) vs. changing average yield from each source (ie. model coefficients) to observed changes in stream chemistry.
- Look at change in average yields for different hydrogeologic settings

Water-Quality Results from Four Chesapeake Bay Showcase Watersheds:

Monitoring and Analysis Designed to Assess and Inform Restoration

April 21st, 2016

Jimmy Webber
USGS Virginia Water Science Center
Richmond, VA
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<u>Primary Collaborators:</u>

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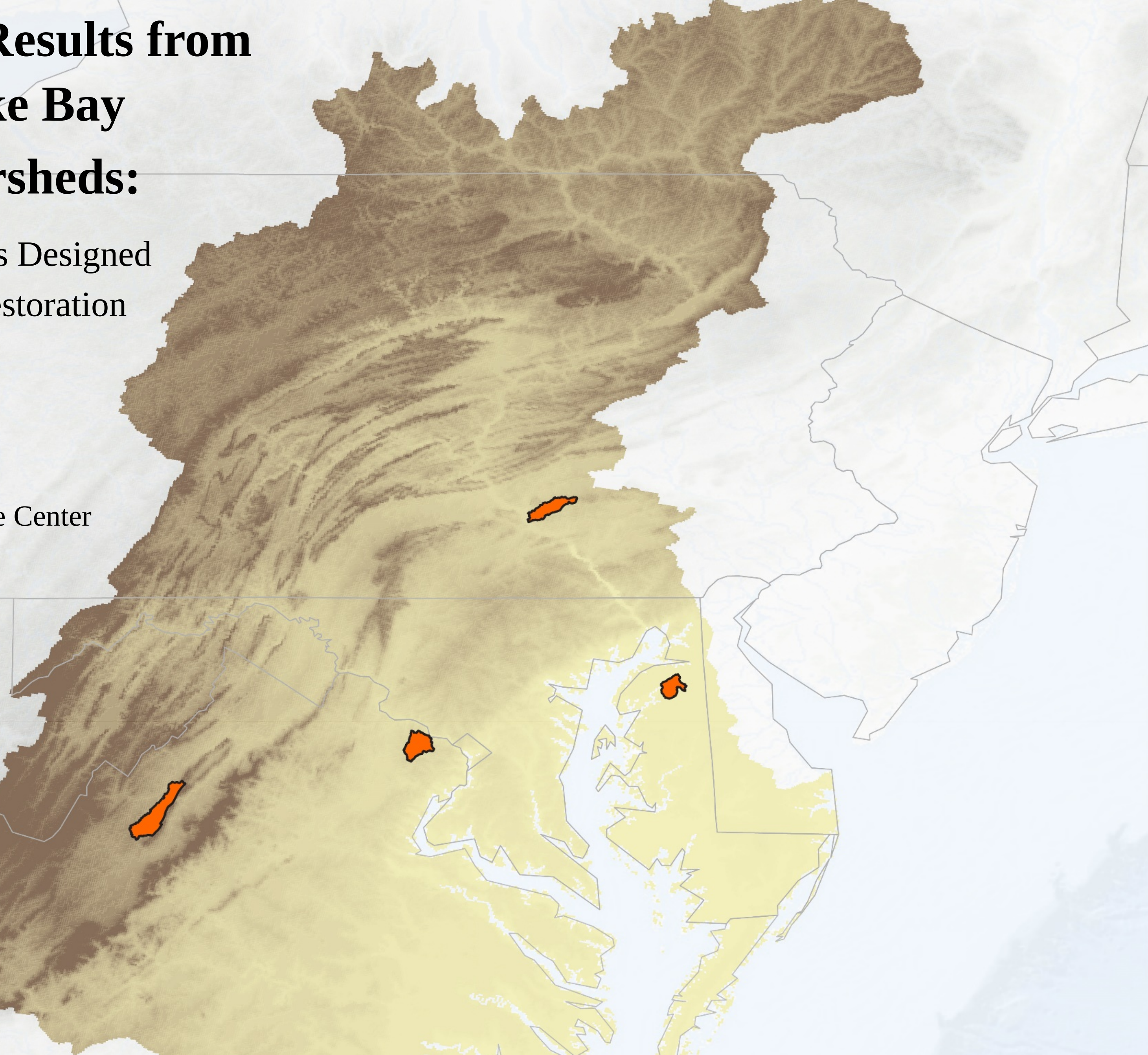

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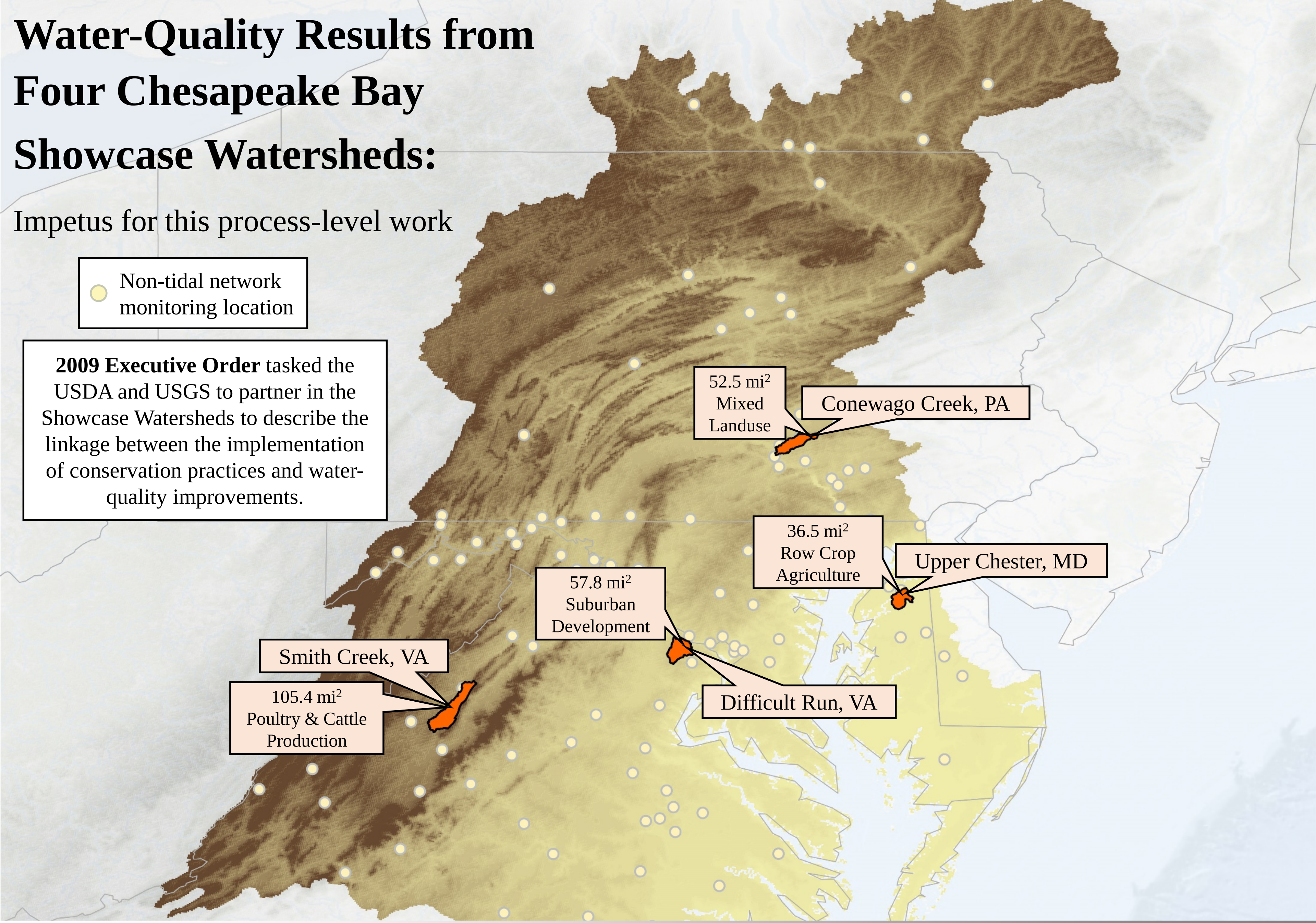
Water-Quality Results from Four Chesapeake Bay Showcase Watersheds:

Impetus for this process-level work

2009 Executive Order tasked the USDA and USGS to partner in the Showcase Watersheds to describe the linkage between the implementation of conservation practices and water-quality improvements.



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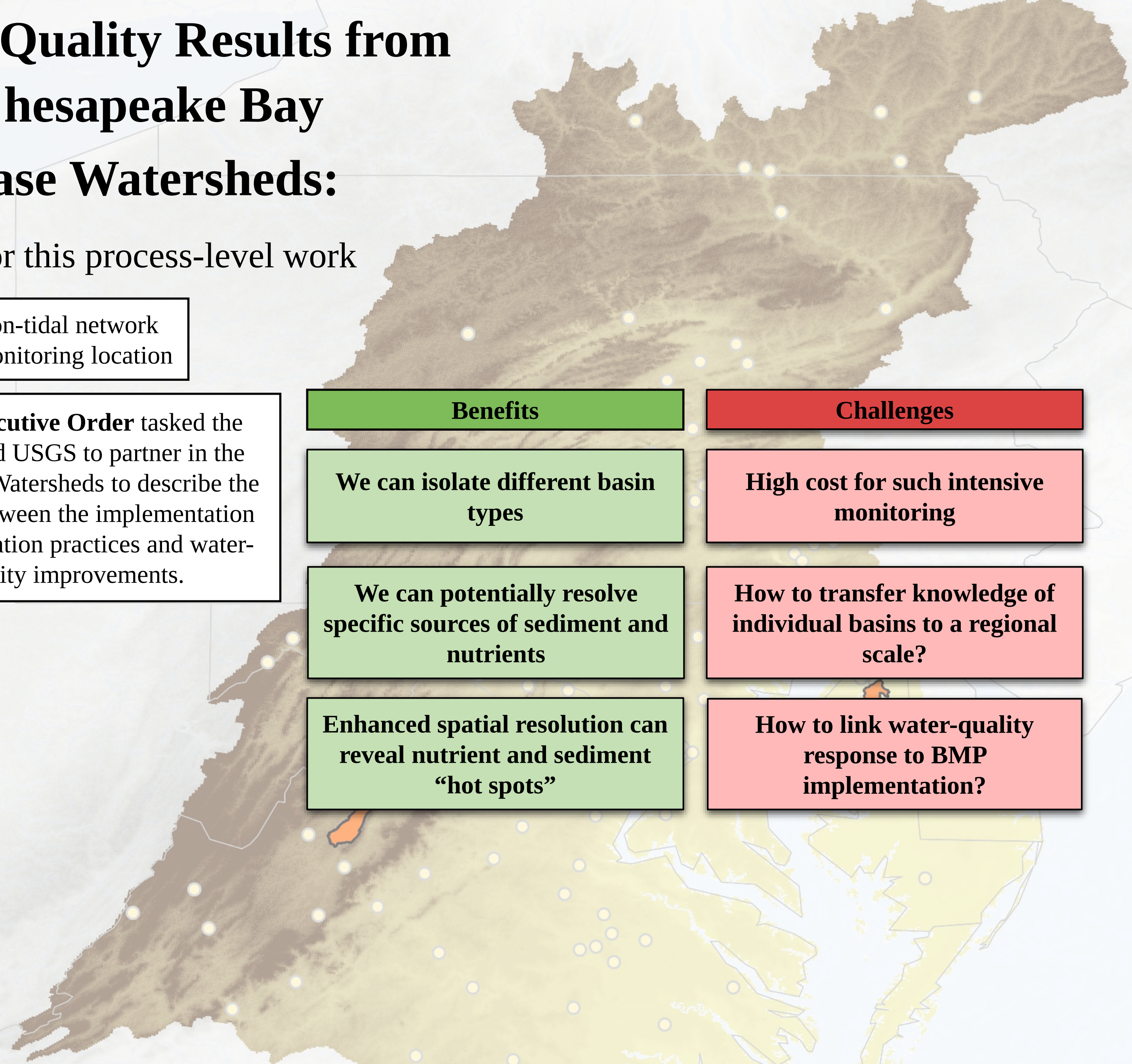

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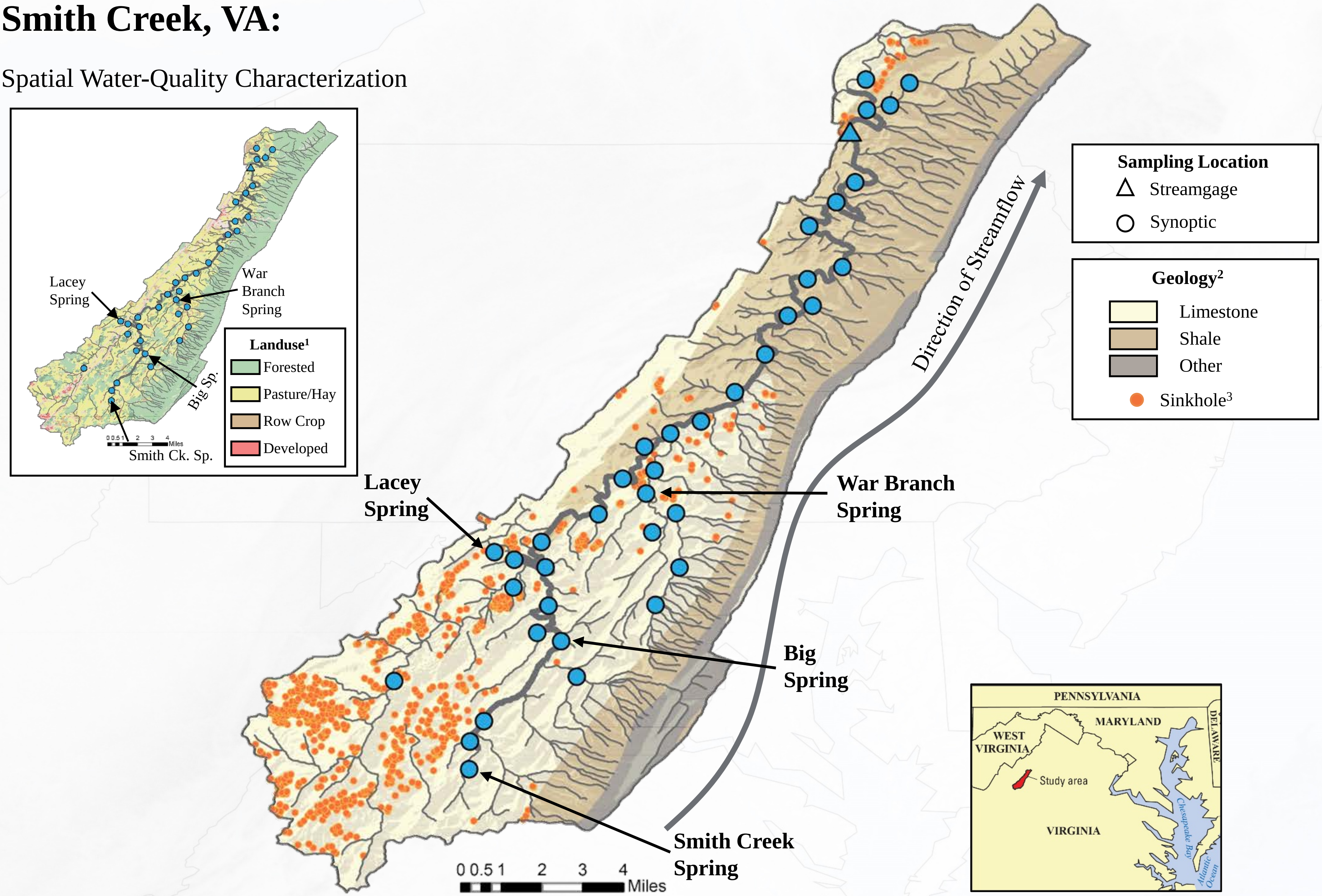
Benefits	Challenges
We can isolate different basin types	**High cost for such intensive monitoring**
We can potentially resolve specific sources of sediment and nutrients	**How to transfer knowledge of individual basins to a regional scale?**
Enhanced spatial resolution can reveal nutrient and sediment "hot spots"	**How to link water-quality response to BMP implementation?**

Smith Creek, VA:

Spatial Water-Quality Characterization



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[1]Landuse from NLCD 2011

[2]Geology from Dicken and others (2005)

[3]Sinkholes from Hubbard (1983)

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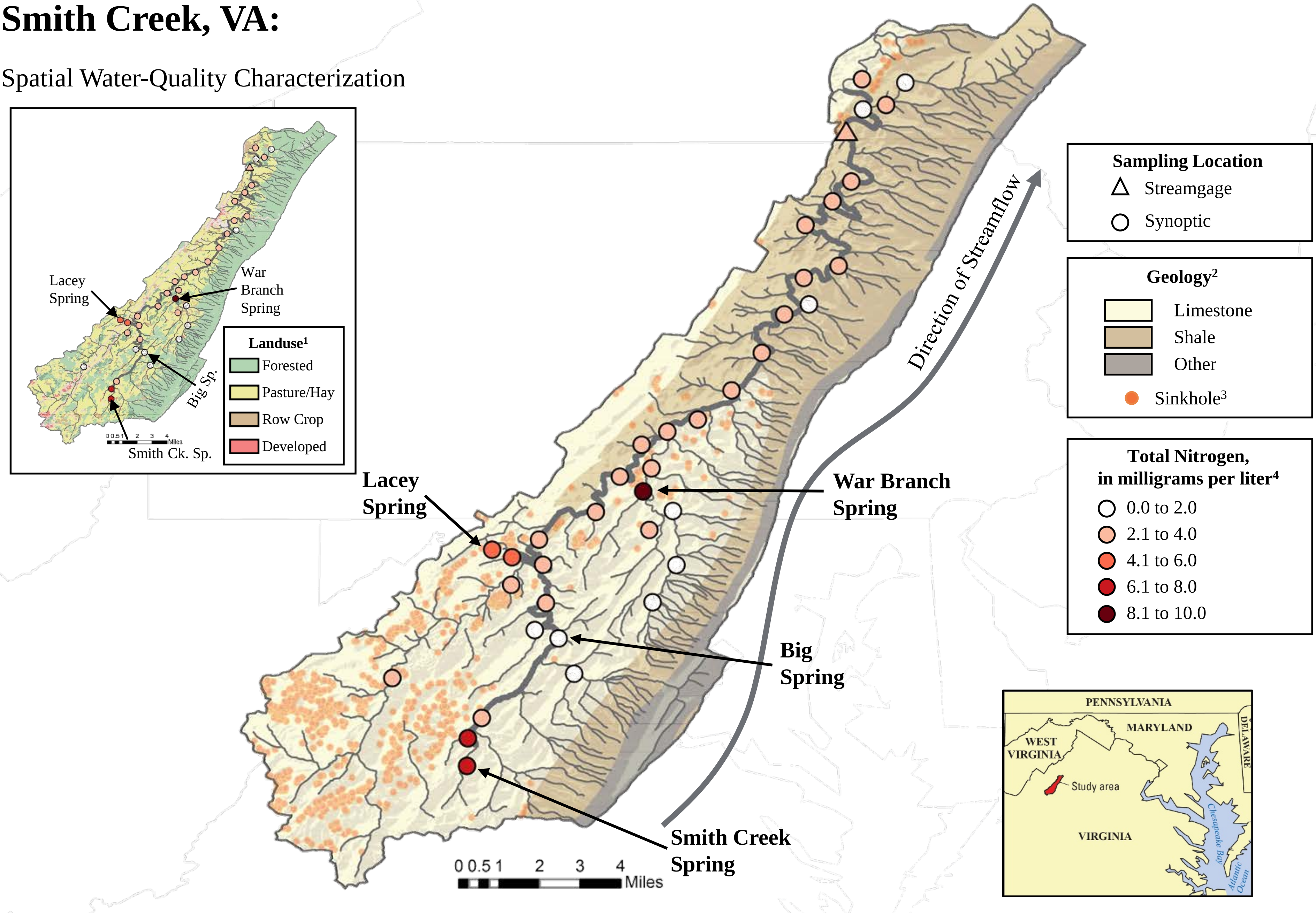

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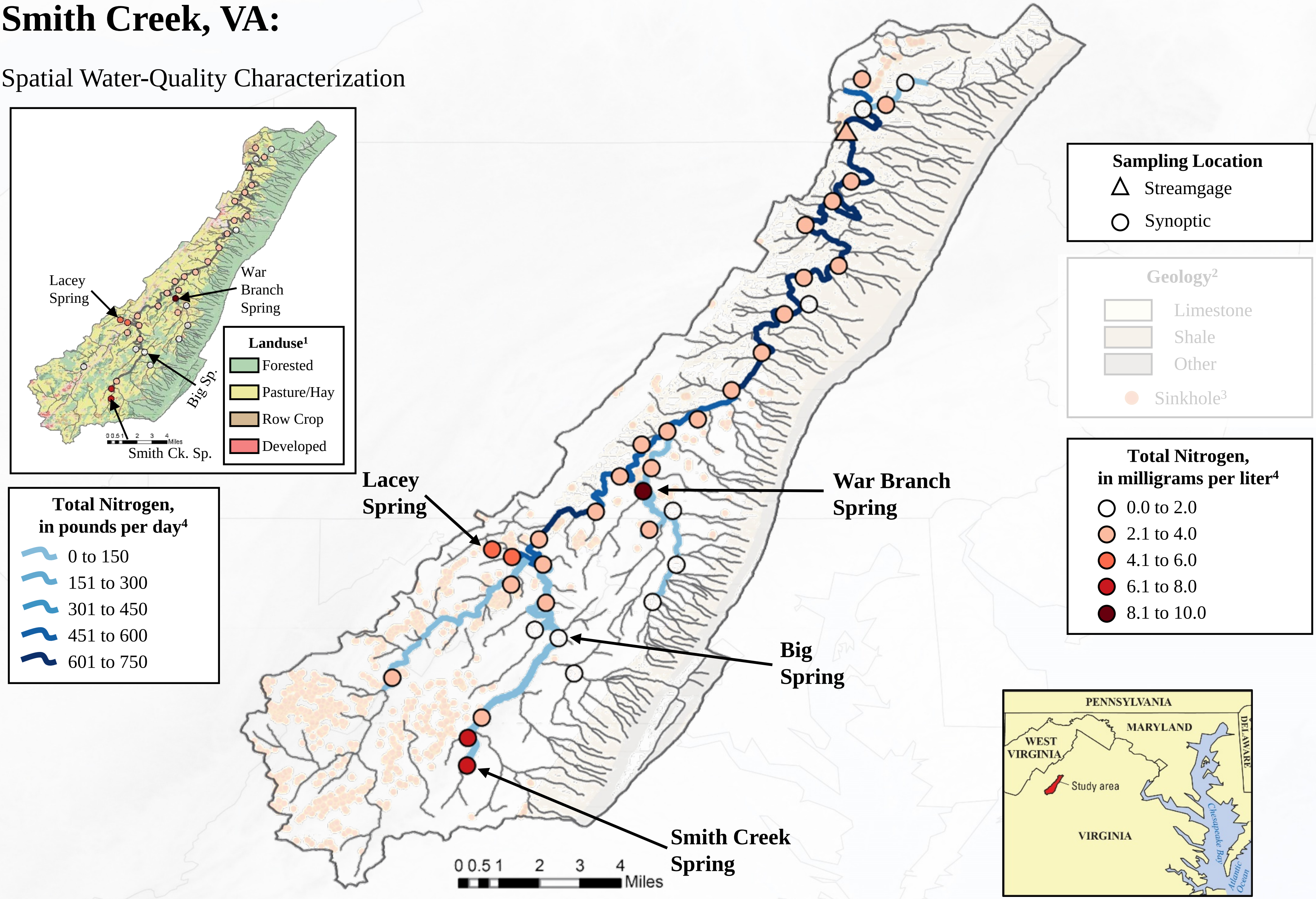

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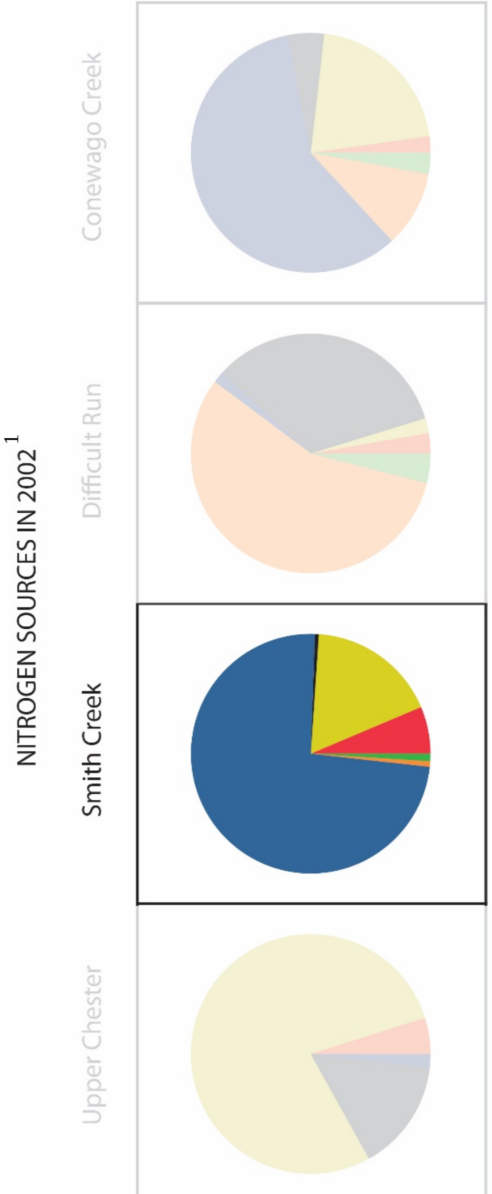
Nitrogen Sources: Smith Creek, VA



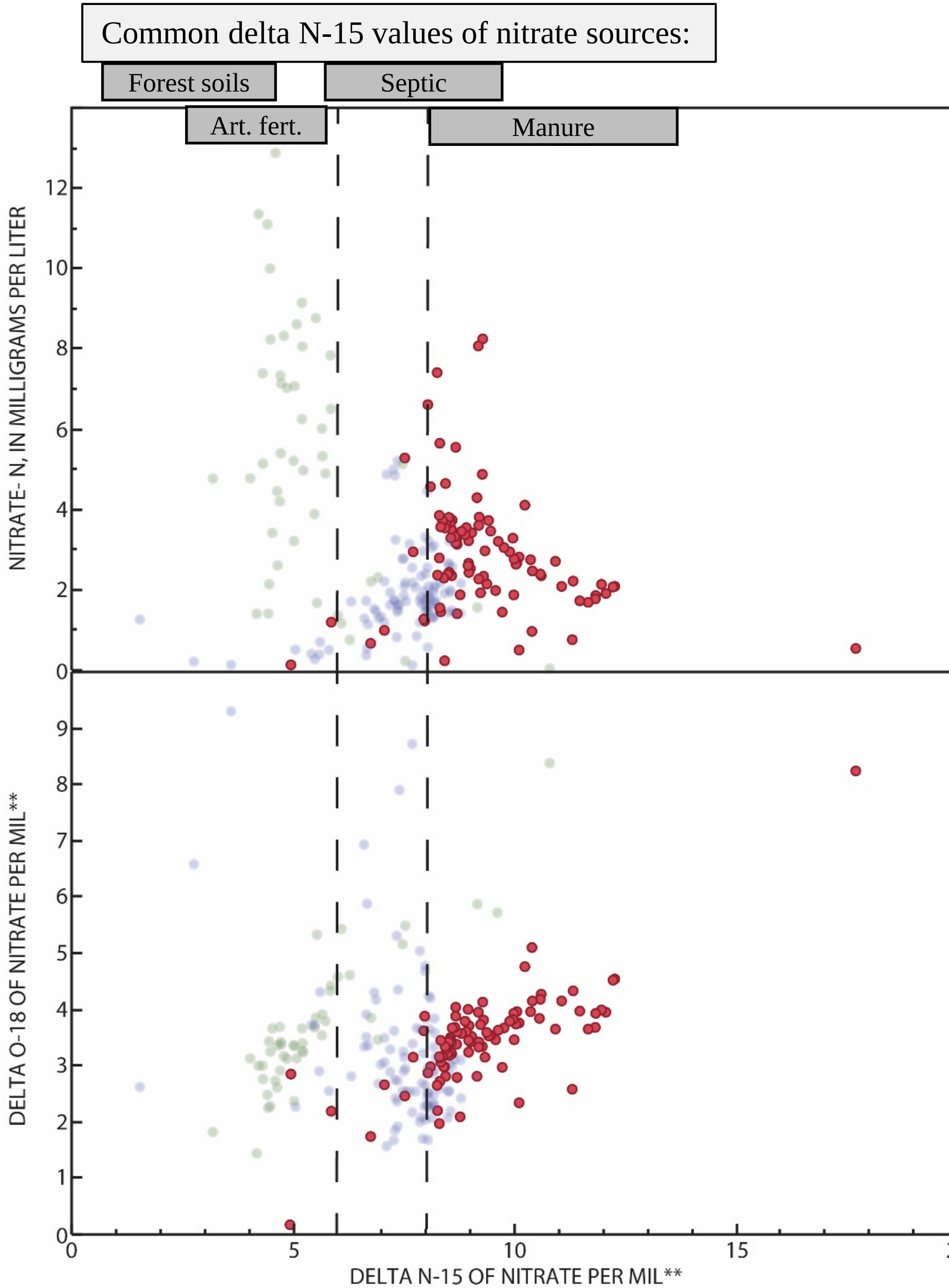
EXPLANATION

- Fertilizer (Farm)
- Fertilizer (Nonfarm)
- Manure
- Atmospheric Deposition
- Sanitary Sewer
- Septic

EXPLANATION

- Difficult Run
- Upper Chester
- Smith Creek

**Typical range of error, 2-sigma:
delta N-15: 0.5 per mil
delta O-18: 1.0 per mil



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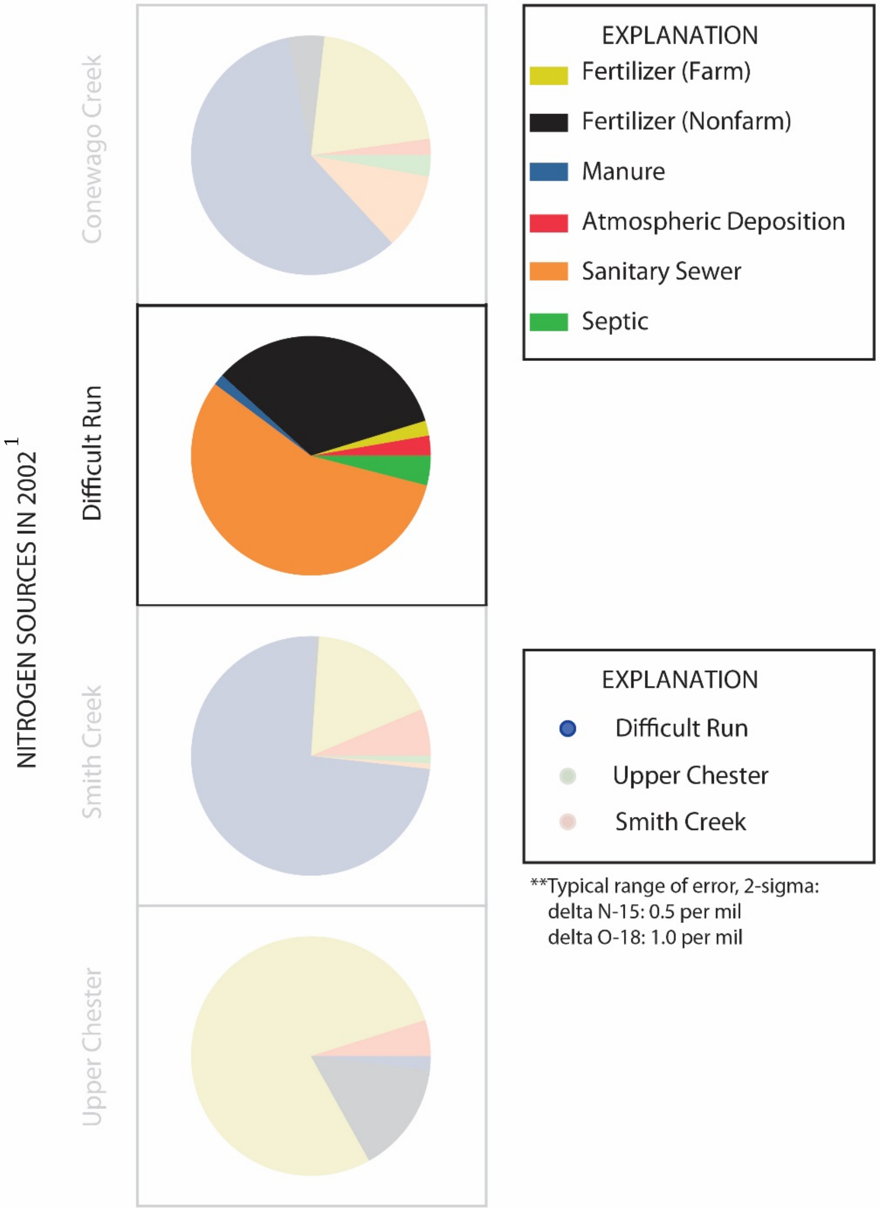
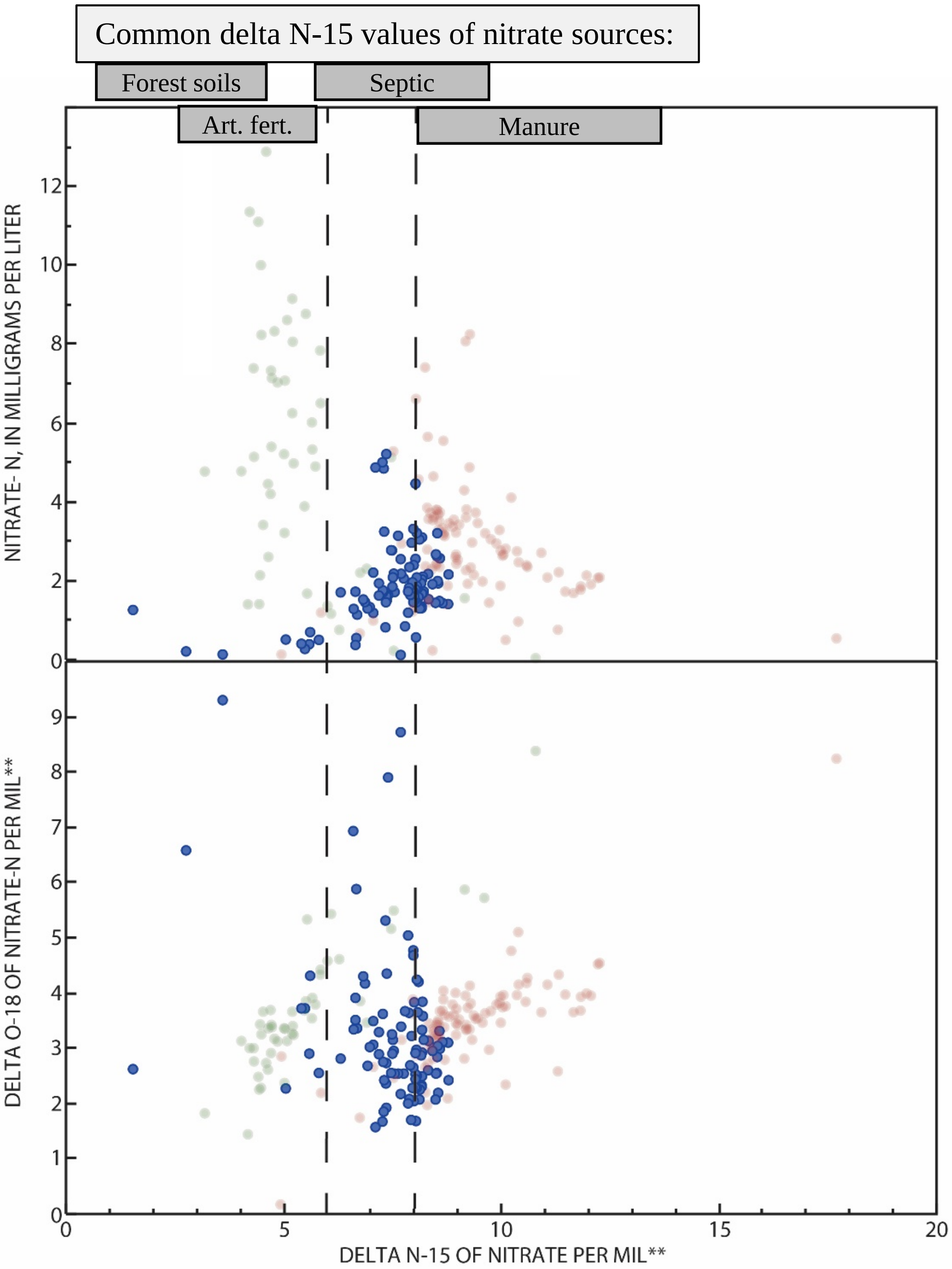
[1]Sources derived from county-based landuse estimates from 2002. Conewago Creek is an average of Dauphin and Lebanon Counties (PA), Difficult Run is based on Fairfax County (VA), Smith Creek is an average of Shenandoah and Rockingham Counties (VA), Upper Chester is an average of Kent and Queen Anne's Counties (MD).

Nitrogen Sources: Difficult Run, VA





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Detecting Change Over Time

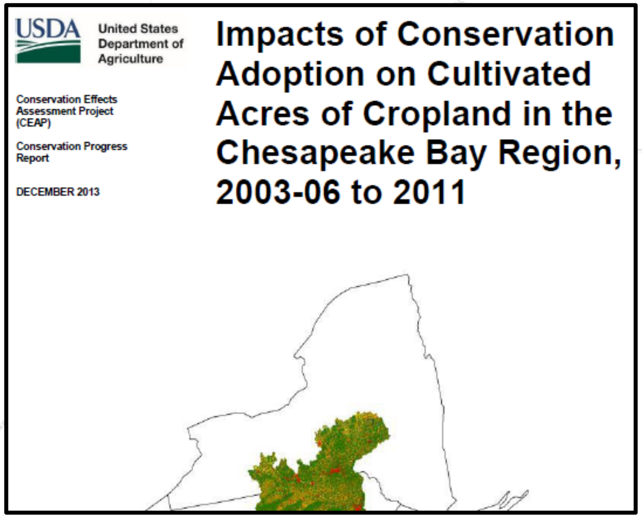
Increased Conservation Practices

Total number of federally funded conservation practices implemented annually within the Showcase Watersheds.

Watershed	2007	2008	2009	2010	2011	2012	2013	Total
Conewago Creek	131	50	110	90	122	86	93	682
Smith Creek	**292**	**66**	**99**	**117**	**202**	**312**	**316**	**1,404**
Upper Chester	179	106	103	189	193	264	79	1,113

Vs.

Increased Inputs?


USDA United States Department of Agriculture

Conservation Effects Assessment Project (CEAP)

Conservation Progress Report

DECEMBER 2013

Impacts of Conservation Adoption on Cultivated Acres of Cropland in the Chesapeake Bay Region, 2003-06 to 2011

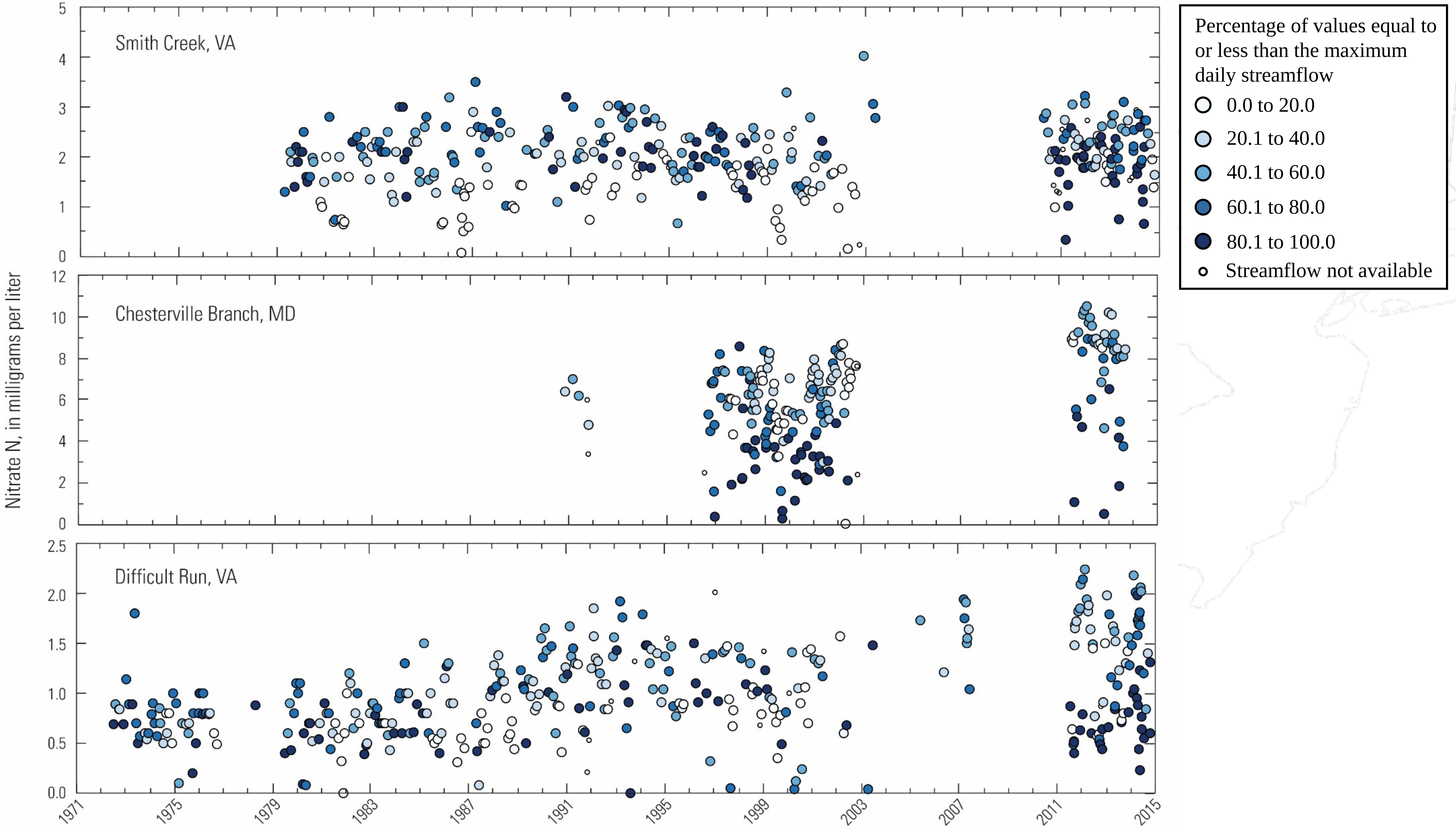
Manure Application Rate: 25% increase[1]

Commercial Fertilizer Application Rate: 9% increase[1]

Appropriate nitrogen application rate: 9% decrease[1]

[1]U.S. Department of Agriculture, Natural Resources Conservation Service, 2013, Impacts of conservation adoption on cultivated acres of cropland in the Chesapeake Bay region, 2003–06 to 2011: 113 p.

Detecting Change Over Time



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Lessons Learned

Intensive water-quality sampling has resulted in a relatively strong understanding of:

- Spatial Variability in Water Chemistry
- Nitrogen Transport Processes
- Nitrogen Sources
  - Manure in Smith Creek
  - Inorganic commercial fertilizer in the Upper Chester River
  - A mixture of sources that likely includes septic effluent in Difficult Run

Observed empirical nitrate concentrations indicate that conditions are not yet improving

Implementation of conservation practices may be offset by increased nitrogen inputs.

These empirical data are critical for validating and improving various regional modeling tools such as the Chesapeake Bay Program's Watershed model, and the USGS SPARROW model.

Future Directions

- Evaluate phosphorus sources and transport processes
- Understand the relation between BMP implementation and changes in water-quality
- Regionalize results to the Chesapeake Bay watershed

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Questions and Discussion topics

- **How can you help**
  - Tell your watershed story
  - Compile detailed histories of changes at the basin level
    - Population
    - Development
    - CSO
    - BMP
    - WWTP upgrades
    - Etc.…

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