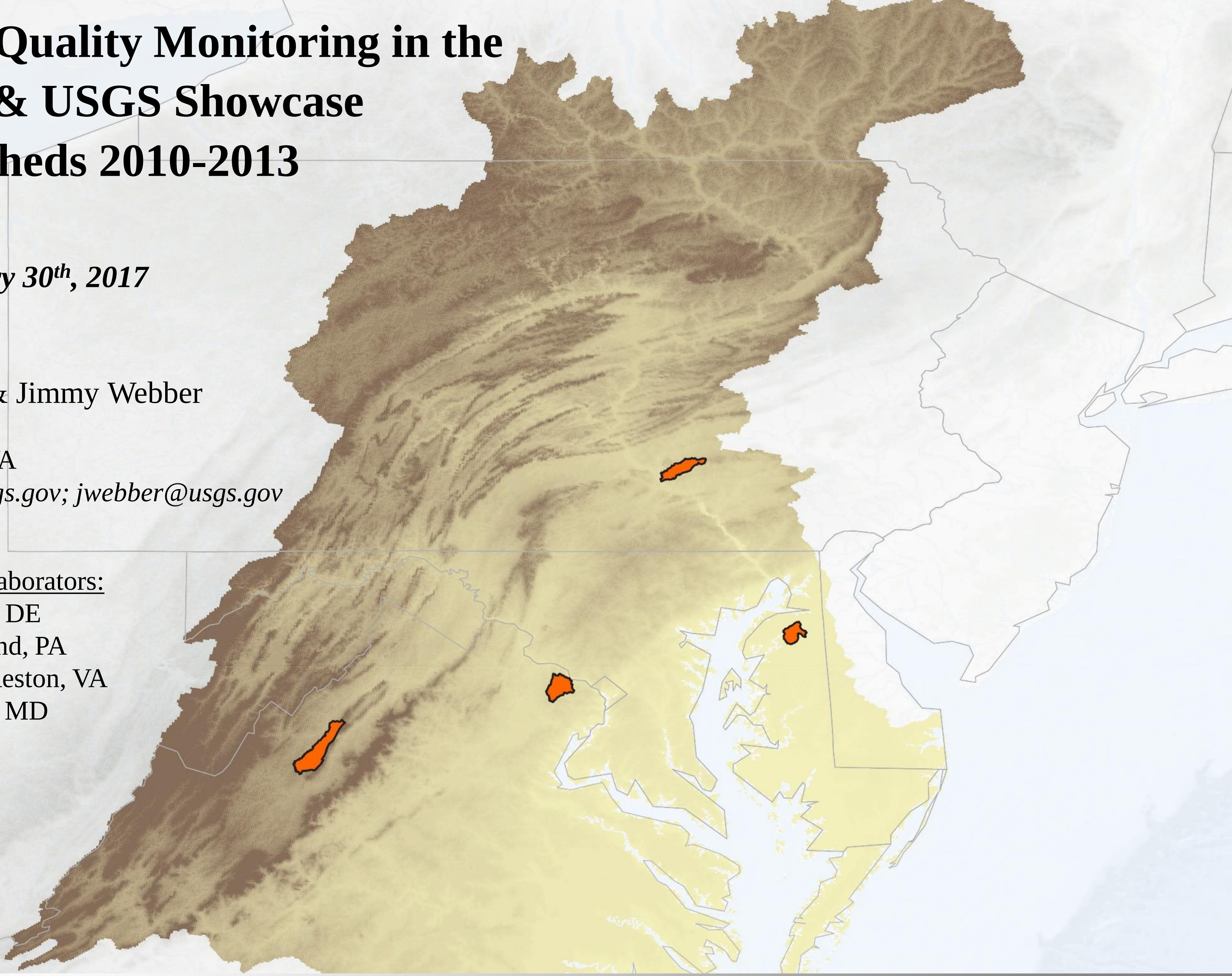
Water-Quality Monitoring in the USDA & USGS Showcase Watersheds 2010-2013

January 30th, 2017

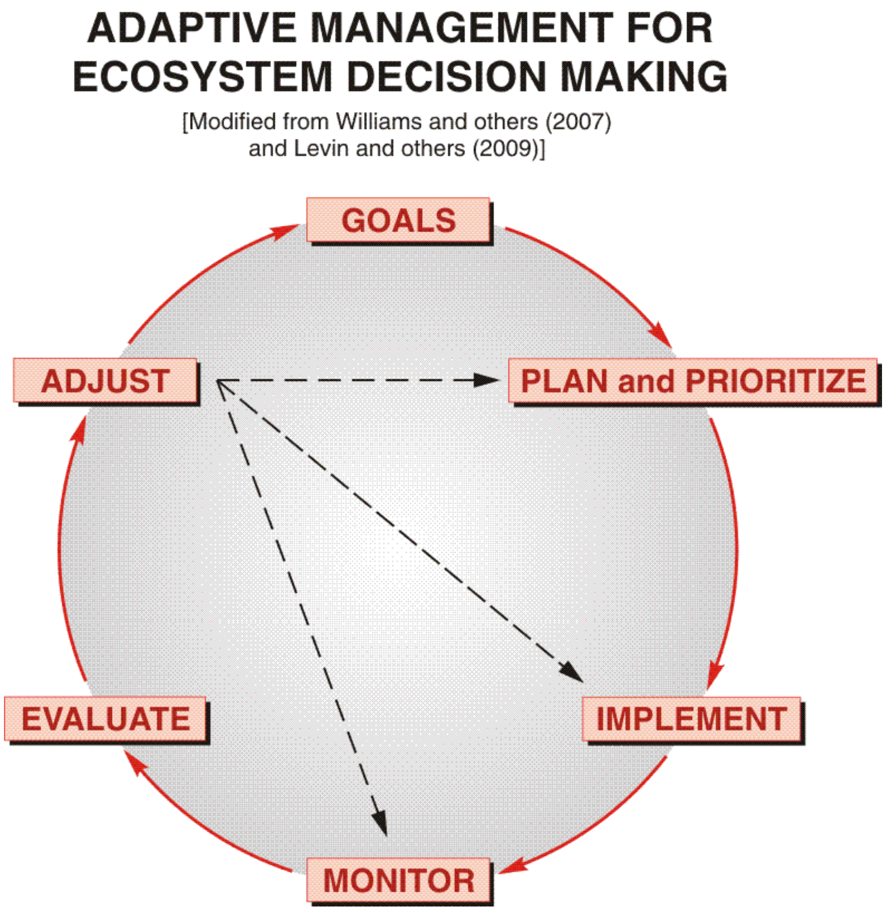
Ken Hyer & Jimmy Webber
USGS
Richmond, VA
kenhyer@usgs.gov; jwebber@usgs.gov

<u>Primary Collaborators:</u>
Judy Denver, DE
Mike Langland, PA
JK Böhlke, Reston, VA
Dean Hively, MD



USGS and the Chesapeake

- Science for Effective Decisions
- Watershed Agreement
- USGS Science Themes
  - Fish, wildlife and habitats
  - Water quality
  - Climate and land change
  - Summarize and inform



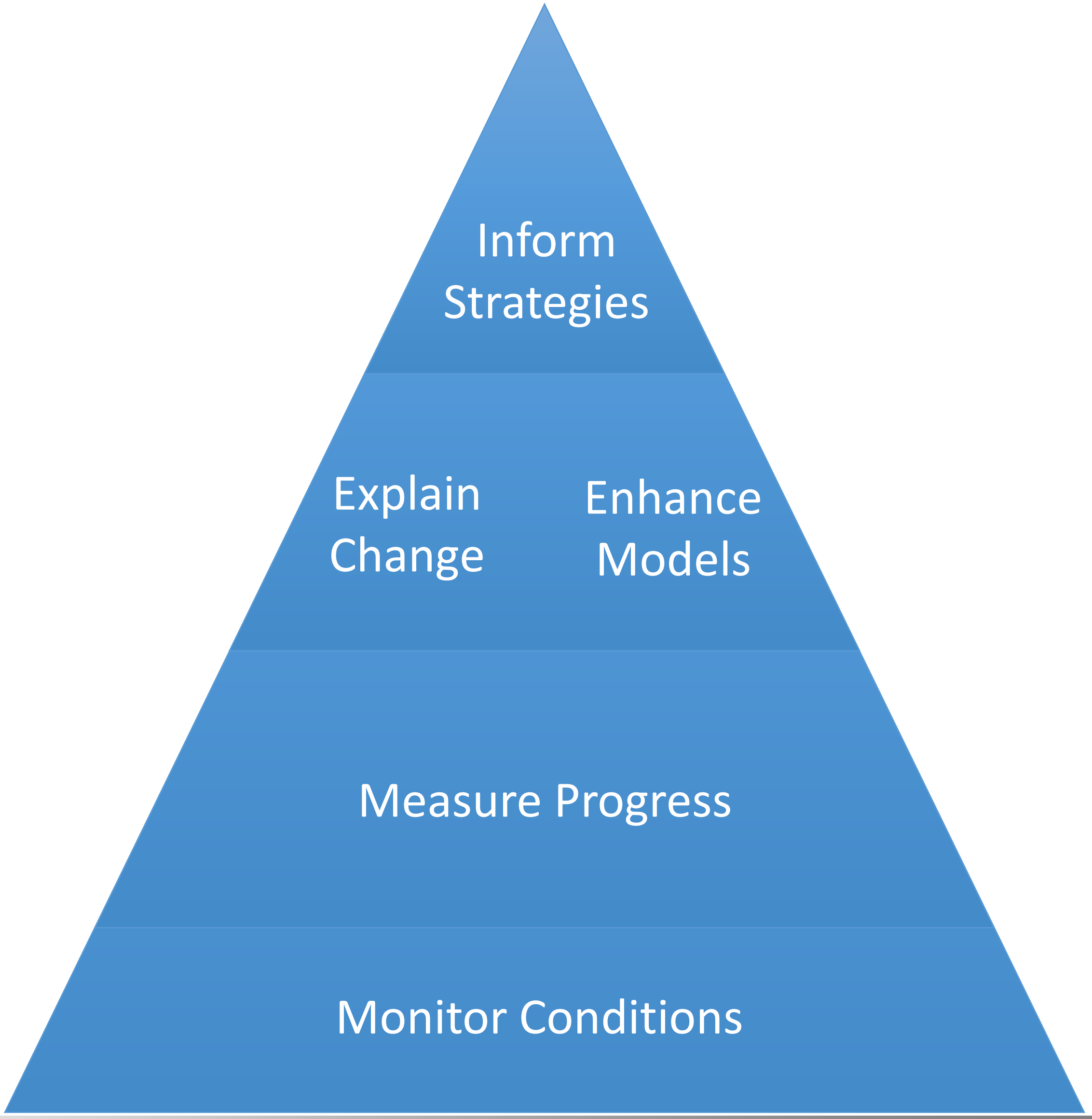
Measure and Explain Water-Quality Change

1. Measure progress
    - Loads
    - Trends

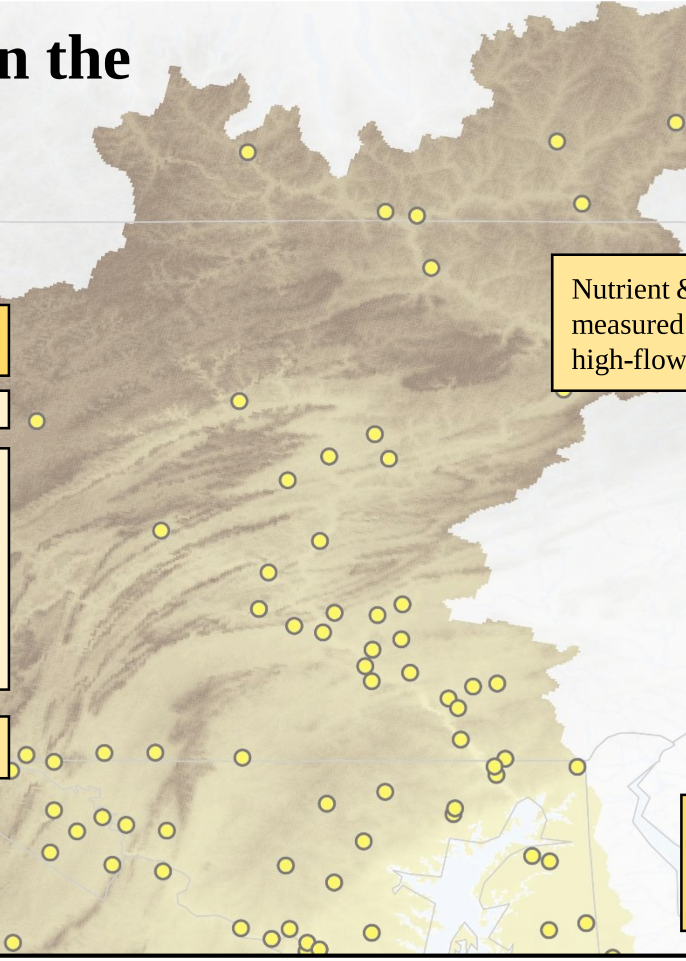
2. Explain water-quality changes
    - Sources, land change
    - Management practices

3. Enhance CBP models

4. Inform management



Load & Trend Estimation in the Chesapeake Bay Nontidal Network



Chesapeake Bay Nontidal Monitoring Network

Goals:

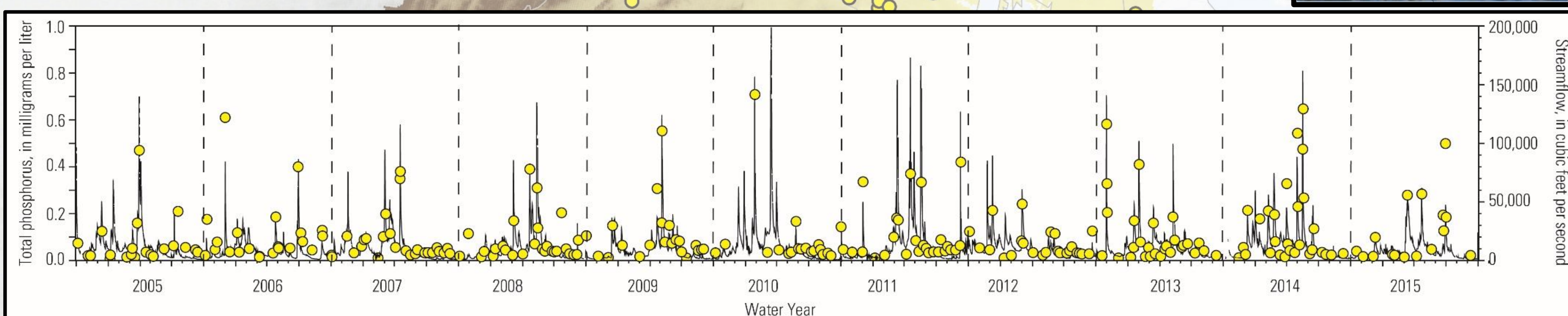
Quantify *loads* of nutrients and sediment in the nontidal rivers of the Chesapeake Bay watershed

Estimate *trends* in loads to detect effects of changes in land management effects on water quality

Daily Load = Daily Concentration * Mean Daily Discharge

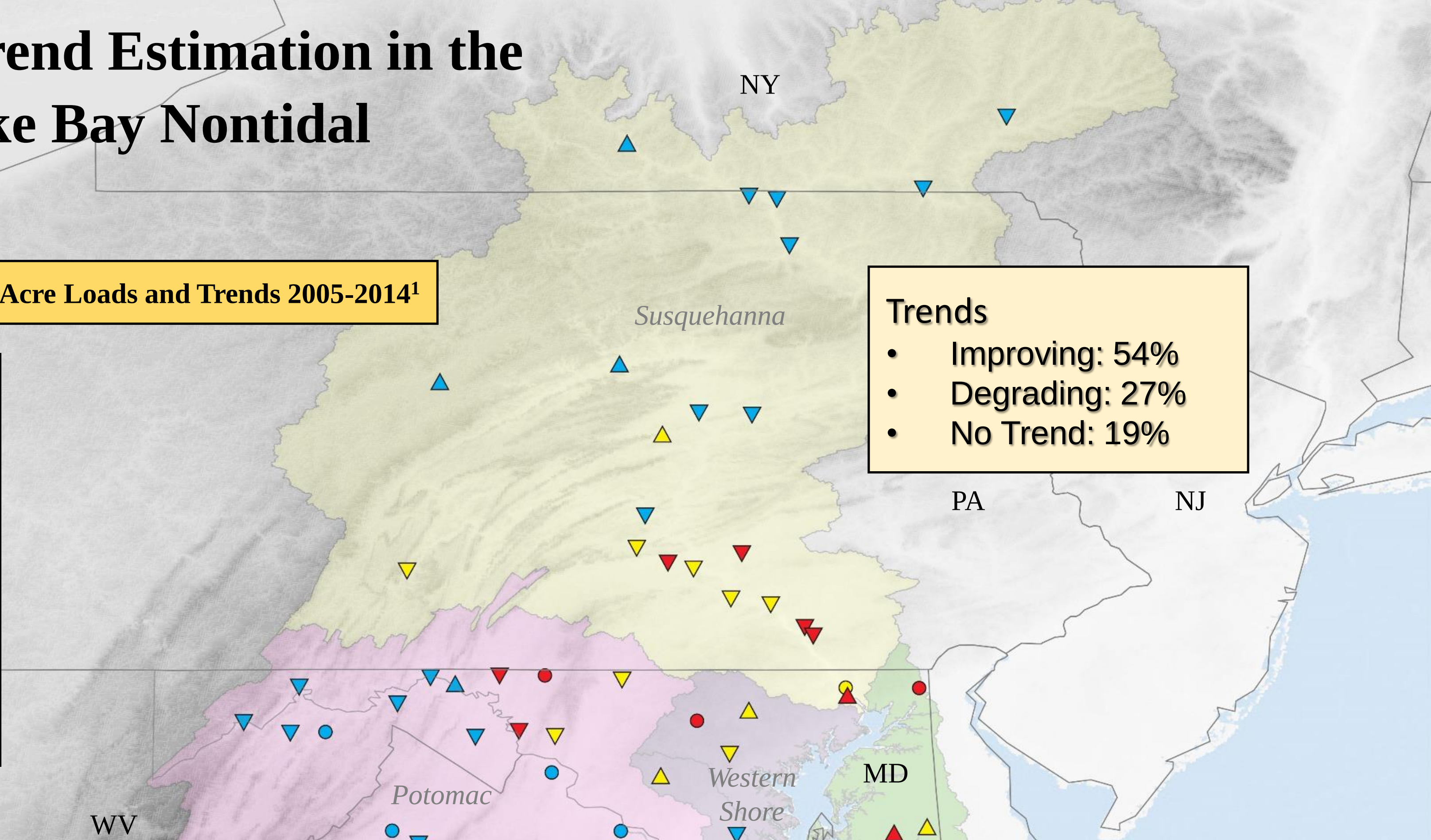
Nutrient & sediment concentrations are measured during monthly and targeted high-flow sampling events.

2,340 annual samples!



Load & Trend Estimation in the Chesapeake Bay Nontidal Network

Total Nitrogen per Acre Loads and Trends 2005-2014[1]



Trend Direction

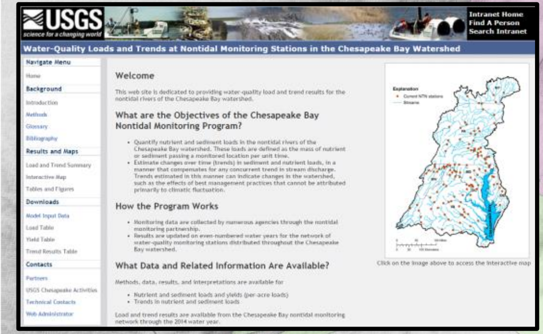
- ○ No Trend
- ▽ Improving
- △ Degrading

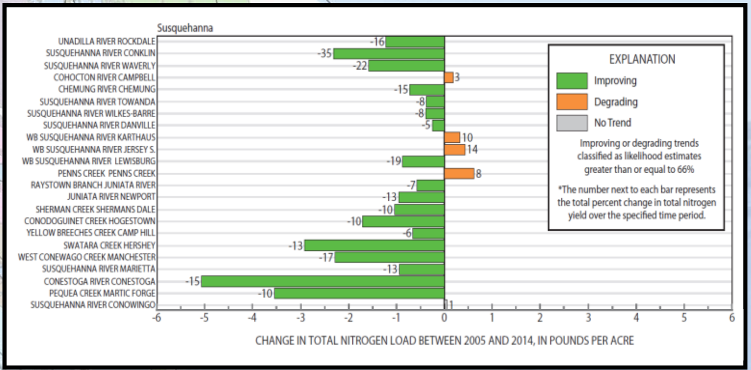
Average Yield (lbs/ac)

- 1.19 – 6.88
- 6.89 – 13.75
- 13.76 – 33.44

Trends

- Improving: 54%
- Degrading: 27%
- No Trend: 19%





Why are trends improving or degrading?

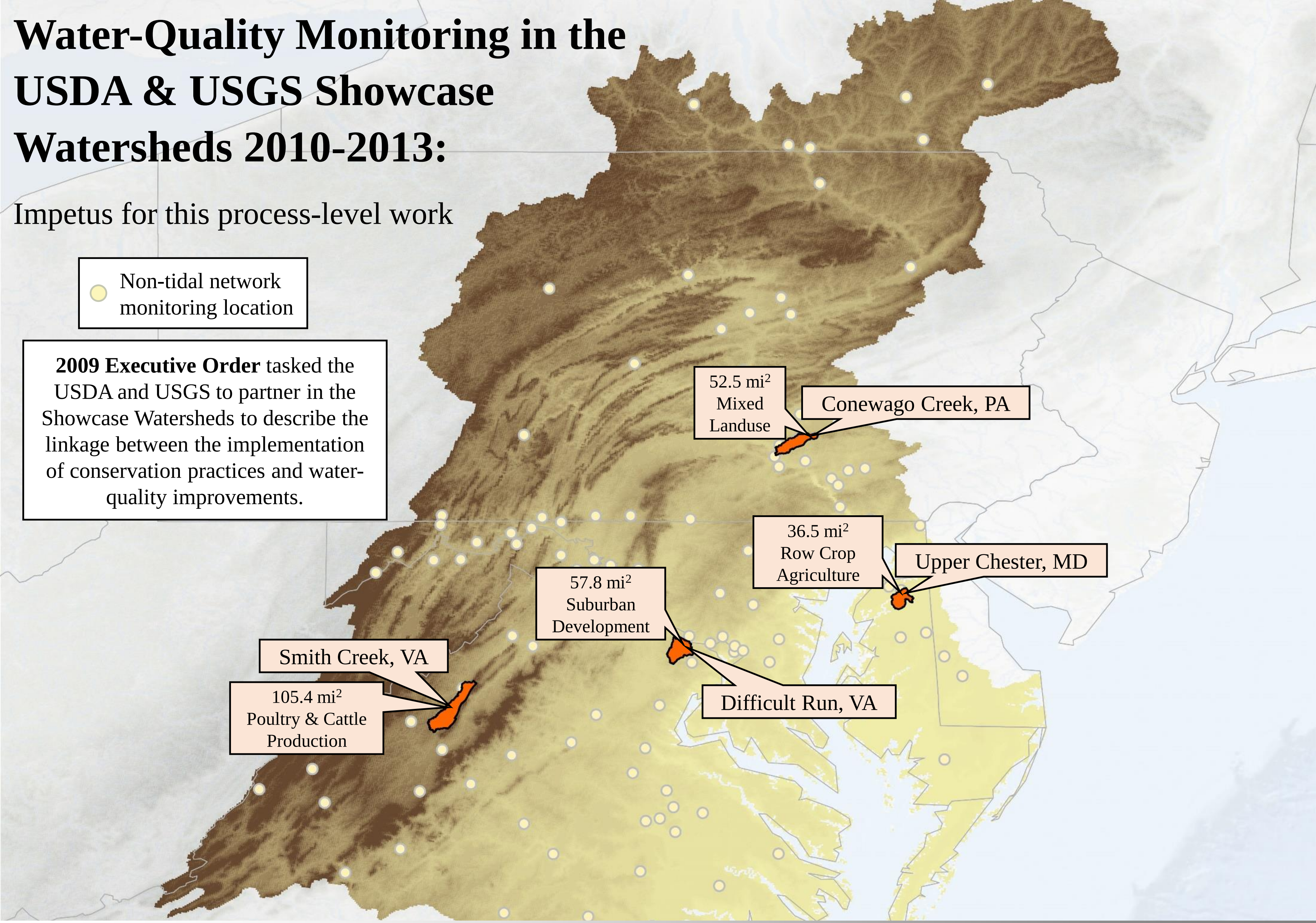
USGS science for a changing world

[1]Data available online: *http://cbrim.er.usgs.gov/*

Water-Quality Monitoring in the USDA & USGS Showcase Watersheds 2010-2013:

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.



Hyer and others (2016)

Water-Quality Monitoring in the USDA & USGS Showcase Watersheds 2010-2013:

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.

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?**

Water-Quality Monitoring in the USDA & USGS Showcase Watersheds 2010-2013: Objectives

To investigate sediment and nutrient dynamics in four relatively small watersheds that represent a range of land-use patterns and underlying geology.

Objectives for the initial phase of this study:

To characterize current water-quality conditions.

To identify the dominant sources, sinks, and transport process of nitrogen and, to a lesser extent, phosphorus.

To provide guidance to study partners related to the implementation of conservation practices.

To quantify the implementation of conservation practices

To document patterns in water quality using existing long-term nitrogen data.

Future Objectives:
These objectives will be achieved through continued monitoring and analysis and are not addressed by the initial 3 years of this ongoing study.

To continue monitoring to compute short and long-term nutrient and sediment trends.

To further enhance the understanding of nutrient sources and transport processes.

To link the implementation of conservation practices with the understanding of nutrient and sediment sources and transport processes to explain the observed water-quality trends.

To determine how regionally representative the observations and conditions encountered within these four watersheds are within the Chesapeake Bay watershed.

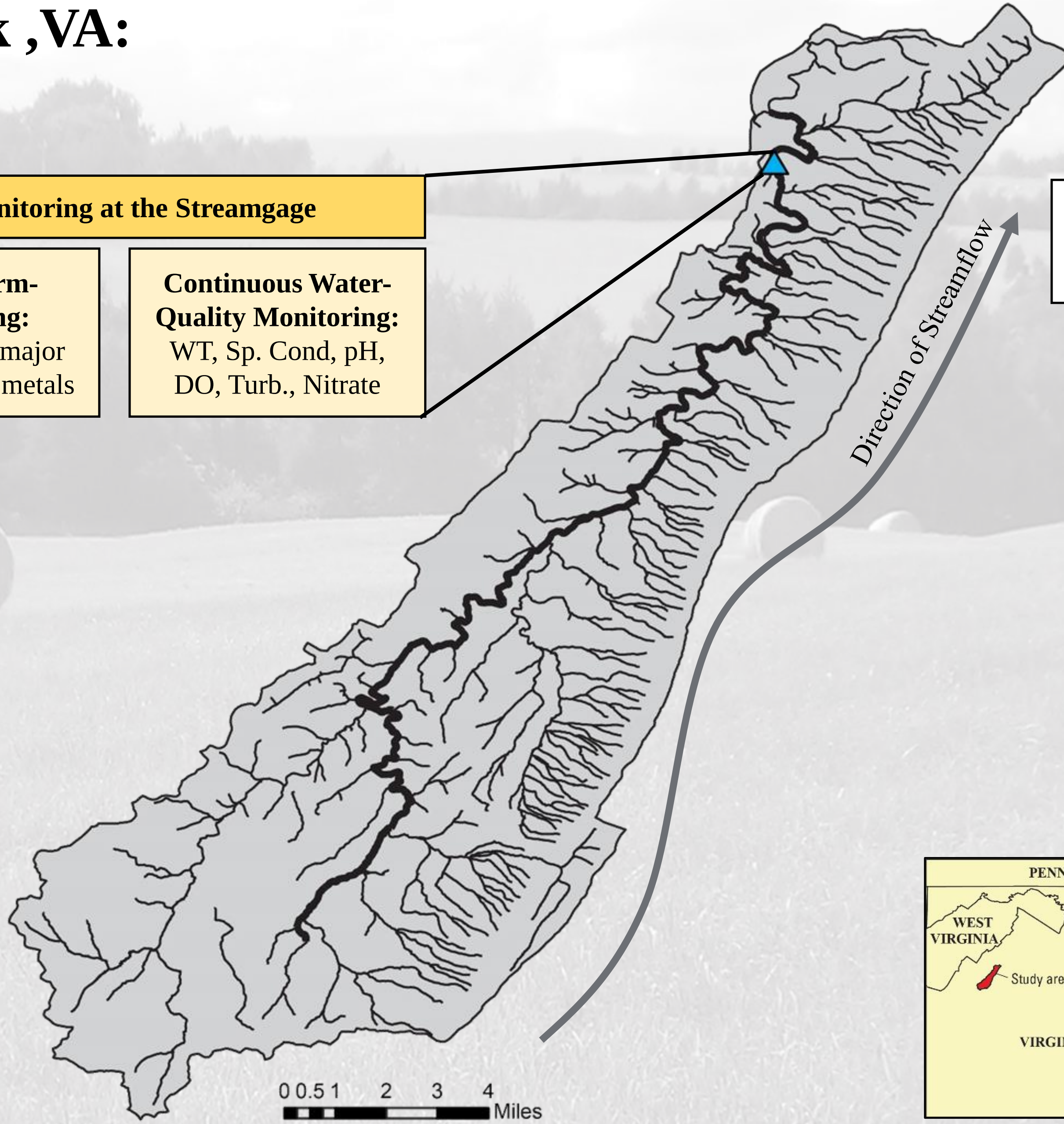
Smith Creek ,VA:

Study Design

Intensive Monitoring at the Streamgage

Monthly and Storm-targeted Sampling:
Nutrients, sediment, major ions, nitrate isotopes, metals

Continuous Water-Quality Monitoring:
WT, Sp. Cond, pH, DO, Turb., Nitrate



Sampling Location
△ Streamgage

Smith Creek ,VA:

Study Design

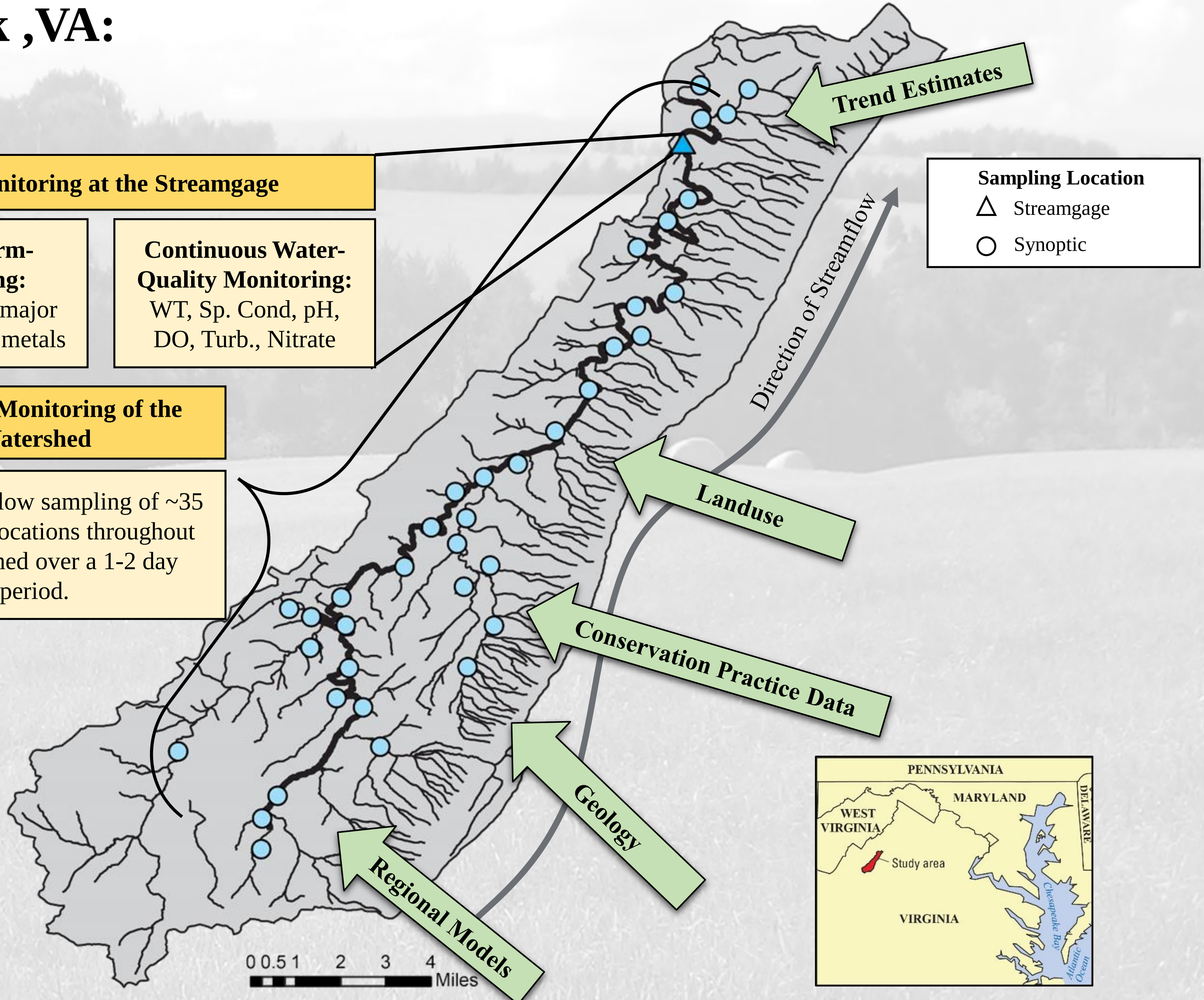
Intensive Monitoring at the Streamgage

Monthly and Storm-targeted Sampling: Nutrients, sediment, major ions, nitrate isotopes, metals

Continuous Water-Quality Monitoring: WT, Sp. Cond, pH, DO, Turb., Nitrate

Extensive Monitoring of the Watershed

Annual baseflow sampling of ~35 monitoring locations throughout the watershed over a 1-2 day period.

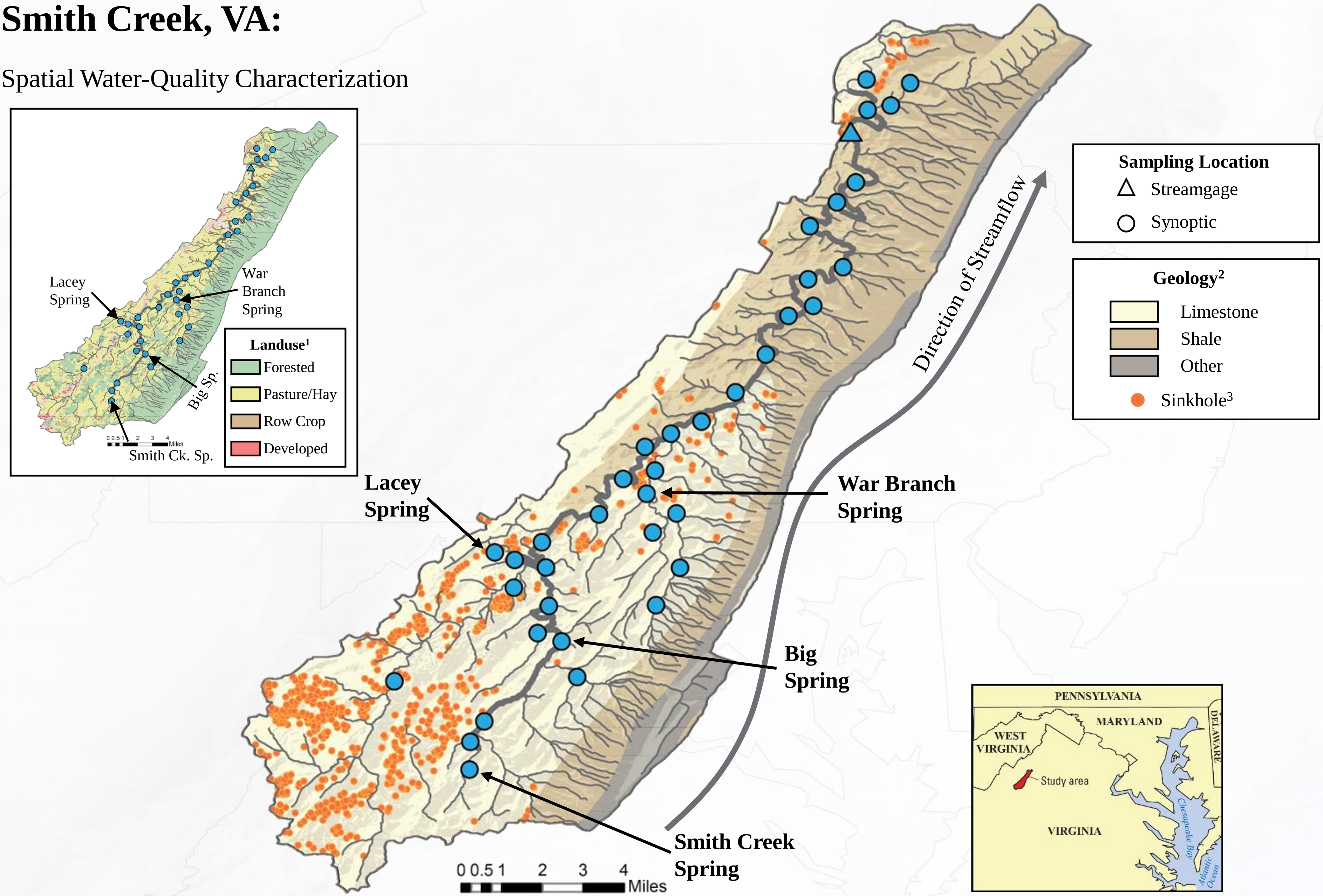


USGS
science for a changing world

Hyer and others (2016)

Smith Creek, VA:

Spatial Water-Quality Characterization



[1]Landuse from NLCD 2011

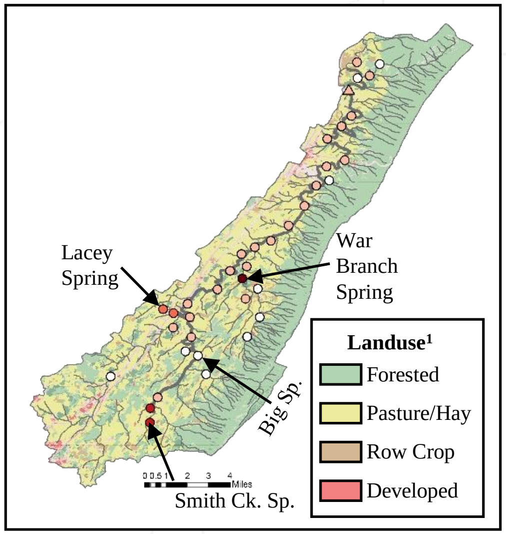
[2]Geology from Dicken and others (2005)

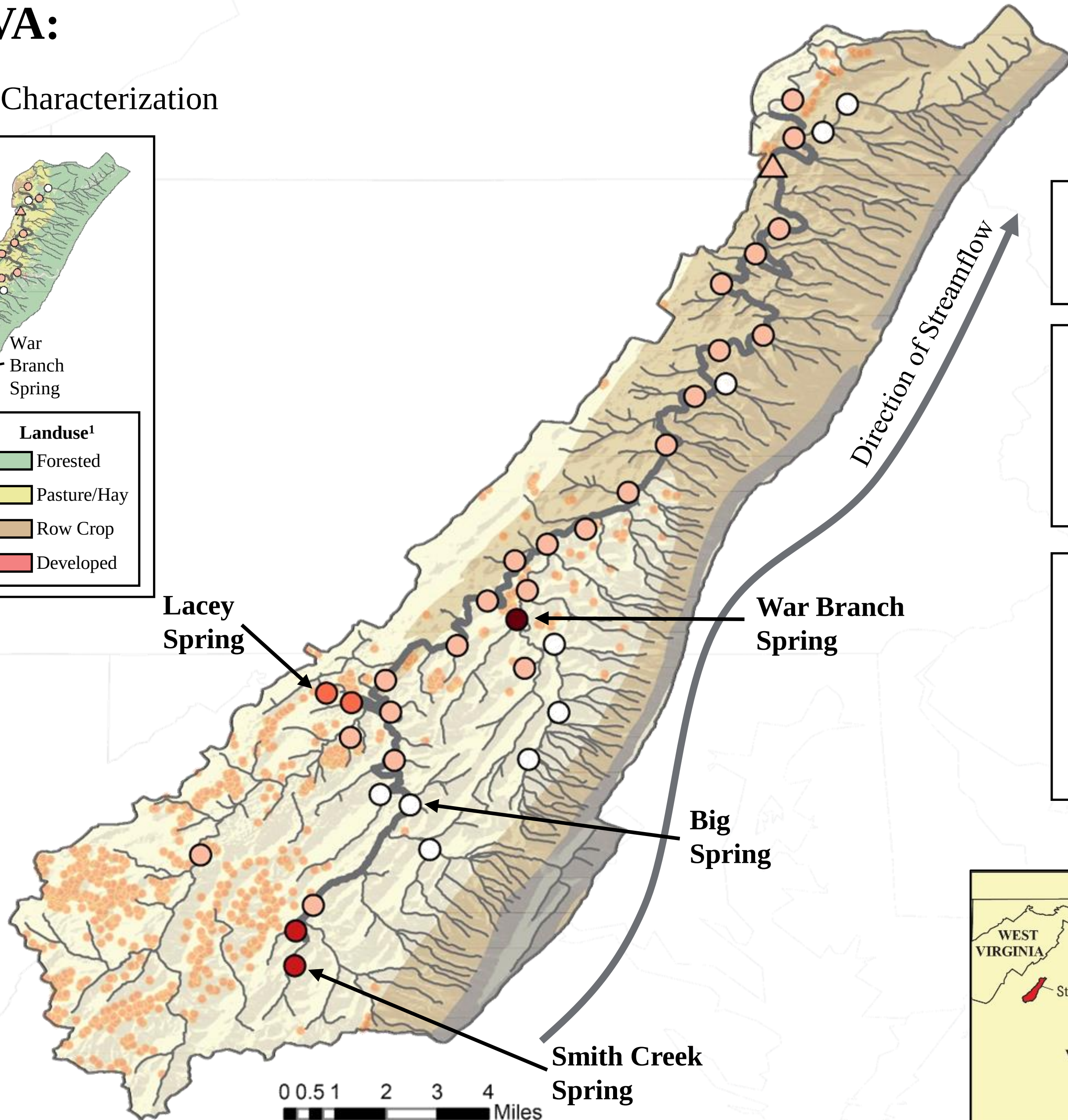
[3]Sinkholes from Hubbard (1983)

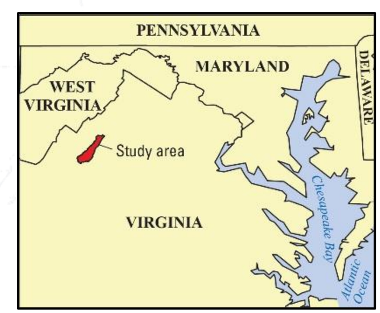
Hyer and others (2016)

Smith Creek, VA:

Spatial Water-Quality Characterization







USGS science for a changing world

[1]Landuse from NLCD 2011

[2]Geology from Dicken and others (2005)

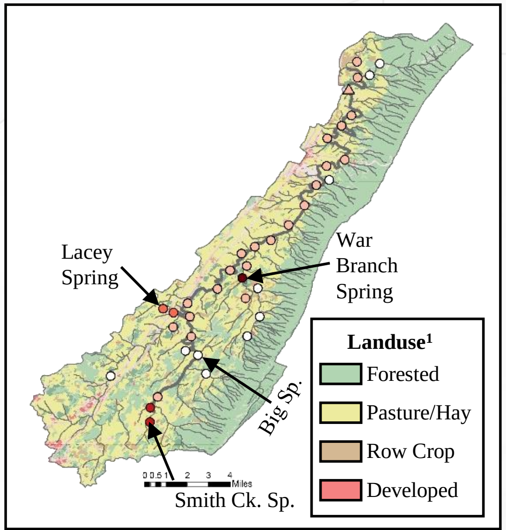
[3]Sinkholes from Hubbard (1983)

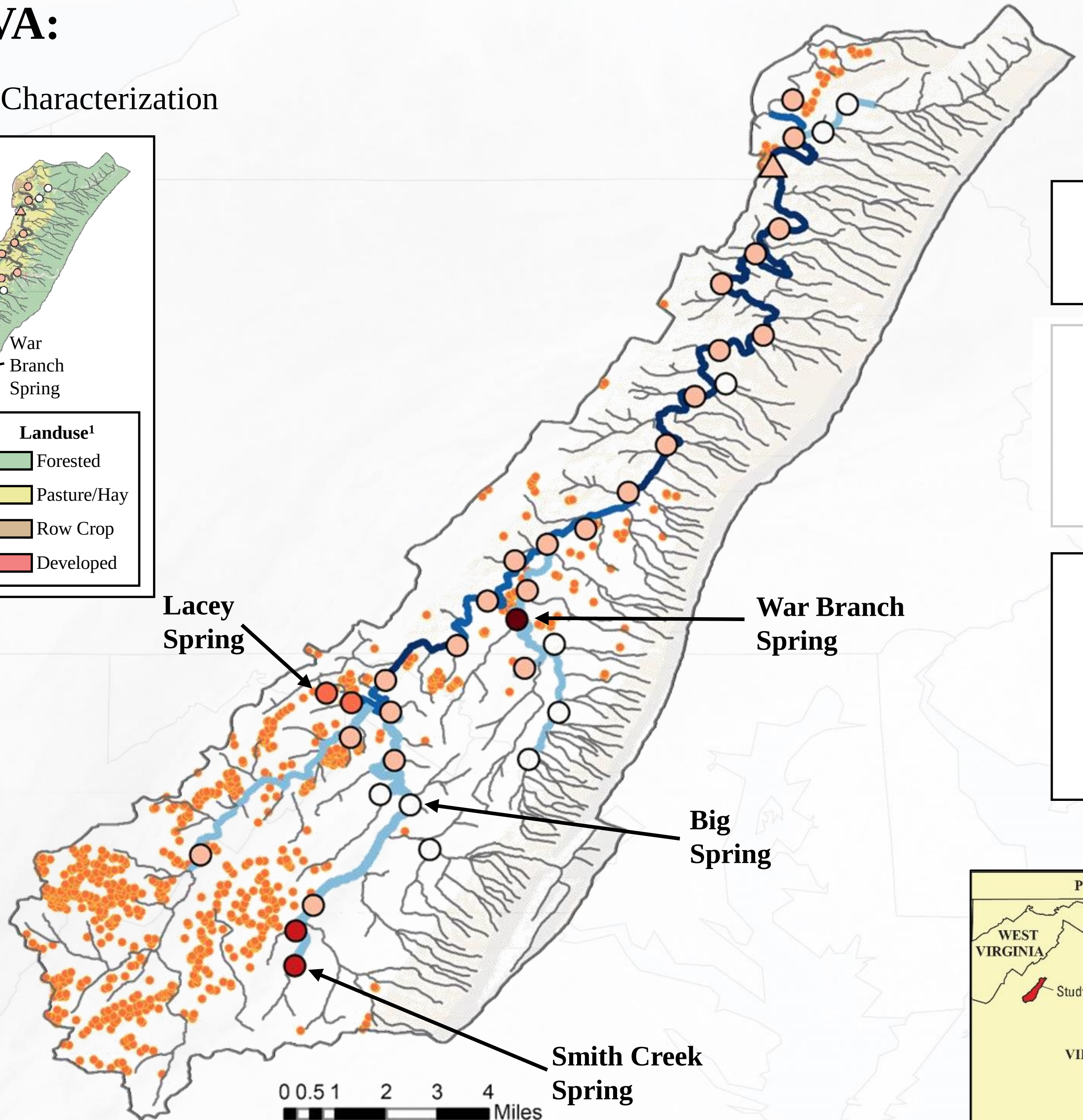
[4]Total nitrogen concentrations from May 2013 synoptic sampling event.

Hyer and others (2016)

Smith Creek, VA:

Spatial Water-Quality Characterization





Total Nitrogen, in pounds per day[4]

- 0 to 150
- 151 to 300
- 301 to 450
- 451 to 600
- 601 to 750

Sampling Location

- Streamgage
- Synoptic

Geology[2]

- Limestone
- Shale
- Other
- Sinkhole[3]

Total Nitrogen, in milligrams per liter[4]

- 0.0 to 2.0
- 2.1 to 4.0
- 4.1 to 6.0
- 6.1 to 8.0
- 8.1 to 10.0

USGS science for a changing world

[1]Landuse from NLCD 2011

[2]Geology from Dicken and others (2005)

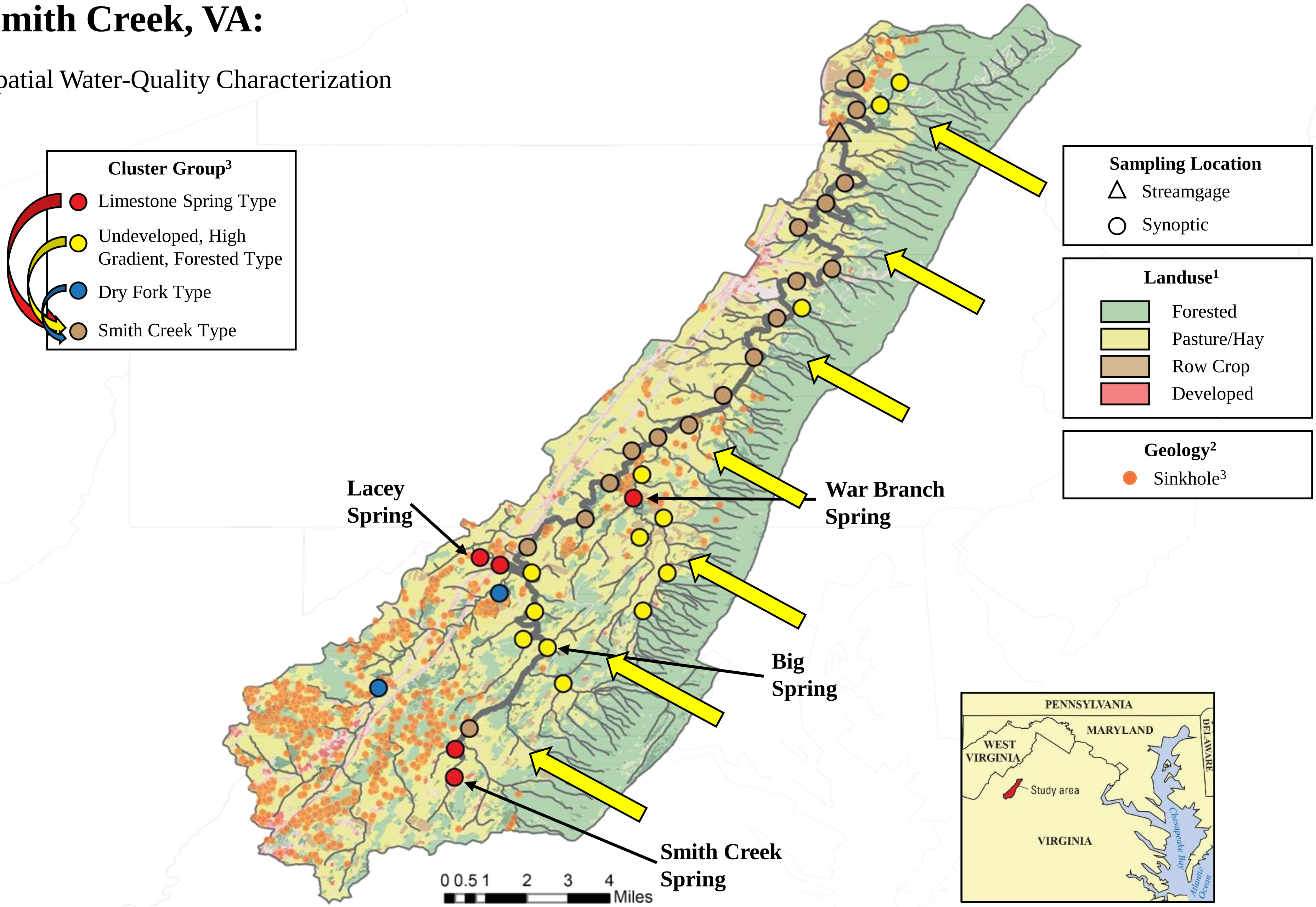
[3]Sinkholes from Hubbard (1983)

[4]Total nitrogen concentrations from May 2013 synoptic sampling event.

Hyer and others (2016)

Smith Creek, VA:

Spatial Water-Quality Characterization



USGS science for a changing world

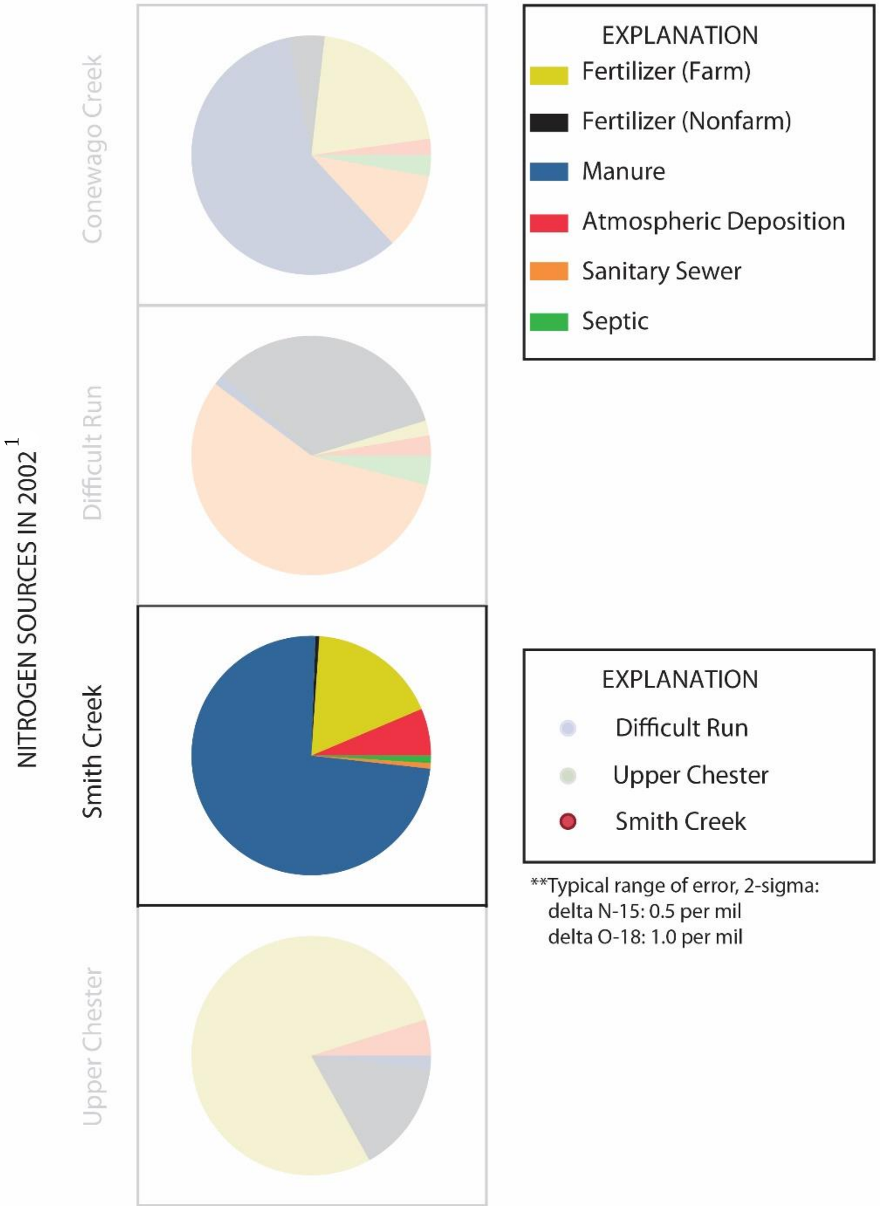
[1]Landuse from NLCD 2011

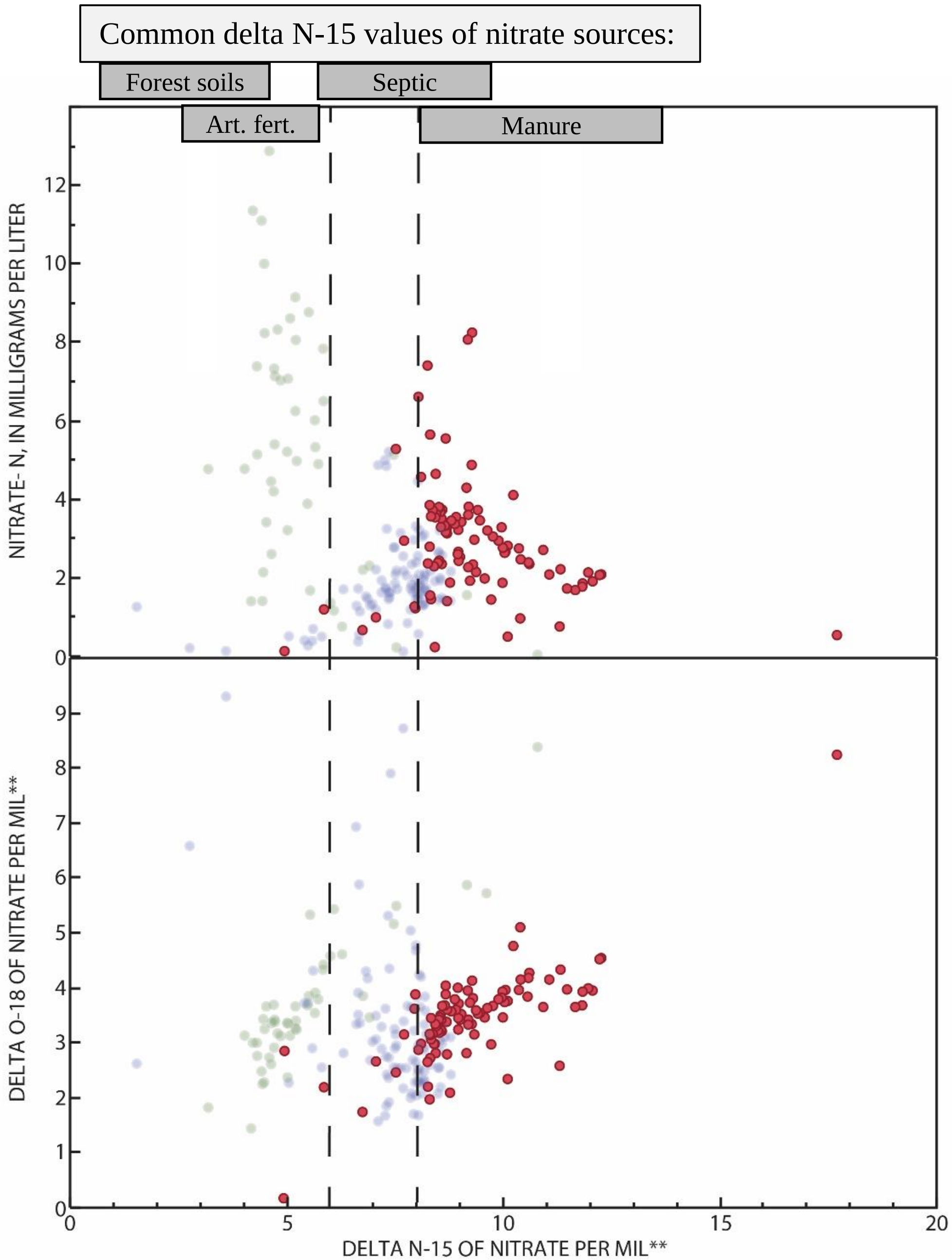
[2]Sinkholes from Hubbard (1983)

[3]Cluster groups assigned to samples during May 2013 synoptic sampling event.

Hyer and others (2016)

Nitrogen Sources: Smith Creek, VA

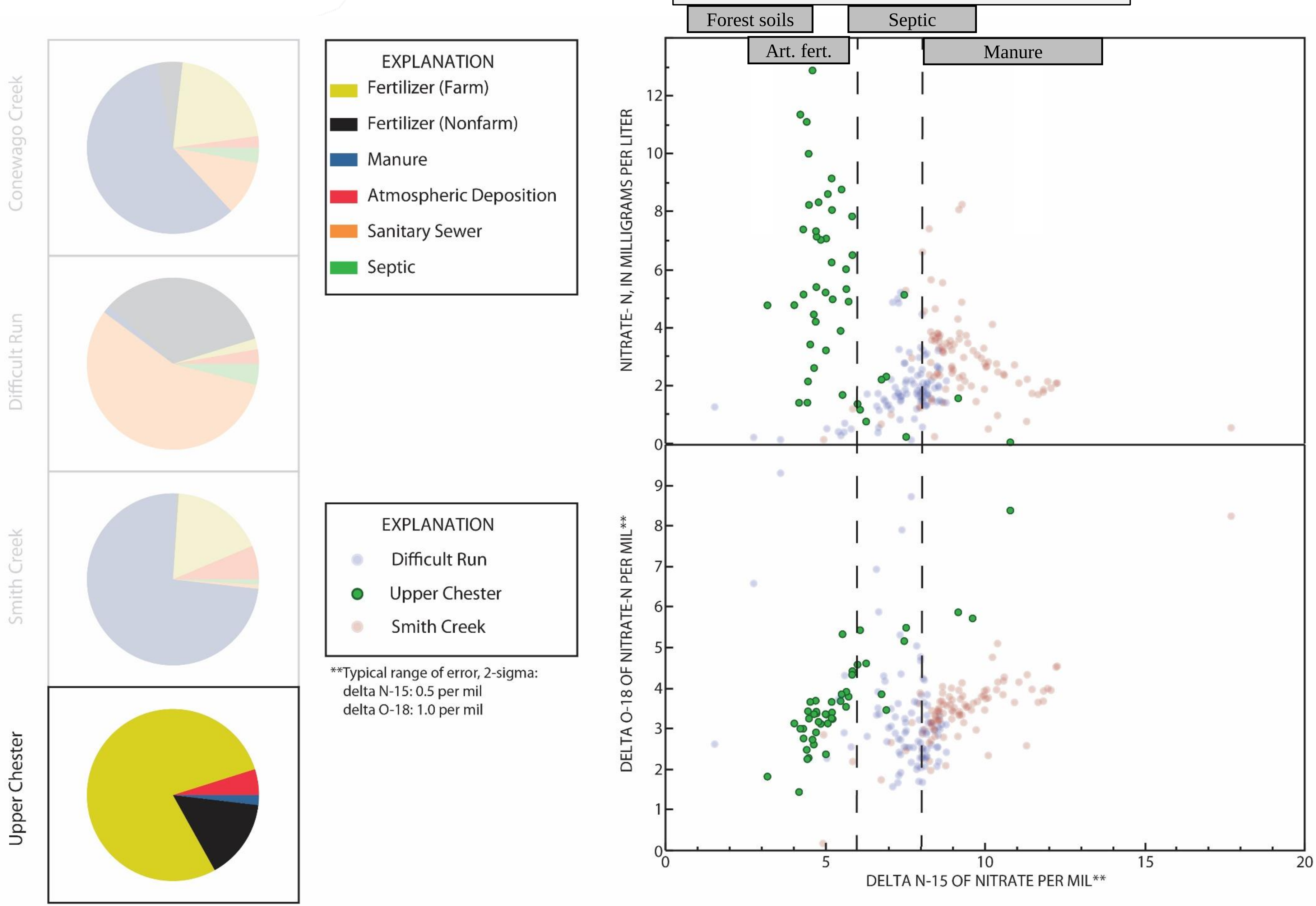




[1]Sources derived from county-based landuse estimates from 2002. Conewago Creek is an average of Dauphin and Lebanon Counties (PA), Difficult Run is based on Fairfax County (VA), Smith Creek is an average of Shenandoah and Rockingham Counties (VA), Upper Chester is an average of Kent and Queen Anne's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

Hyer and others (2016)

Nitrogen Sources: Upper Chester, MD



[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).

Hyer and others (2016)

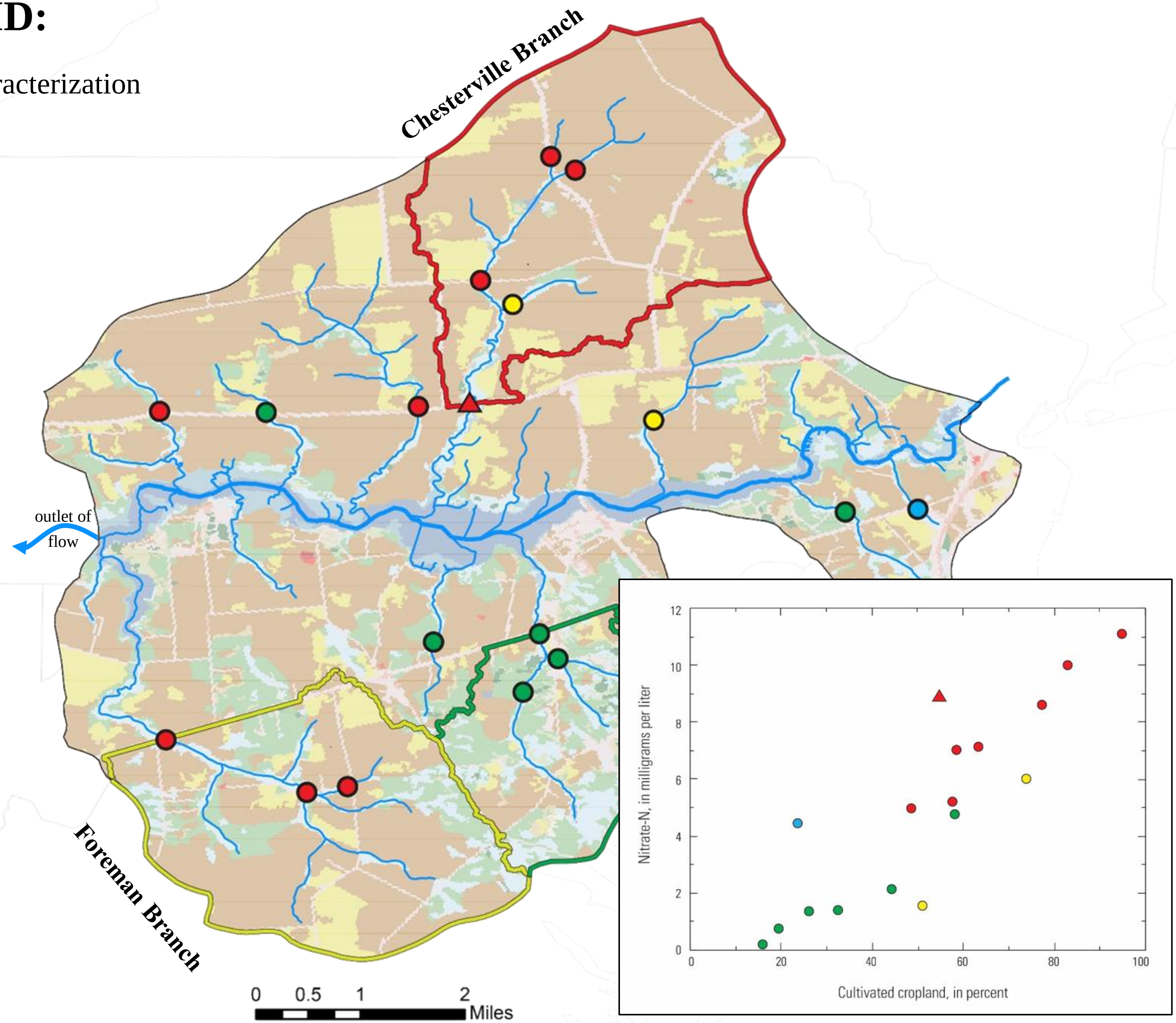
Upper Chester, MD:

Spatial Water-Quality Characterization

Sampling Location
- △ Streamgage
- ○ Synoptic

Landuse[1]
- Forested
- Pasture/Hay
- Row Crop
- Developed

Cluster Group[2]
- Oxic, high agriculture type
- Anoxic, low agriculture type
- Northern, high total phosphorus type
- High-NaCl type

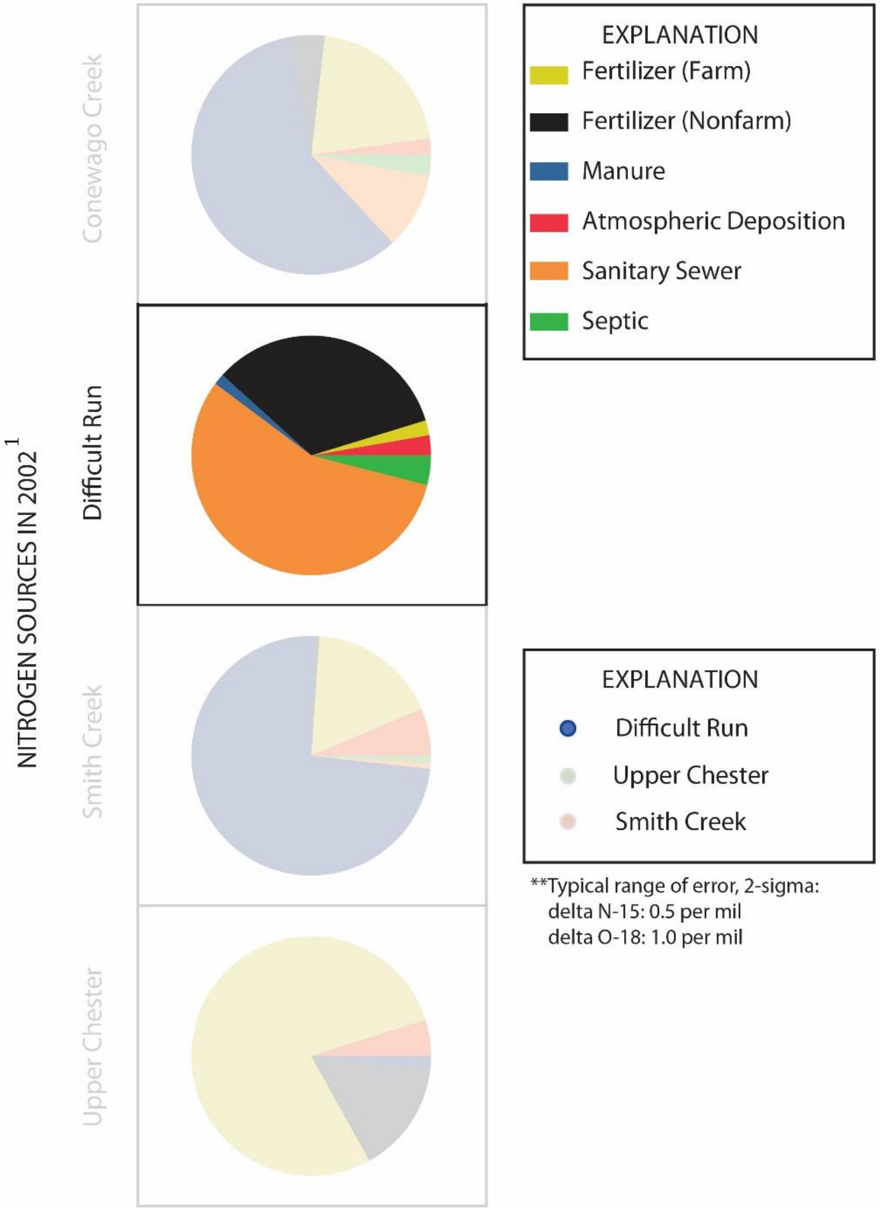


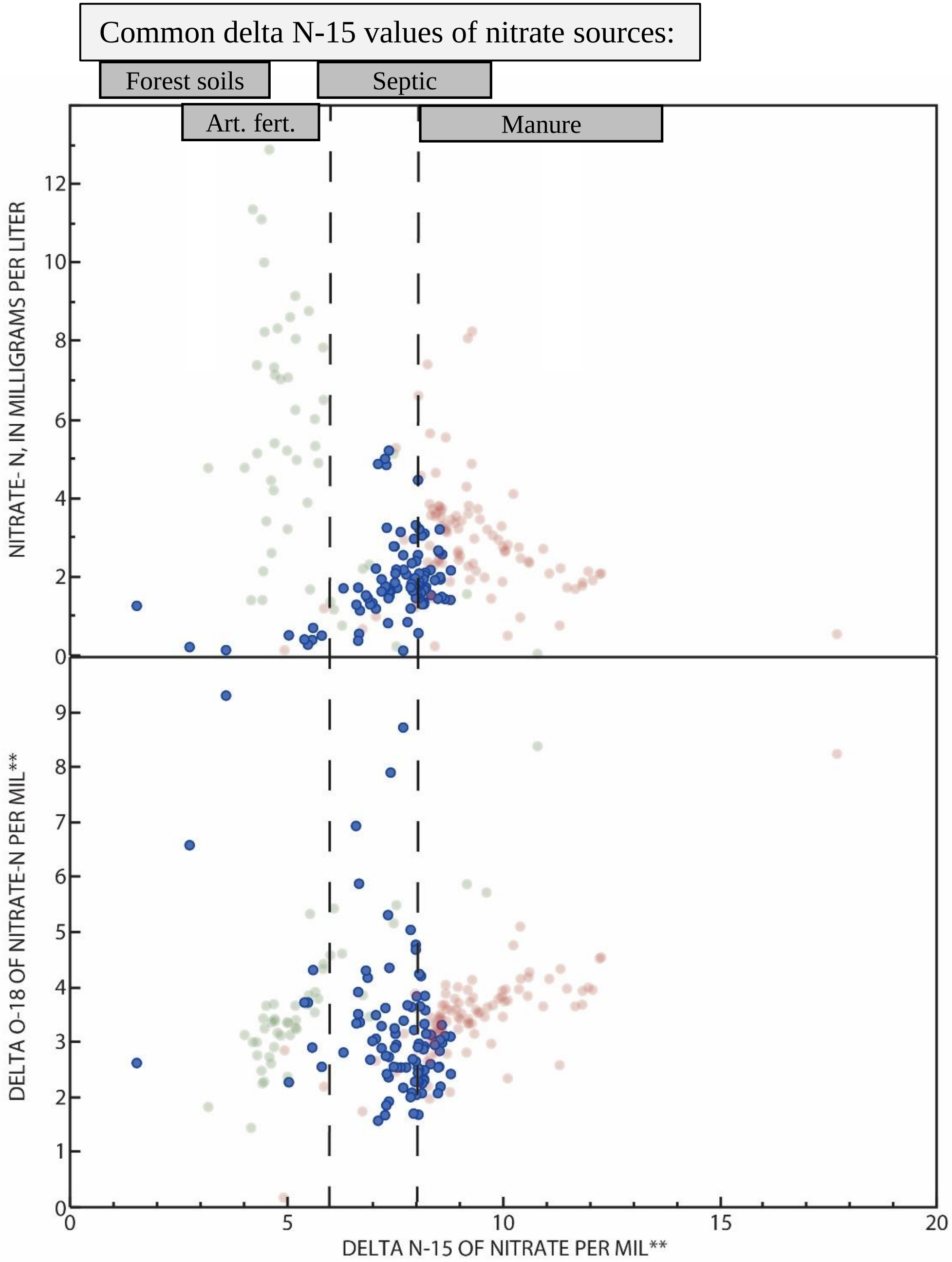
[1]Landuse from NLCD 2011

[2]Cluster groups assigned to samples during April 2013 synoptic sampling event.

Hyer and others (2016)

Nitrogen Sources: Difficult Run, VA





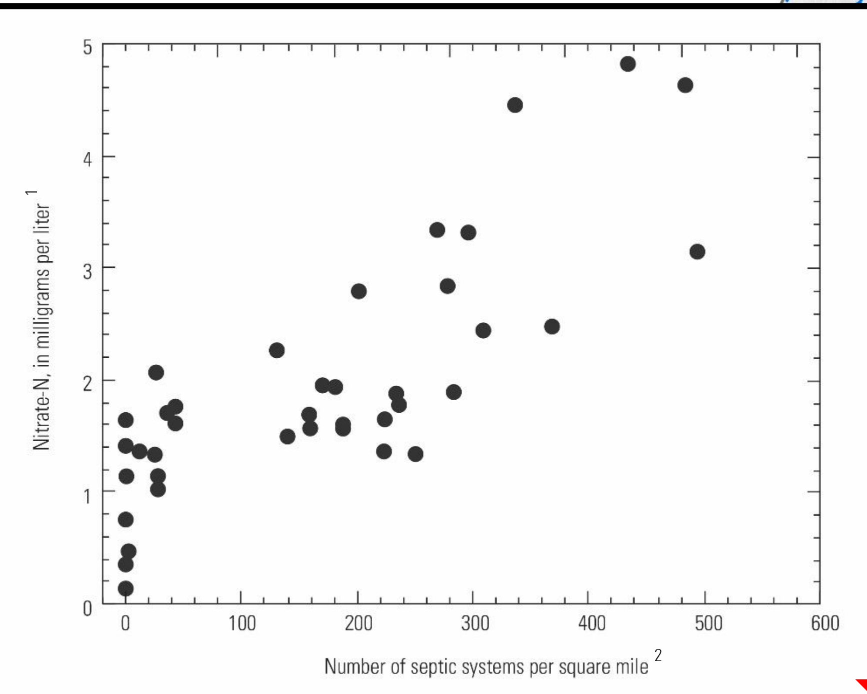
**Typical range of error, 2-sigma:
delta N-15: 0.5 per mil
delta O-18: 1.0 per mil

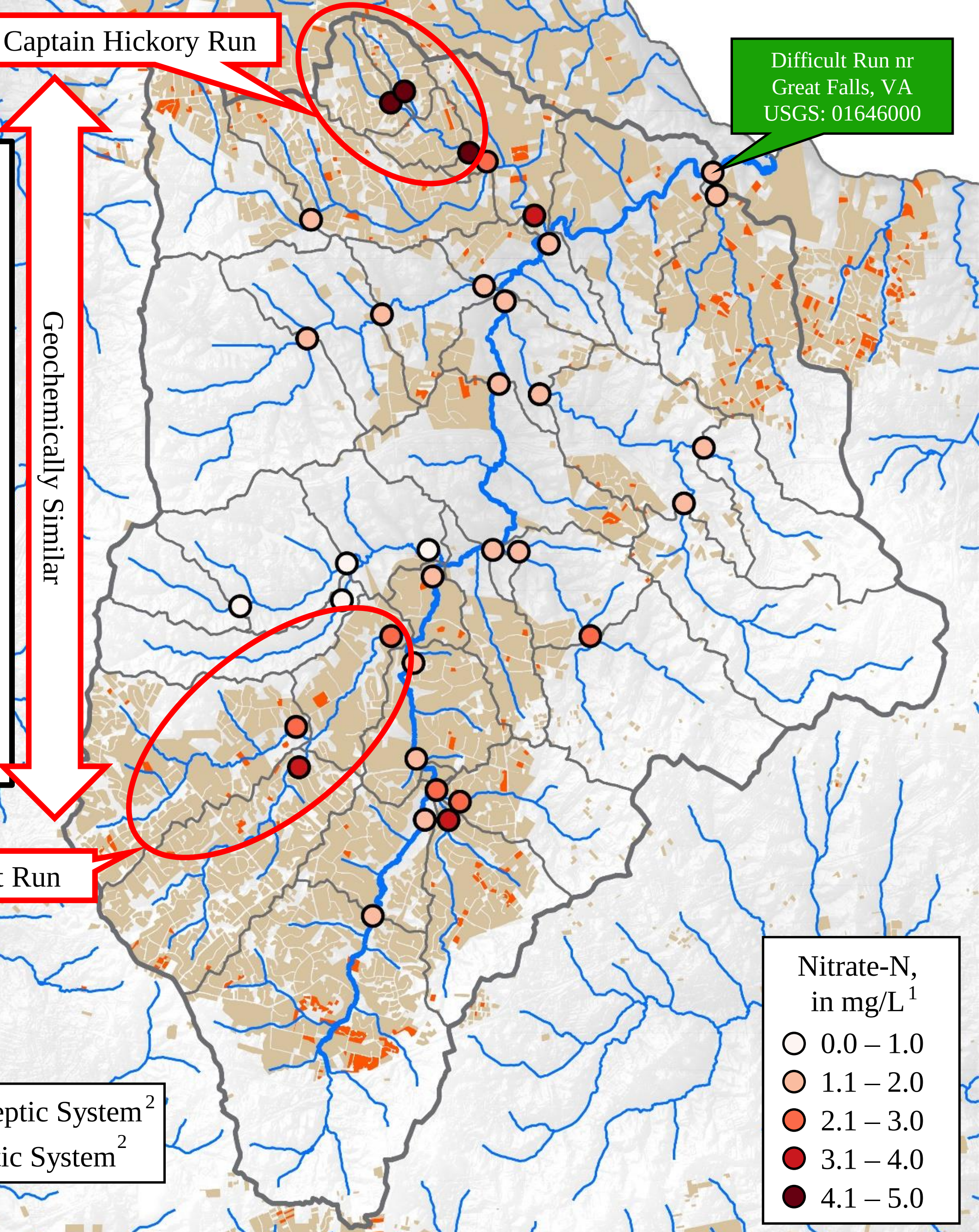
[1]Sources derived from county-based landuse estimates from 2002. Conewago Creek is an average of Dauphin and Lebanon Counties (PA), Difficult Run is based on Fairfax County (VA), Smith Creek is an average of Shenandoah and Rockingham Counties (VA), Upper Chester is an average of Kent and Queen Anne's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

Hyer and others (2016)

Difficult Run:

Nitrate-N Concentrations





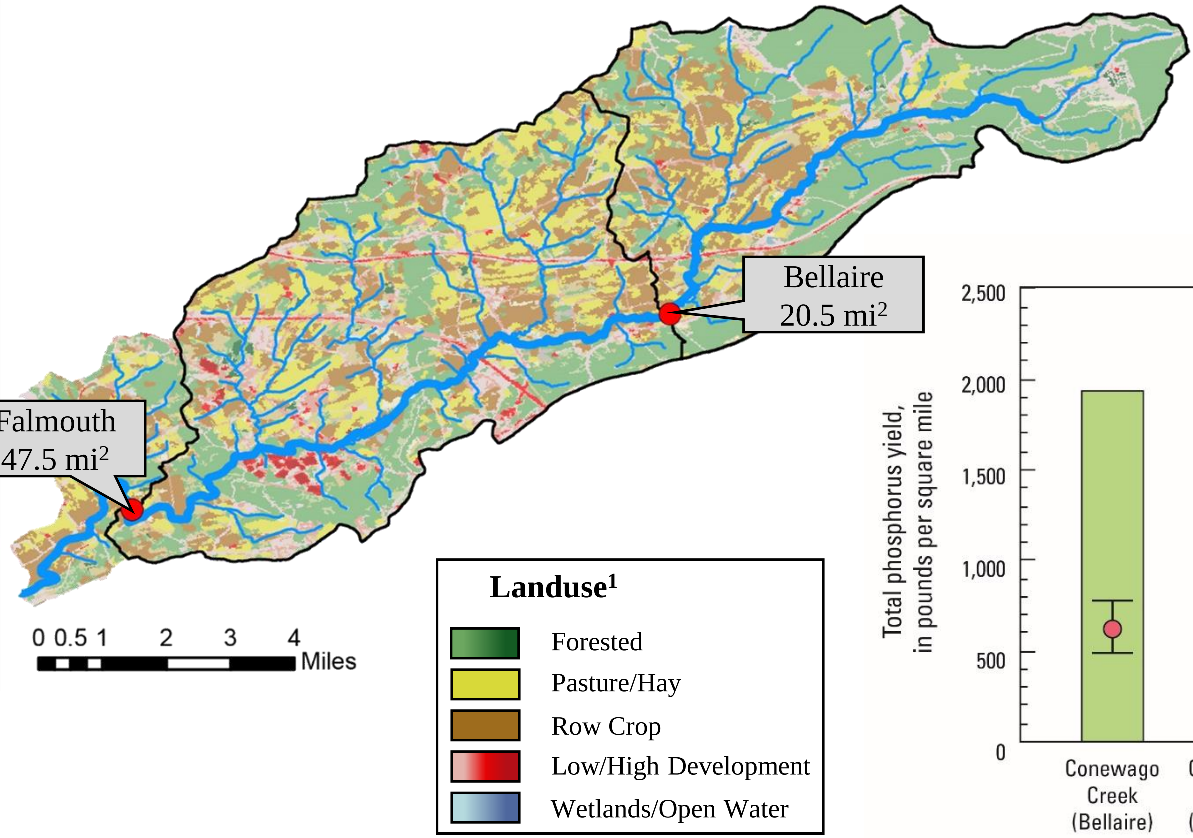
[1]Nitrate-N data based on the average of 6 synoptic events between 2011 and 2015.

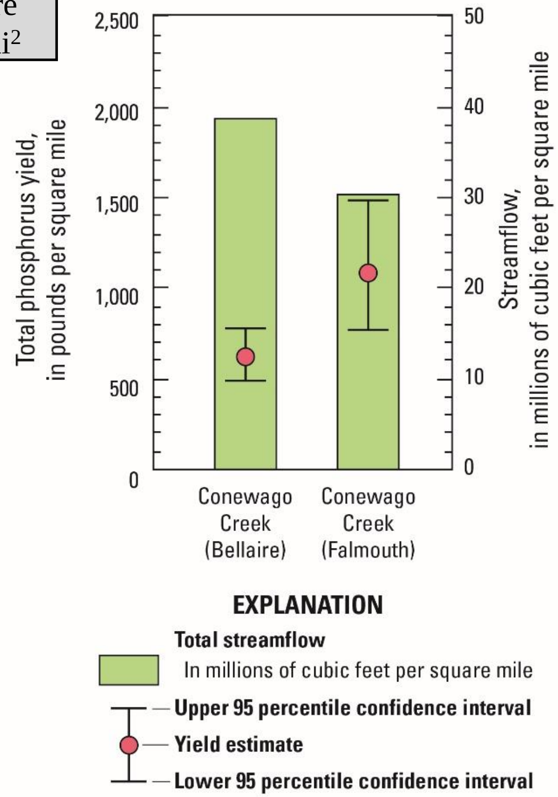
[2]GIS data of properties served by septic systems provided by Fairfax County, May 2015.

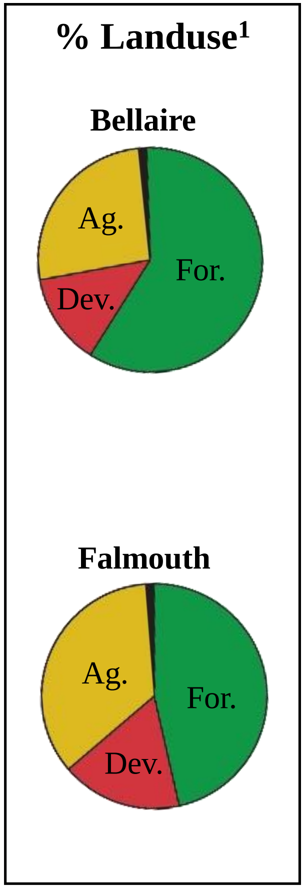
Hyer and others (2016)

Conewago Creek, PA:

Total Phosphorus Yields







[1]Landuse from 2011 National Land Cover Dataset. http://www.mrlc.gov/nlcd2011.php

USGS science for a changing world

Hyer and others (2016)

Implementation of Conservation Practices

Table 32. Implementation of USDA-compliant conservation practices within the Conewago Creek watershed for water years 2007 through 2013.

[—, values are privacy protected due to fewer than five customers participating]

Practice code[1]	Practice name	Lifespan (years)	Units	2007	2008	2009	2010	2011	2012	2013	Aggregate implementation: 2007 to 2013[2]
412	Grassed Waterway	10	acres	8	—	—	—	6	—	—	30
329	Residue and Tillage Management, No-Till	1	acres	—	—	—	864	453	304	—	2,160
328	Conservation Crop Rotation	1	acres	—	—	—	—	366	—	—	2,284
620	Underground Outlet	20	feet	—	—	—	—	7,773	—	—	17,487
590	Nutrient Management	1	acres	535	—	—	—	—	—	—	1,379
600	Terrace	10	feet	—	—	—	—	19,912	—	—	32,377
606	Subsurface Drain	20	feet	—	—	—	—	6,418	—	—	20,961

[1]Practice codes from the U.S. Department of Agriculture, Natural Resources Conservation Service (2016).

[2]Aggregate implementation is greater than the sum of reported annual practices because privacy protections restrict the reporting of annual results for practices with fewer than five participating customers.

Table 33. Implementation of State-level conservation practices sponsored by the EPA Section 319 Nonpoint Source Management Program within the Conewago Creek watershed in water years 2007 through 2013.

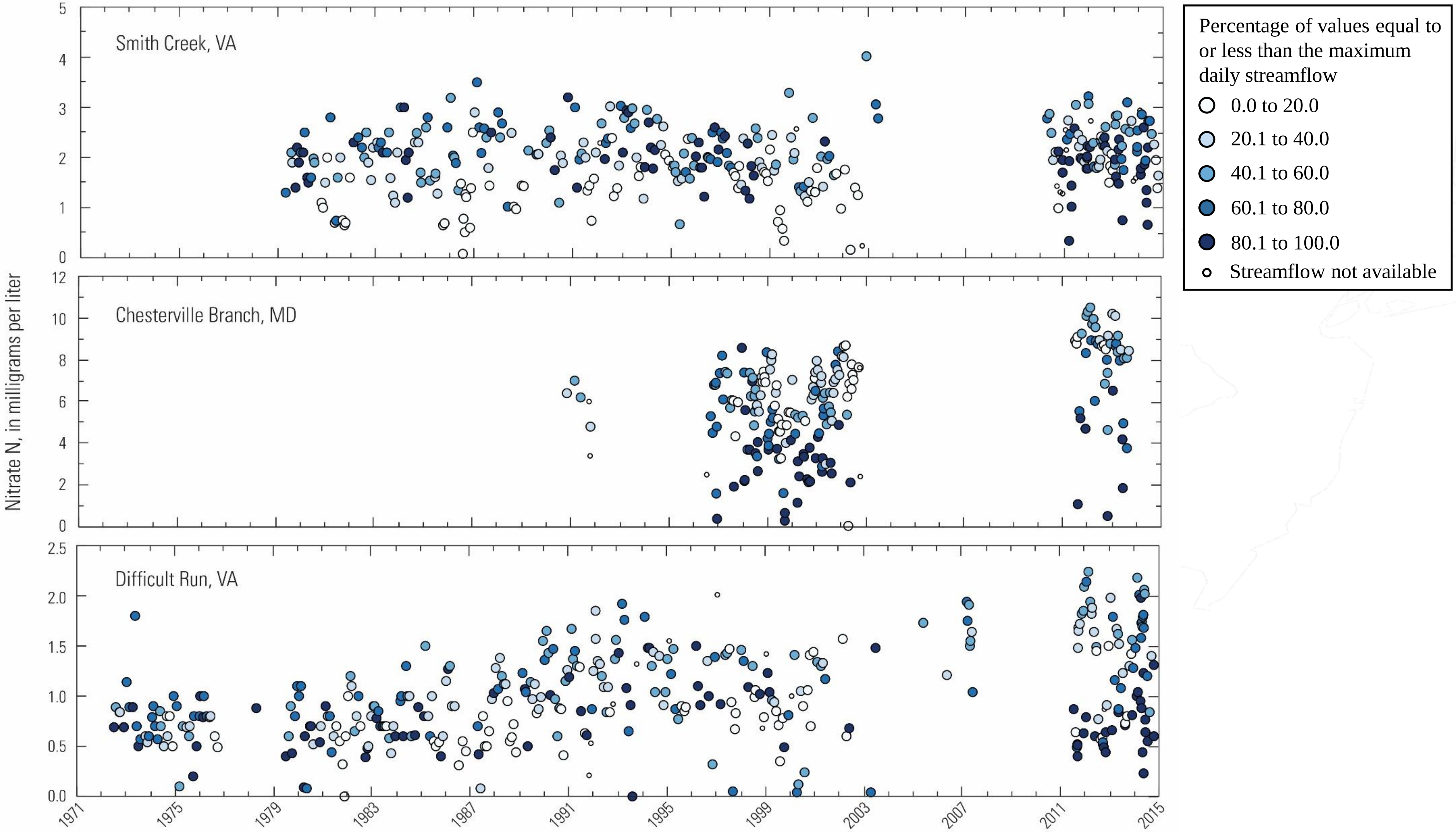
[EPA, U.S. Environmental Protection Agency]

Practice name	Units	Amount
Access Road	feet	218
Animal trails and walkways	feet	4,799
Diversion	acres	424
Grassed Waterway	acres	11
Grazing Planned Systems	acres	29
Heavy Use Area Protection	acres	0
Nutrient Management	acres	660
Riparian Forest Buffer	acres	18
Stream Channel Stabilization	feet	4,840
Stream Exclusion with Grazing Land Management	feet	6,310
Stream Habitat Improvement and Management	feet	3,370
Streambank and Shoreline Protection	feet	9,680
Terrace	feet	12,425
Waste Storage Facility	number	2
Wetland Restoration	acres	16

Number of USDA-compliant conservation practices implemented in the Showcase Watersheds

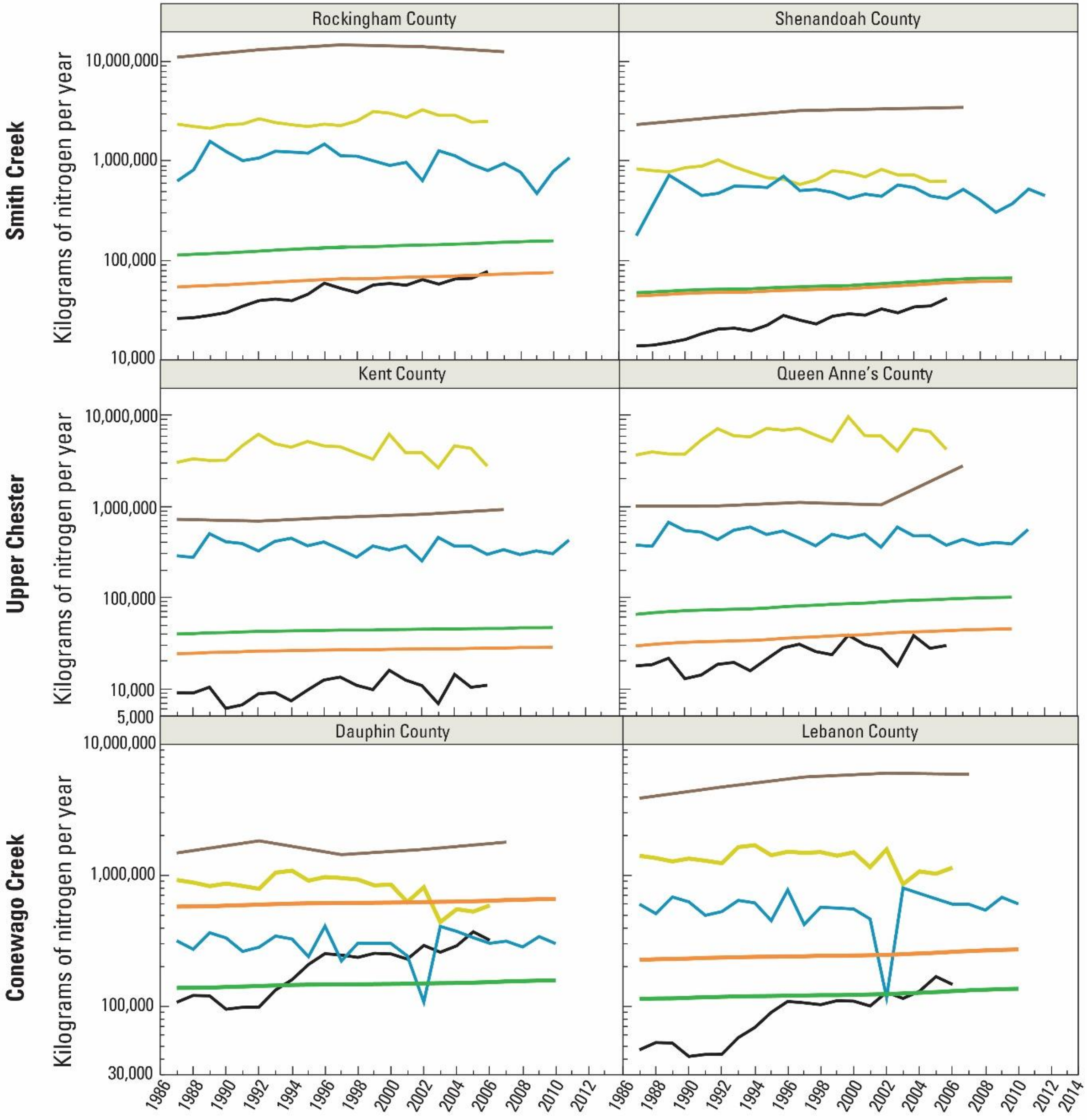
Watershed	2007	2008	2009	2010	2011	2012	2013	Total
Conewago Creek	131	50	110	90	122	86	93	682
Smith Creek	292	66	99	117	202	312	316	1,404
Upper Chester	183	120	117	210	200	276	88	1194

Water-Quality Patterns



Hyer and others (2016)

Nitrogen Input Patterns



Future objectives will be addressed using watershed specific dynamic nitrogen input datasets.

Nitrogen Sources

- Manure[1]
- Atmospheric Deposition[2]
- Fertilizer (farm)[3]
- Fertilizer (nonfarm)[3]
- Septic[4]
- Sanitary Sewer[4]

USGS science for a changing world

[1]Mass of nitrogen available from manure computed following methods outlined by Ruddy and others (2006) using livestock counts as reported by the Census of Agriculture.

[2]Atmospheric wet deposition data computed following methods outlined by Ruddy and others (2006) using data from the National Atmospheric Deposition Program.

[3]Fertilizer inputs were computed using the approach outlined by Gronberg and Spahr (2012).

[4]Wastewater inputs were computed following methods outlined by Lindsey and others (2009) using population data from the US Census.

Water-Quality Monitoring in the USDA & USGS Showcase Watersheds 2010-2013: Lessons Learned

To characterize current water-quality conditions.	Monthly, stormflow, and spatial water-quality monitoring resulted in a detailed understanding of hydrologic, seasonal, and spatial water chemistry patterns within the study watersheds.

To identify the dominant sources, sinks, and transport process of nitrogen and, to a lesser extent, phosphorus.	**Smith Creek and Conewago Creek:** The primary source of nitrogen is likely agricultural manure.	**Upper Chester:** The primary source of nitrogen and phosphorus are likely inorganic fertilizers and nitrogen fixation by legume crops.	**Difficult Run:** The primary source of nitrogen is likely from a mixture of sources including septic system leachate, atmospheric deposition, and fertilizer application.

To provide guidance to study partners related to the implementation of conservation practices.	Conservation practices that target the application of manure and fertilizer could be important for reducing the nitrogen load within the agricultural watersheds.	Management activities for nitrogen would likely be most effective by the ongoing maintance of septic systems, the management of fertilizer applications, and the possible expansion of the sanitary-sewer infrastructure within Difficult Run.

Hyer and others (2016)

Water-Quality Monitoring in the USDA & USGS Showcase Watersheds 2010-2013: Lessons Learned (continued)

To quantify the implementation of conservation practices	The implementation of conservation practices increased in the agricultural watersheds during the study period, with cover cropping, nutrient management plans, streambank fencing, and terracing being some of the principle management activities.		Implementation of conservation practices within Difficult Run increased during the study period, with stream restoration becoming one of the principle management activities.
To document changes in water quality using existing long-term nitrogen data.	Within Smith Creek, WRTDS trends report slight increases in nitrate concentration and slight decreases in nitrate load from 1985-2014.	Within Difficult Run, WRTDS trends report slight increases in nitrate concentration and load from 1985-2014.	Long-term data do not exist within Upper Chester to support a trend analysis, however, empirical nitrate concentrations appear to have increased between 1996 and 2014.

The initial 3 years of this ongoing study do not address the relation between water-quality changes and the implementation of conservation practices. Future work will investigate these linkages, which are likely complicated because

→ Changes in management actions may take several years or decades to be fully realized in streams due to groundwater residence times and transport processes.

→ The functionality and efficiency of each conservation practice is difficult to quantify.

Water-Quality Monitoring in the USDA & USGS Showcase Watersheds 2010-2013

January 30th, 2017

Ken Hyer & Jimmy Webber
USGS
Richmond, VA
kenhyer@usgs.gov;
jwebber@usgs.gov

Primary Collaborators:
Judy Denver, DE
Mike Langland, PA
JK Böhlke, Reston, VA
Dean Hively, MD

References Cited

Gronberg, J.M., and Spahr, N.E., 2012, County-level estimates of nitrogen and phosphorus from commercial fertilizer for the conterminous United States, 1987-2006: U.S. Geological Survey Scientific Investigations Report 2012-5207, 20 p.

Hyer, K.E., Denver, J.M., Langland, M.J., Webber, J.S., Böhlke, J.K., Hively, W.D., and Clune, J.W., 2016, Spatial and temporal variation of stream chemistry associated with contrasting geology and land-use patterns in the Chesapeake Bay watershed—Summary of results from Smith Creek, Virginia; Upper Chester River, Maryland; Conewago Creek, Pennsylvania; and Difficult Run, Virginia, 2010–2013: U.S. Geological Survey Scientific Investigations Report 2016–5093, 211 p., http://dx.doi.org/10.3133/sir20165093.

Lindsey, B.D., Berndt, M.P., Katz, B.G., Ardis, A.F., and Skach, K.A., 2009, Factors affecting water quality in selected carbonate aquifers in the United States 1993-2005: U.S. Geological Survey Scientific Investigations Report 2008-5240, 117 p.

Ruddy, B.C., Lorenz, D.L., and Mueller, D.K., 2006, County-level estimates of nutrient inputs to the land surface of the conterminous United States, 1982-2001: U.S. Geological Survey Scientific Investigations Report 2006-5012, 17 p.

USGS
science for a changing world
USDA