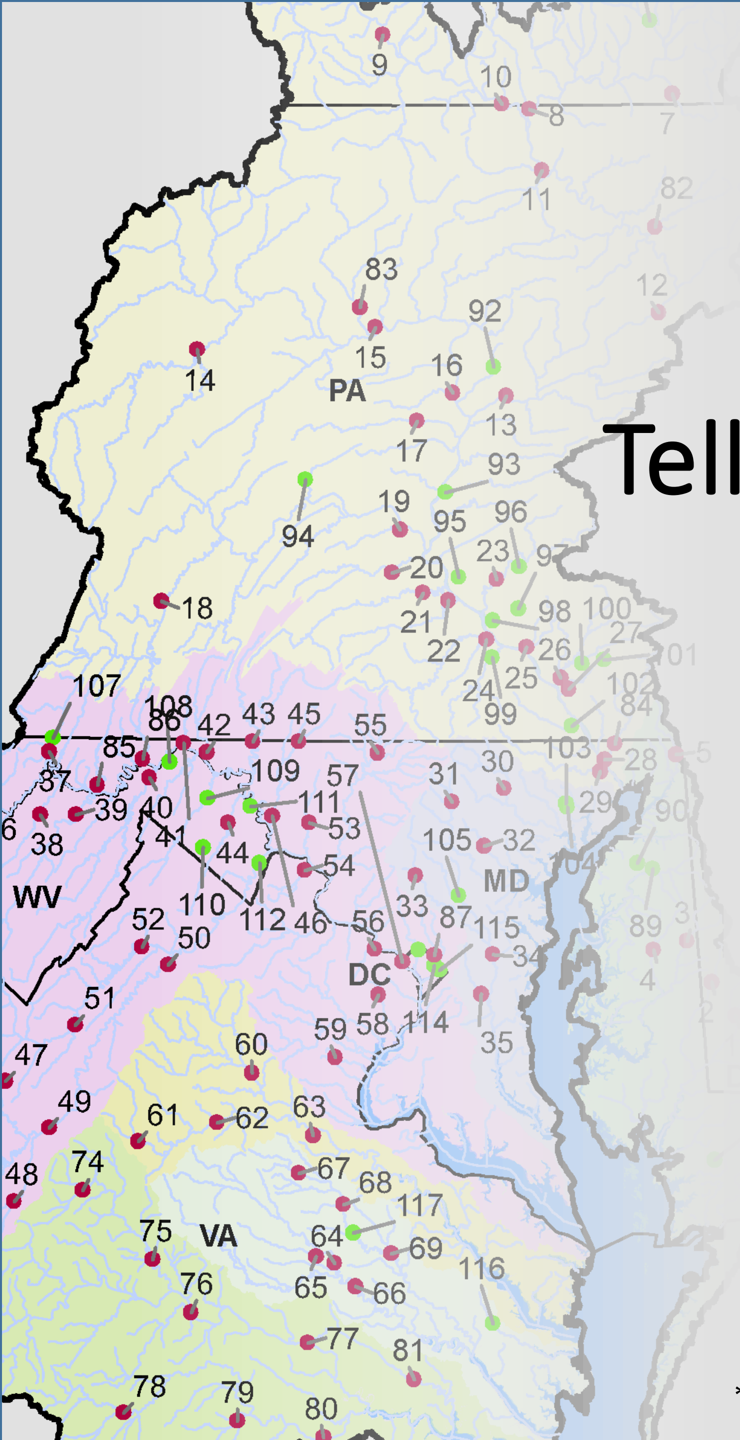


Telling watershed stories with science

An example in Swatara Creek, PA

Emily Trentacoste, PhD
EPA Chesapeake Bay Program Office
Communications Workgroup

11/1/2017

* References & descriptions of data analyses are described at the end of these slides.

A LOT of new and updated info available…

Monitoring & Trends

Nontidal water quality

Tidal water quality

Tidal attainment

Stream & tidal benthic

Submerged aquatic vegetation

Modeling Tools

CBP Watershed Model

Geographic load distribution

Geographic influence on Bay

BMP progress reports

Synthesis Analyses

USGS Non-tidal Syntheses

-Regional Nitrogen, Phosphorus and Sediment

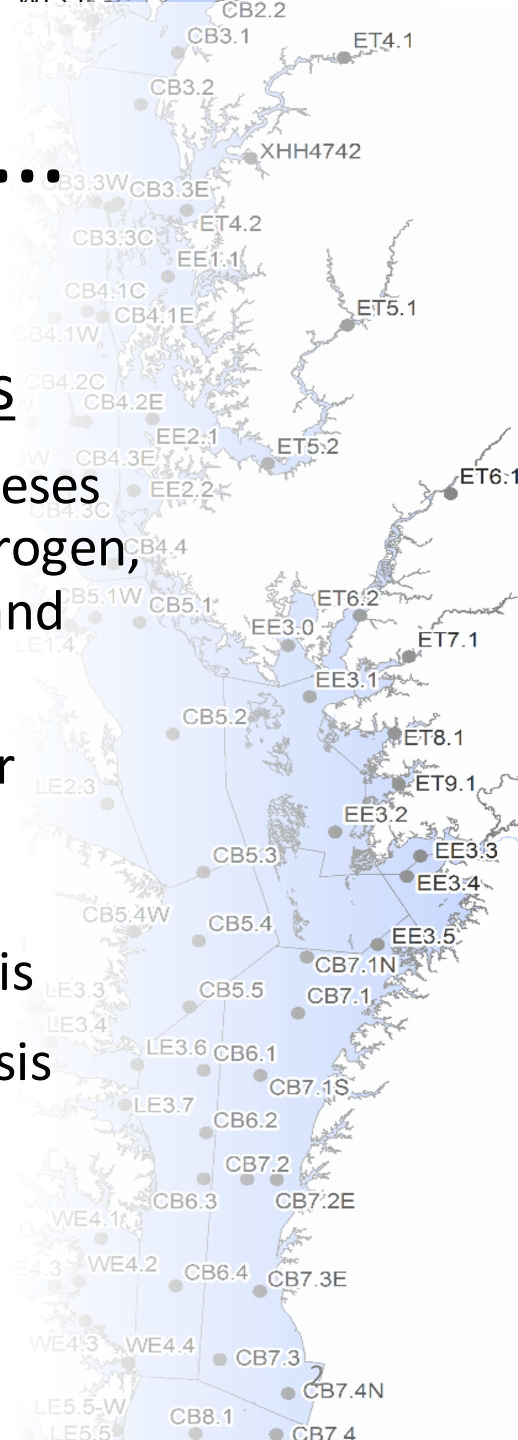
-Groundwater

SAV Syntheses

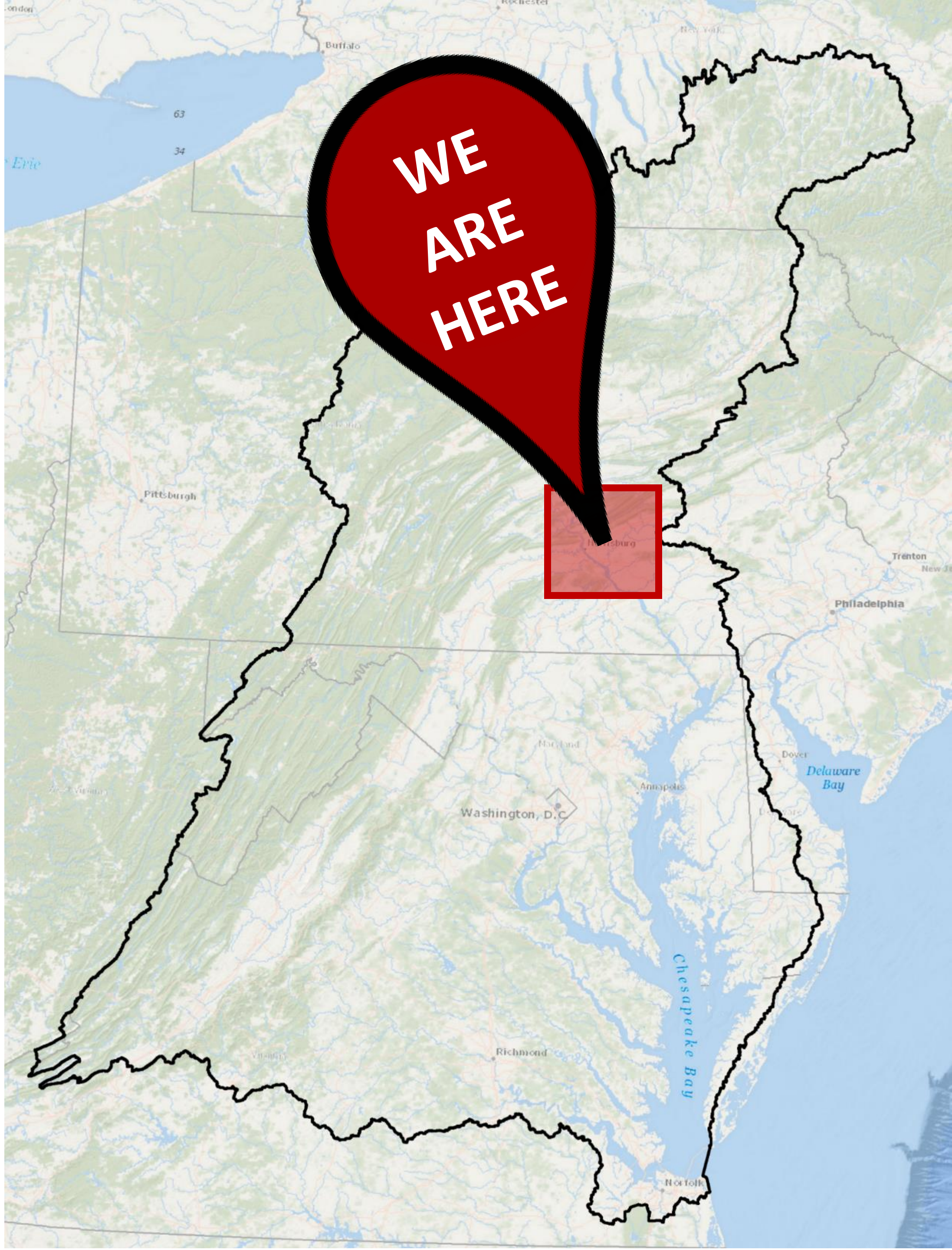
Water Clarity Synthesis

Water Quality Synthesis

…and more to come



Swatara Creek Storyline

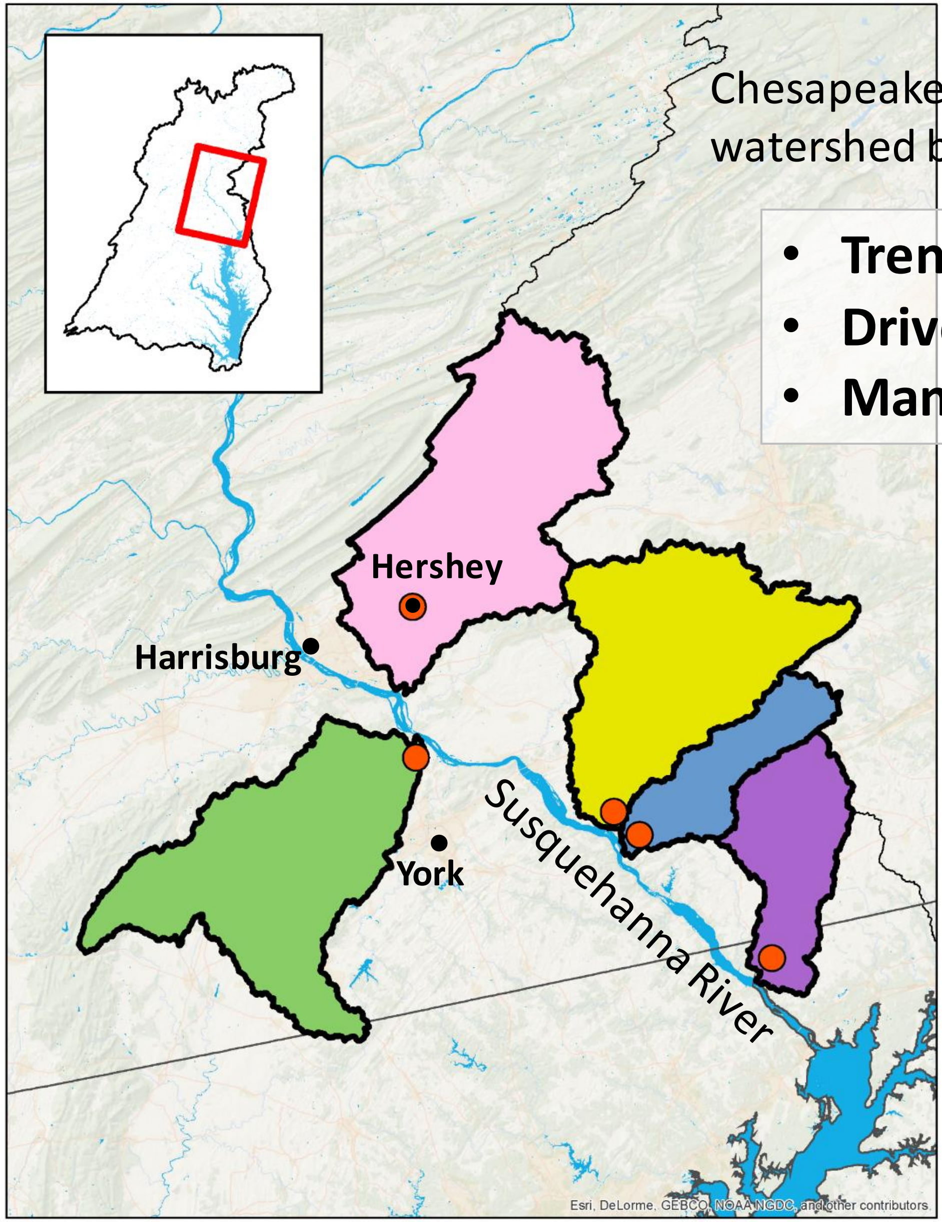


Key Lower Susquehanna Watersheds

● = Water quality monitoring stations

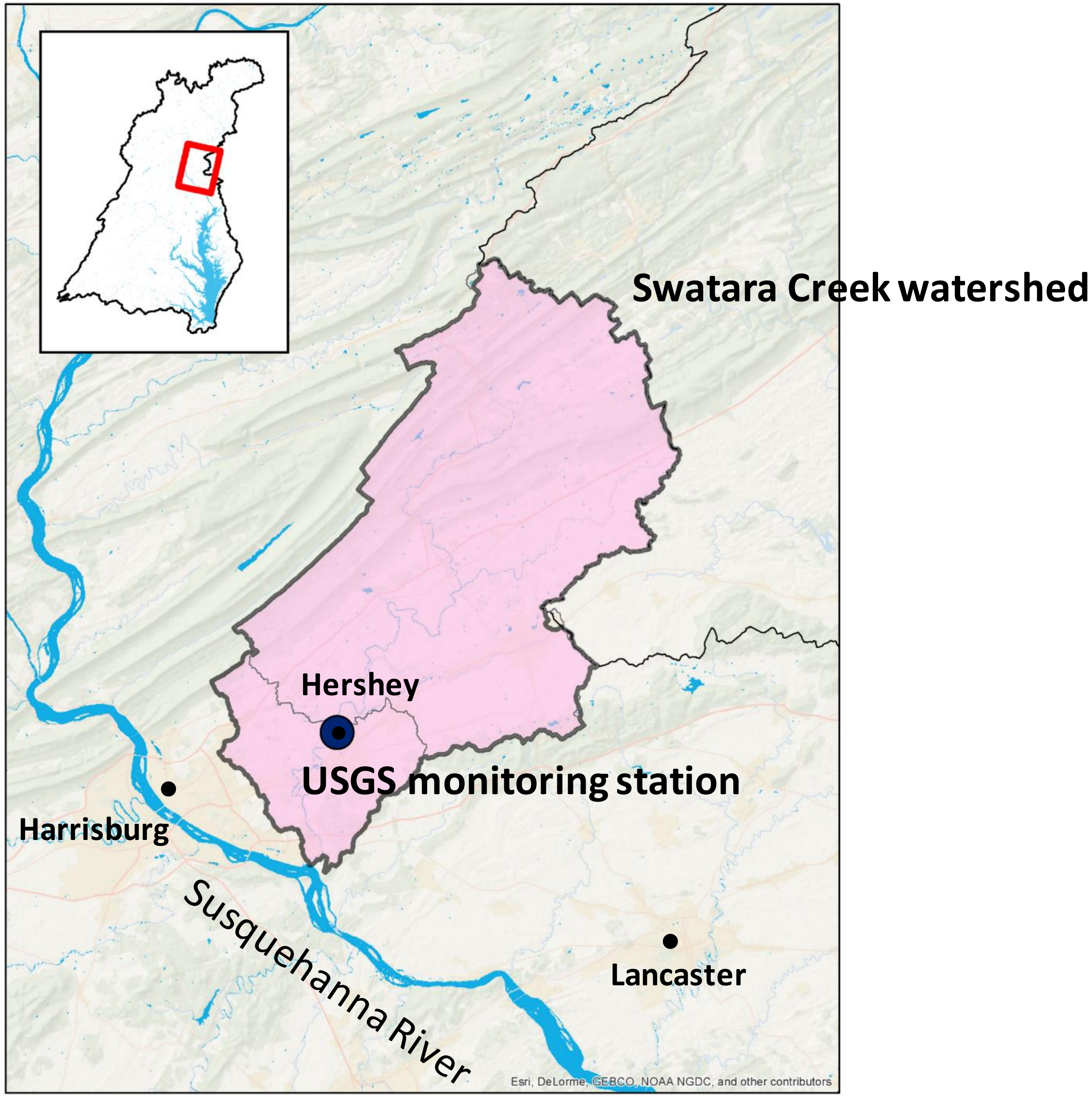
Watersheds

- Swatara Creek
- West Conewago Creek
- Conestoga River
- Pequea Creek
- Octoraro Creek



- **Trends**
- **Drivers**
- **Management implications**

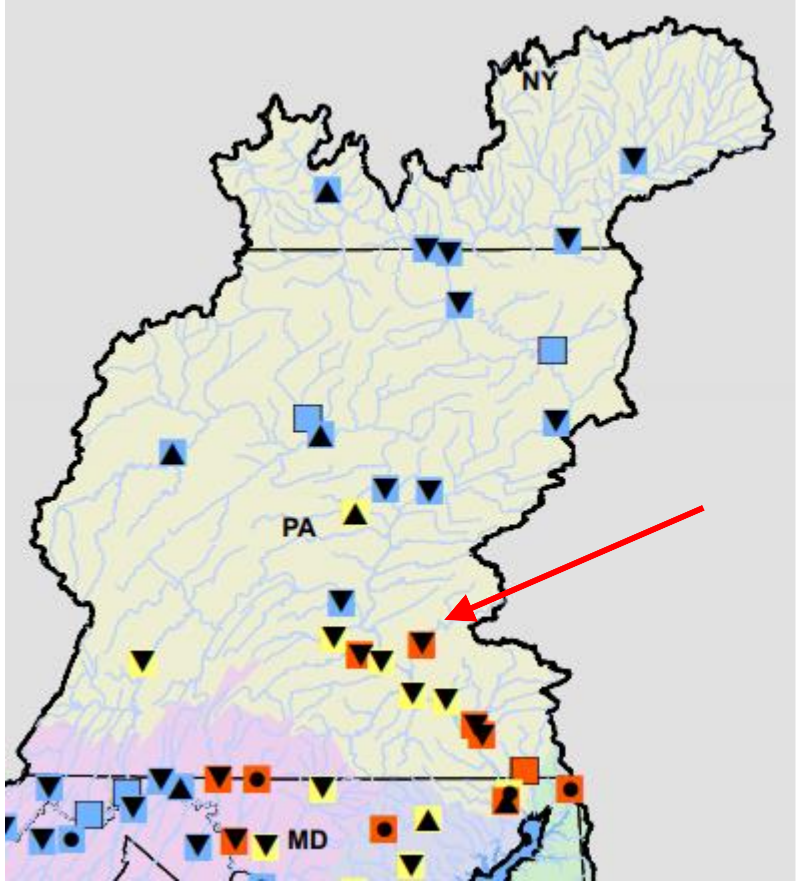
Swatara Creek Watershed



Water Quality Trends in Nitrogen

- **Total nitrogen and nitrate are decreasing**
- **Nitrogen loads are on the higher range for the Chesapeake Bay watershed**

Change in Total Nitrogen per acre loads (2005-2014)



Trend Direction

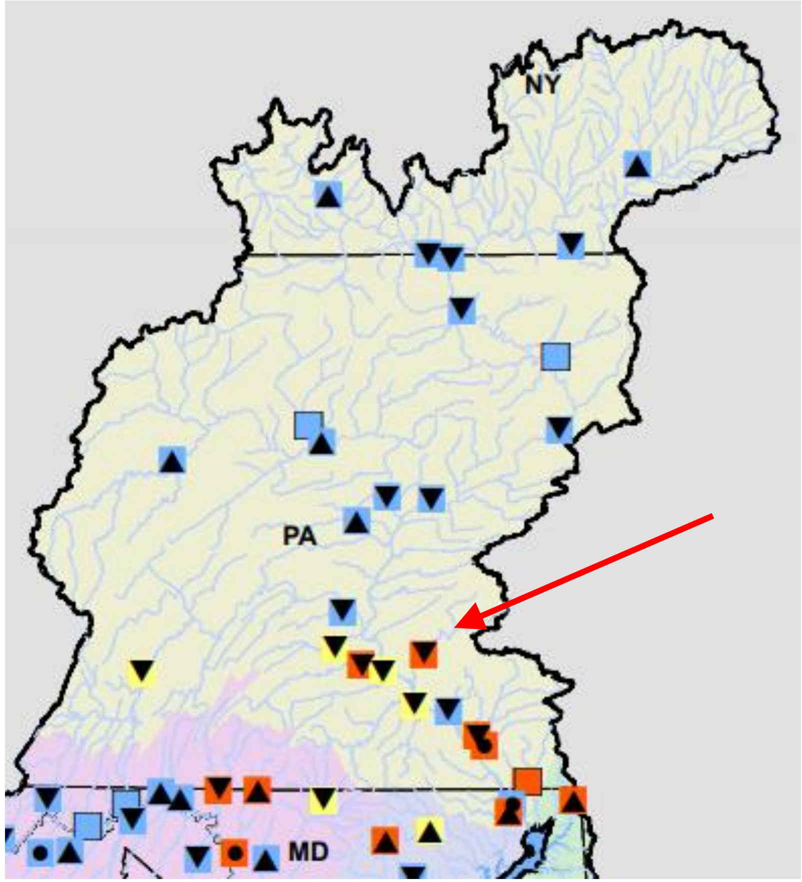
- ● No Trend
- ▼ Improving
- ▲ Degrading

Average Load (lbs/ac)

- 0.14 - 5.84
- 5.85 - 11.69
- 11.70 - 28.78

Squares with black outline are yields based on 2010-2014.

Change in Nitrate per acre loads (2005-2014)



From USGS Chesapeake Bay non-tidal network: https://cbrim.er.usgs.gov/

Water Quality Trends in Nitrogen

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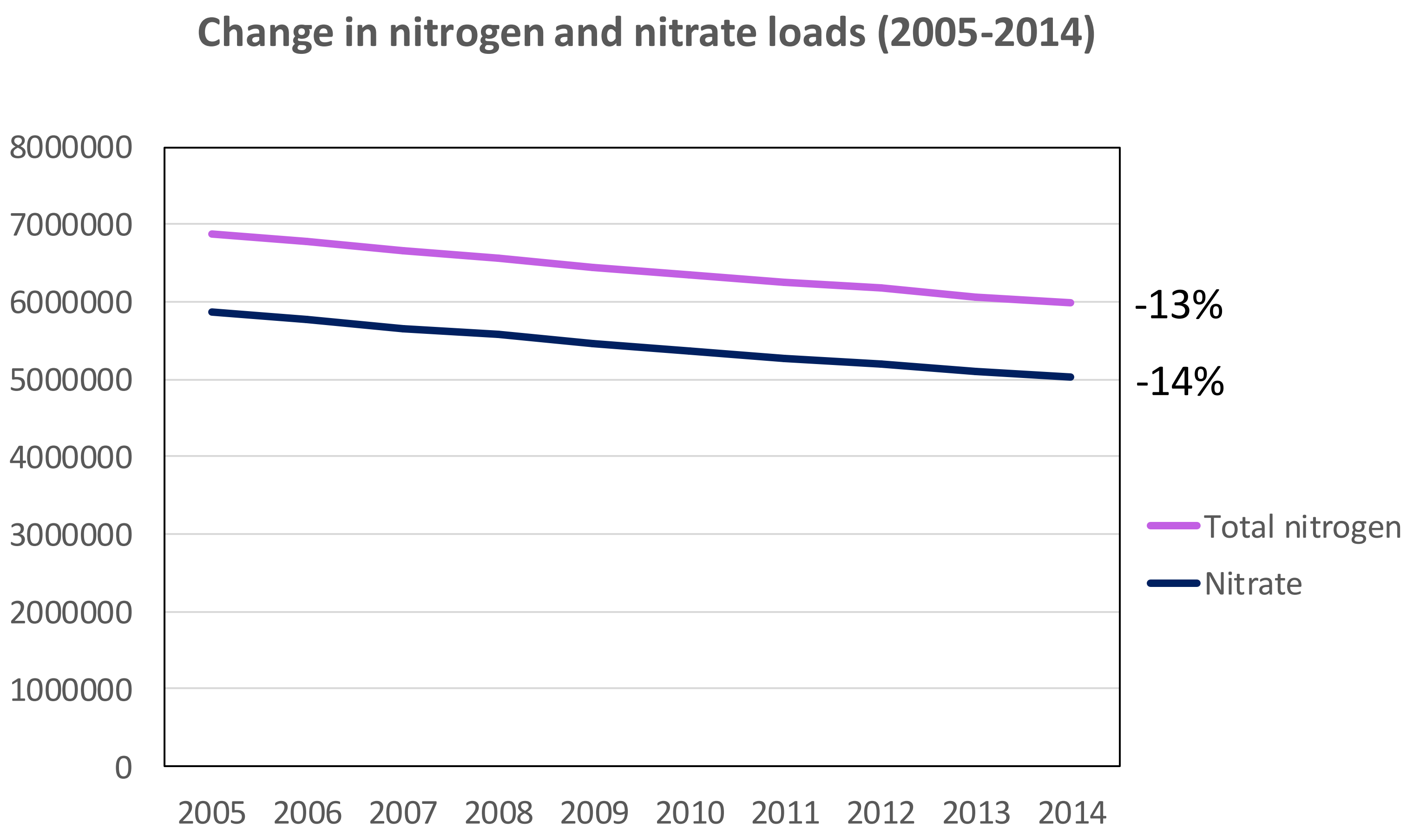

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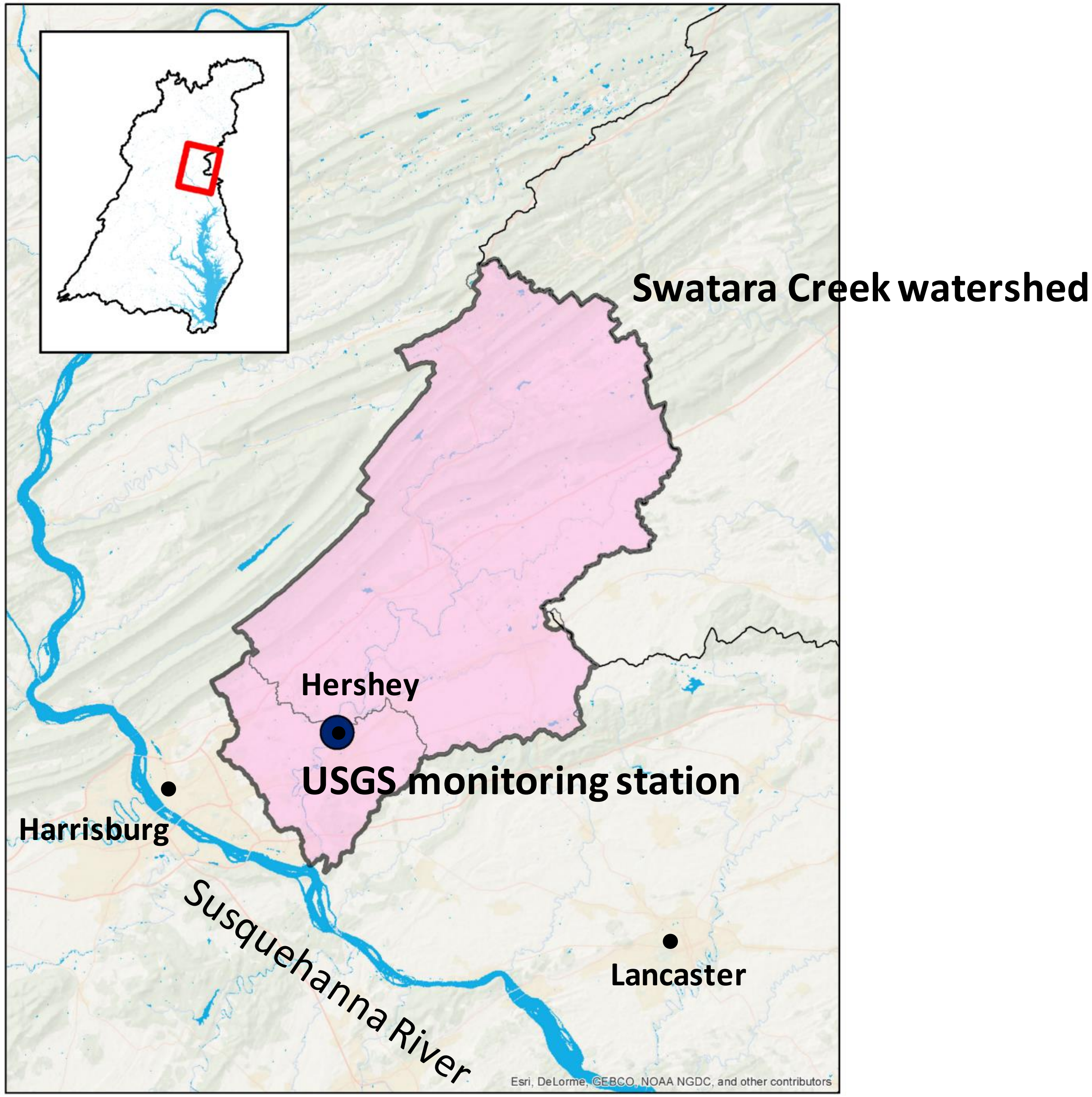
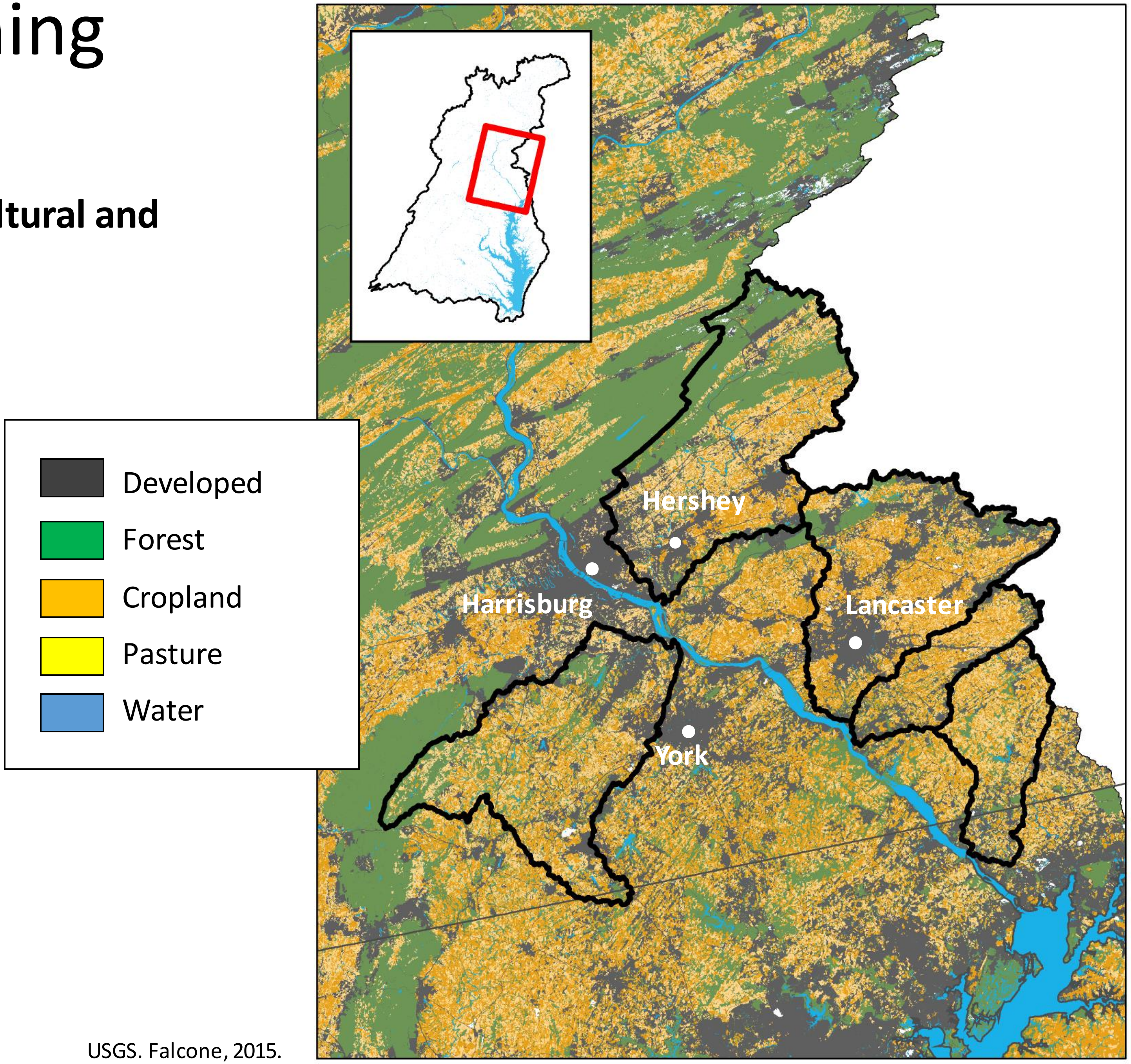
Swatara Creek Watershed



Where is nitrogen coming from?

- **Land-use is a mixture of natural, agricultural and developed**



From CBP WSM Phase 6 2013 Progress Report. See data analysis at end of this document.

USGS. Falcone, 2015.

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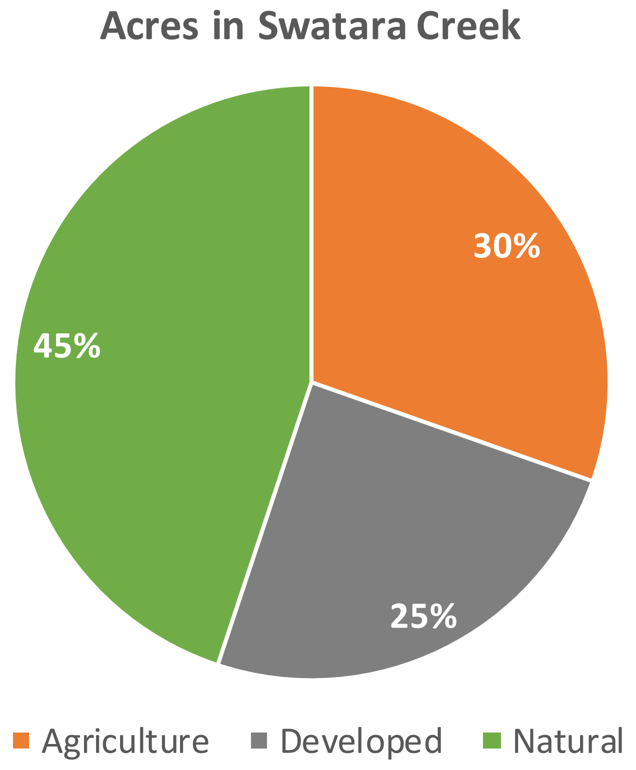
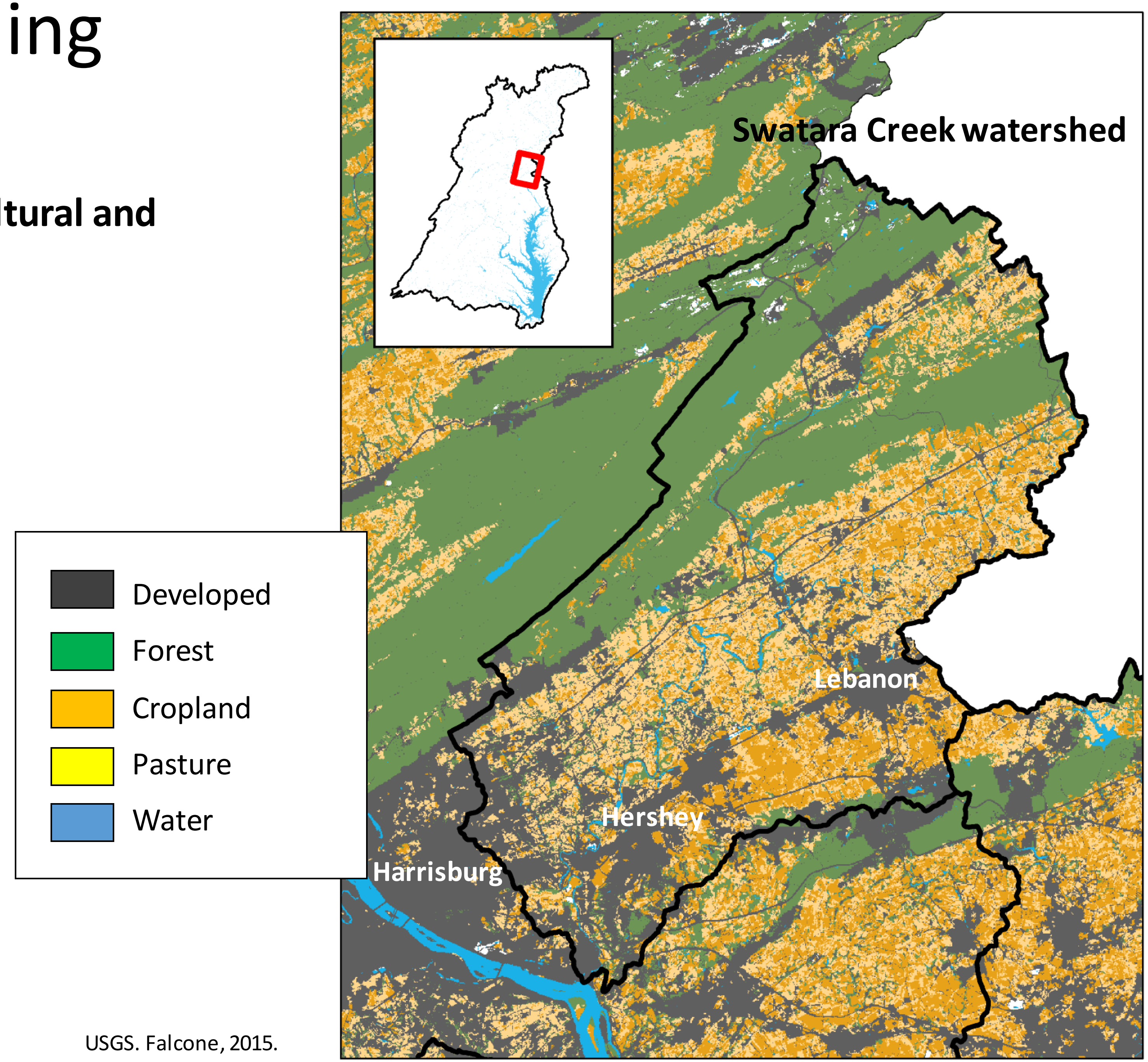


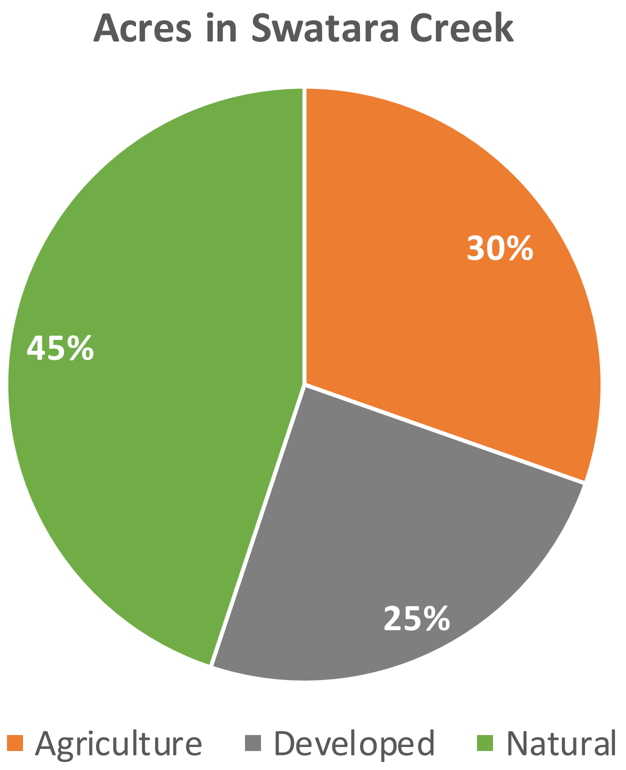


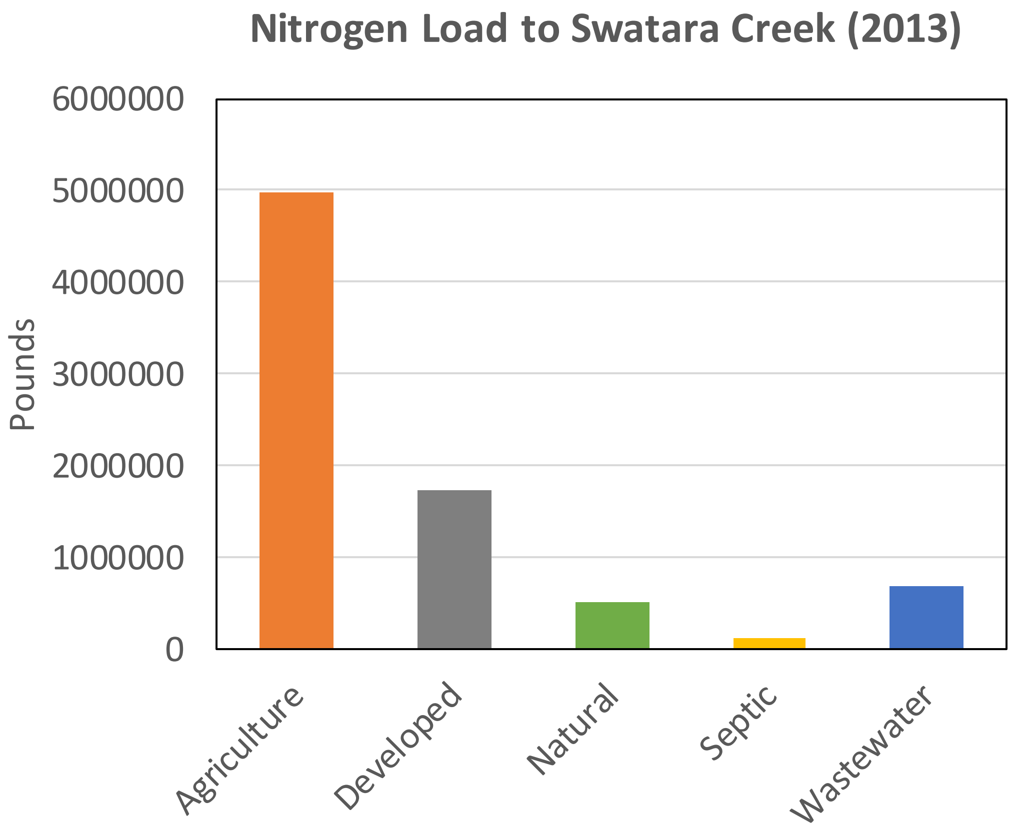
From CBP WSM Phase 6 2013 Progress Report. See data analysis at end of this document.

USGS. Falcone, 2015.

Where is nitrogen coming from?

- **Land-use is a mixture of natural, agricultural and developed**
- **The predominant source of nitrogen is agriculture, followed by developed land**





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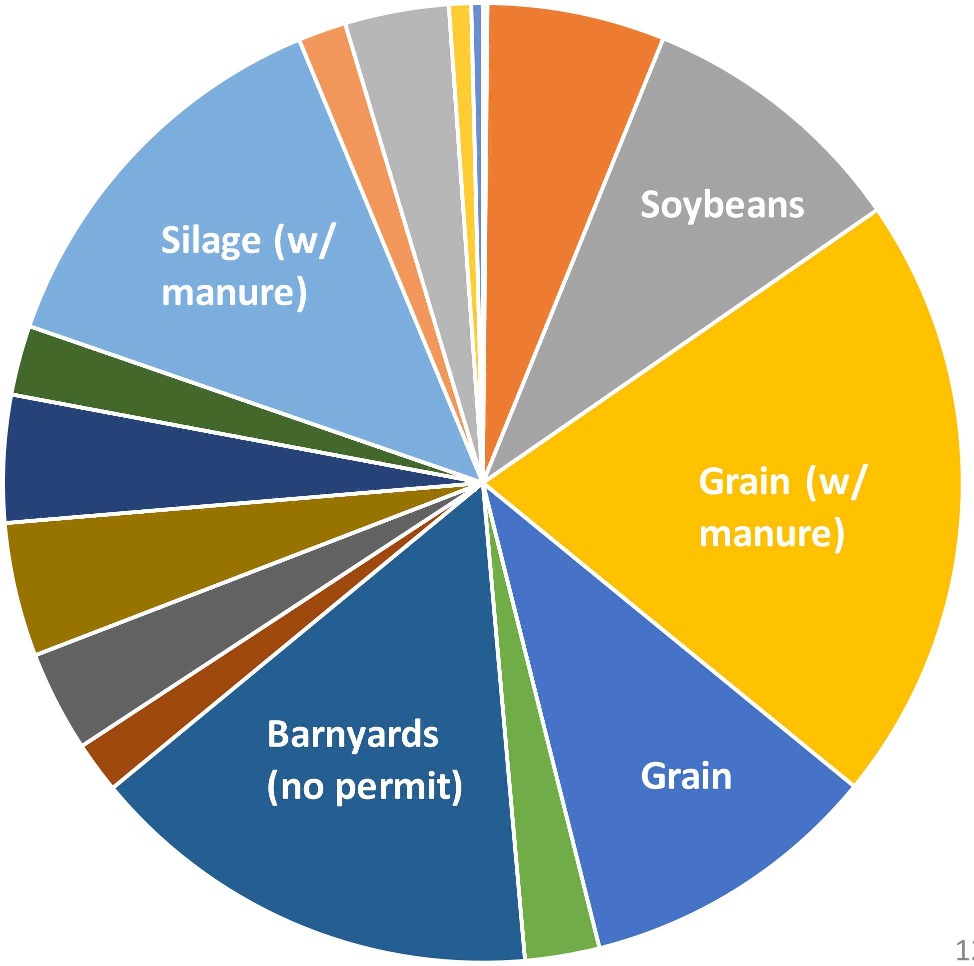
Nitrogen Load to Swatara Creek (2013) from Agriculture



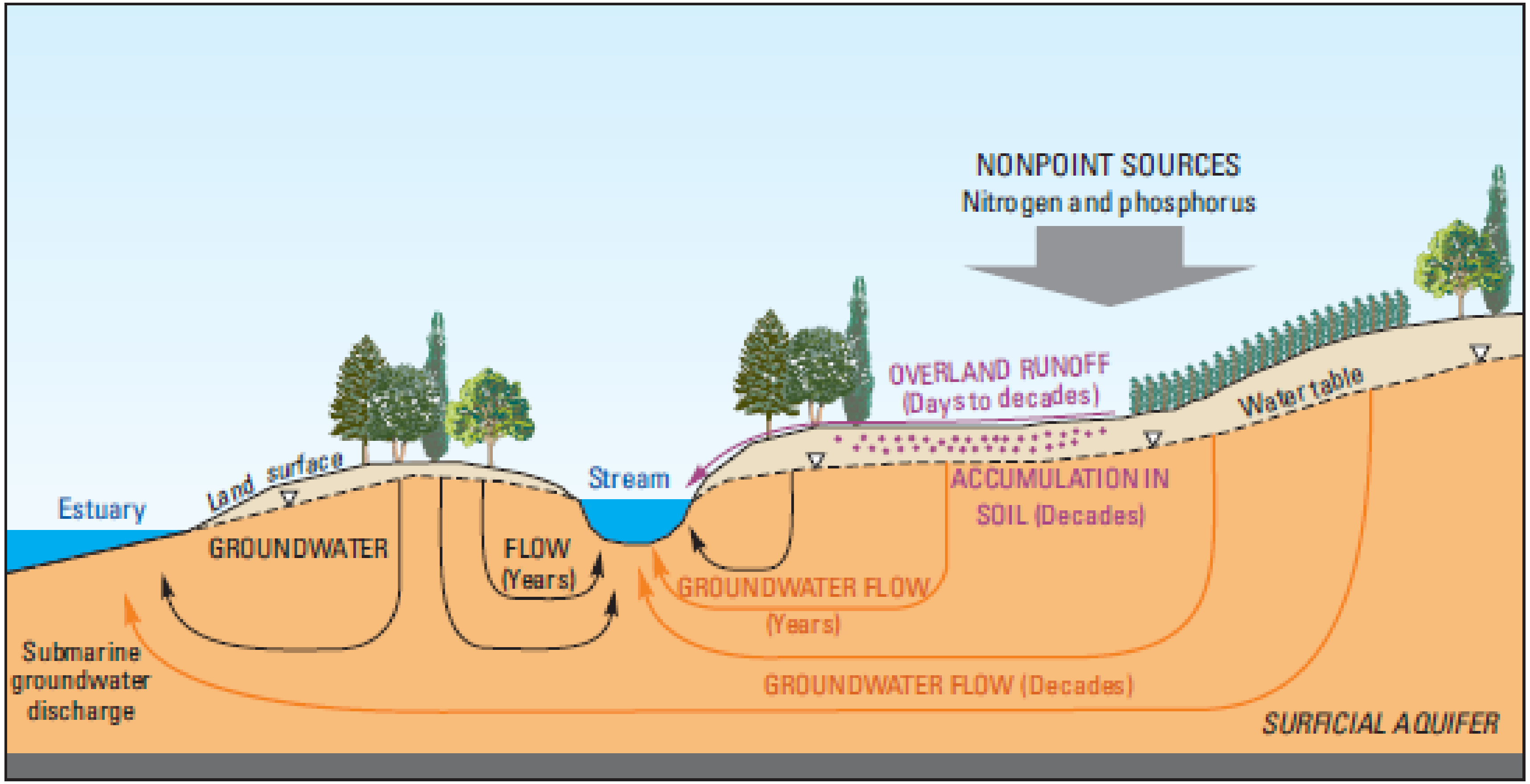
From CBP WSM Phase 6 2013 Progress Report. See data analysis at end of this document.

How is nitrogen reaching streams?

- **Nitrogen reaches streams either from surface runoff or through groundwater (often as nitrate)**
- **A high proportion of nitrate in streams is likely indicative of groundwater sources**

46%

54%



From Ator, S.W., and Denver, J.M., 2015. *USGS Circular 1406*; Bachman, L.J. et al., 1998. *Water Resources Investigations Report 98-4059.*

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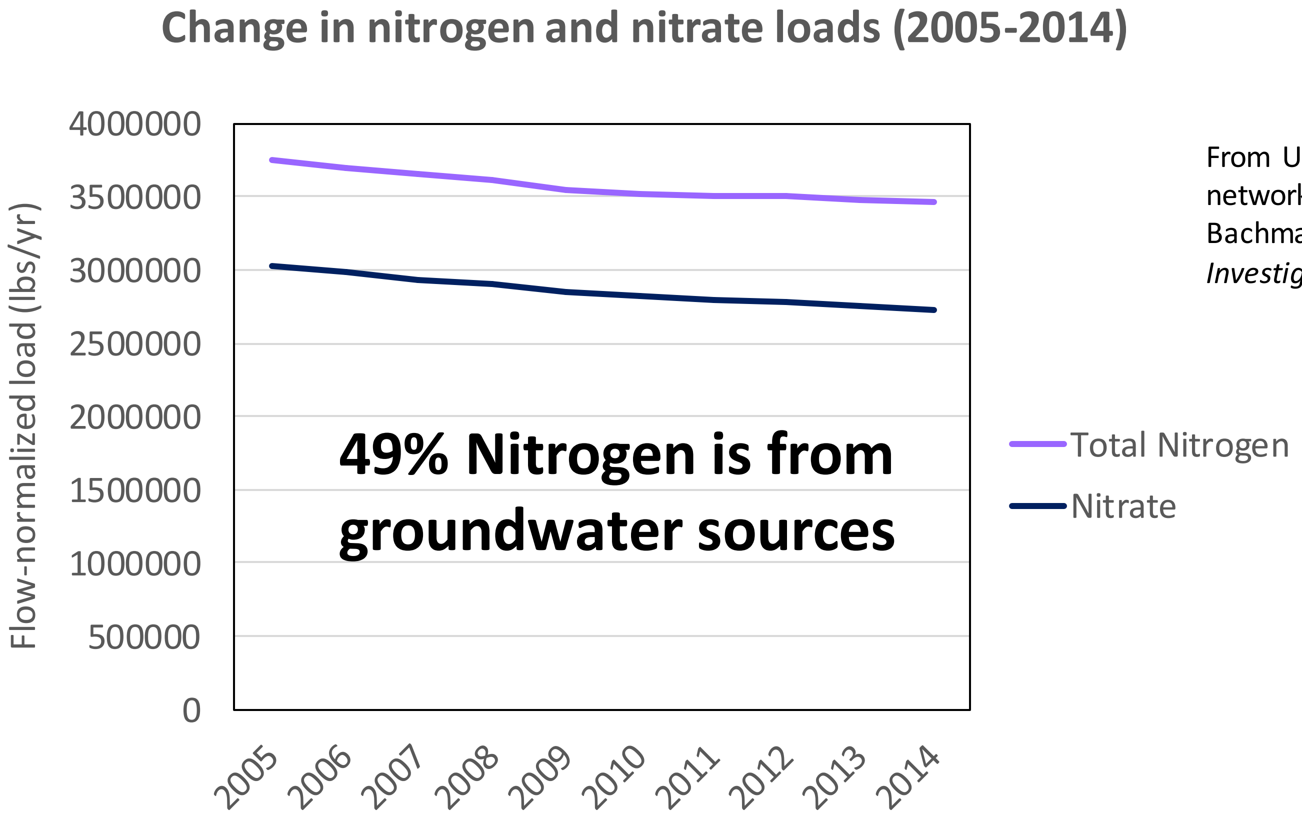
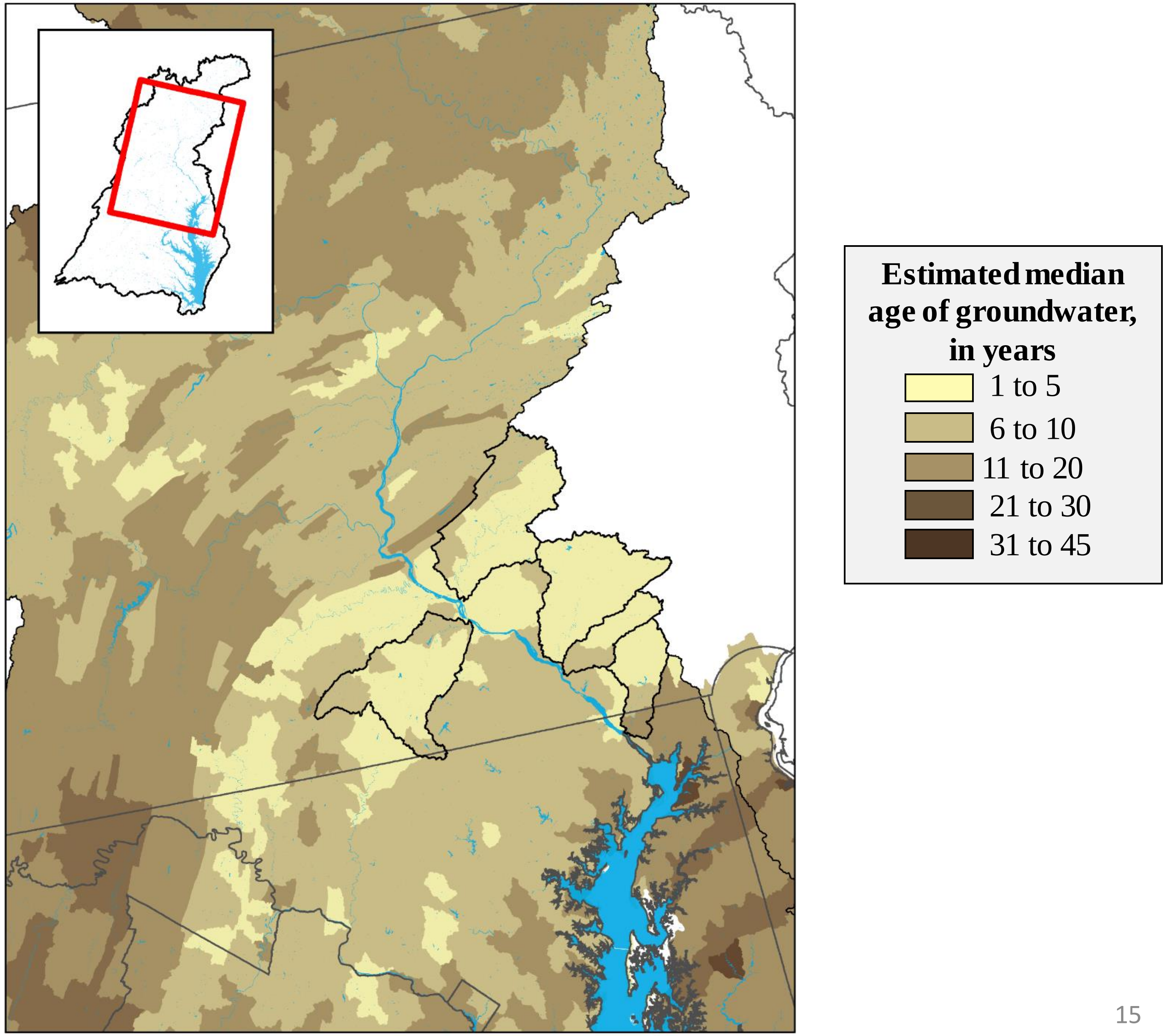


From USGS Chesapeake Bay non-tidal network: https://cbrim.er.usgs.gov/; Bachman, L.J. et al., 1998. *Water Investigations Report 98-4059.*

How is nitrogen reaching streams?

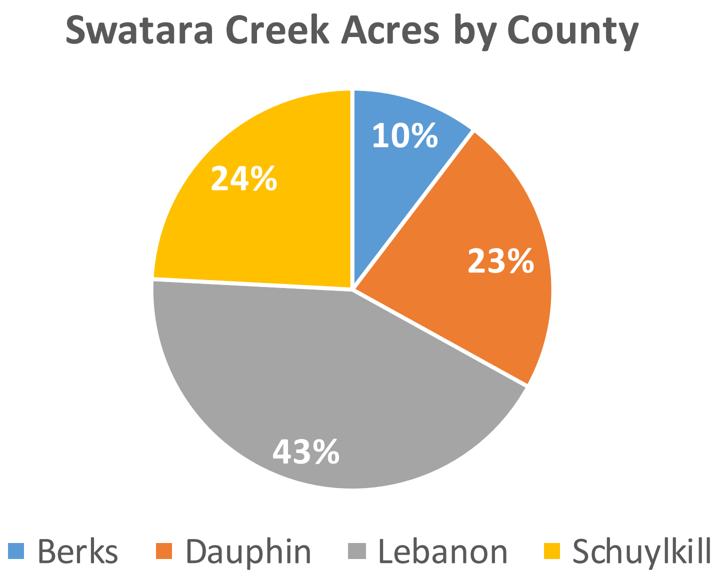
- **Nitrate in groundwater represents a range of ages from recent to decades old**
- **Nitrogen in streams is a reflection of both recent and past nitrogen applications**
- **The median groundwater age in this area is 1-10 years old**

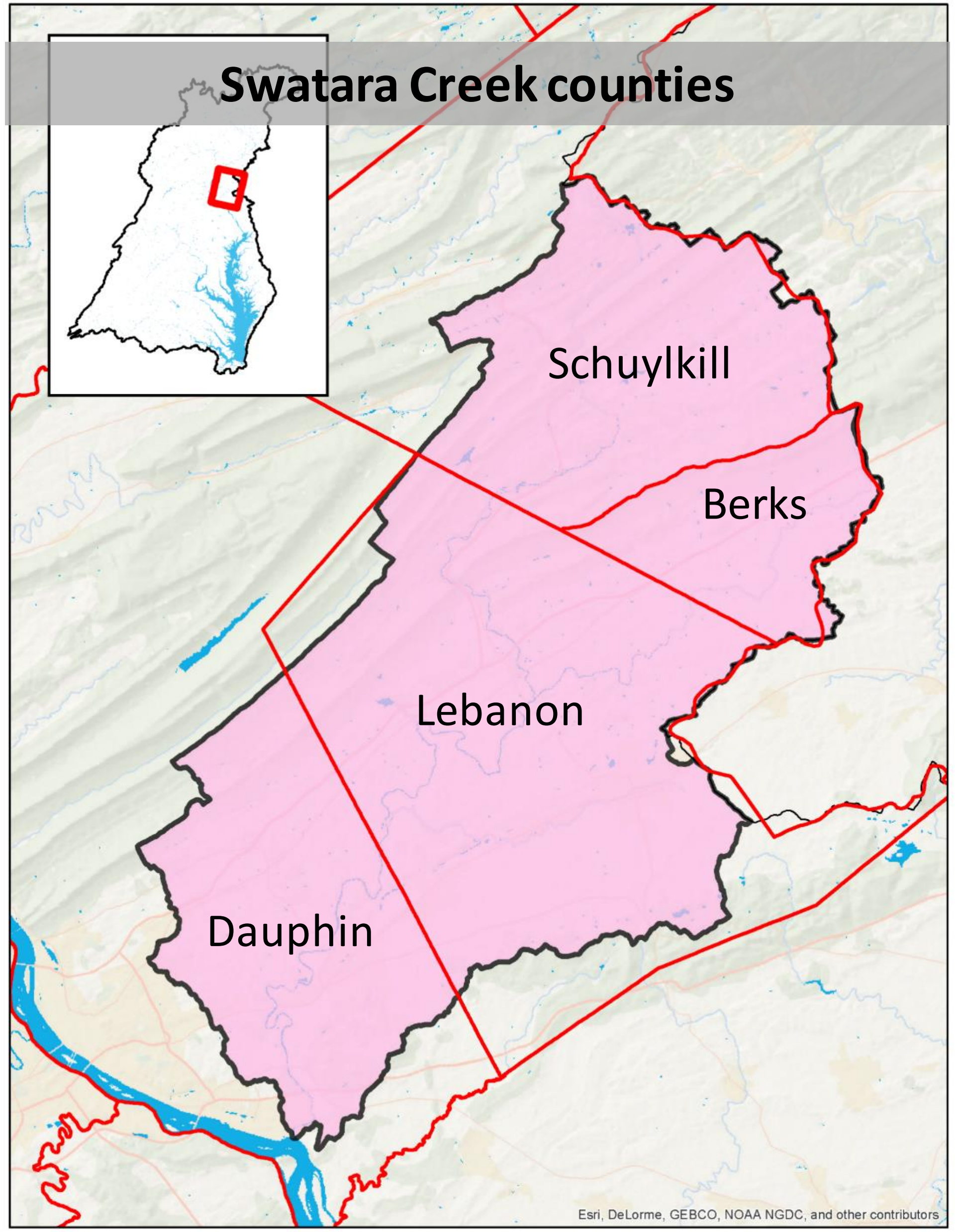


Phase 6 WSM groundwater age estimates. DRAFT from Jimmy Webber, USGS. DO NOT CITE OR DISTRIBUTE.

What are drivers behind changes in nitrogen?

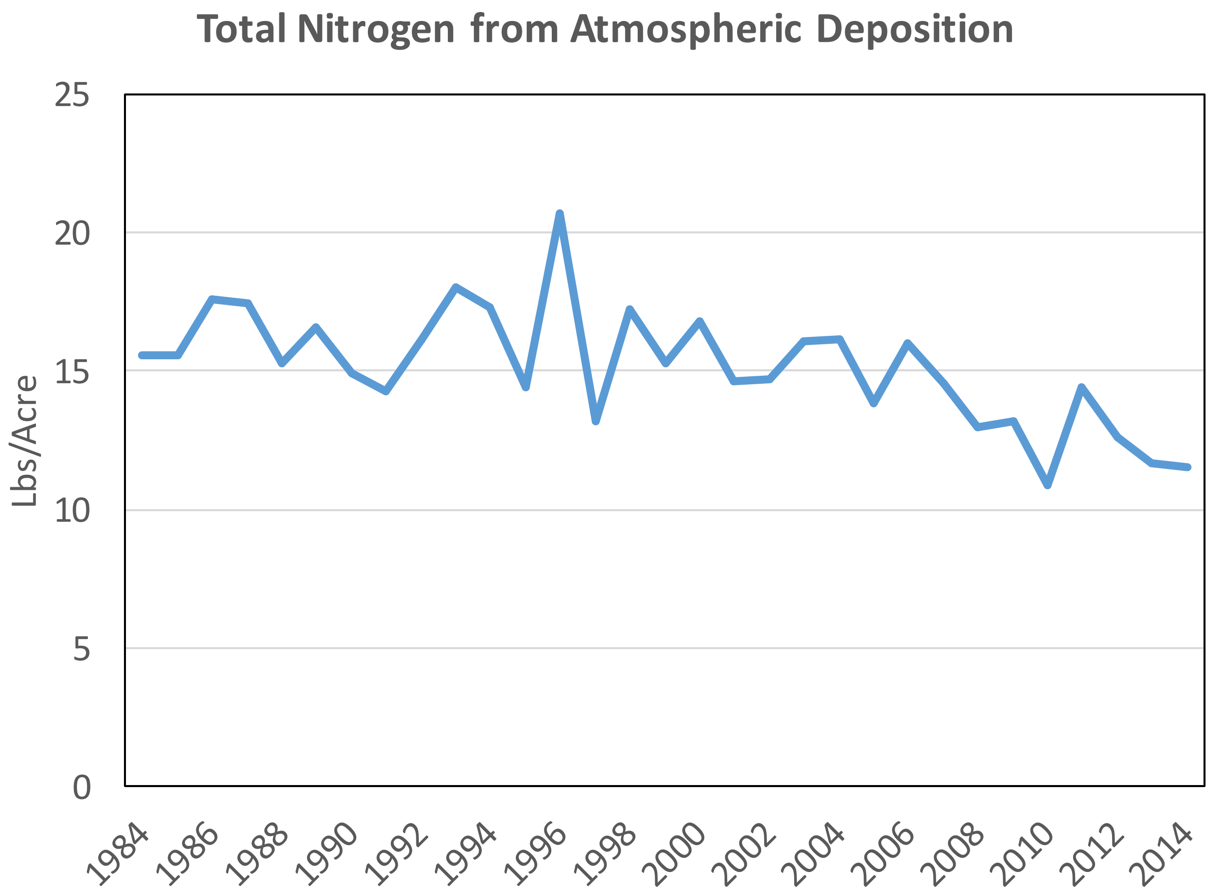
- **The Swatara Creek drainage basin is made of Berks, Dauphin, Lebanon and Schuylkill Counties**
- **Lebanon County has most area**





How have nitrogen inputs changed?

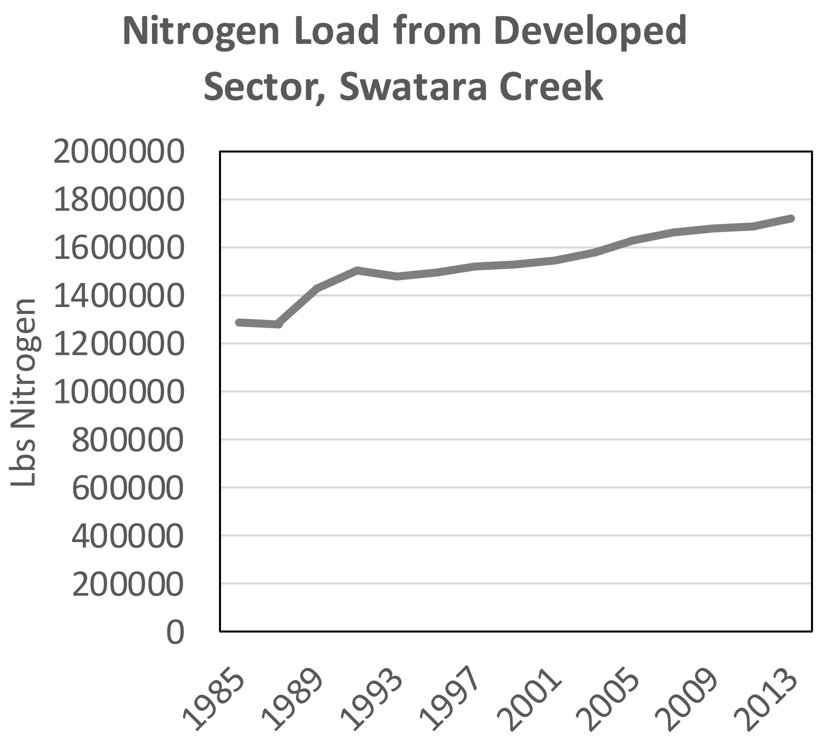
- **Nitrogen inputs from atmospheric deposition have decreased**

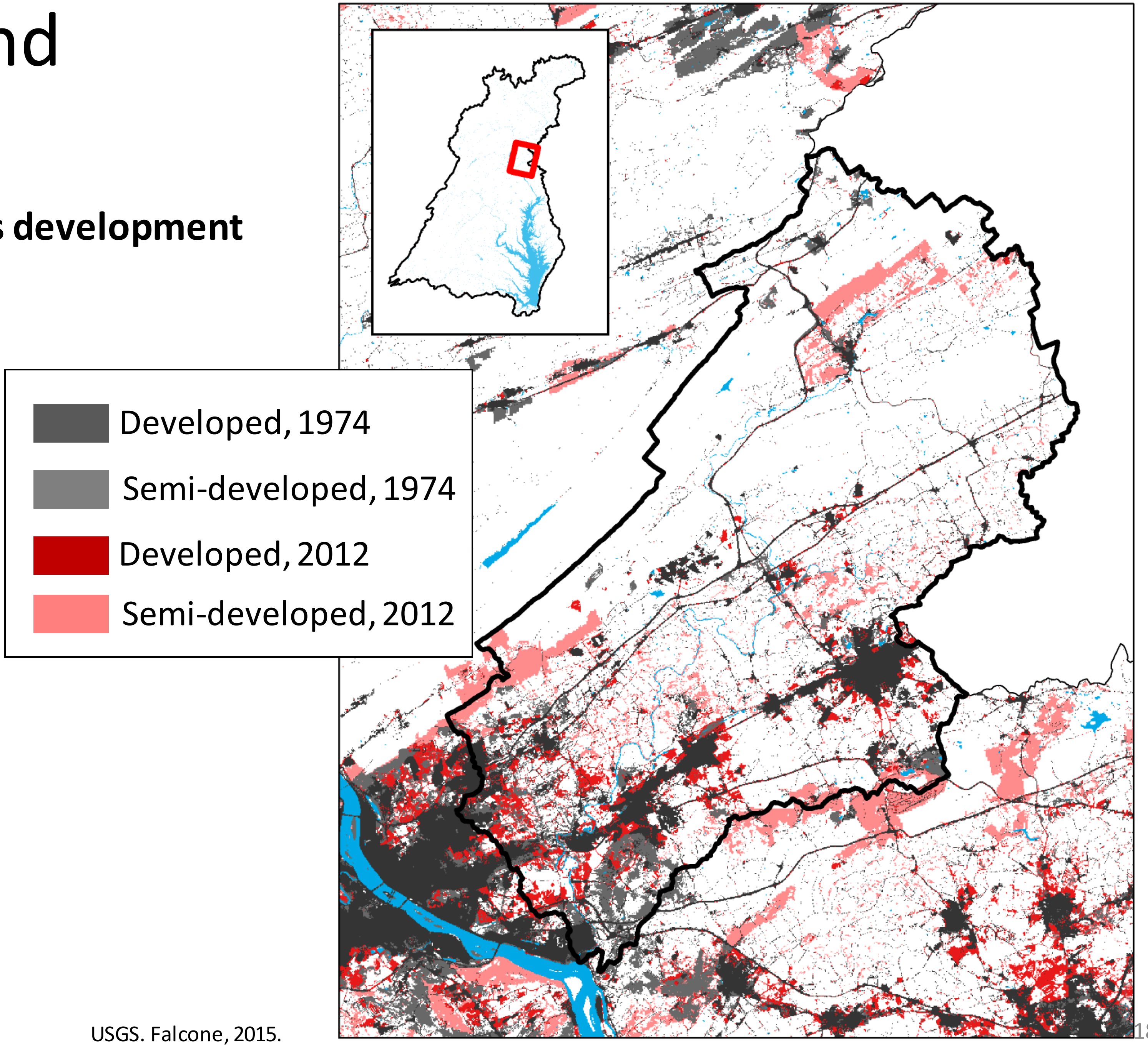


From CBP WSM Phase 6 inputs;
https://mpa.chesapeakebay.net/
Phase6DataVisualization.html

What are drivers behind changes in nitrogen?

- **Loads from developed have increased as development has increased**



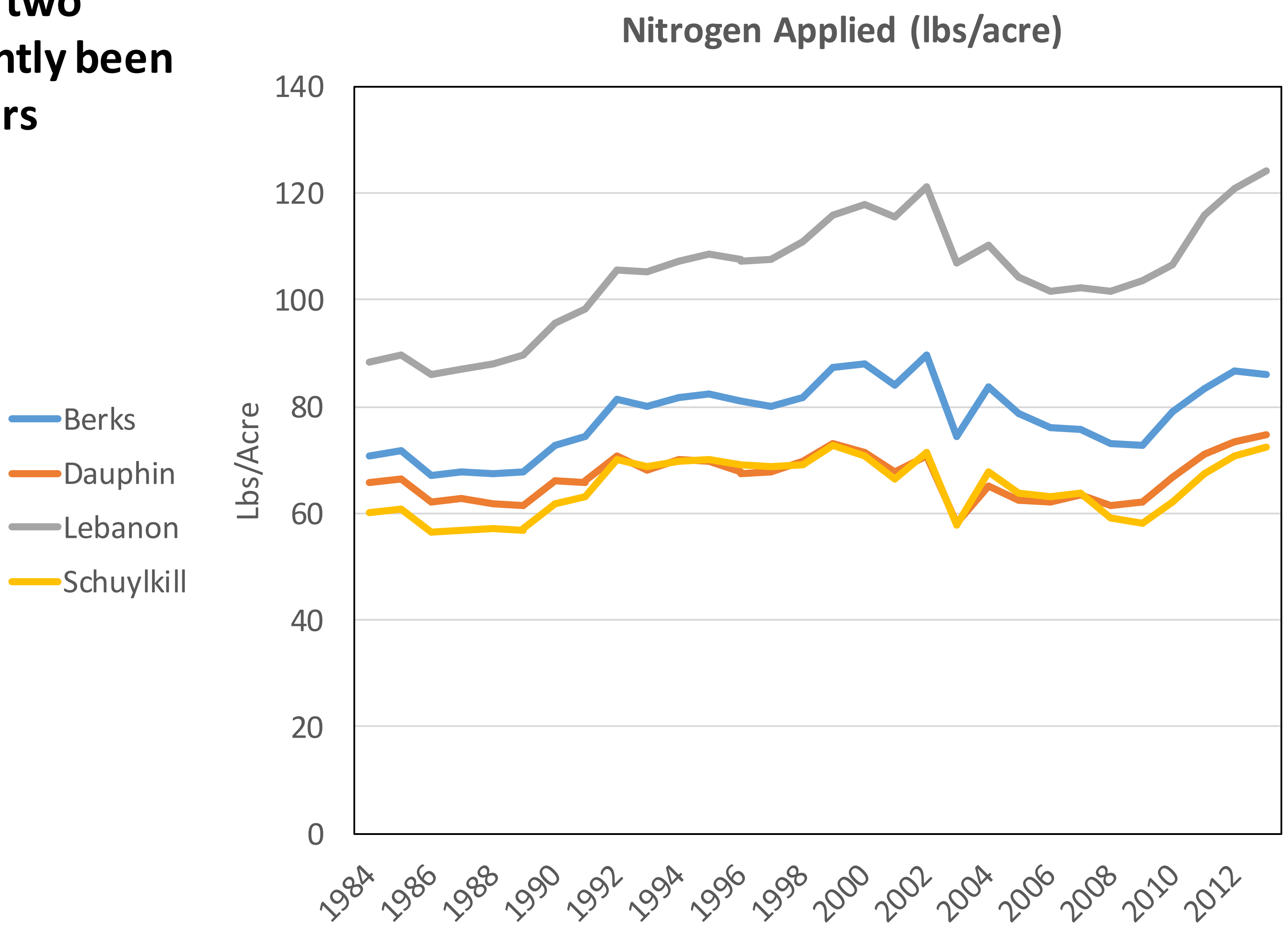


From CBP WSM Phase 6 Progress Reports. See data analysis at end of this document.

USGS. Falcone, 2015.

How have nitrogen inputs changed?

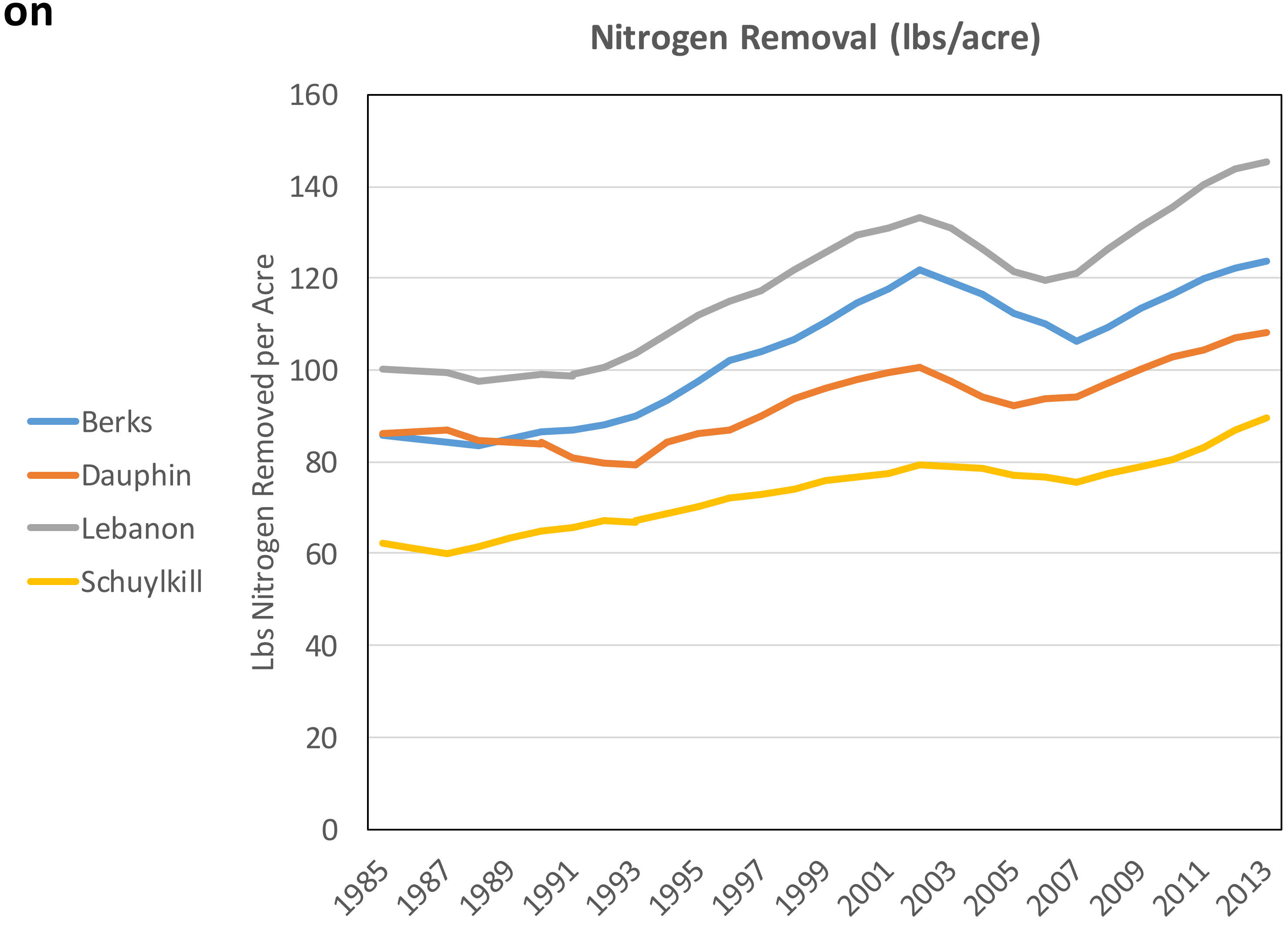
- **Nitrogen inputs on agriculture have decreased over the last two decades, but have recently been increasing in recent years**



From CBP WSM Phase 6 inputs; https://mpa.chesapeakebay.net/Phase6DataVisualization.html

How have nitrogen inputs changed?

- **Removal of nitrogen in crops often mirrors nitrogen input on agriculture**



From CBP WSM Phase 6 inputs; https://mpa.chesapeakebay.net/Phase6DataVisualization.html

Where to focus efforts geographically?

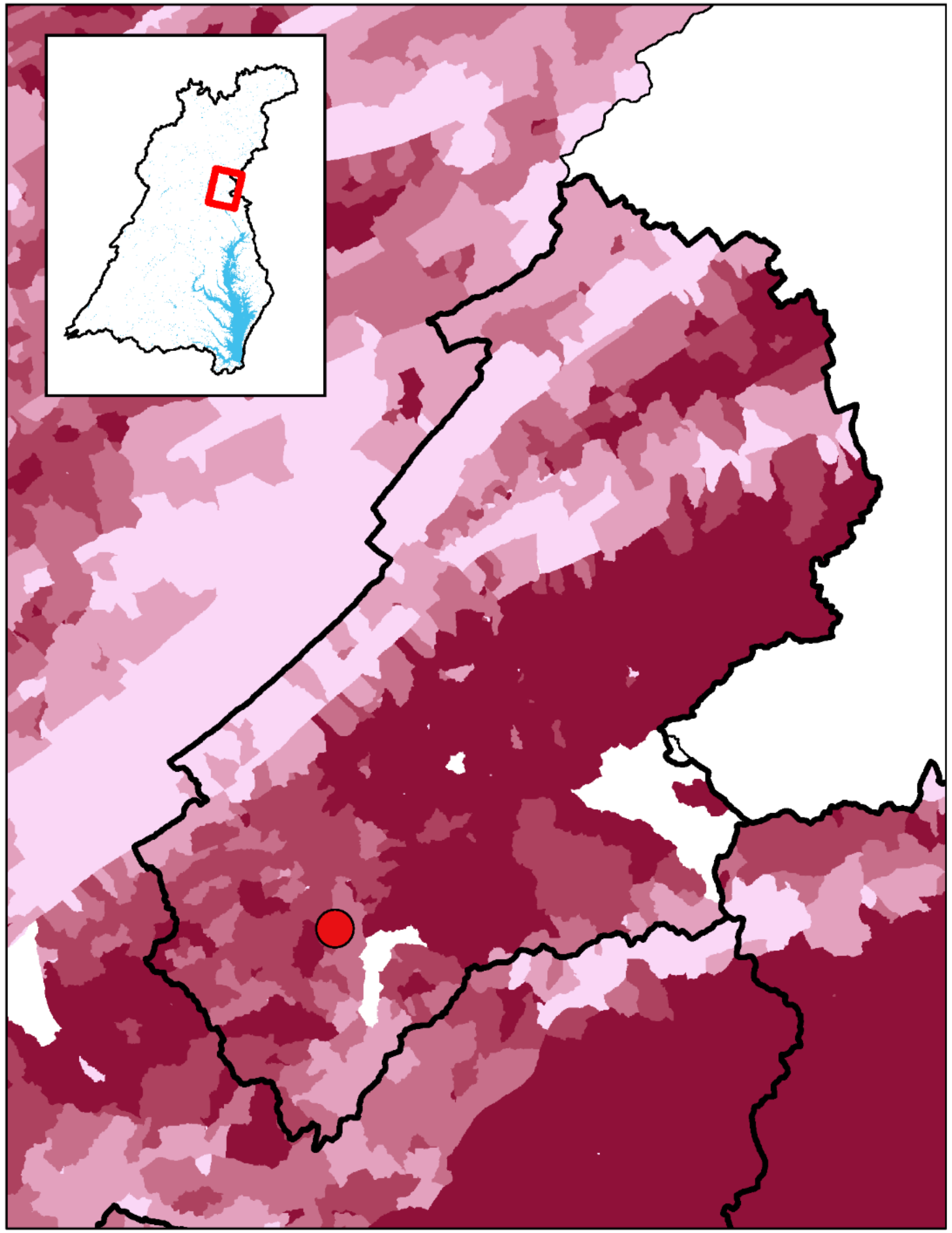
- **Certain areas of the watershed are higher loading than others**
- **These can be the more effective areas to focus restoration efforts**

Total nitrogen yield to local waters in lbs/acre

<5
5 to 10
10 to 15
15 to 20
20 to 25
>25

Average Total Nitrogen yield (2005-2014) in lbs/acre

0 to 6.88
6.89 to 13.8
13.9 to 33.4



Modified from Jimmy Webber, USGS, using Ator, S. et al, 2011.

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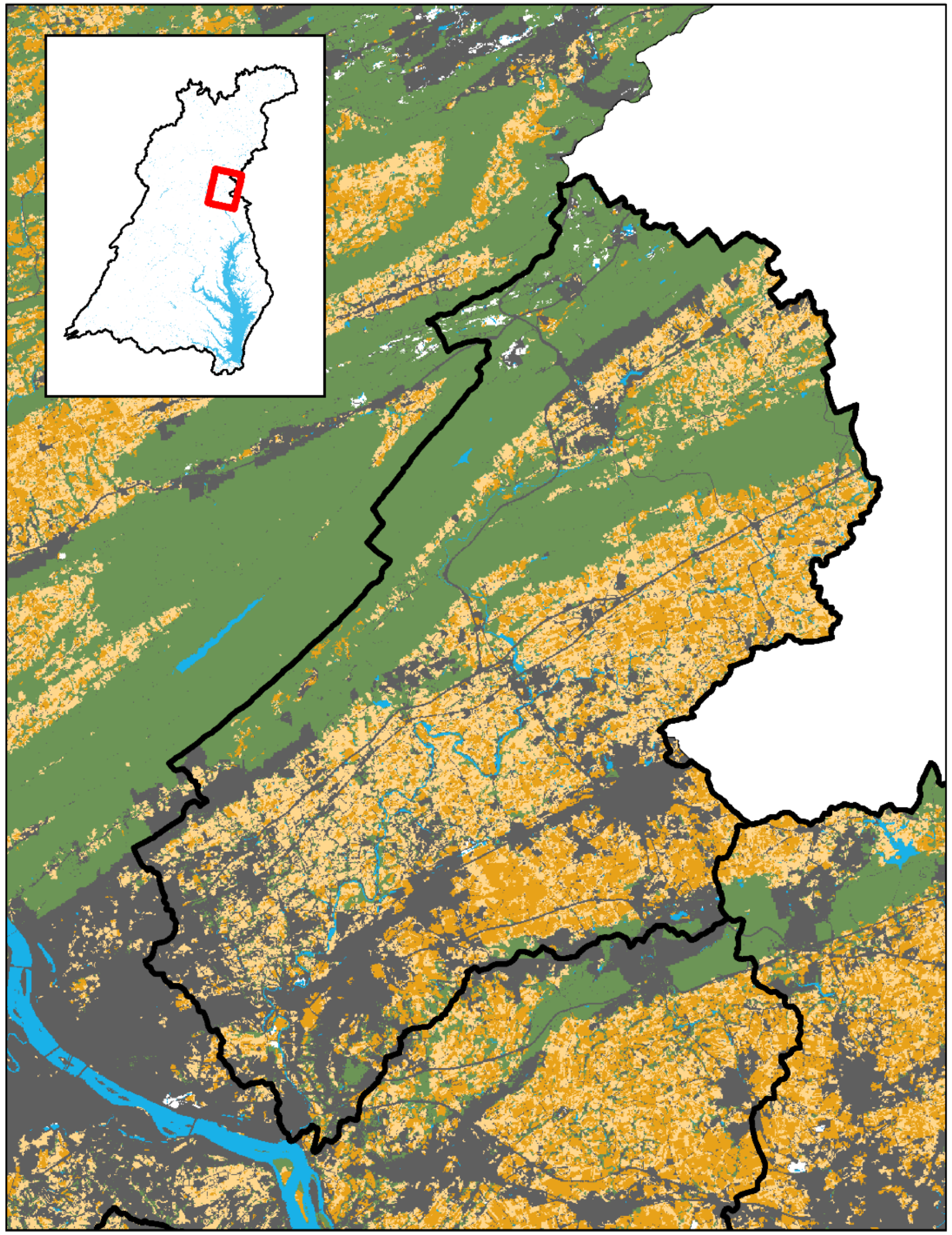

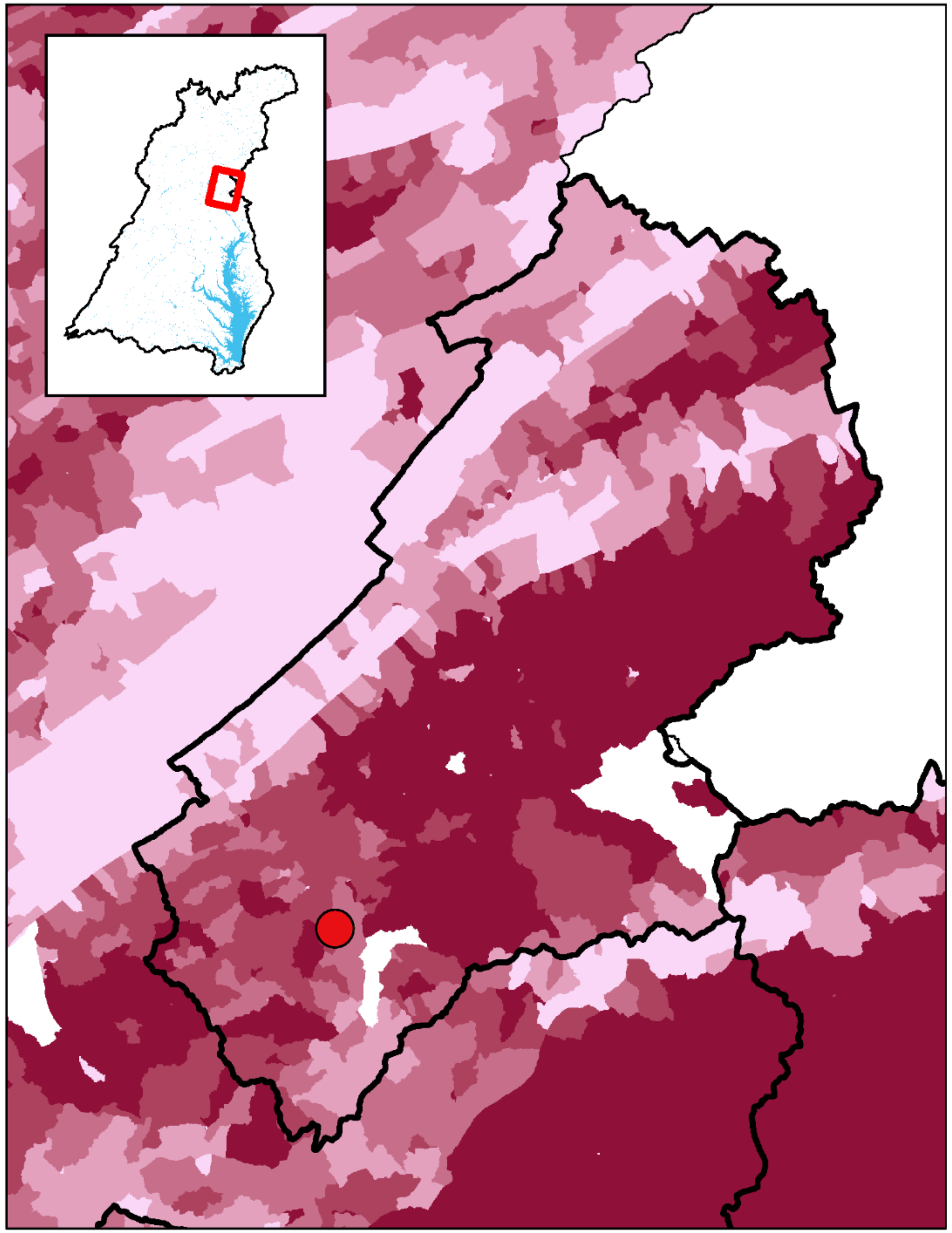

Modified from Jimmy Webber, USGS, using Ator, S. et al, 2011; Falcone, et al. 2015.

Where to focus efforts geographically?

- **Geology makes the groundwater (and therefore streams) in some areas especially vulnerable to high nitrogen inputs**
- **These areas can be the most effective to focus practices for nitrate in groundwater**

Vulnerable geology

(Areas underlain by carbonate rocks or coarse coastal sediments)

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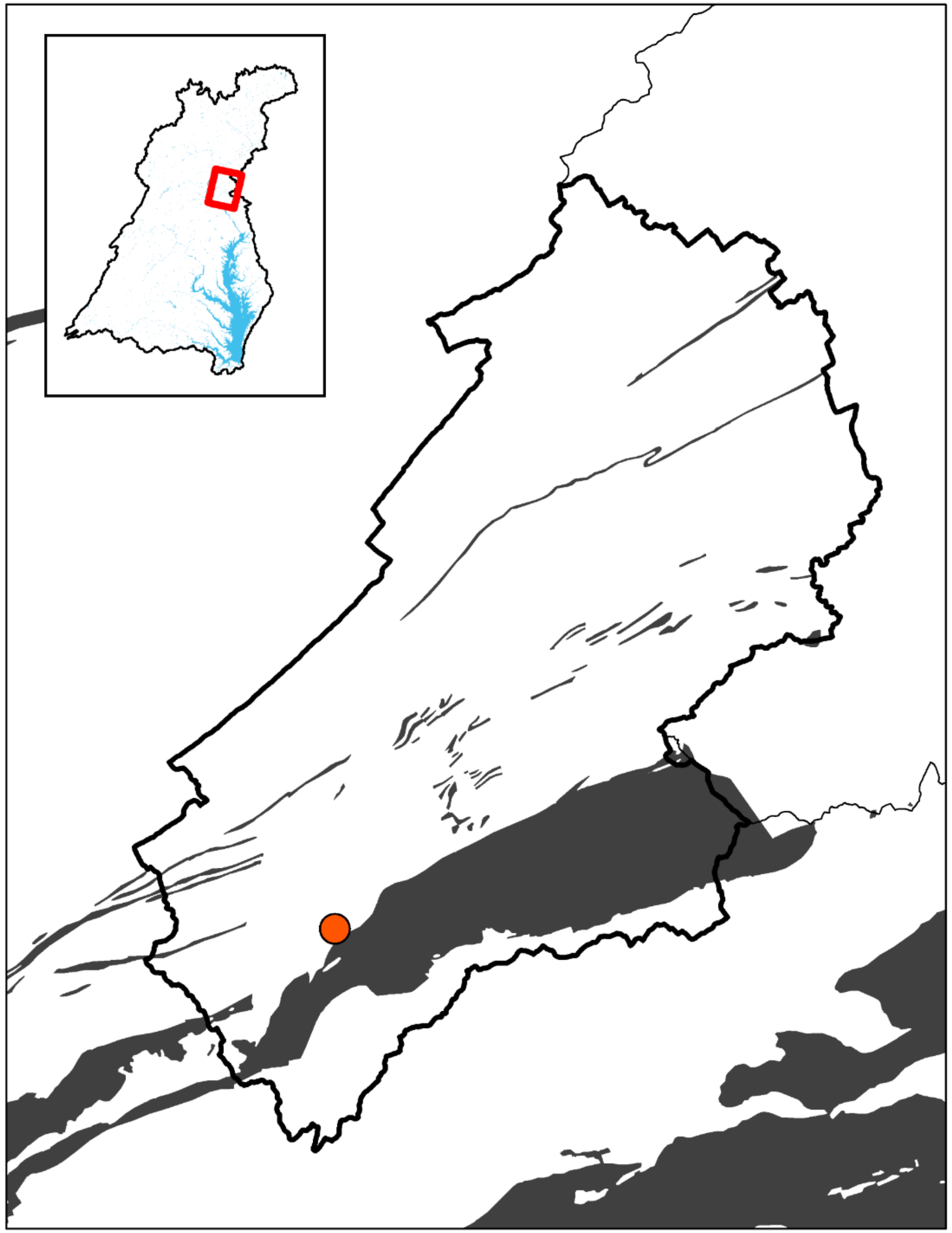

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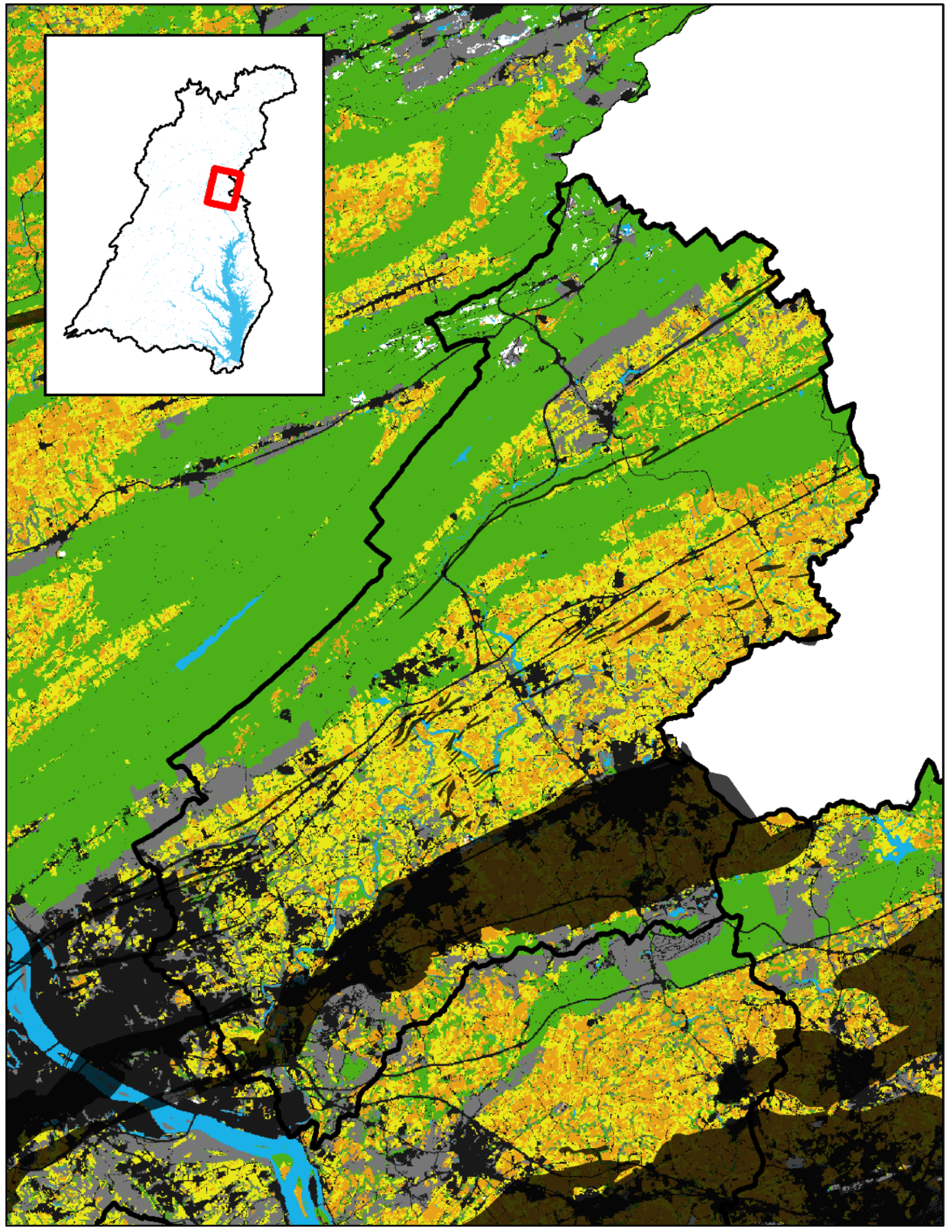

Modified from Jimmy Webber, USGS, using Brakebill, JW 2000, Ator, S. et al. 2005 and Nolan & Hitt, 2006.
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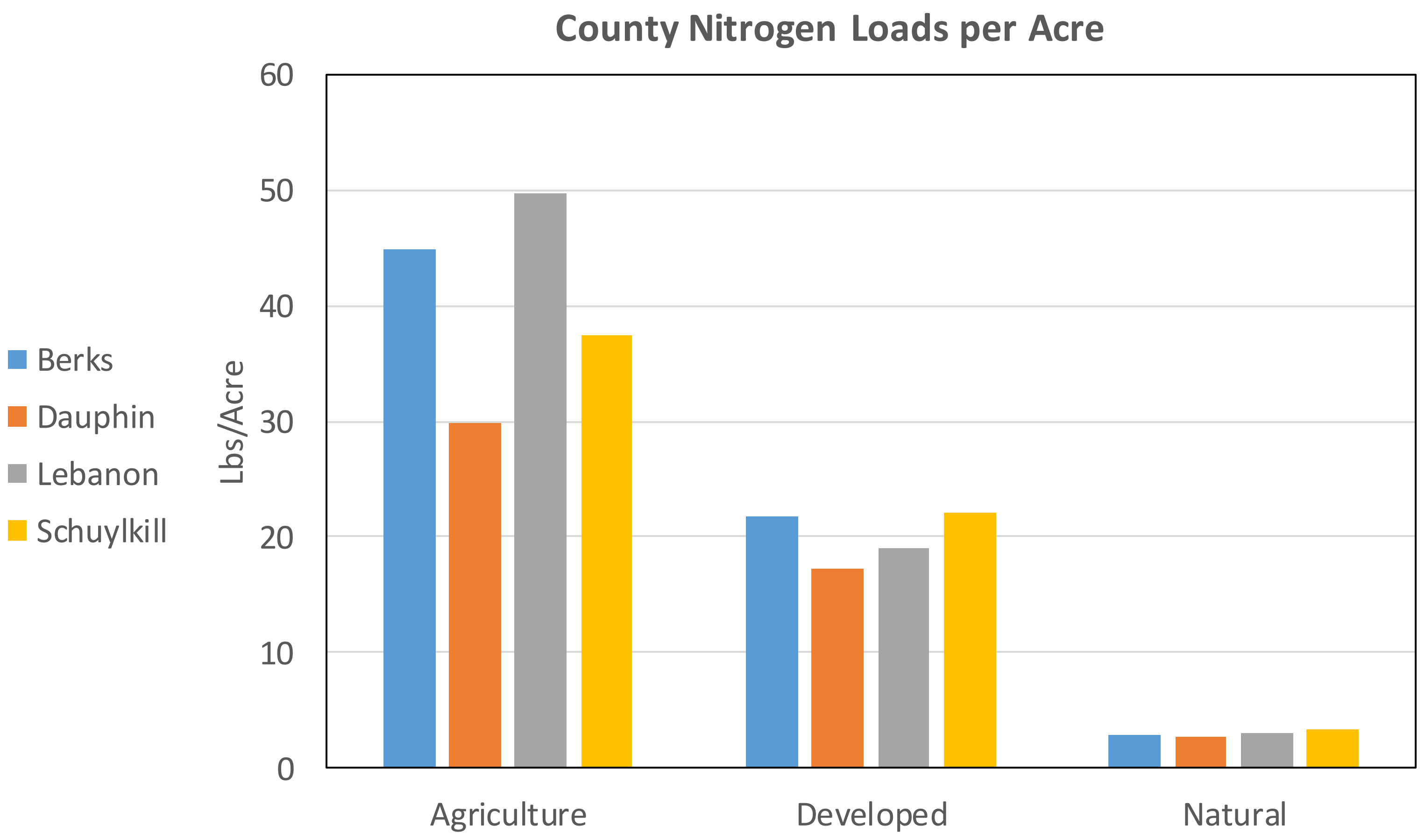
Where to focus efforts geographically?

- **Loads and practices can differ between counties**



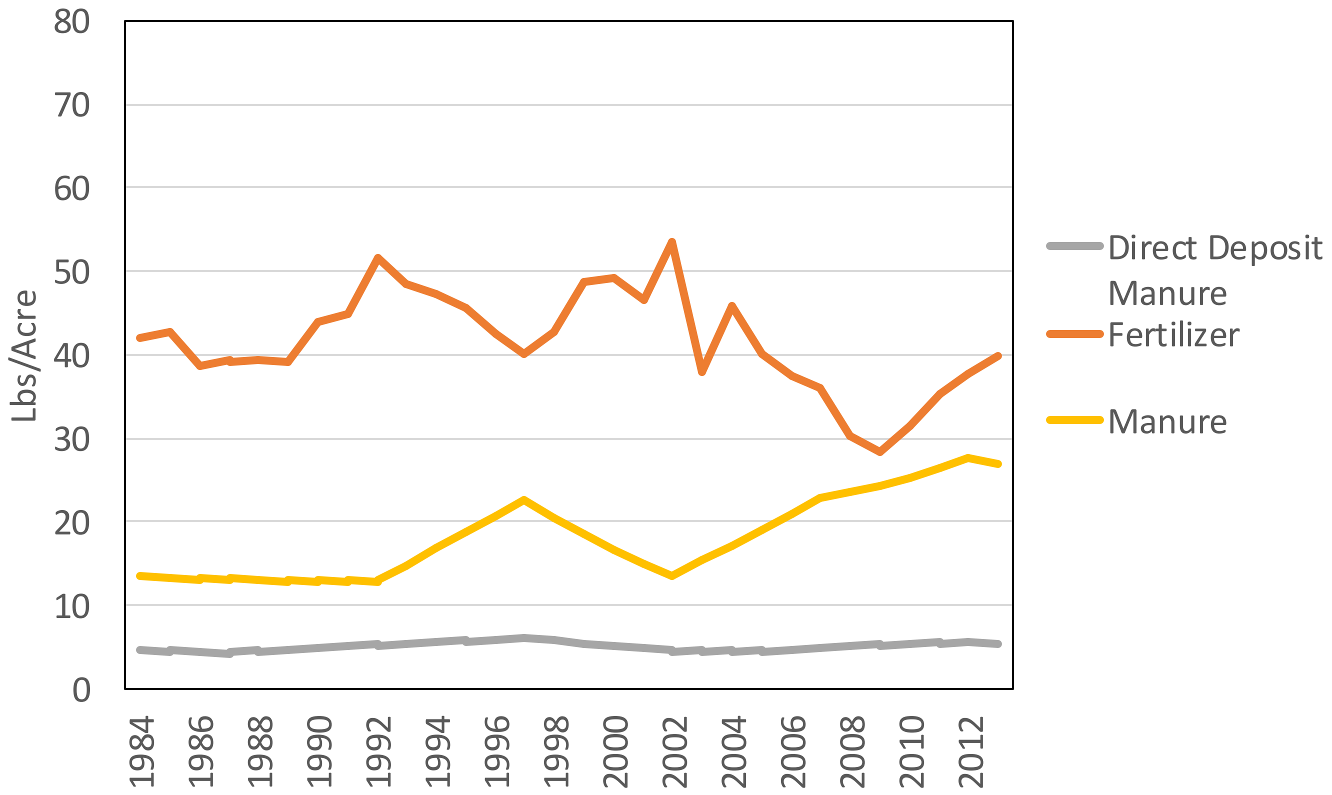
From CBP WSM Phase 6 2013 Progress Run. http://cast.chesapeakebay.net

Where to focus efforts geographically?

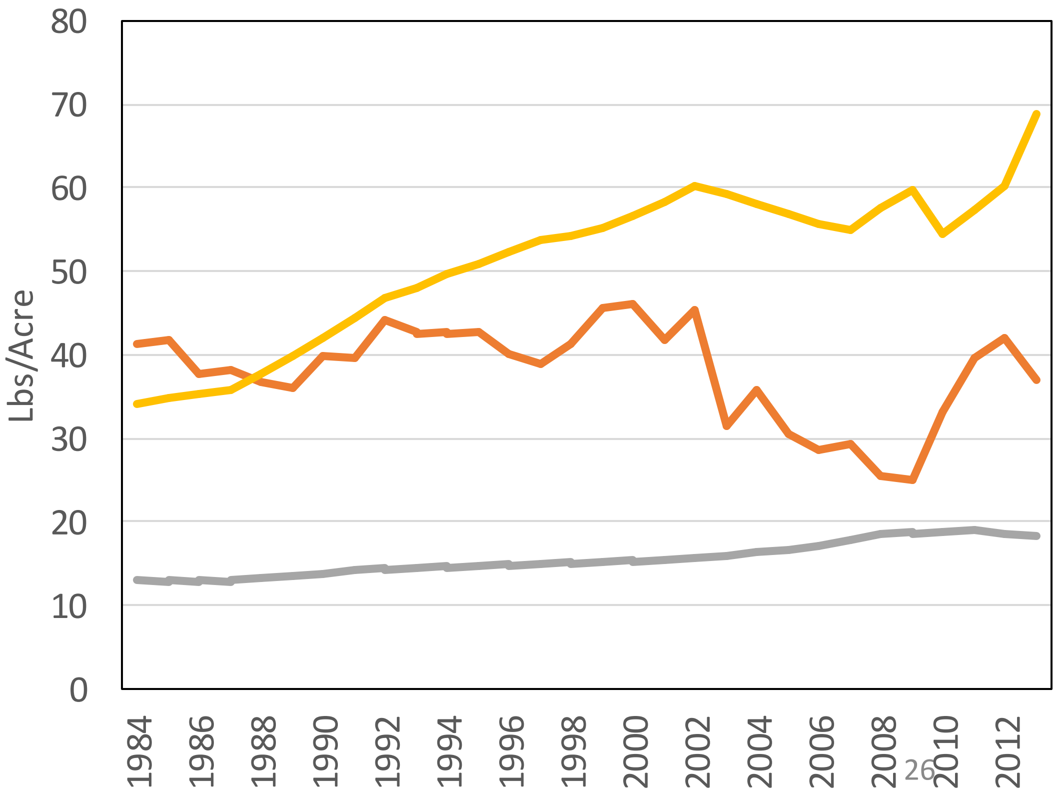
- **Loads and practices can differ between counties**
- **For example, Lebanon county has more intense application of nitrogen per acre, and increasing application of manure, correlating to animal production**

From CBP WSM Phase 6 inputs; https://mpa.chesapeakebay.net/Phase6DataVisualization.html

Nitrogen Applied to Agriculture - Schuylkill



Nitrogen Applied to Agriculture - Lebanon



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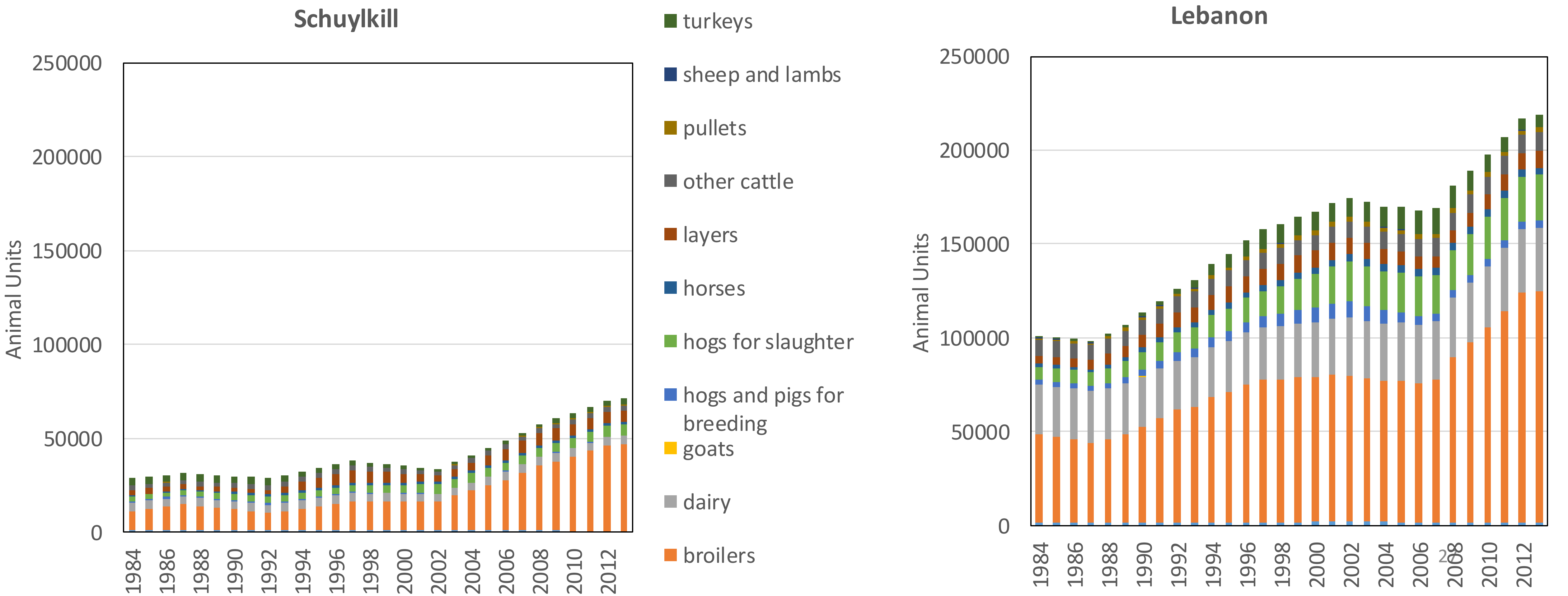
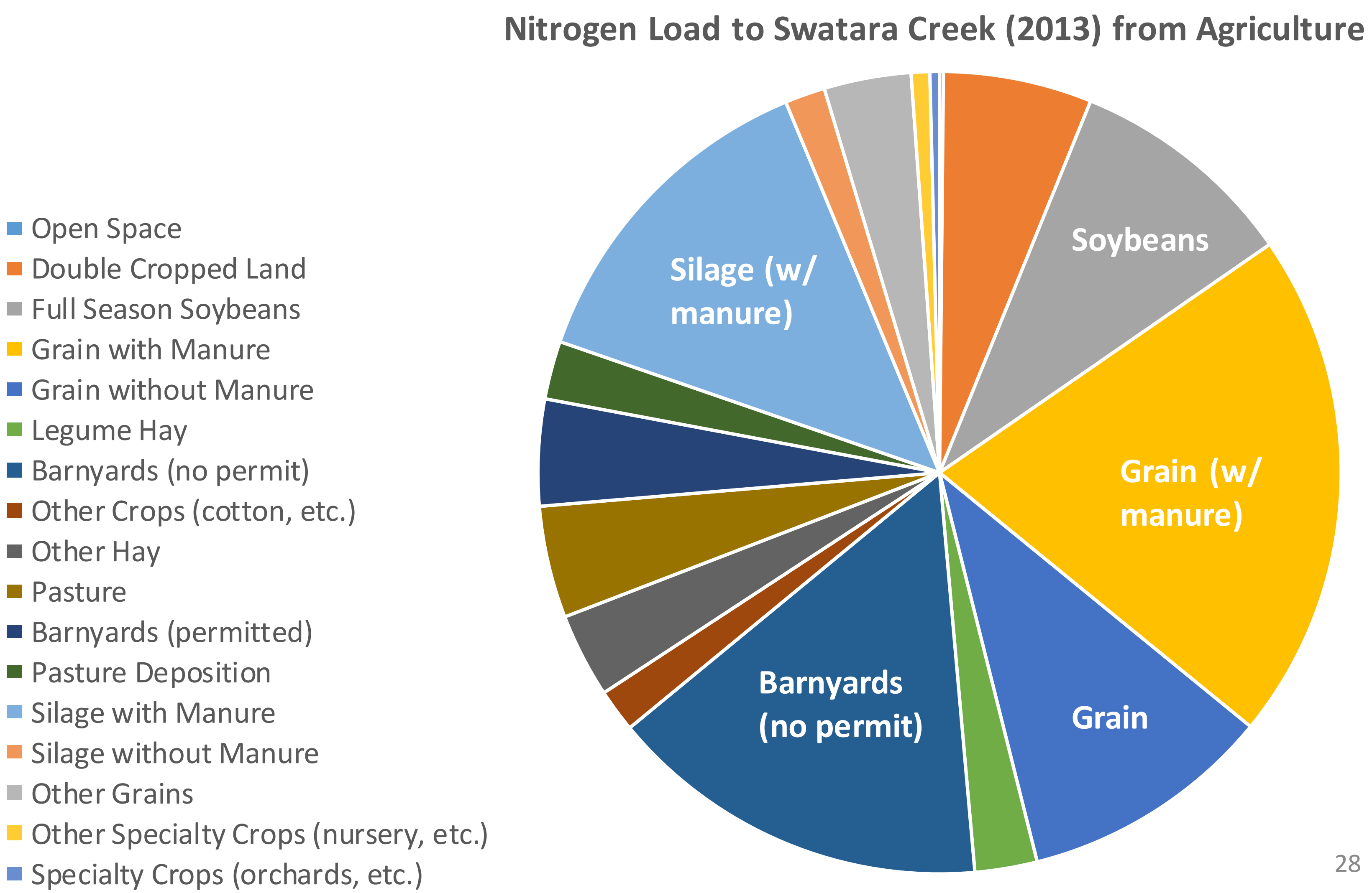


What practices to focus on?

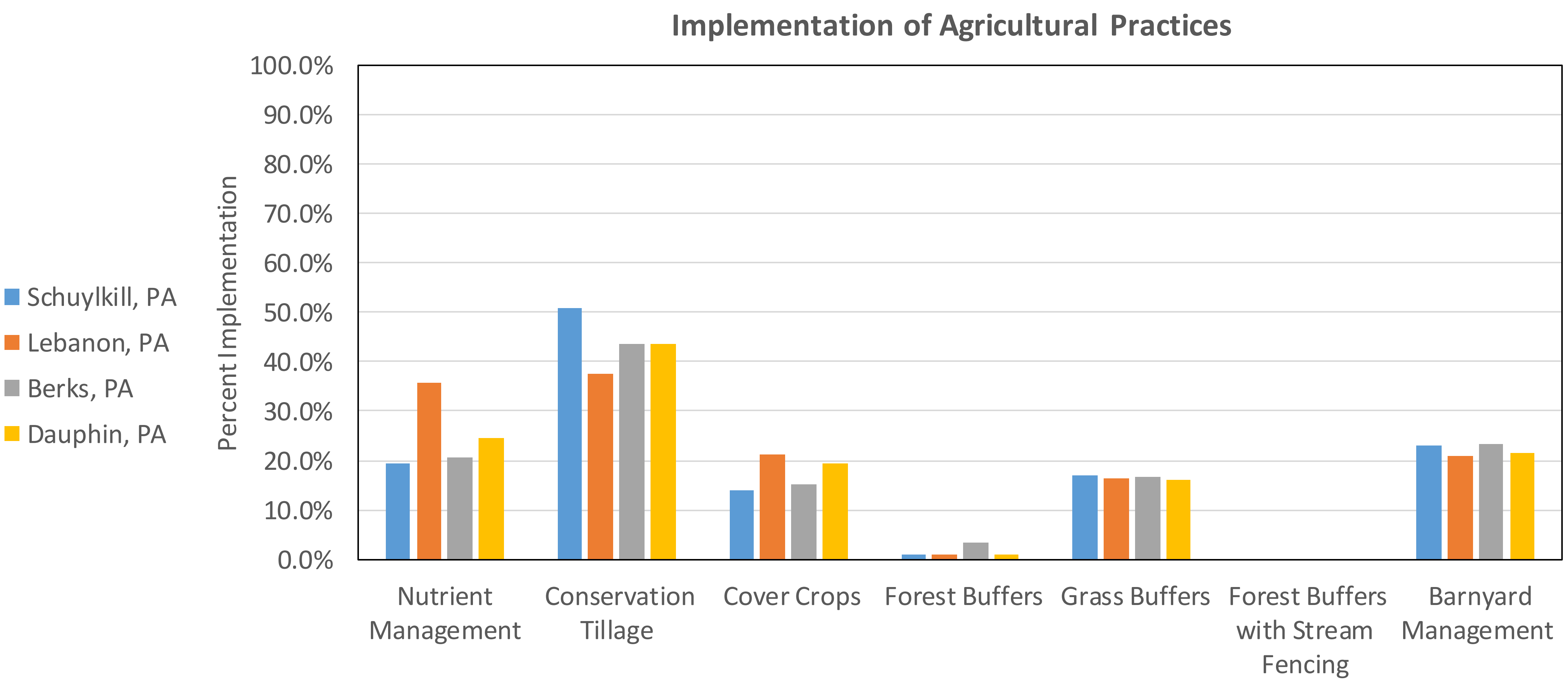
- **The highest loading sources are different types of cropland and barnyards**



From CBP WSM Phase 6 2013 Progress Report. See data analysis at end of this document.

What practices to focus on?

- **The highest loading sources are different types of cropland and barnyards**
- **Effective practices for these sources can include buffers, barnyard management, and cover crops**



Phase 6 WSM 2013 BMP Progress Report

*Percent implementation = acres with practice implemented out of acres available for practice

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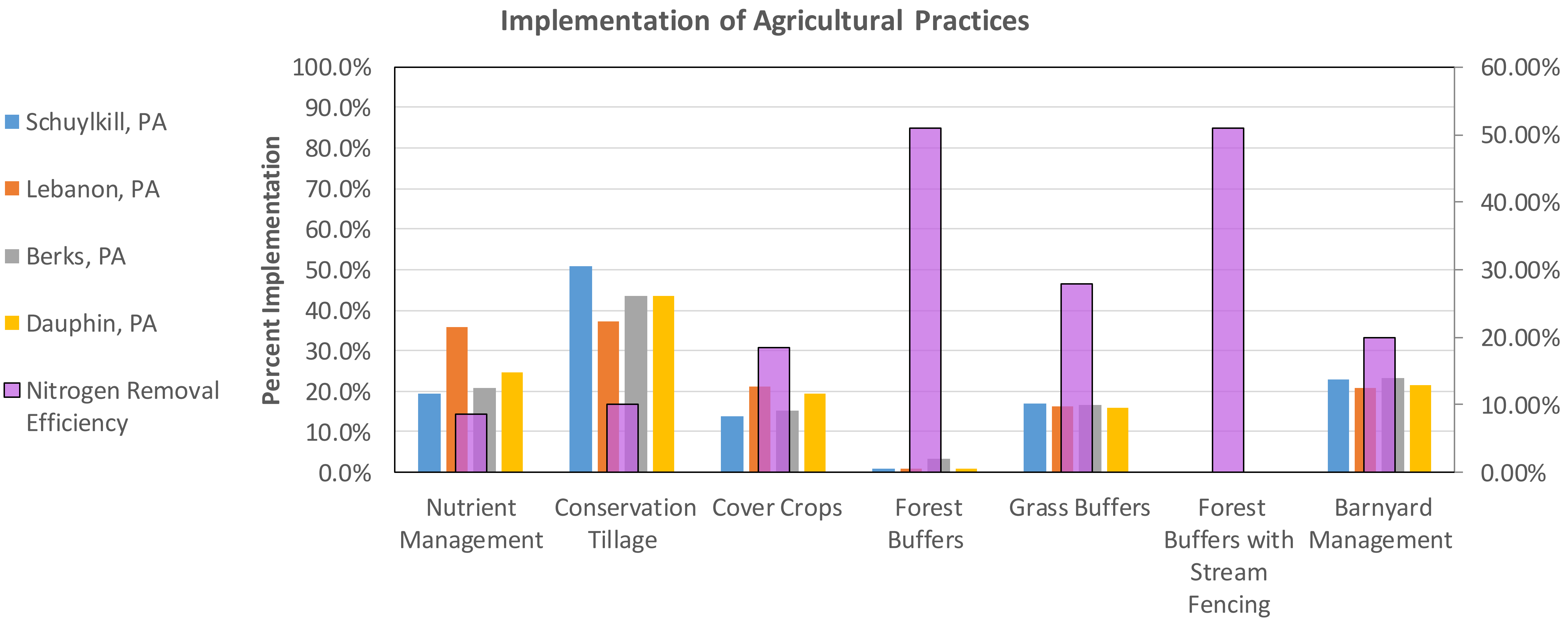
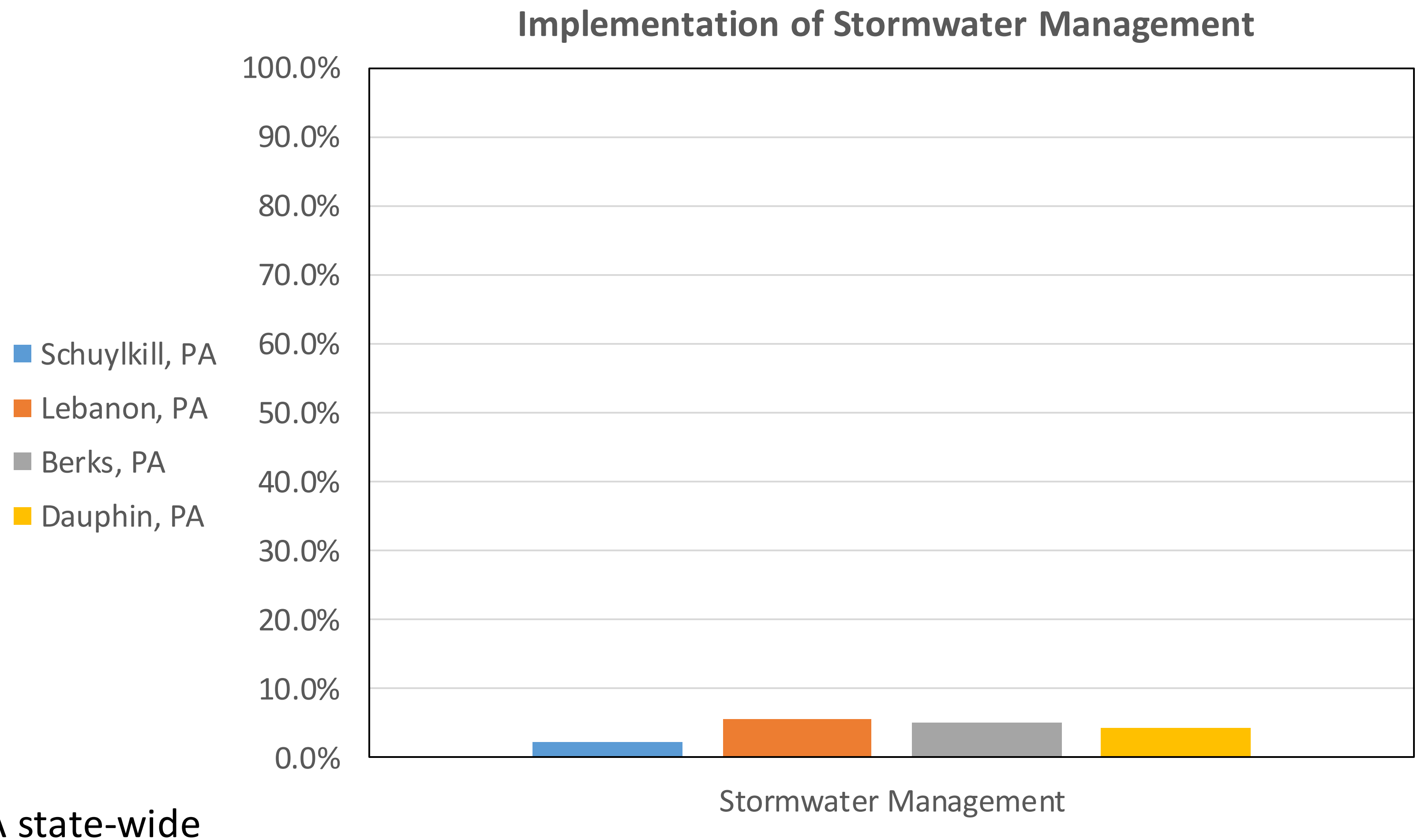


Phase 6 WSM 2013 BMP Progress Report

What practices to focus on?

- **Loads from developed land are not insignificant in these areas and are increasing**
- **Stormwater management will be important to address issues associated with increasingly developed areas**

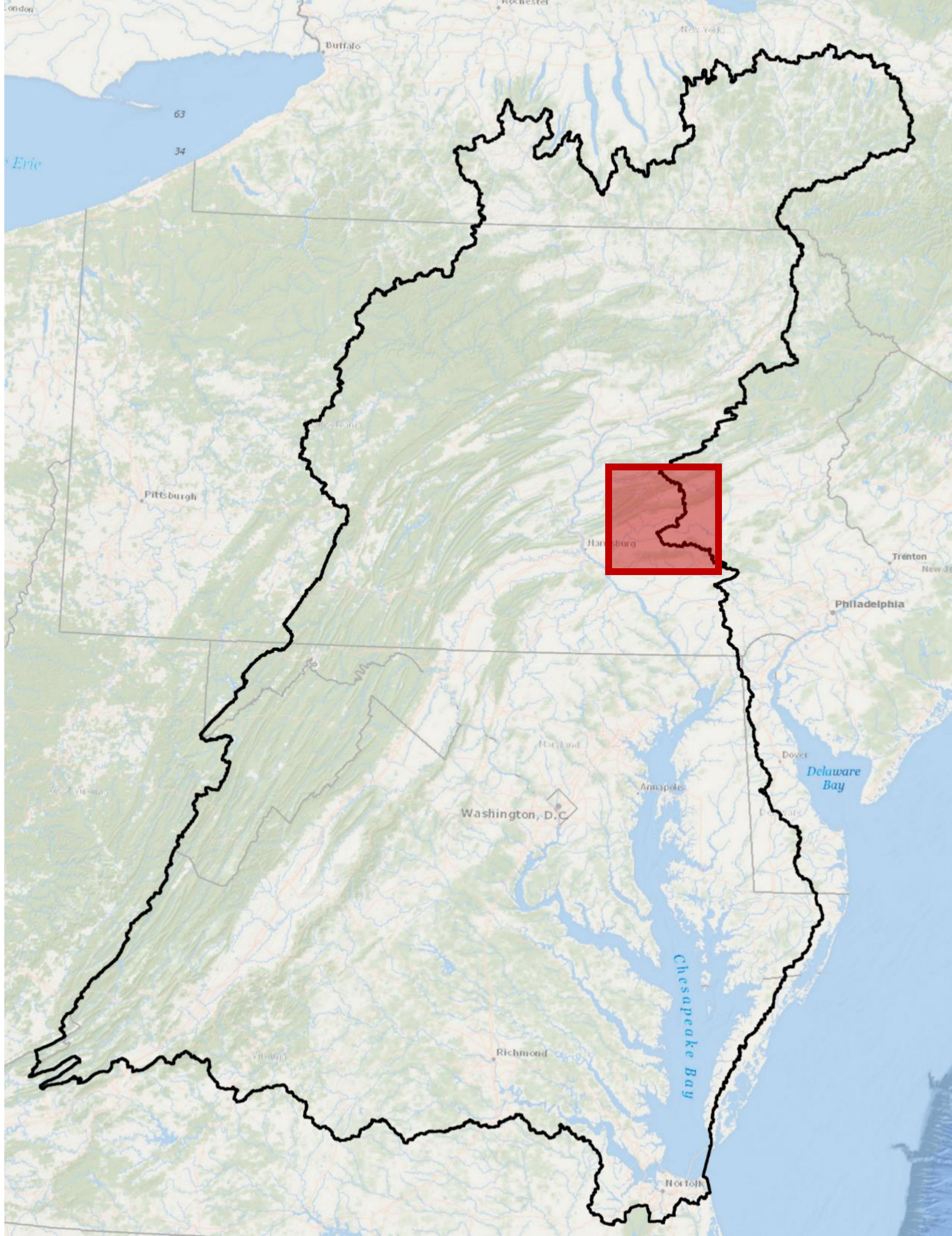


PA state-wide implementation (2013) 2.9%

Phase 6 WSM 2013 BMP Progress Report

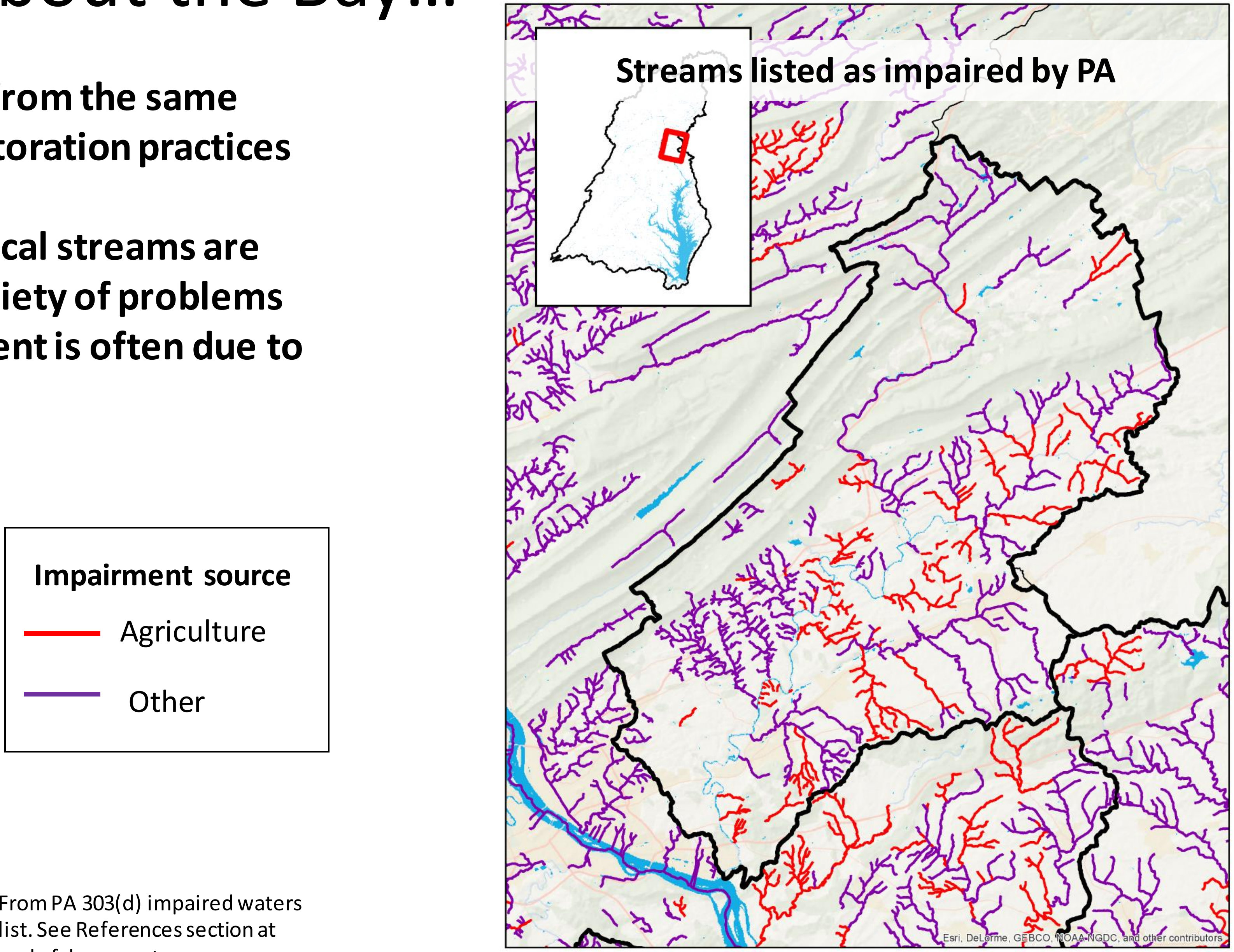
Management Implications Summary

- Certain geographic areas within this region can be more effective to target based on loads and geology
- Counties differ in their practices, which should be taken into account when focusing efforts
- In these areas, practices such as cover crops, forest buffers, and barnyard control can be effective
- Stormwater practices will be important to address increasing development



It’s not just about the Bay…

- **Local waters benefit from the same conservation and restoration practices that help the Bay**
- **For example, many local streams are impaired due to a variety of problems**
- **In this area, impairment is often due to agricultural sources**

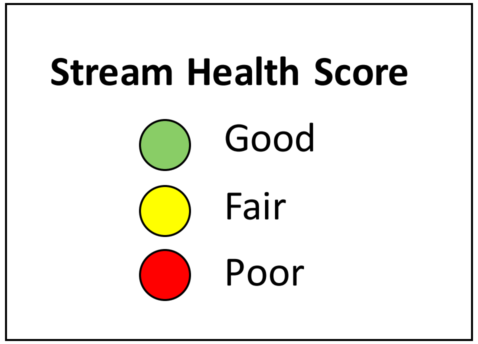


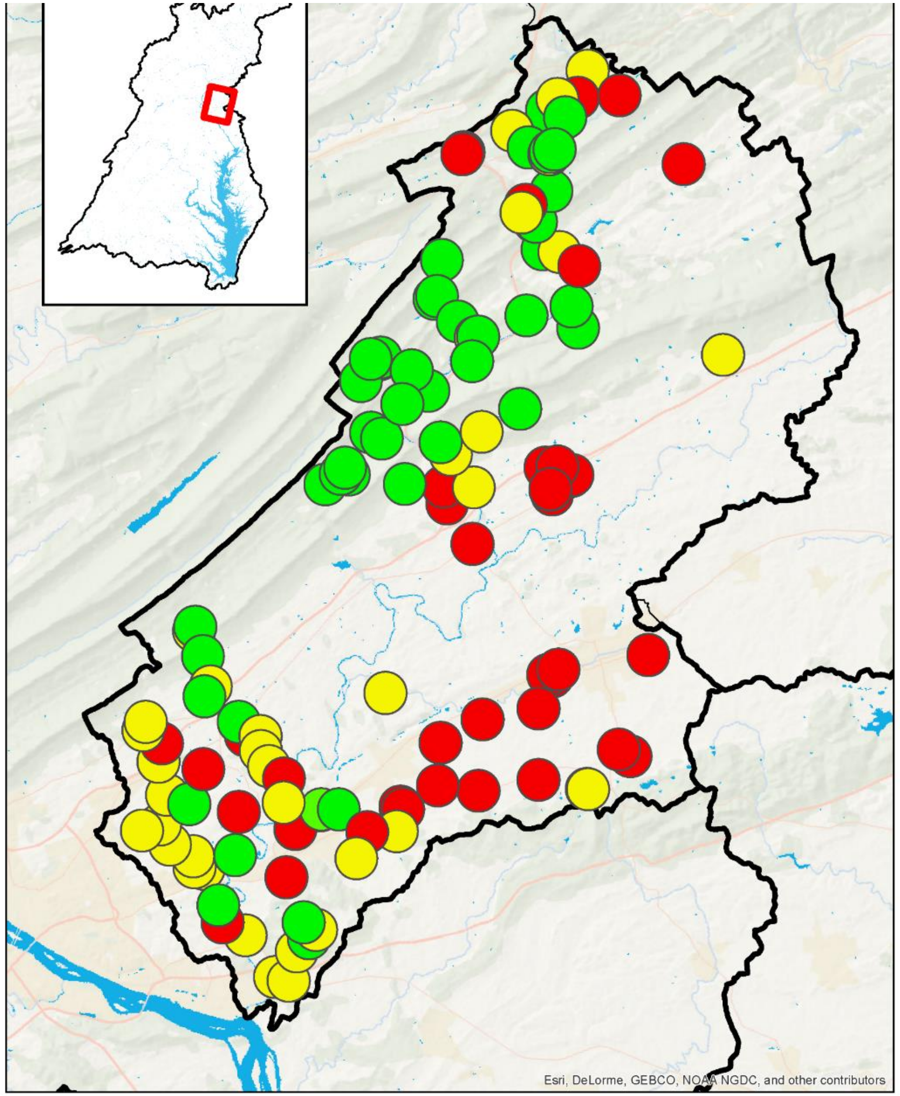
From PA 303(d) impaired waters list. See References section at end of document.

And it's not just about water quality…

- **There are other economically and recreationally important goals influenced by water quality**
- **For example, stream health in this area ranges from fair to very poor**

Macroinvertebrate Sampling as a Proxy for Stream Health



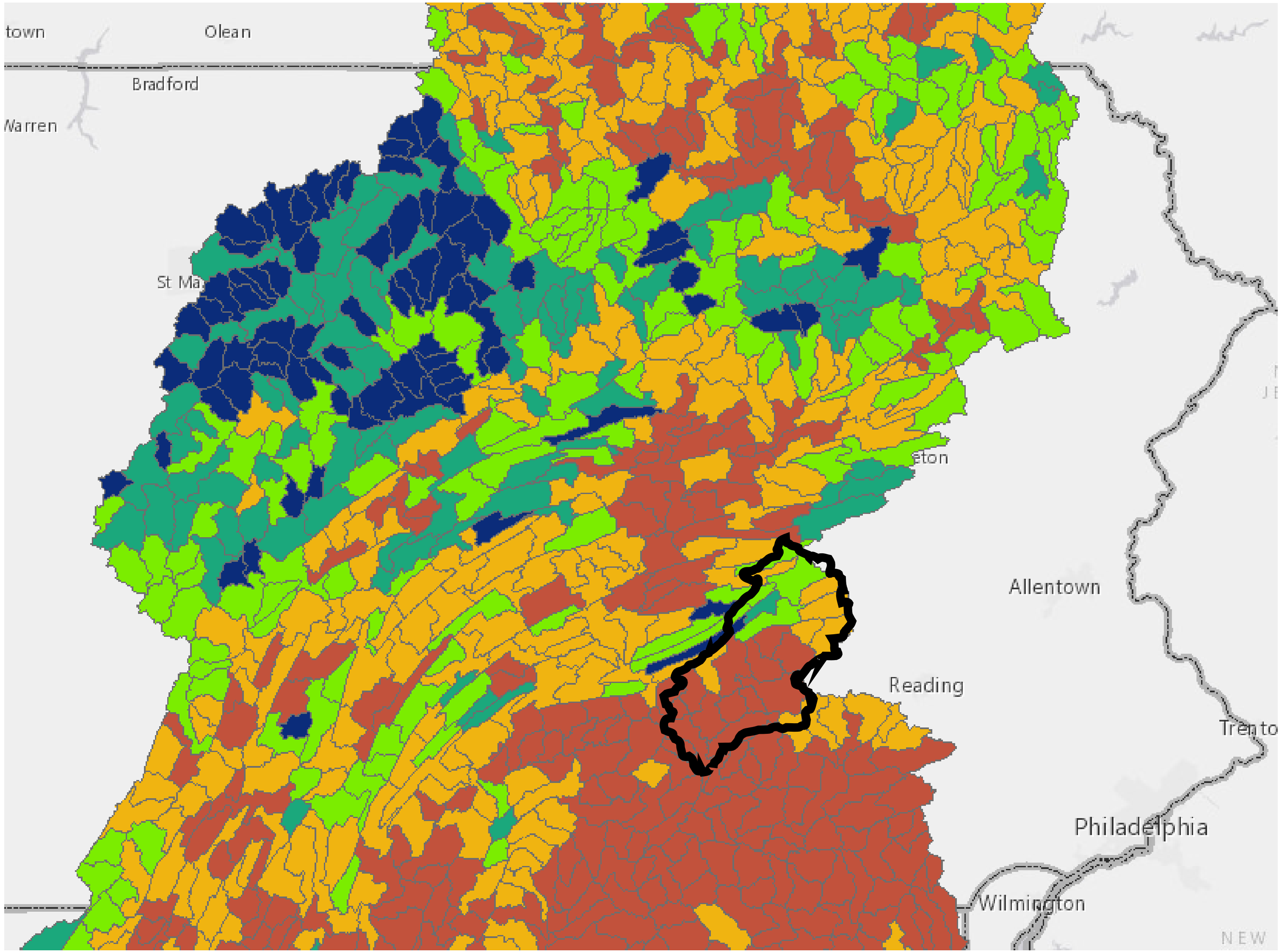


Smith, Z.C. et al. 2017.

And it's not just about water quality…

- **These areas contain watersheds that have low predicted occurrence of Brook Trout due to a combination of factors such as habitat and natural and anthropogenic stressors**

Predicted Likelihood of Brook Trout Occurrence



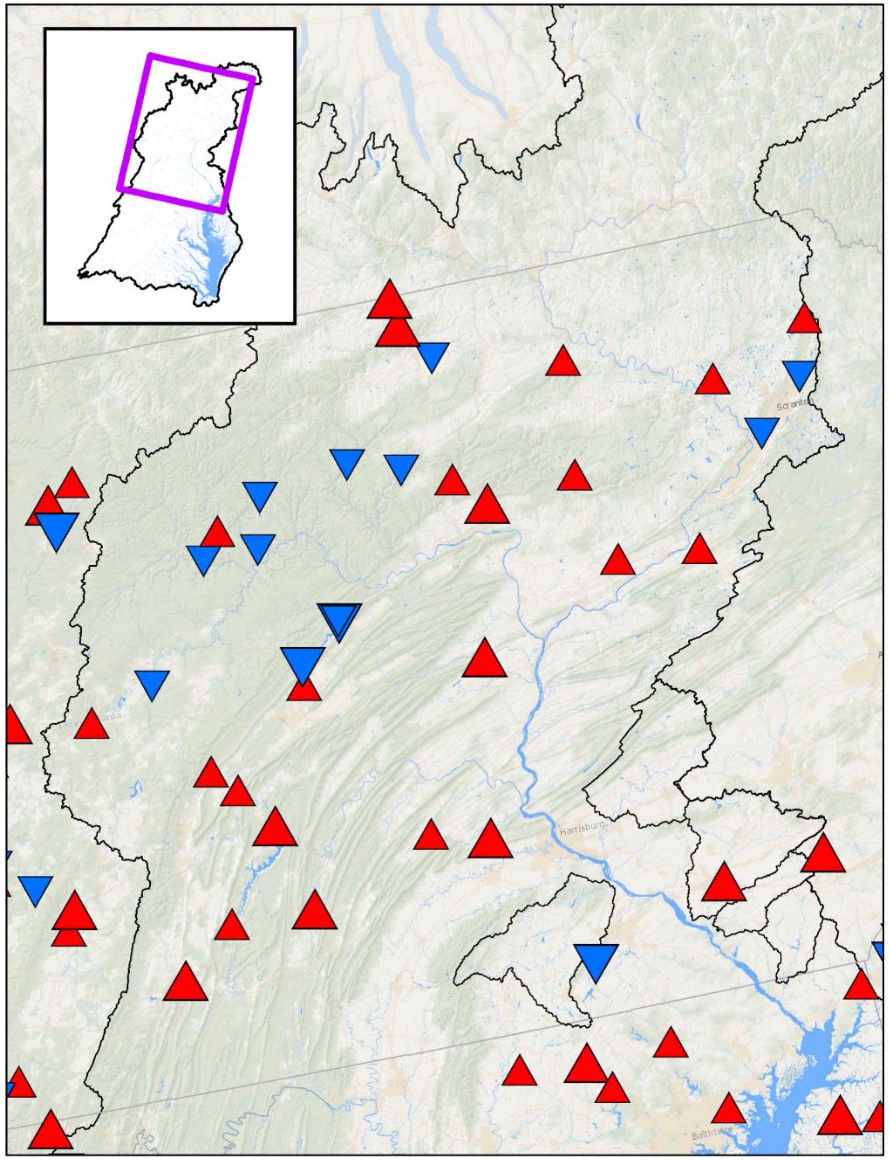
Predicted Likelihood of Occurrence
- Low
- Moderately Low
- Moderate
- Moderately High
- High

Fish Habitat Decision Support Tool; http://www.fishhabitattool.org/

And it’s not just about water quality…

- **Local waters benefit from the same conservation and restoration practices that help the Bay**
- **For example, stream temperatures are rising across the region, which impacts native fish species such as brook trout**

Modified from Rice, K. & Jastram, J.D., 2015.



Temperature Trends

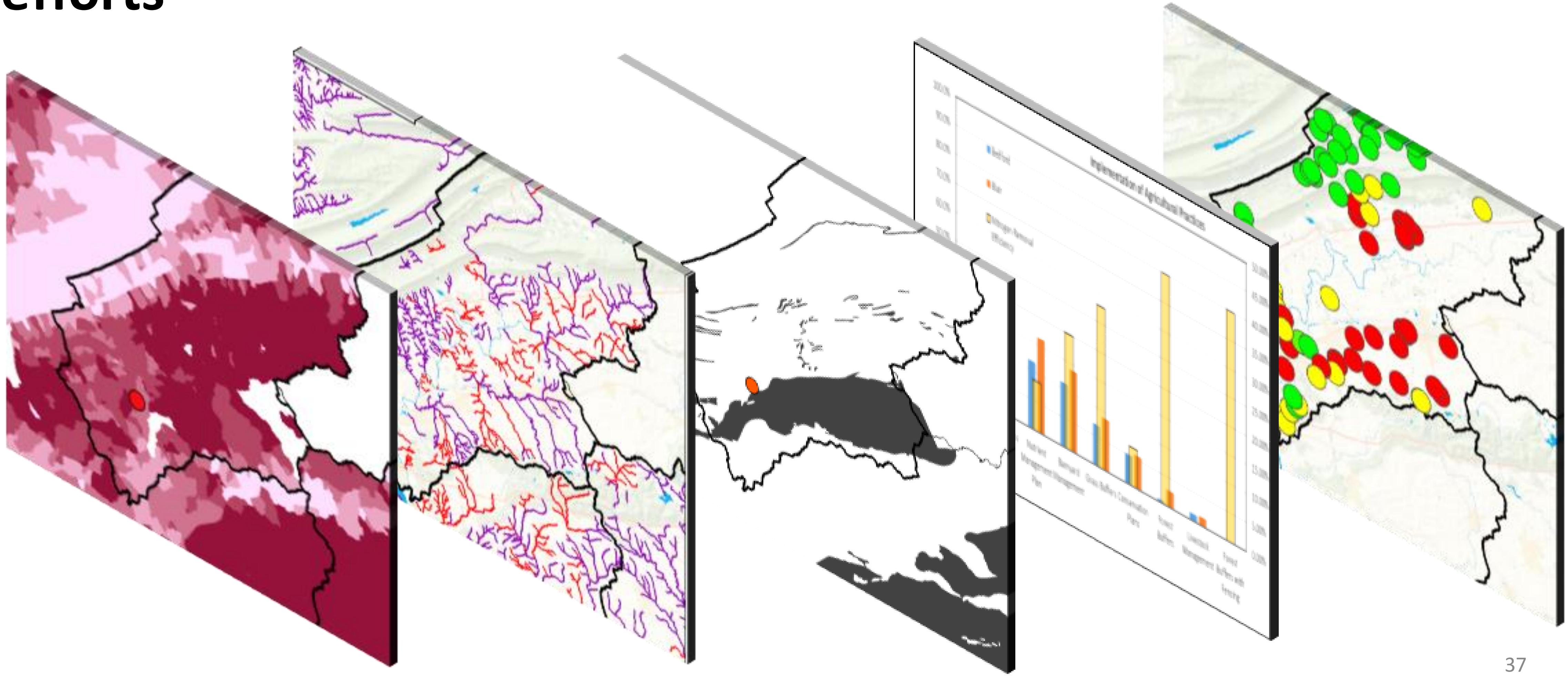
Increasing

Decreasing

*larger symbol represents trend is significant

A LOT of new and updated info available…

…that can be integrated together to answer questions and inform efforts



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Falcone, J.A., 2015, U.S. conterminous wall-to-wall anthropogenic land use trends (NWALT), 1974–2012: U.S. Geological Survey Data Series 948, 33 p. plus appendixes 3–6 as separate files, http://dx.doi.org/10.3133/ds948.

Ator, S.W., and Denver, J.M., 2015, Understanding nutrients in the Chesapeake Bay watershed and implications for management and restoration—the Eastern Shore (ver. 1.2, June 2015): U.S. Geological Survey Circular 1406, 72 p., *http://dx.doi.org/10.3133/cir1406*.

Bachman, L.J., Lindsey, B., Brakebill, J., & Powars, D.S. 1998. Ground-water discharge and base-flow nitrate loads of nontidal streams, and their relation to a hydrogeomorphic classification of the Chesapeake Bay watershed, Middle Atlantic Coast: U.S. Geological Survey Water Resources Investigations Report 98-4059, 77 p., http://

Explaining nitrogen loads and trends in Chesapeake Bay tributaries: an interim report. Jimmy Webber, USGS, unpublished. DO NOT CITE OR DISTRIBUTE.

Ator, S.W., Brakebill, J.W., and Blomquist, J.D., 2011, Sources, fate, and transport of nitrogen and phosphorus in the Chesapeake Bay watershed—An empirical model: U.S. Geological Survey Scientific Investigations Report 2011–5167, 27 p. (Also available at http://pubs.usgs.gov/sir/2011/5167/.)

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Ator, S.W., Denver, J.M. Krantz, D.E. Newell, W.L., Martucci, S.K., 2005. A Surficial Hydrogeologic Framework for the Mid-Atlantic Coastal Plain. U.S. Geological Survey Professional Paper 1680. 49 p. (Also available at https://pubs.usgs.gov/pp/2005/pp1680/#pdf).

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Data Analysis

Land area and loads by source sector from monitoring station basins:

Drainage basins for the USGS stations were taken from USGS. Drainage basins were matched to their land-river segments using ArcGIS (also available on the CBP Watershed Model Segmentation Viewer available off CAST (http://gis.chesapeakebay.net/modeling/). For each land-river segment, total acreage, acreage by individual land-use, and loads by individual land-use were downloaded from Phase 6 CAST 2013 Progress Run (http://cast.chesapeakebay.net). Acreage and loads were aggregated for individual land-uses within each source sector.

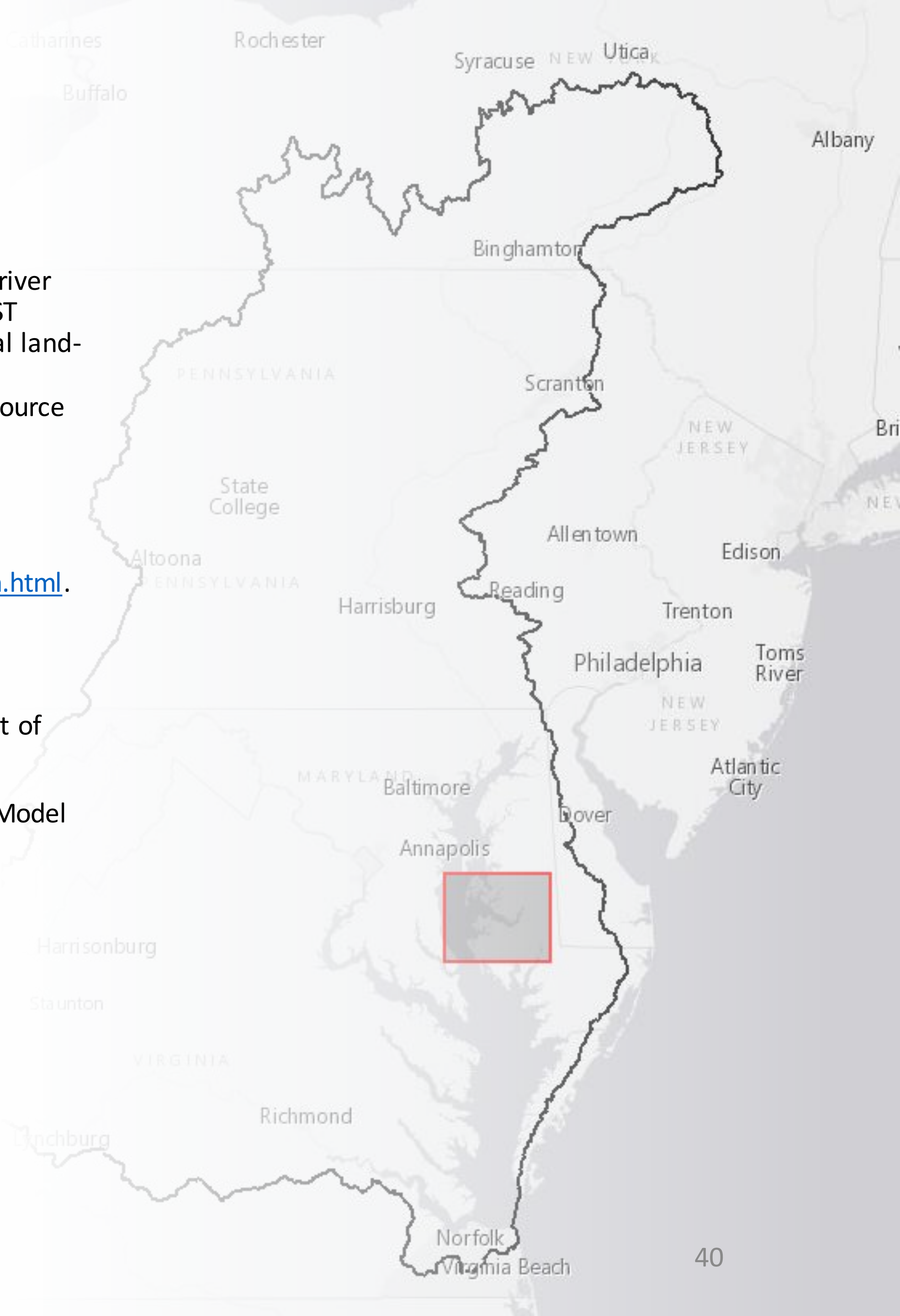
Nitrogen applications:

Nitrogen applications by county and source (lbs/acre/yr) over time were obtained from the Phase 6 Model Calibration Inputs graphical interface available at https://mpa.chesapeakebay.net/Phase6DataVisualization.html.

BMP implementation by practice and county:

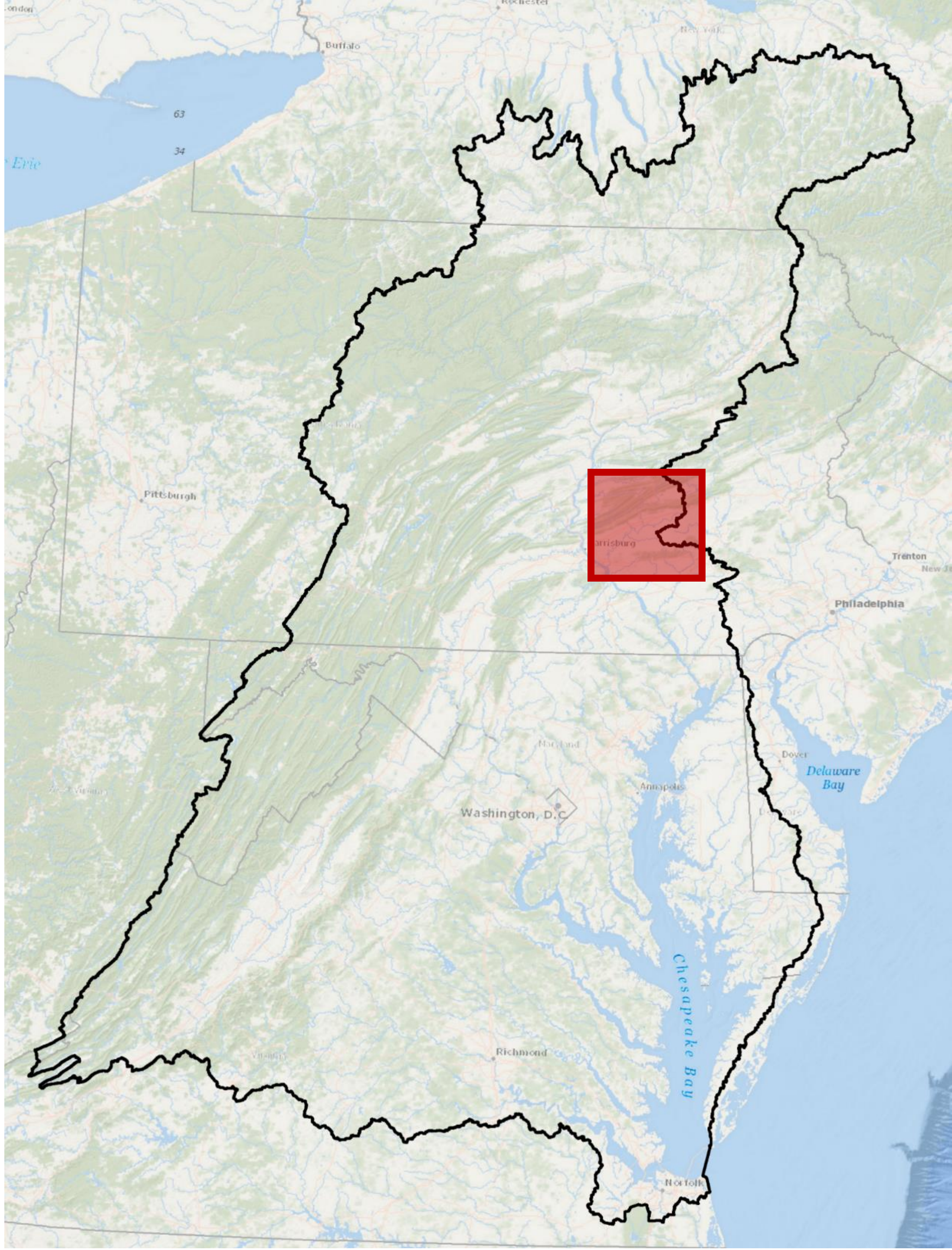
BMP percent implementation was obtained from Phase 6 CAST 2013 BMP Summary Report from http://cast.chesapeakebay.net. Percent implementation is defined as the percent of total acres credited out of the total acres of land-use available for a practice.

Nitrogen effectiveness values for individual agricultural BMPs were obtained from the Phase 6 Watershed Model Source Data, available on Phase 6 CAST (http://cast-beta.chesapeakebay.net/Home/SourceData). Nitrogen effectiveness values for individual agricultural BMPs were averaged by BMP type for the geologic region.



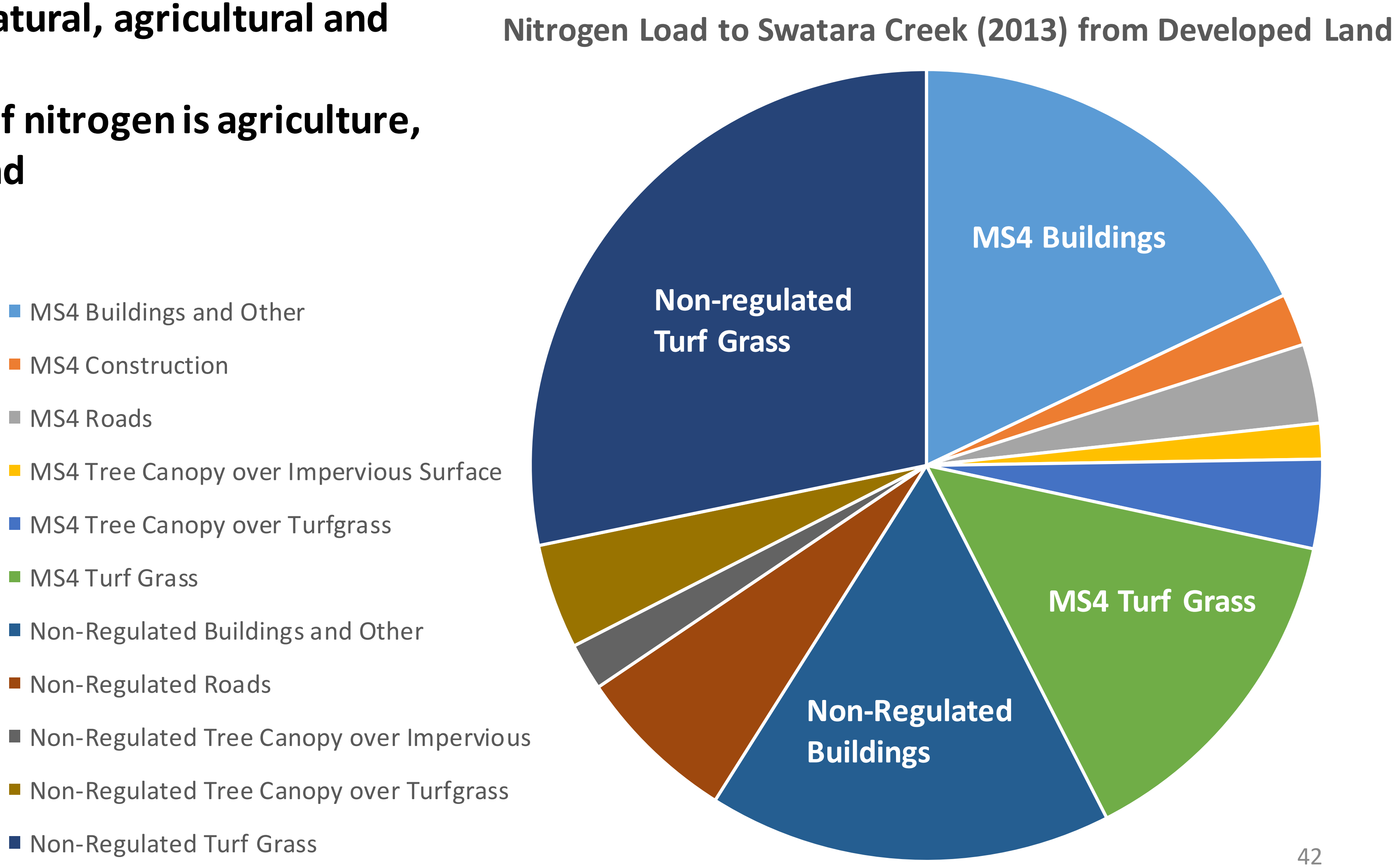
Status & Trends Summary

- Total nitrogen and nitrate trends are improving at Swatara Creek
- Swatara Creek is one of the watershed's highest loading areas
- Swatara Creek is in the mid-range for monitoring stations in percent total nitrogen reduction (2005-2014)



Where is nitrogen coming from?

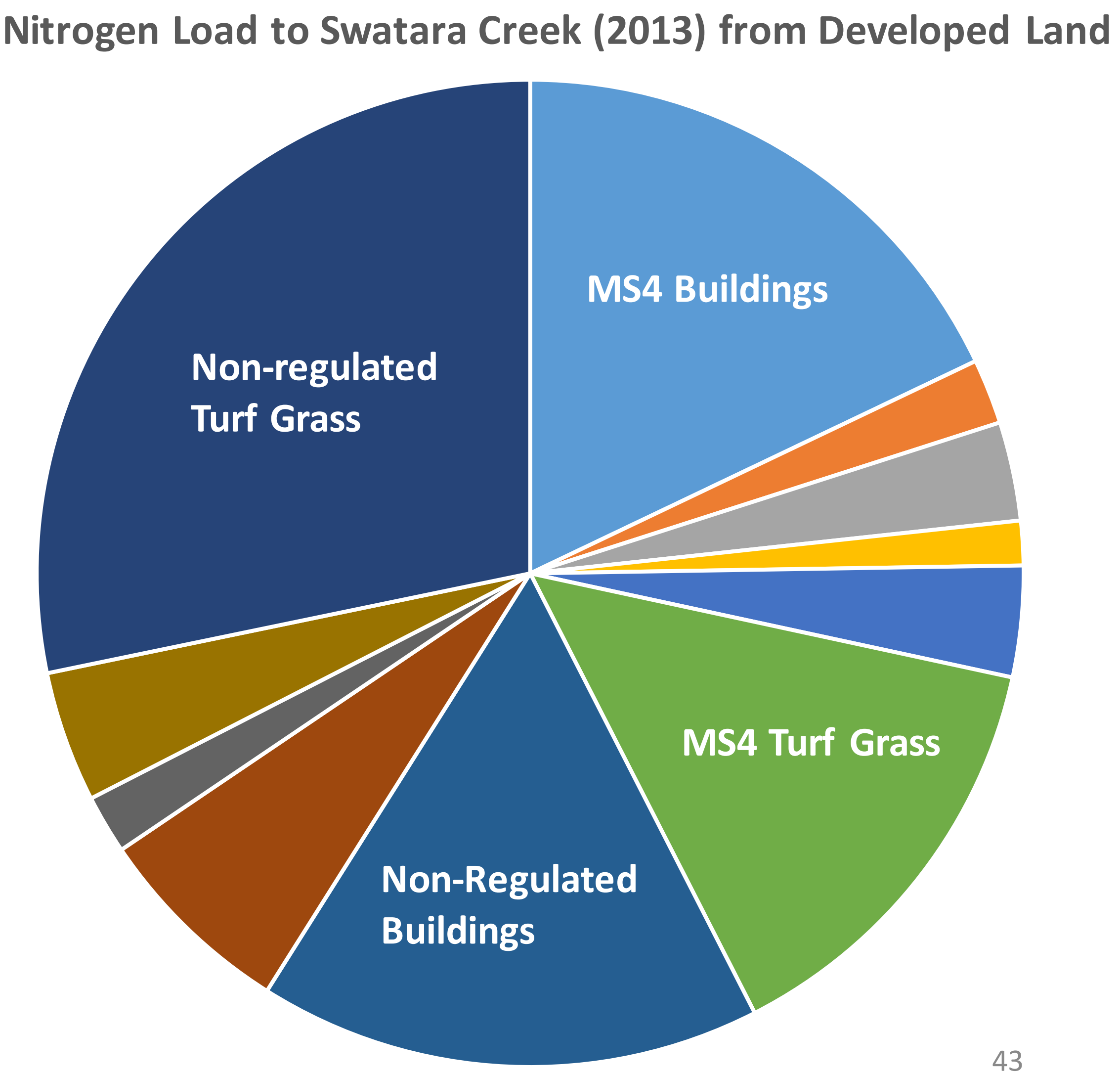
- **Land-use is a mixture of natural, agricultural and developed**
- **The predominant source of nitrogen is agriculture, followed by developed land**



From CBP WSM Phase 6 2013 Progress Report. See data analysis at end of this document.

Where is nitrogen coming from?

- **Turf grass = grassy areas within developed land (e.g. lawns, parks, shopping centers, cemeteries)**
- **MS4 = municipal separate storm sewer systems**
- **Municipalities with MS4s that meet certain standards must obtain NPDES permit coverage**



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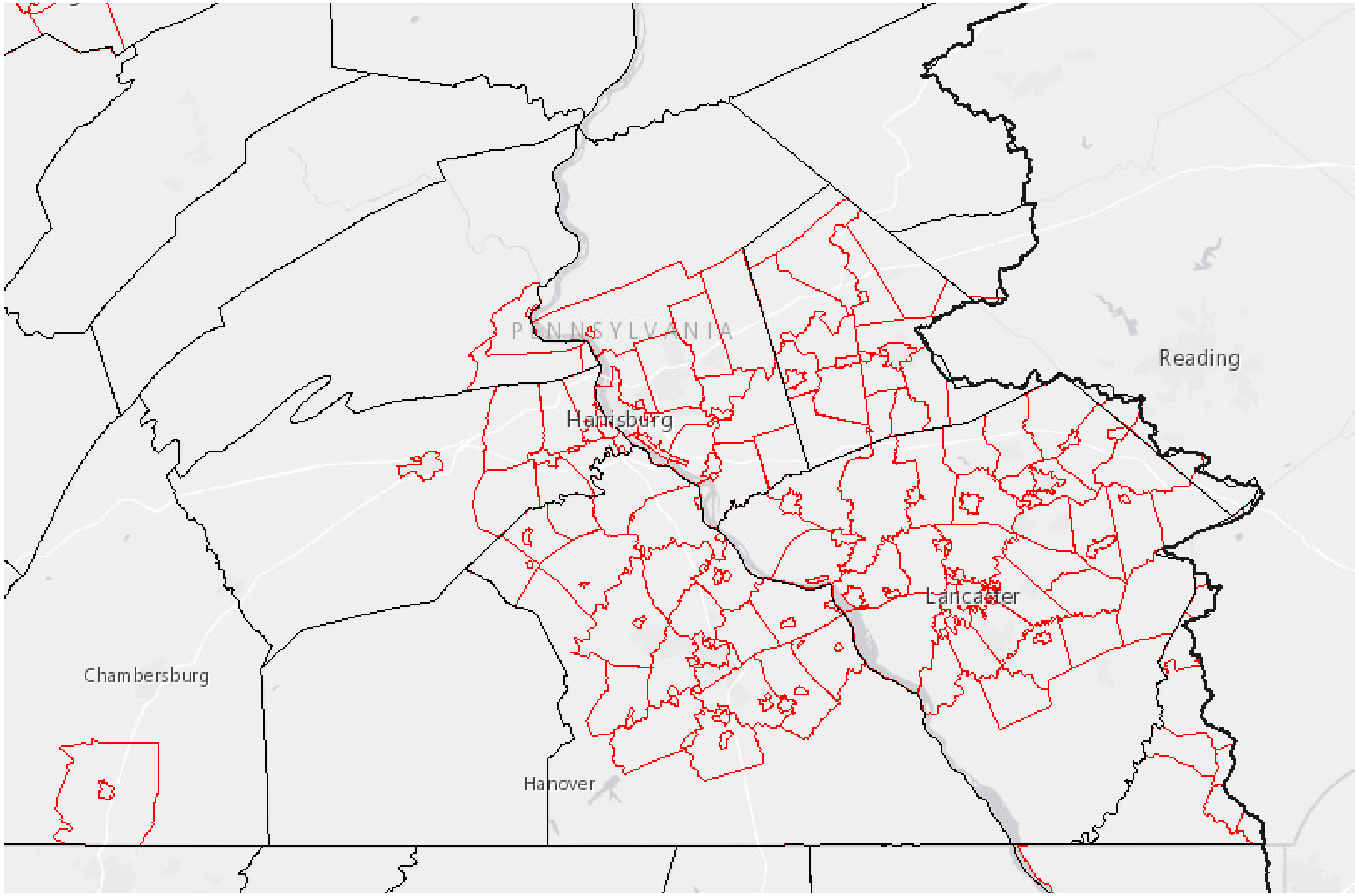
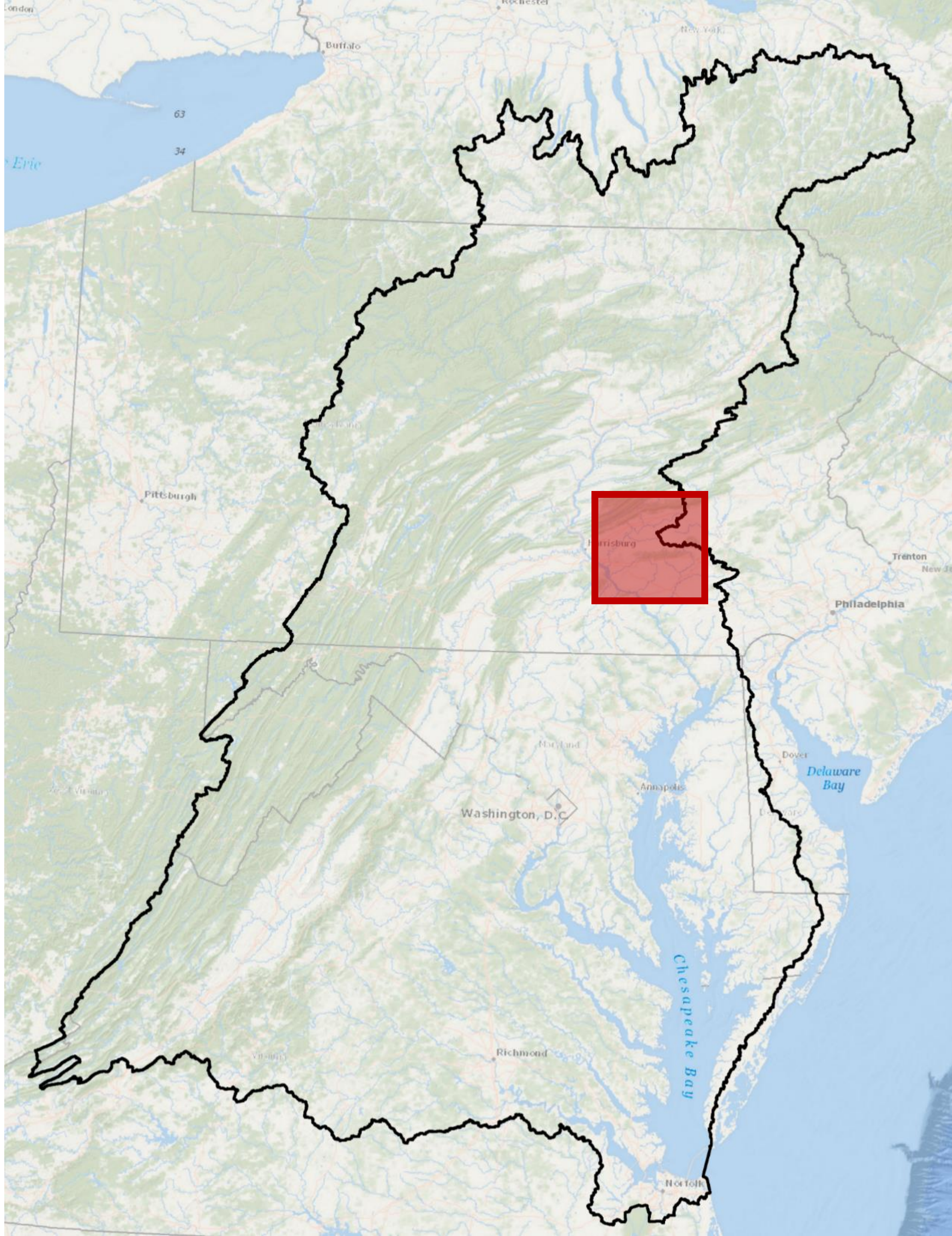
Locations of municipalities with MS4s



From CBP Model Scenario Viewer. Available at cast.chesapeakebay.net.

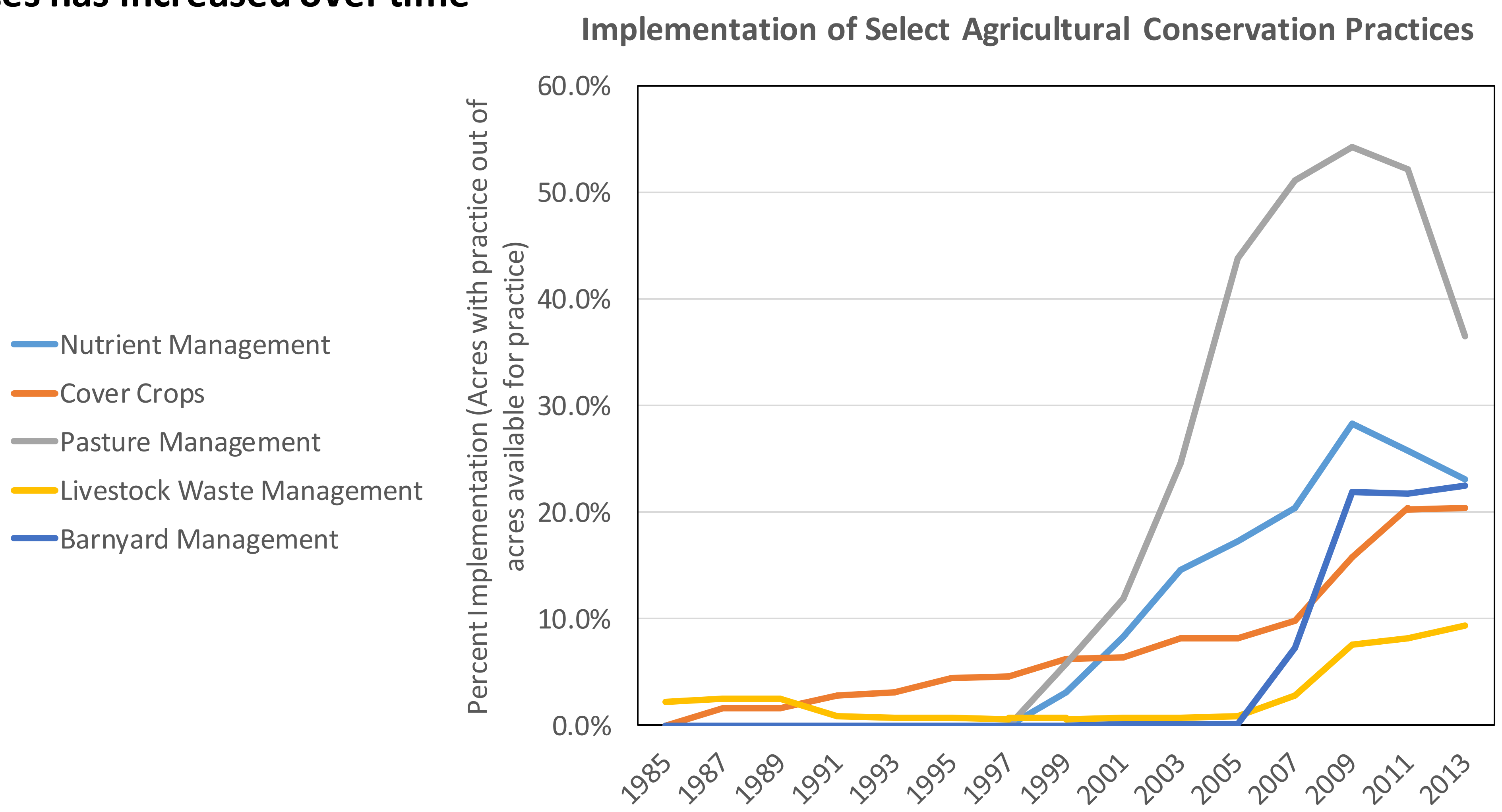
Drivers Summary

- Nitrogen loads come from mixed sources, predominantly agriculture
- Nitrogen reaches streams primarily as nitrate both from groundwater and surface runoff
- Nitrogen in streams reflects recent and past inputs
- Agricultural inputs have decreased over the past few decades, but have recently been increasing
- Inputs from developed land have been increasing



How have practices changed?

- **Implementation of some conservation and restoration practices has increased over time**



From CBP WSM Phase 6 BMP Progress Reports.

Where to focus efforts geographically?

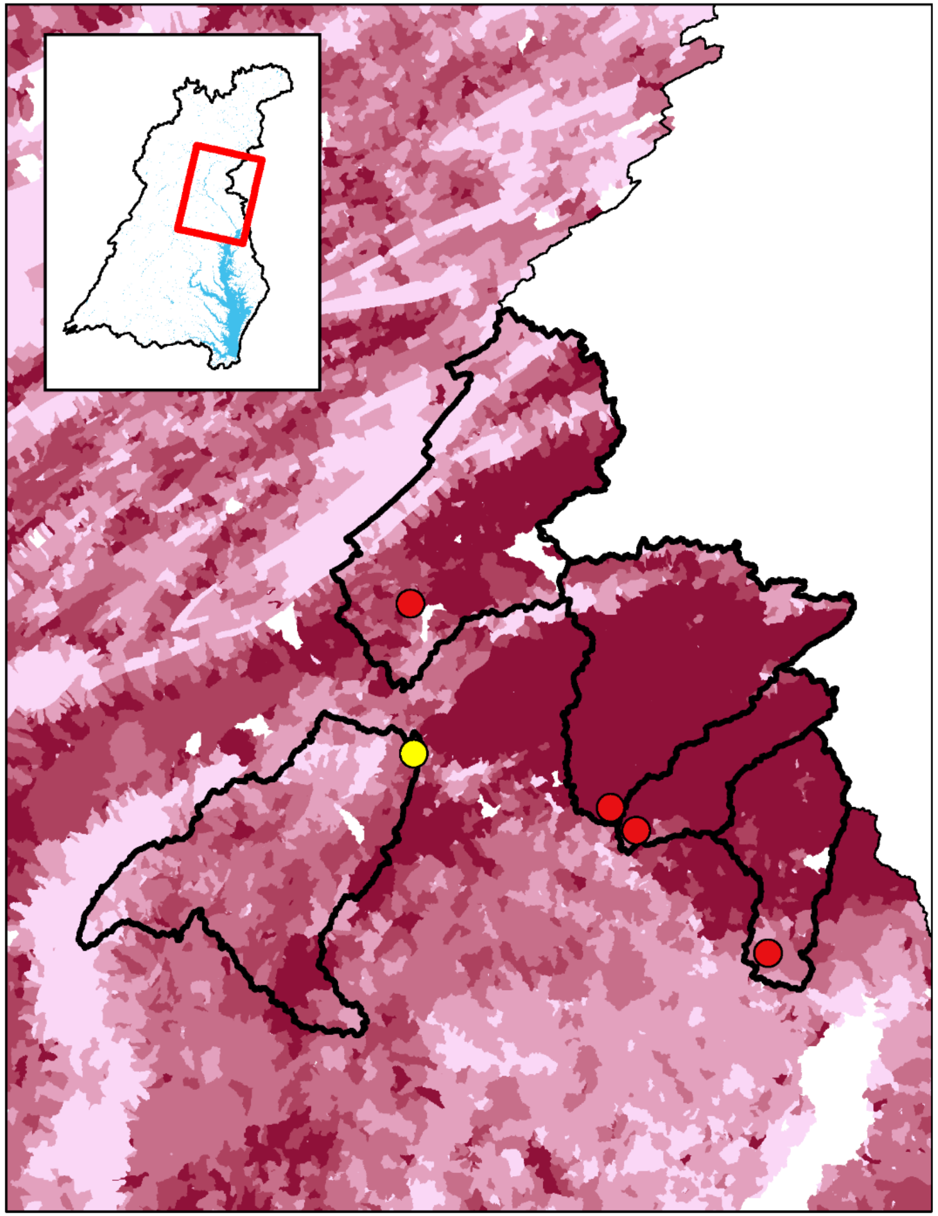
- **Certain areas of the watershed are higher loading than others**
- **These can be the more effective areas to focus restoration efforts**

Total nitrogen yield to local waters in lbs/acre

- <5
- 5 to 10
- 10 to 15
- 15 to 20
- 20 to 25
- >25

Average Total Nitrogen yield (2005-2014) in lbs/acre

- 0 to 6.88
- 6.89 to 13.8
- 13.9 to 33.4



Modified from Jimmy Webber, USGS, using Ator, S. et al, 2011.

Where to focus efforts geographically?

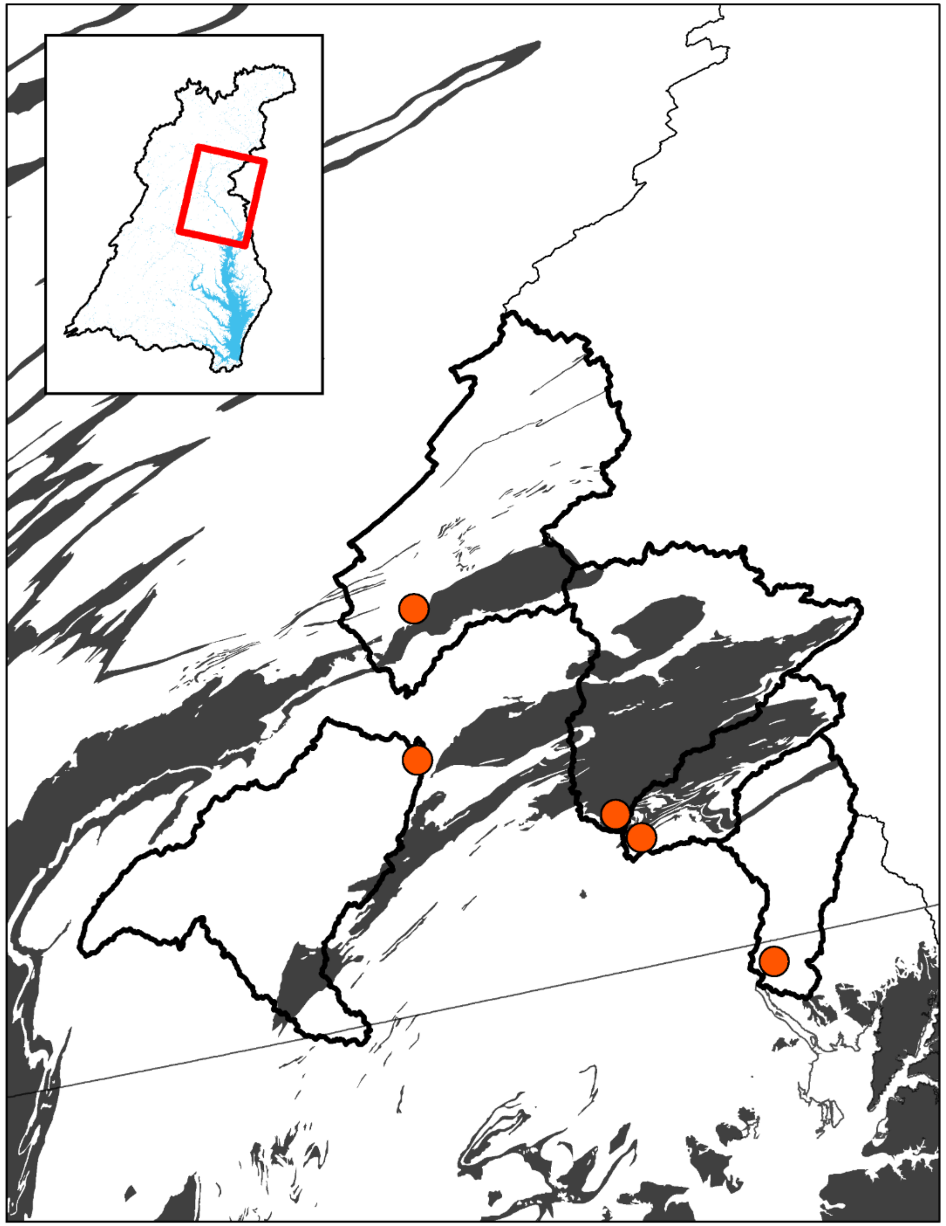
- **Geology makes the groundwater (and therefore streams) in some areas especially vulnerable to high nitrogen inputs**
- **These areas can be the most effective to focus practices for nitrate in groundwater**

■ Vulnerable geology

(Areas underlain by carbonate rocks or coarse coastal sediments)

Average Total Nitrogen yield (2005-2014) in lbs/acre

- 0 to 6.88
- 6.89 to 13.8
- 13.9 to 33.4



Modified from Jimmy Webber, USGS, using Brakebill, JW 2000, Ator, S. et al. 2005 and Nolan & Hitt, 2006.
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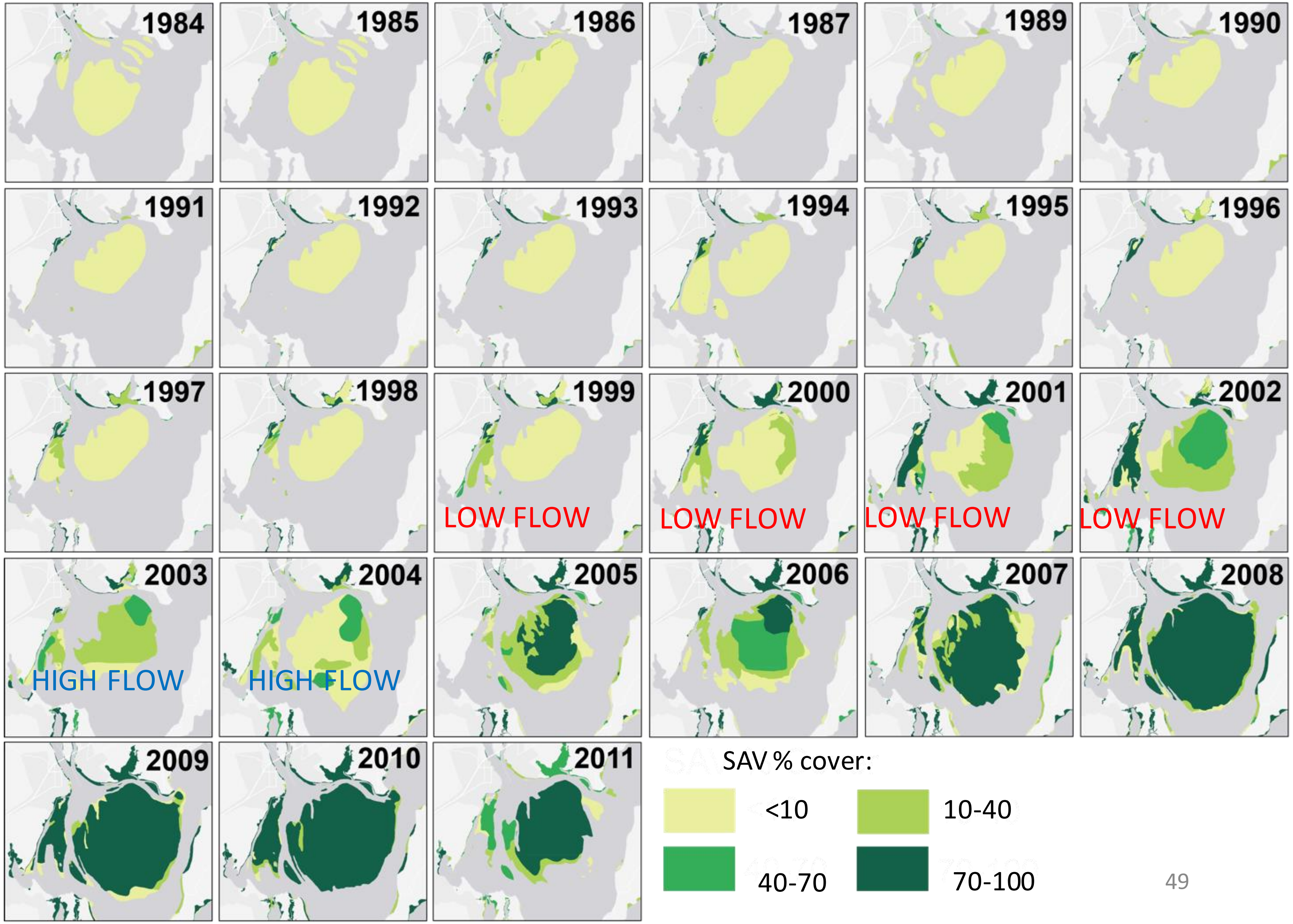
Restoration in Pennsylvania is helping the Bay

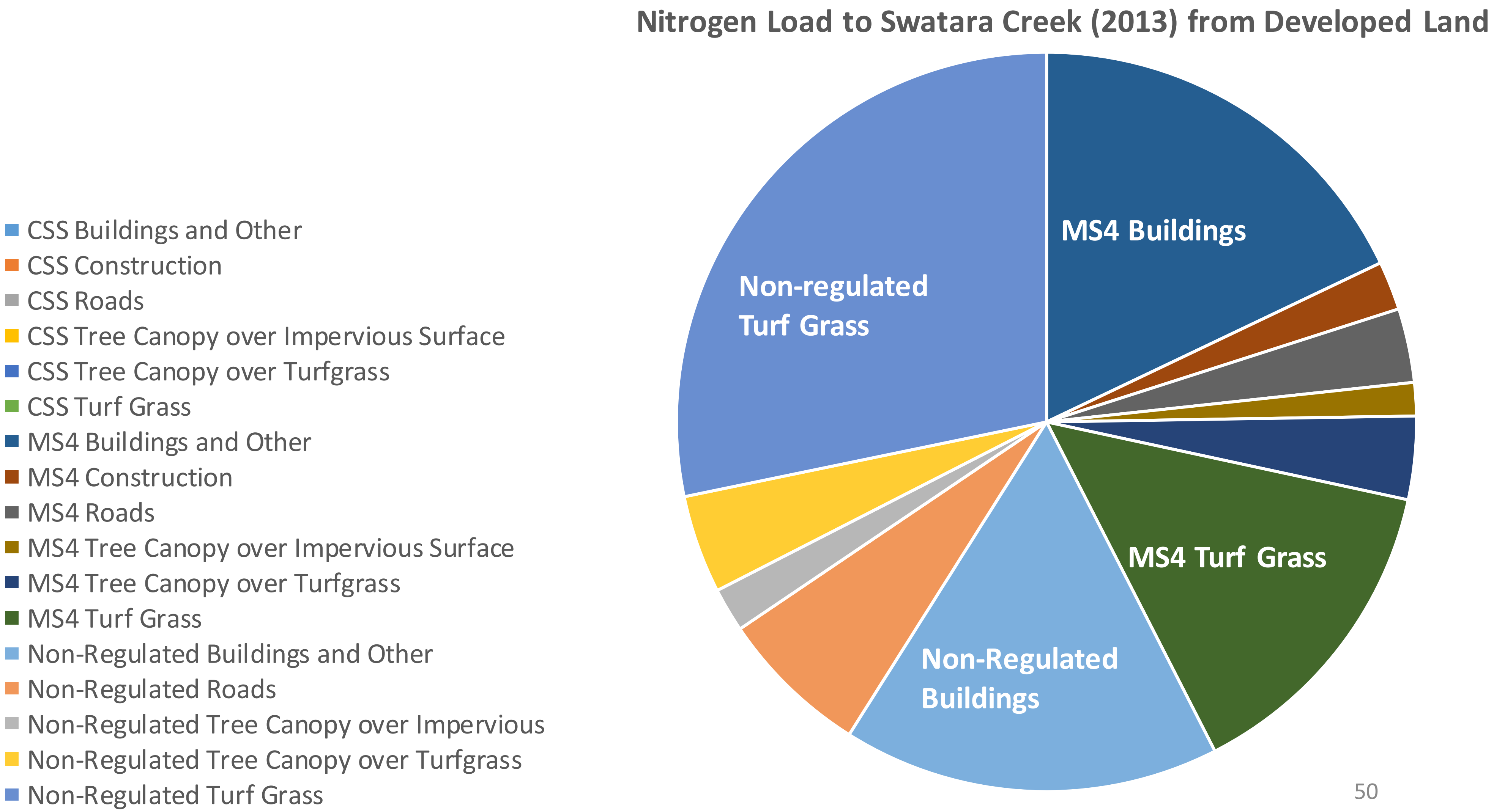
- **Submerged Aquatic Vegetation recovery and resilience have drastically improved in the Susquehanna Flats due to a combination of reduced nutrients and low flow years**



Gurbisz, C. & Kemp, W.M. 2014. *Limonol. Oceanogr.* 59(2):483-494.

What practices to focus on?

- **Loads from developed land are not insignificant in these areas and are increasing**



From CBP WSM Phase 6 2013 Progress Report. See data analysis at end of this document.

A LOT of new and updated info available…

Monitoring & Trends

Nontidal water quality

Tidal water quality

Tidal attainment

Stream & tidal benthic

Submerged aquatic vegetation

Modeling Tools

CBP Watershed Model

Geographic load distribution

Geographic influence on Bay

BMP progress reports

Synthesis Analyses

USGS Non-tidal Syntheses

-Regional Nitrogen, Phosphorus and Sediment

-Groundwater

SAV Synthesis

Water Clarity Synthesis

Water Quality Synthesis

…and more to come