Explaining Three Decades of Watershed and Tidal Water Quality Trends—Implications for Development and Implementation of Phase III WIPs

Requested decisions from PSC

- **Approval of presented approach and schedule for developing and sharing explanations and management implications** of the trends observed at hundreds of monitoring stations around the watershed and across the Bay's tidal waters with the jurisdictions and their local partners.

- **Commitment to work with these explanations of the observed trends and resultant management implications to help inform and guide** the jurisdictions' development of their Phase III Watershed Implementation Plans and adaptively manage their implementation in the years ahead.

These efforts are highly collaborative across the Partnership:

Chesapeake Bay Partnership Office

Rebecca Murphy (UMCES)

Qian Zhang (UMCES)

Melissa Merritt (CRC)

Lindsey Gordon (CRC)

Peter Tango (USGS)

John Wolf (USGS)

Multi-institution research teams

USGS VIMS UMCES

ICPRB VCU

Others

Doug Moyer (USGS)

Jimmy Webber (USGS)

Renee Karrh (MD DNR)

Mike Lane (ODU)

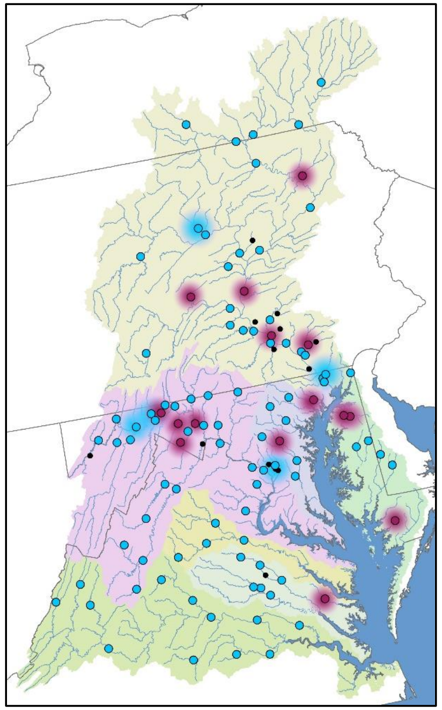
Dozens more…

Nutrient Loads and Trends in the Watershed Stream Network

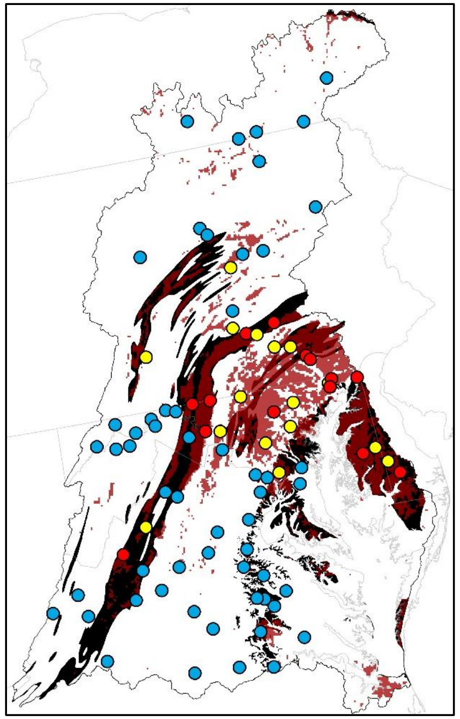
An update of new results and implications for management

Joel Blomquist, USGS, Hydrologist, Explaining Change Coordinator

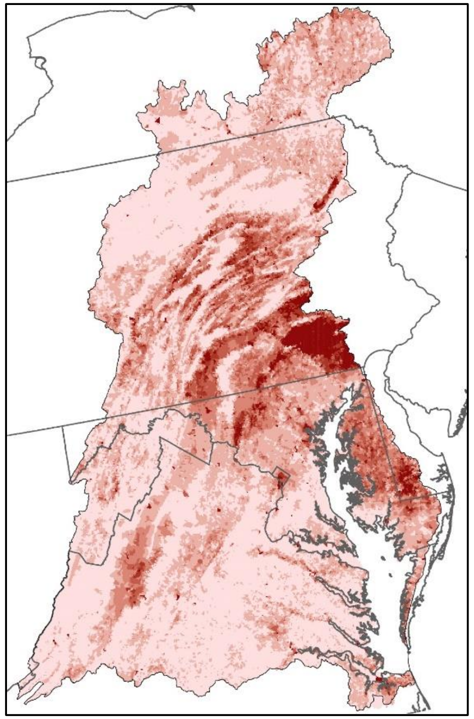
The building blocks necessary to explain water quality trends



Data Collection



Understanding Watershed Processes

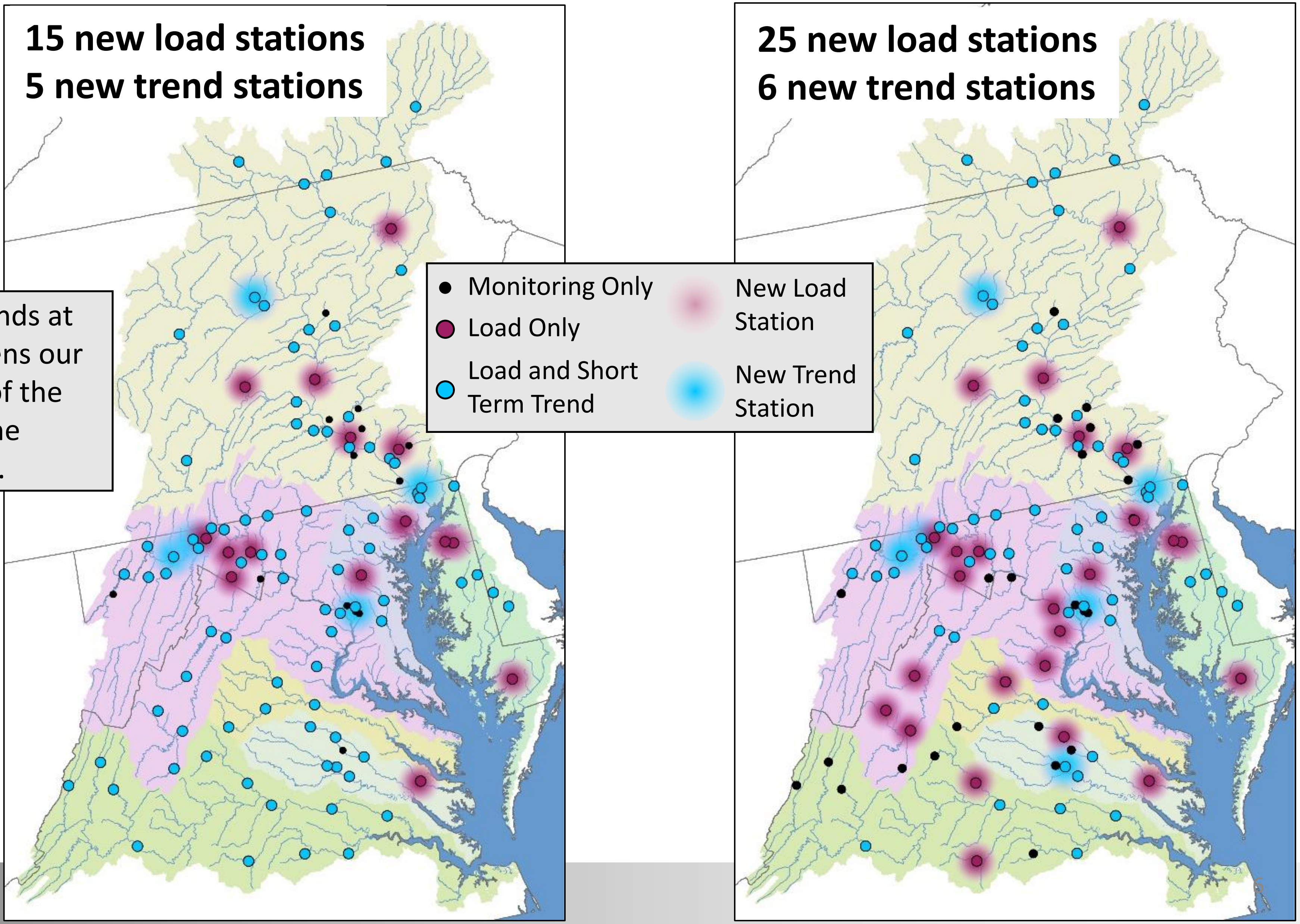


Integrated Understanding

Loads and trend results are available at an increased number of stations

The computation of loads and trends at these additional stations strengthens our science and is possible because of the continued investment from the Chesapeake Bay partnership.

Total Nitrogen **Total Phosphorus**



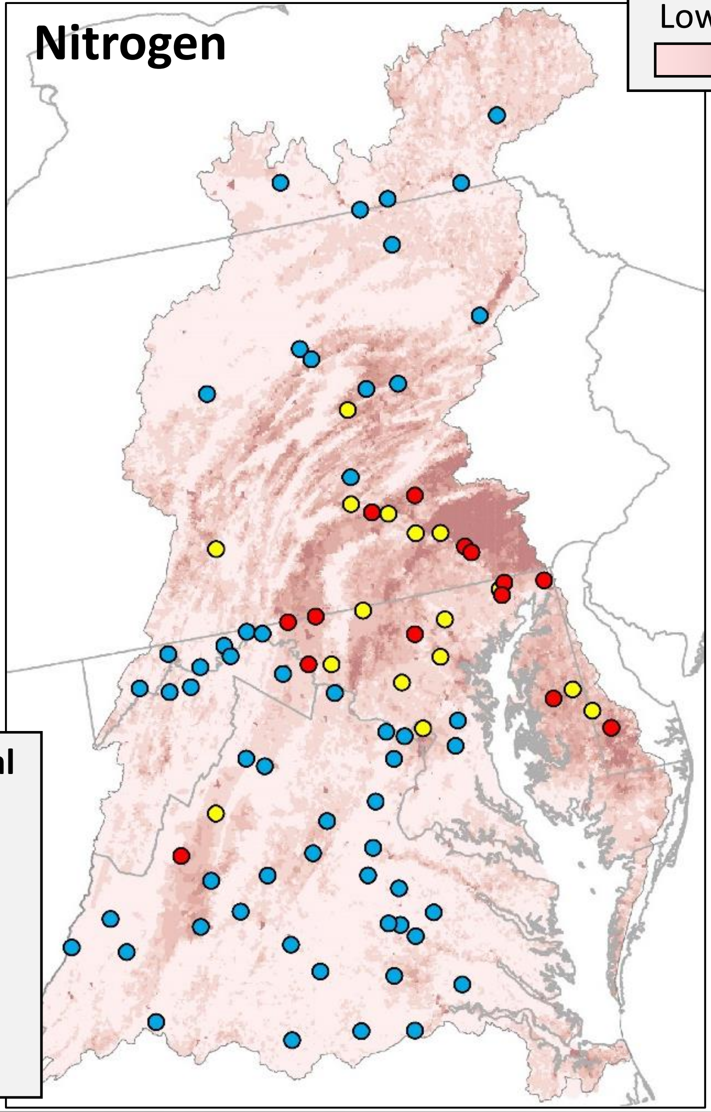
The spatial distribution of nutrient per-acre loads has remained relatively similar through time

High per-acre loads exist in these areas because:

1. These areas have received the greatest amount of nutrient inputs in the watershed.
2. There has been a long history of elevated nutrient inputs in these locations.
3. The environmental setting of these areas promote the transport of nutrients to the stream.

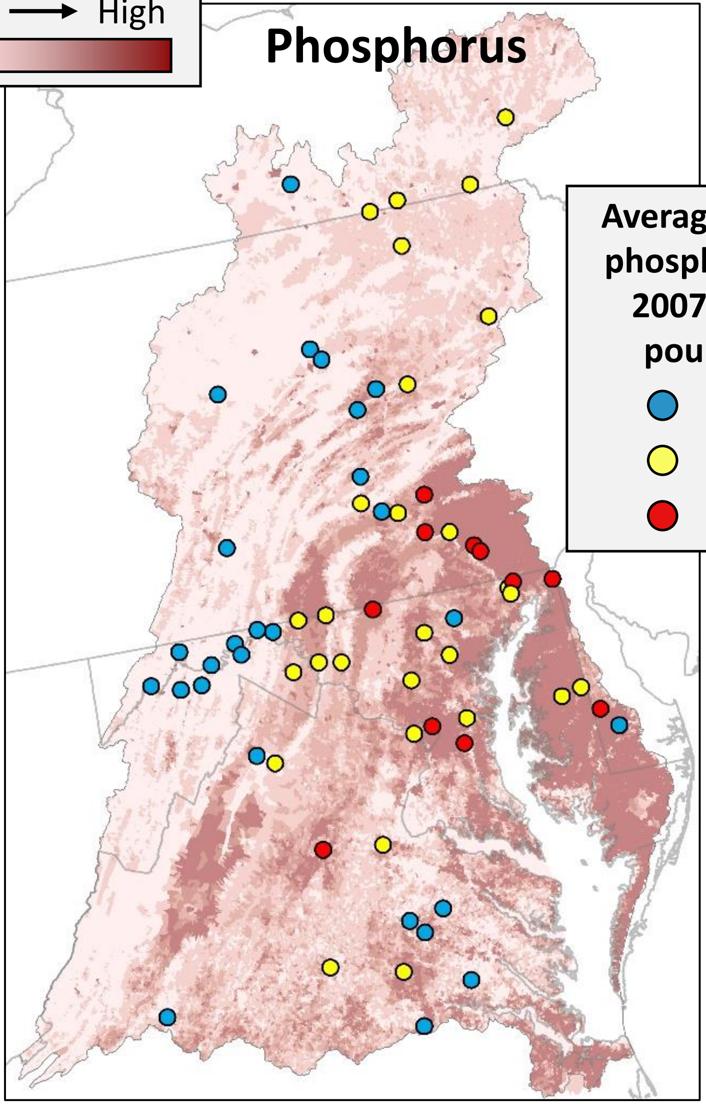
Nutrient per-acre load[2]

Low ⟶ High



Average load[1] of total nitrogen between 2007 and 2016, in pounds per acre

- (blue) 1.19 to 6.33
- (yellow) 6.34 to 12.67
- (red) 12.68 to 30.03



Average load[1] of total phosphorus between 2007 and 2016, in pounds per acre

- (blue) 0.12 to 0.38
- (yellow) 0.39 to 0.75
- (red) 0.76 to 2.01

[1]Moyer and others, 2017

[2]Ator and others, 2011

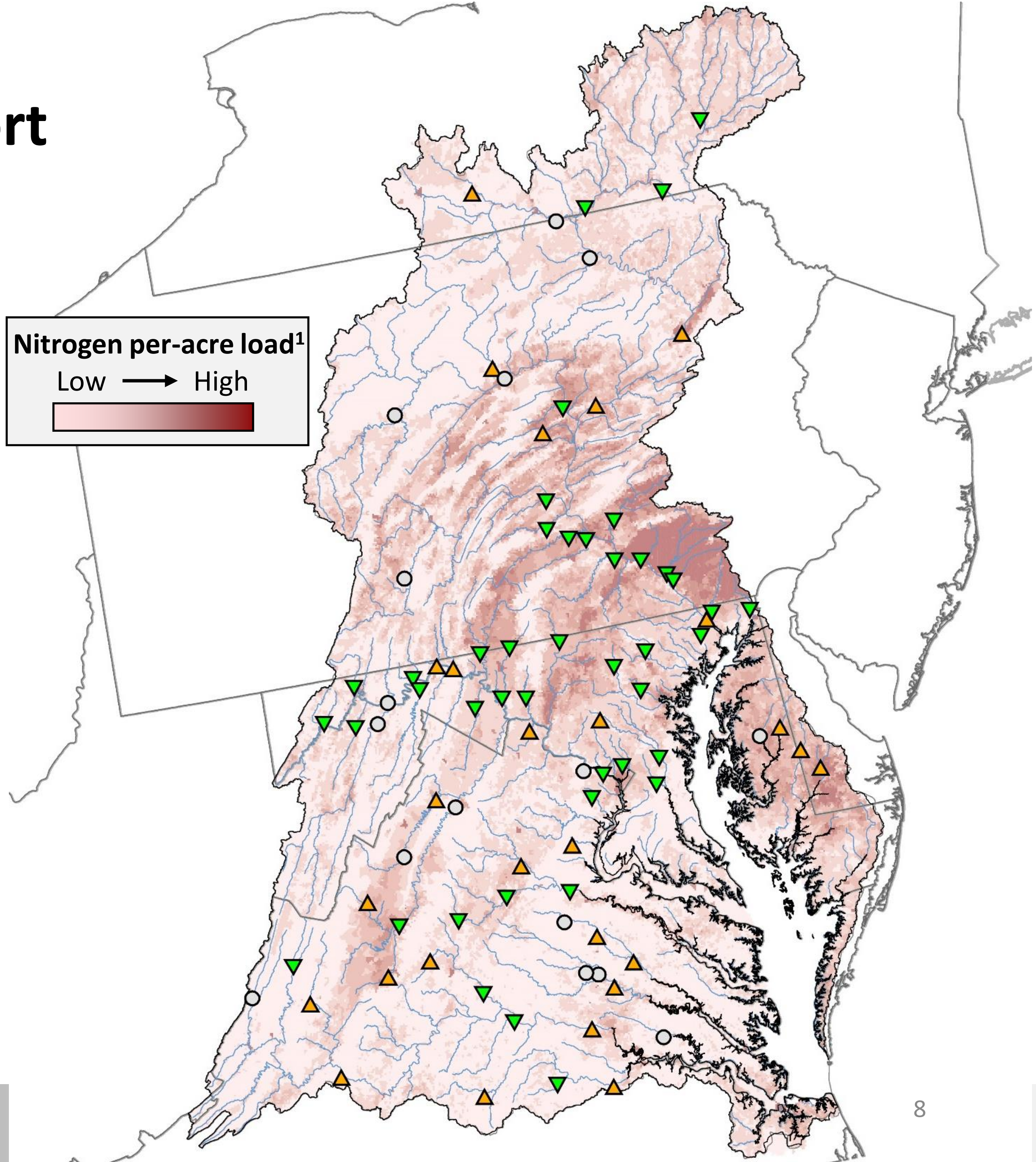
Trends in nitrogen loads result from changing nitrogen inputs or transport

All stations in the most recent ten year period (2007 – 2016)[2]:

% of sites improving: 50%

% of sites degrading: 31%

% of sites with no trend: 19%



[1]Ator and others, 2011 [2]Moyer and others, 2017

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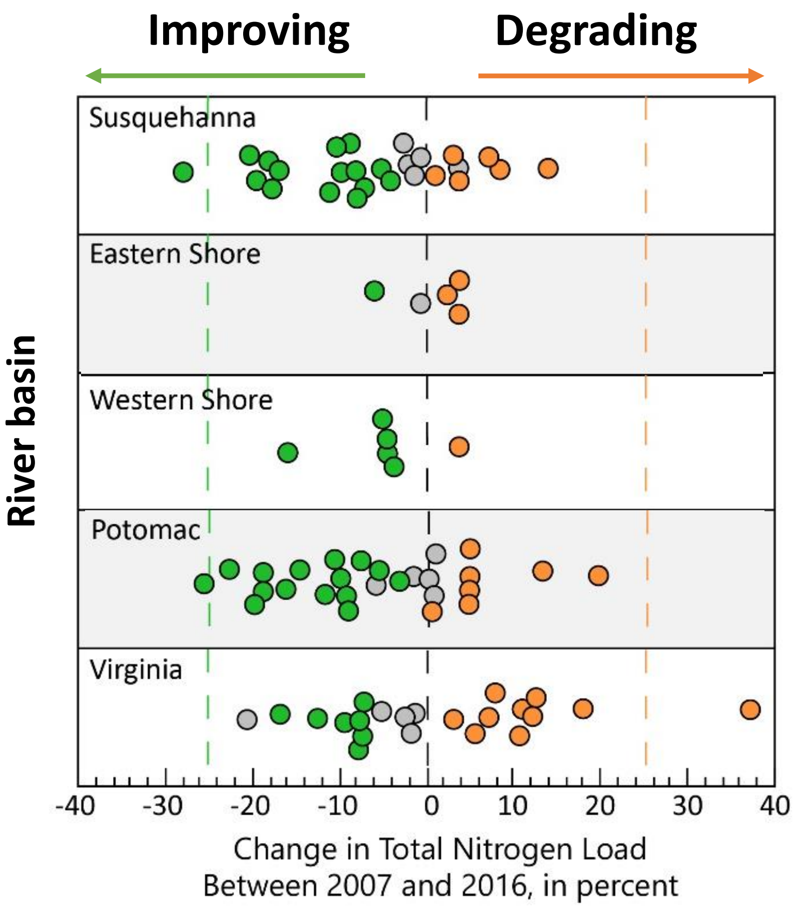

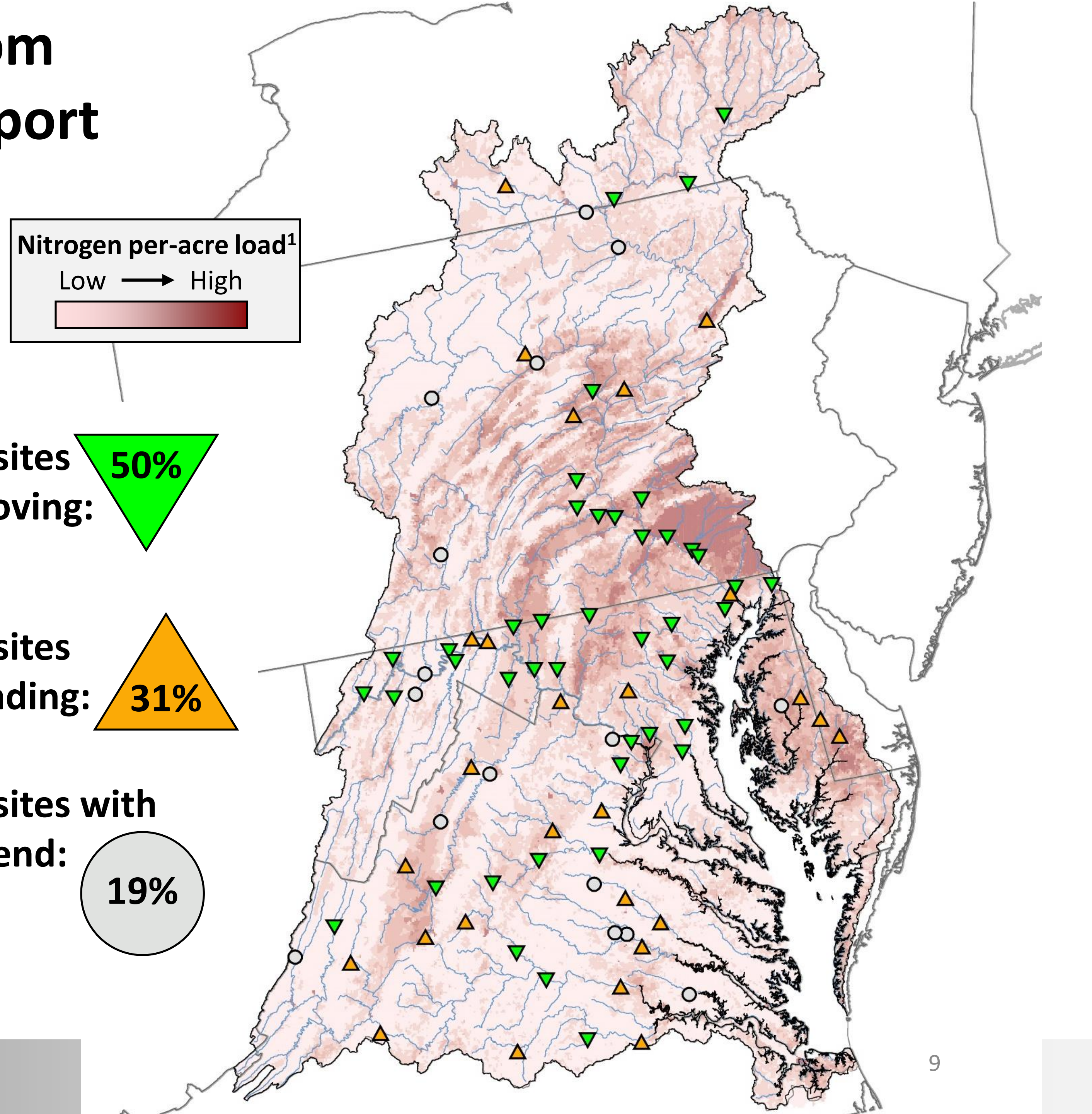

% of sites improving: 50%

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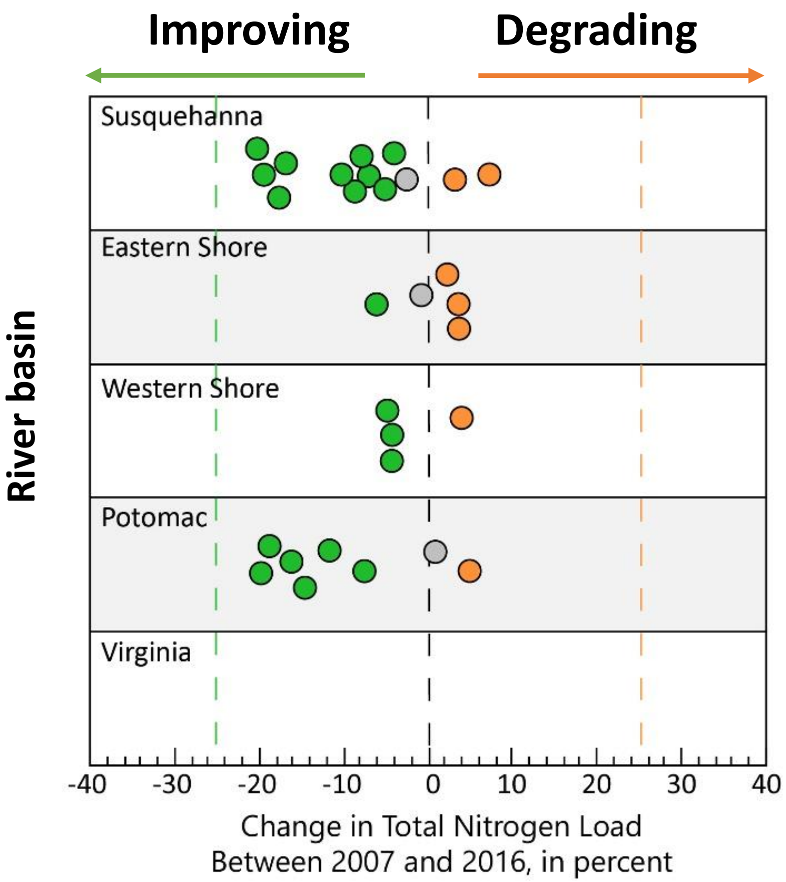
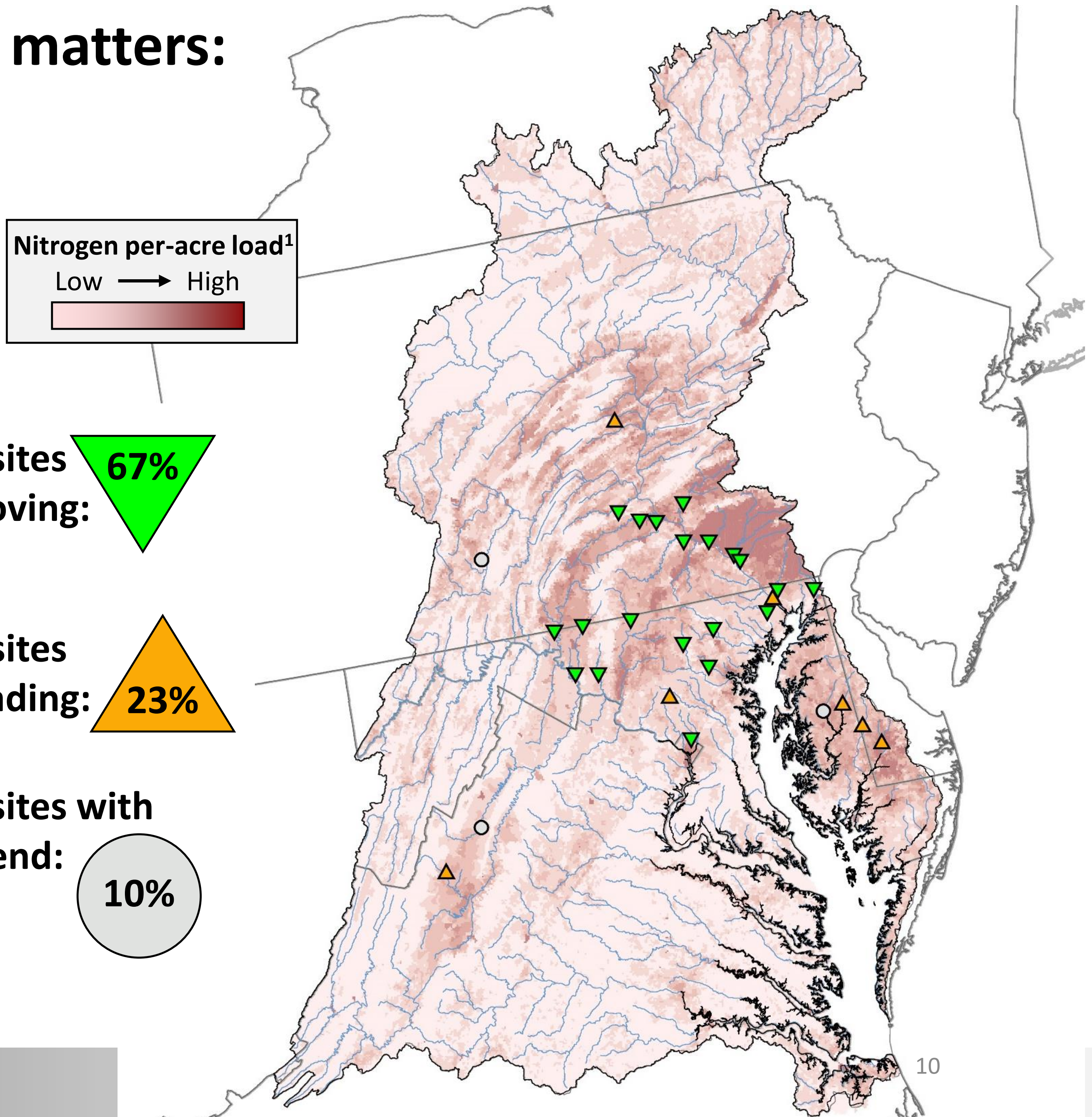
[1]Ator and others, 2011

[2]Moyer and others, 2017

How are we doing where it really matters: nitrogen high-loading areas?

Highest loading areas in the most recent ten year period (2007 – 2016)[2]:





% of sites improving: 67%

% of sites Degrading: 23%

% of sites with no trend: 10%

USGS science for a changing world

[1]Ator and others, 2011

[2]Moyer and others, 2017

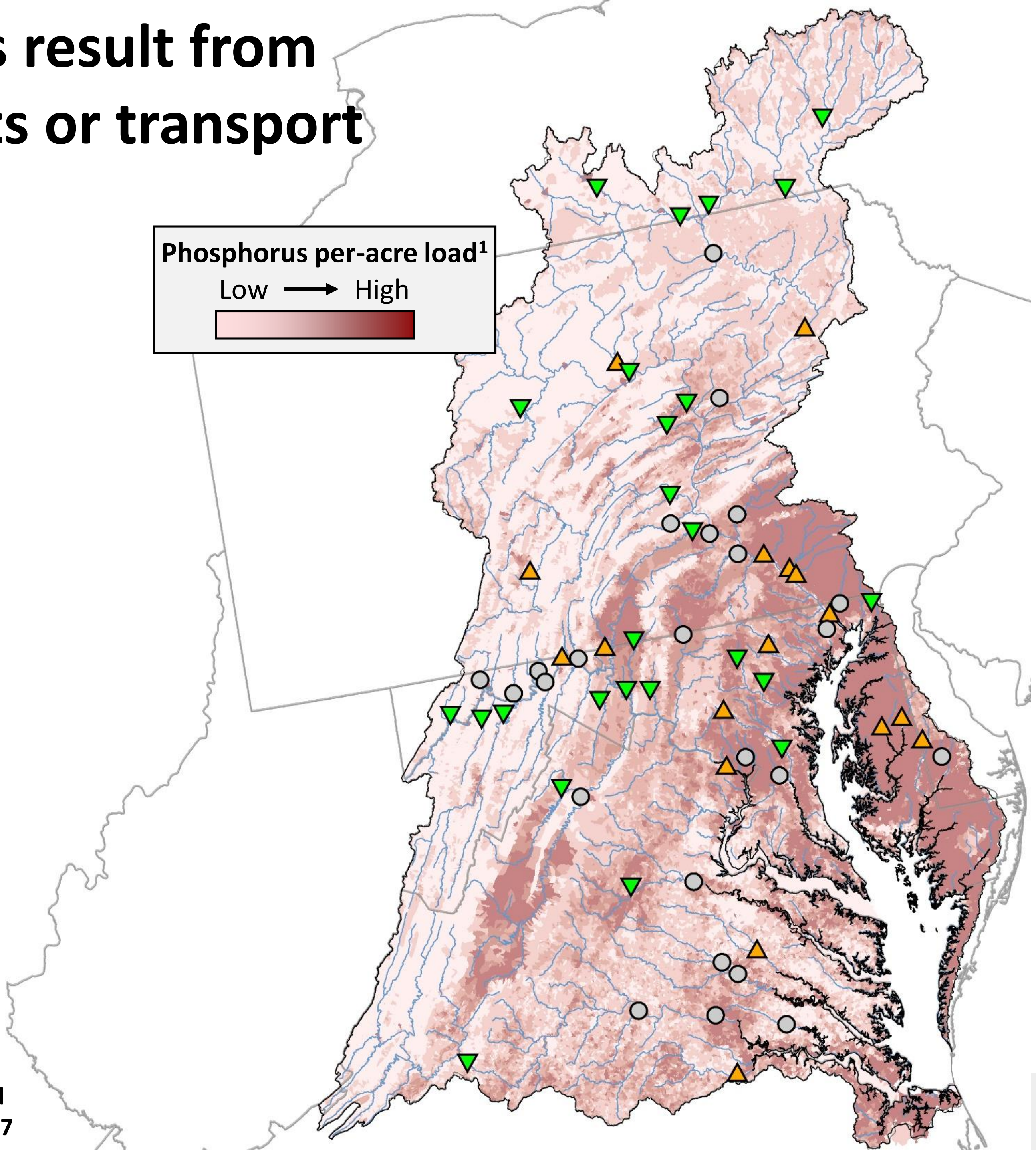
Trends in phosphorus loads result from changing phosphorus inputs or transport

All stations in the most recent ten year period (2007 – 2016)[2]:

% of sites improving: 38%

% of sites Degrading: 26%

% of sites with no trend: 36%



[1]Ator and others, 2011

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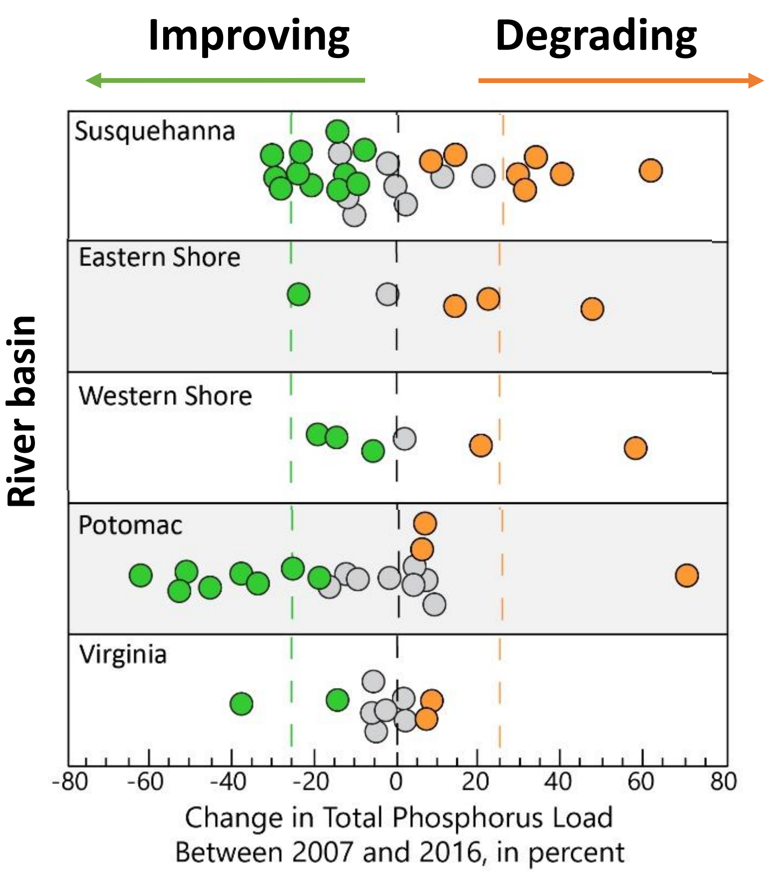

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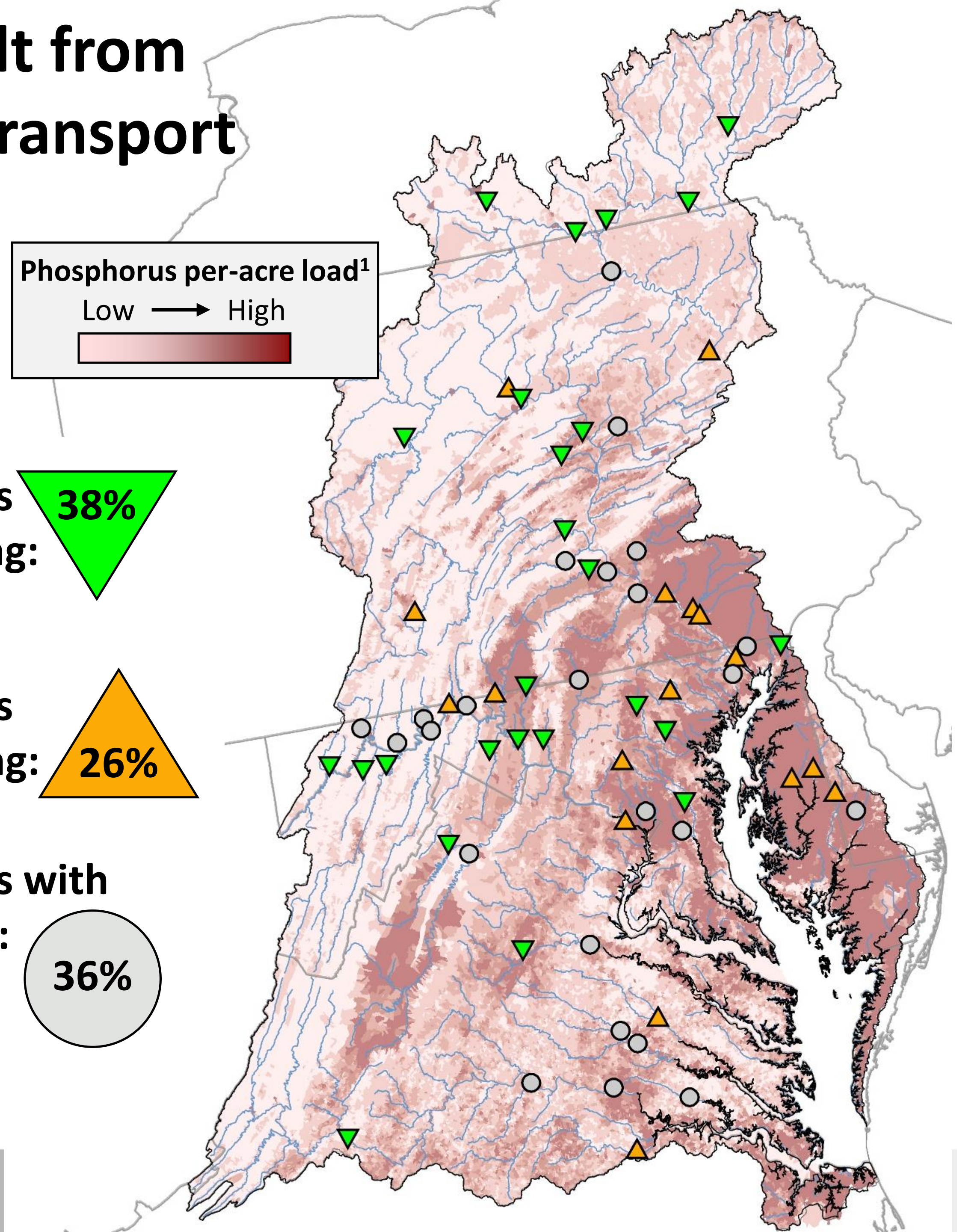
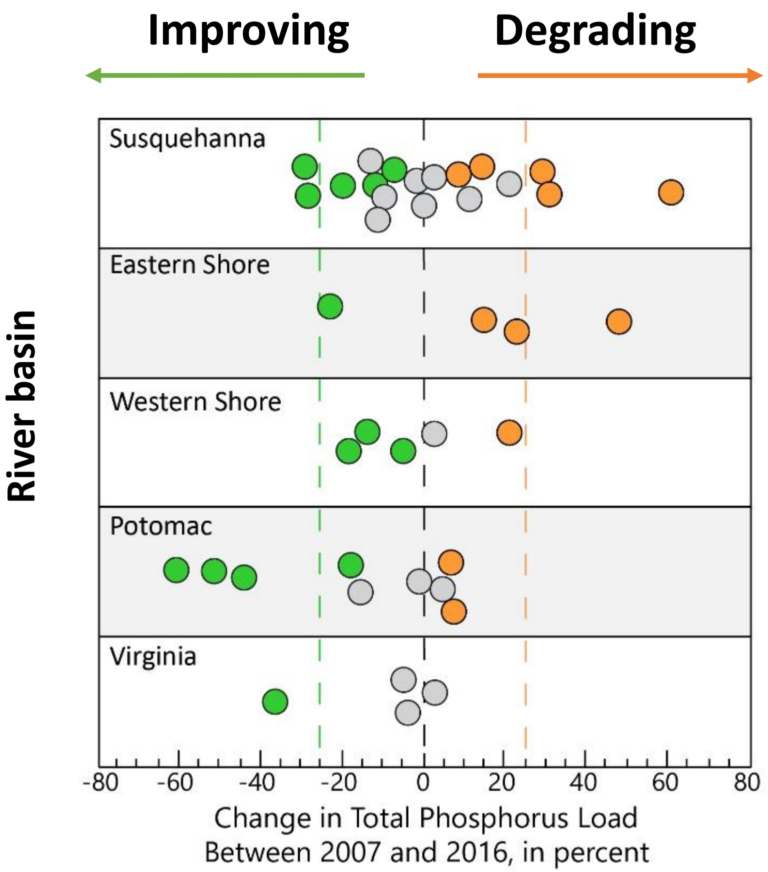


[1]Ator and others, 2011 [2]Moyer and others, 2017

How are we doing where it really matters: phosphorus high-loading areas?

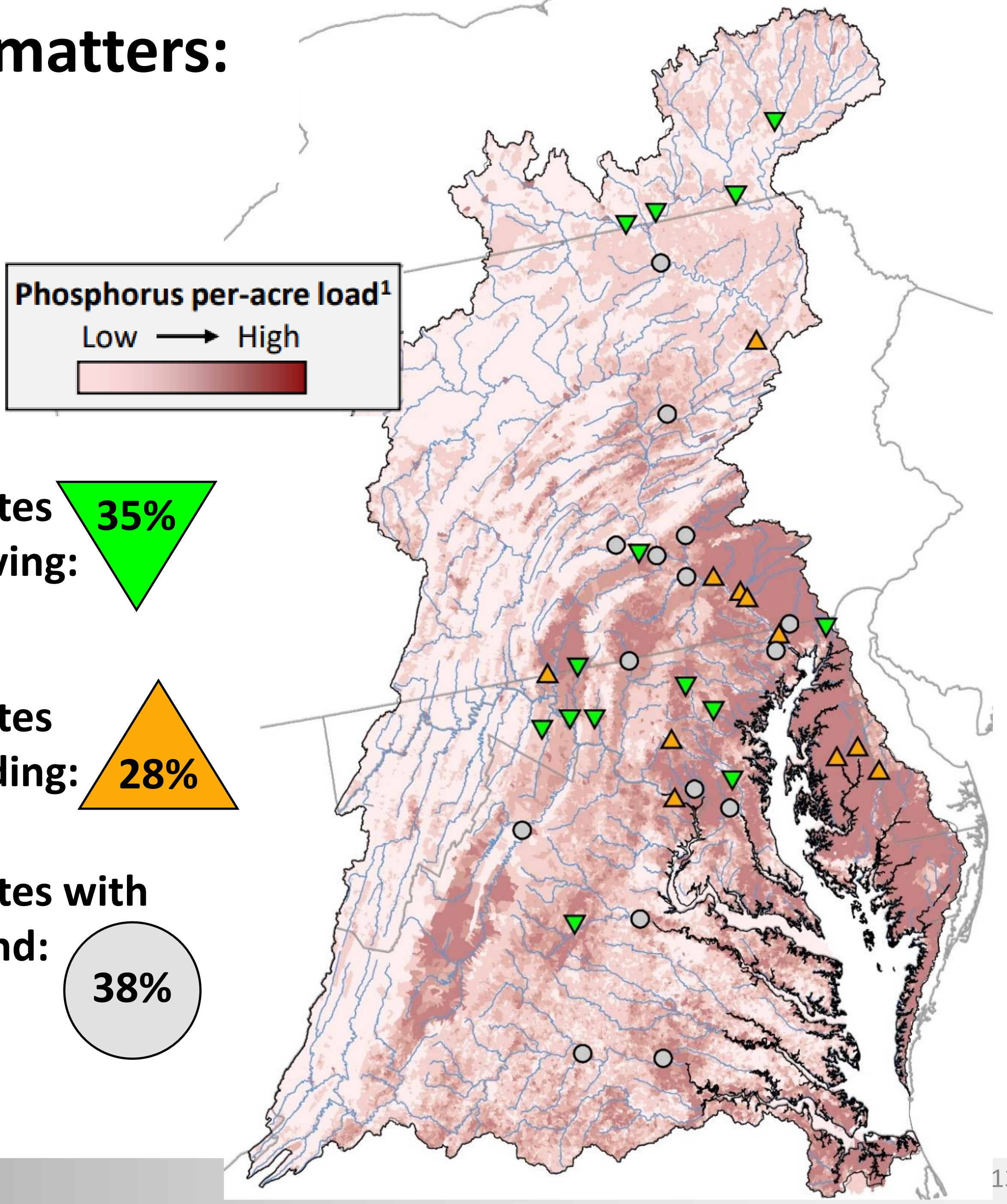
Highest loading areas in the most recent ten year period (2007 – 2016)[1]:



% of sites improving: 35%

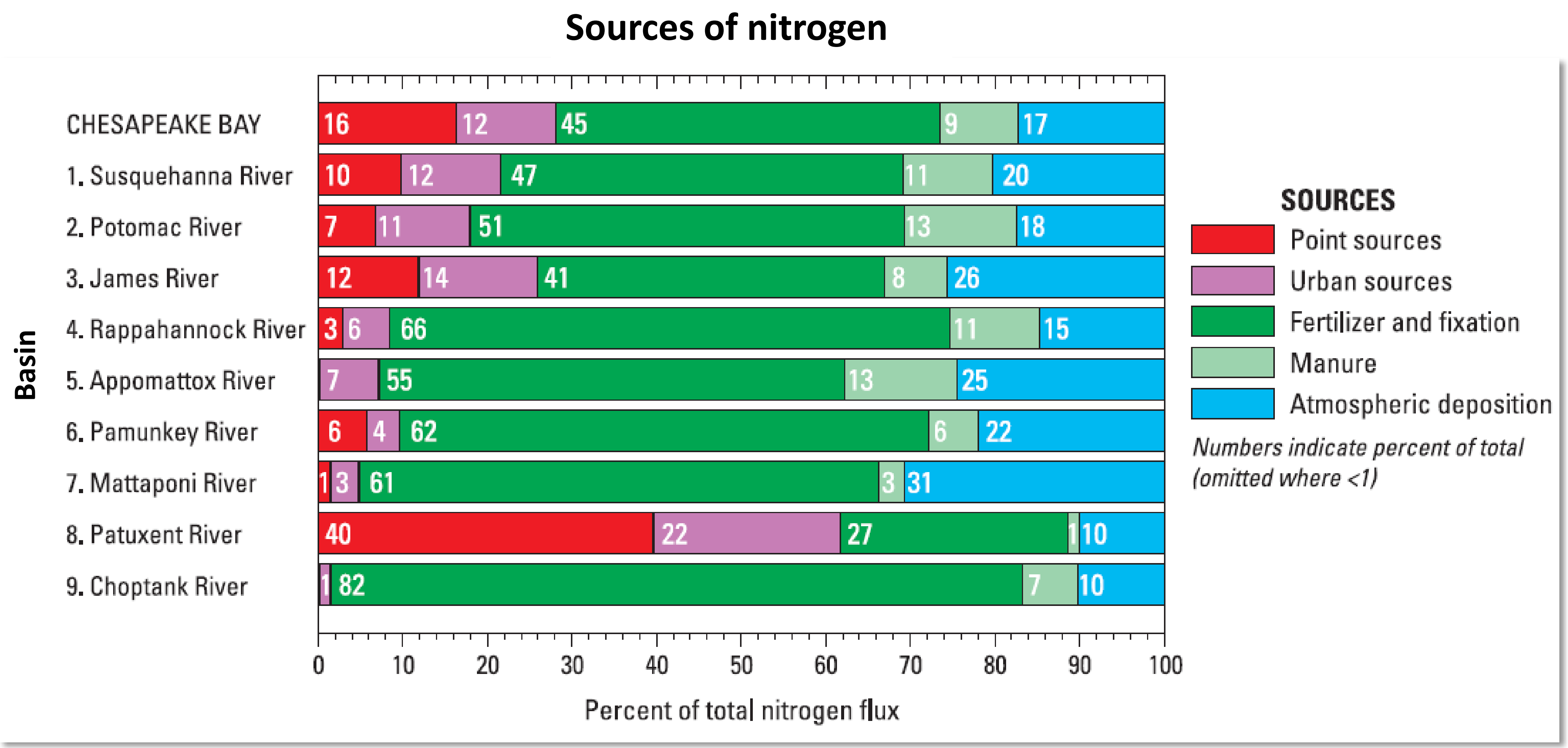
% of sites Degrading: 28%

% of sites with no trend: 38%



[1]Moyer and others, 2017

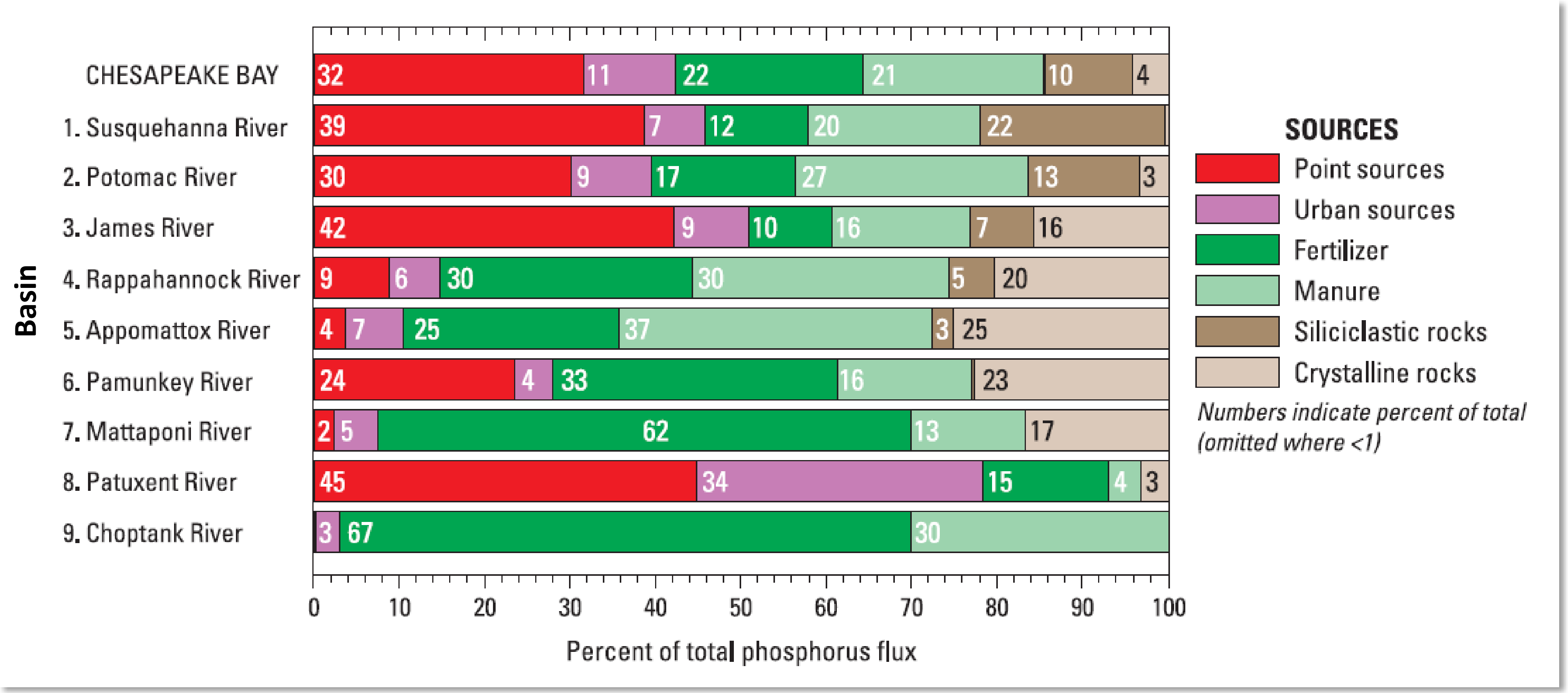
Sources of nitrogen throughout the watershed



USGS science for a changing world

Results from Ator, Brakebill, and Blomquist, 2011: https://pubs.usgs.gov/sir/2011/5167/

Sources of phosphorus throughout the watershed

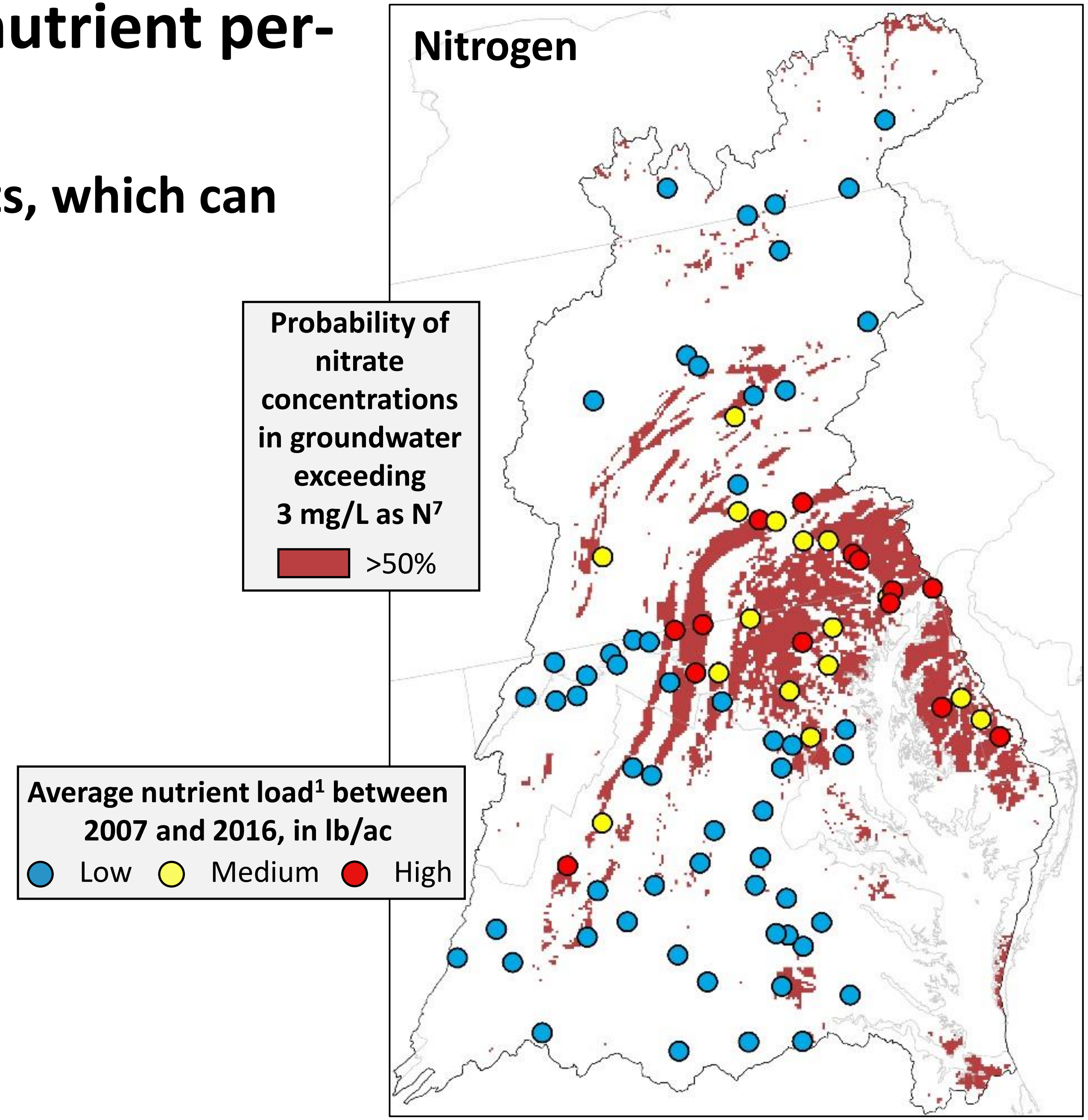


Results from Ator, Brakebill, and Blomquist, 2011: https://pubs.usgs.gov/sir/2011/5167/

Watersheds with the highest nutrient per-acre loads have…

A long history of excess nutrient inputs, which can result in:

Nitrogen movement to groundwater.
Groundwater is the primary delivery pathway of nitrogen to streams and groundwater nitrogen concentrations (as nitrate) are typically elevated in agricultural watersheds.



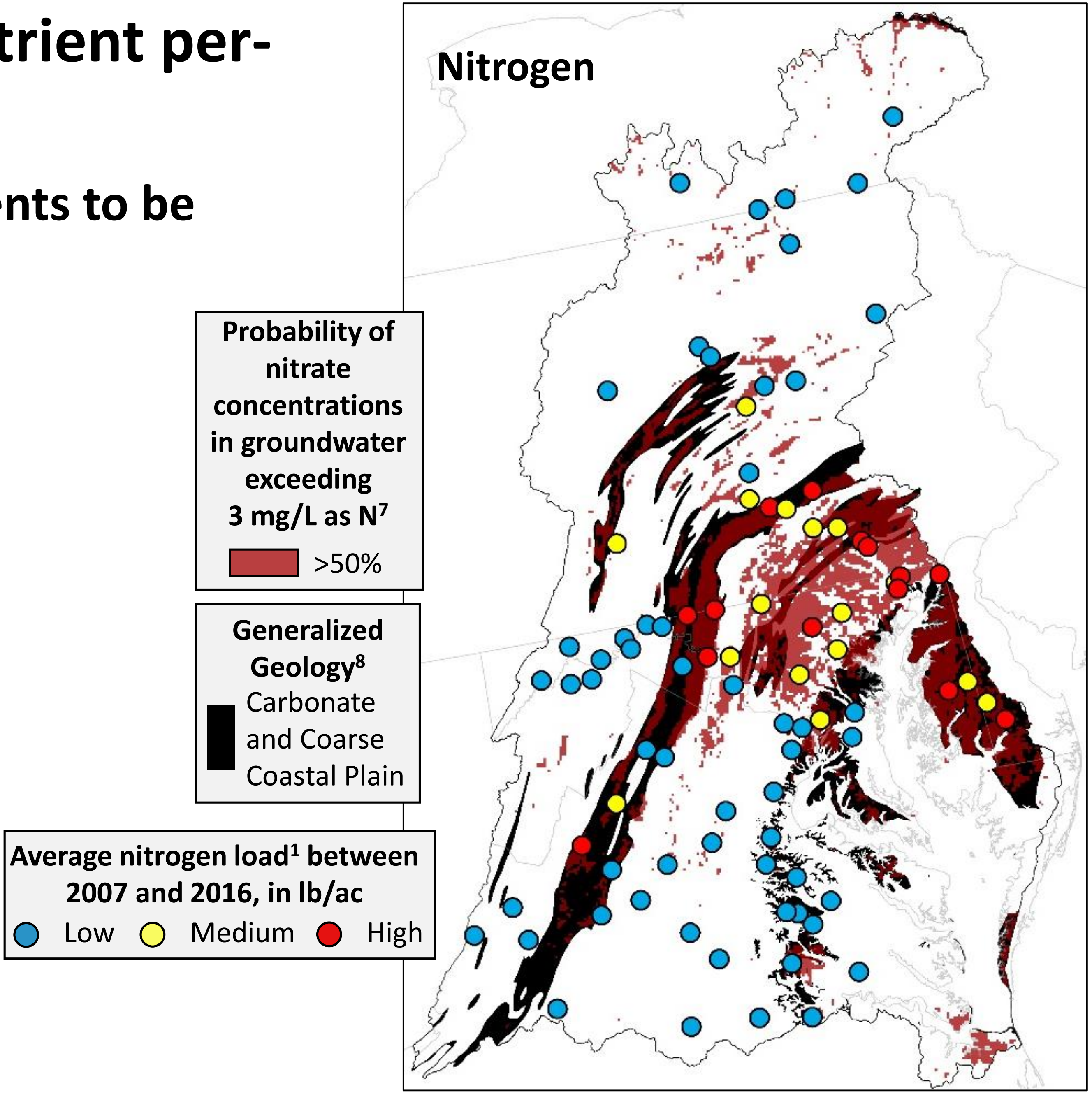
[1]Moyer and others, 2017

[7]Greene and others, 2005

Watersheds with the highest nutrient per-acre loads have…

Environmental settings that allow nutrients to be efficiently transported to streams

Watersheds with carbonate geology or portions of the coastal plain with coarse-grained sediments have very low denitrification rates, which allows nitrogen inputs to move relatively unaltered into the groundwater.



[1]Moyer and others, 2017 [7]Greene and others, 2005 [8]King and Biekman, 1974

Summary

- Investments in monitoring are providing actionable information
  - Greater confidence in suspected high loading areas
  - New trends are identifying successes and challenges
- Focusing and optimizing management actions on regional and local scales is key to achieving desired reductions
- **What to Expect in the coming months:**
  - New “integration” reports and findings
  - Synthesis products
  - Increased outreach to jurisdictions in support of:
    - WIP development
    - WIP implementation

Tidal Water Quality Status and Trends

Aquatic conditions respond to watershed changes

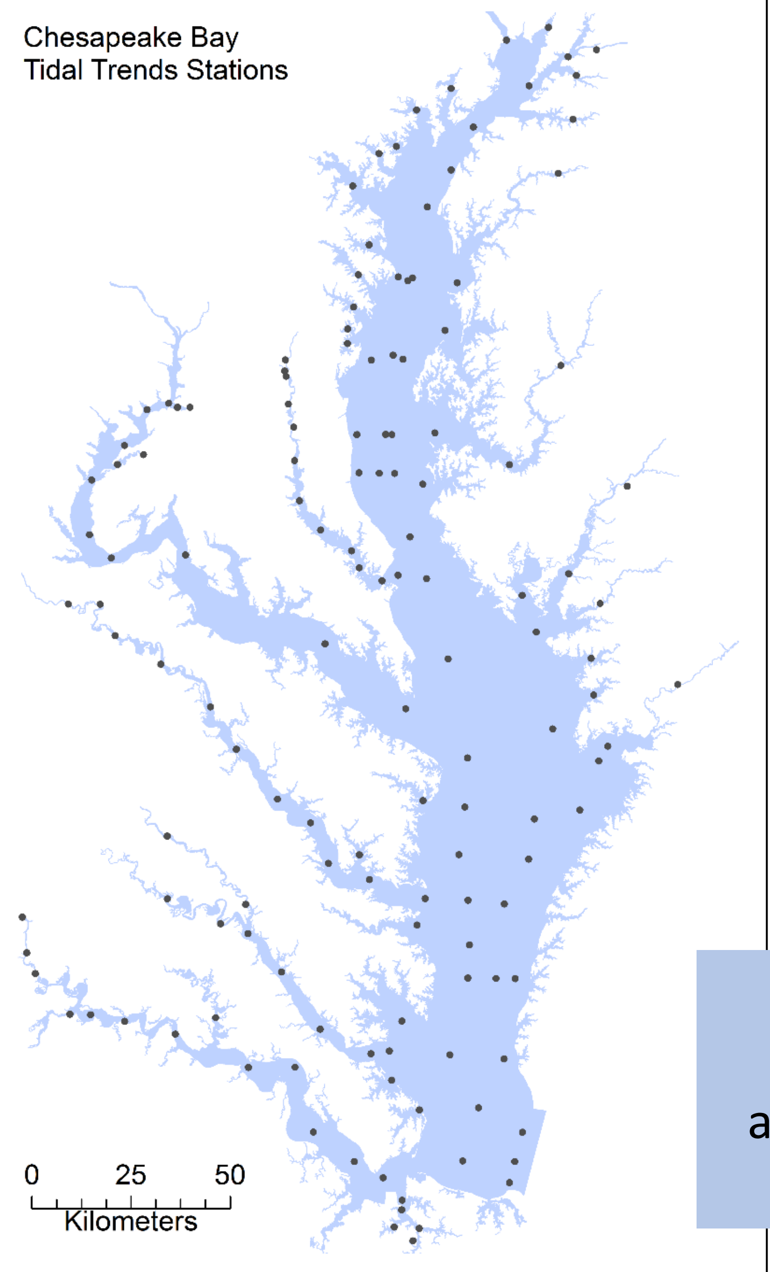
Jeni Keisman, USGS, Biologist

Tidal Water Quality Monitoring Programs

Water quality data are collected at 150+ locations in tidal waters throughout Chesapeake Bay. Long-term monitoring stations have been visited by boat 1 or 2 times per month every year since 1985.

Photo: Matt Rath

This monitoring program is a cooperative effort between MD DNR, VA DEQ, and the EPA CBPO.



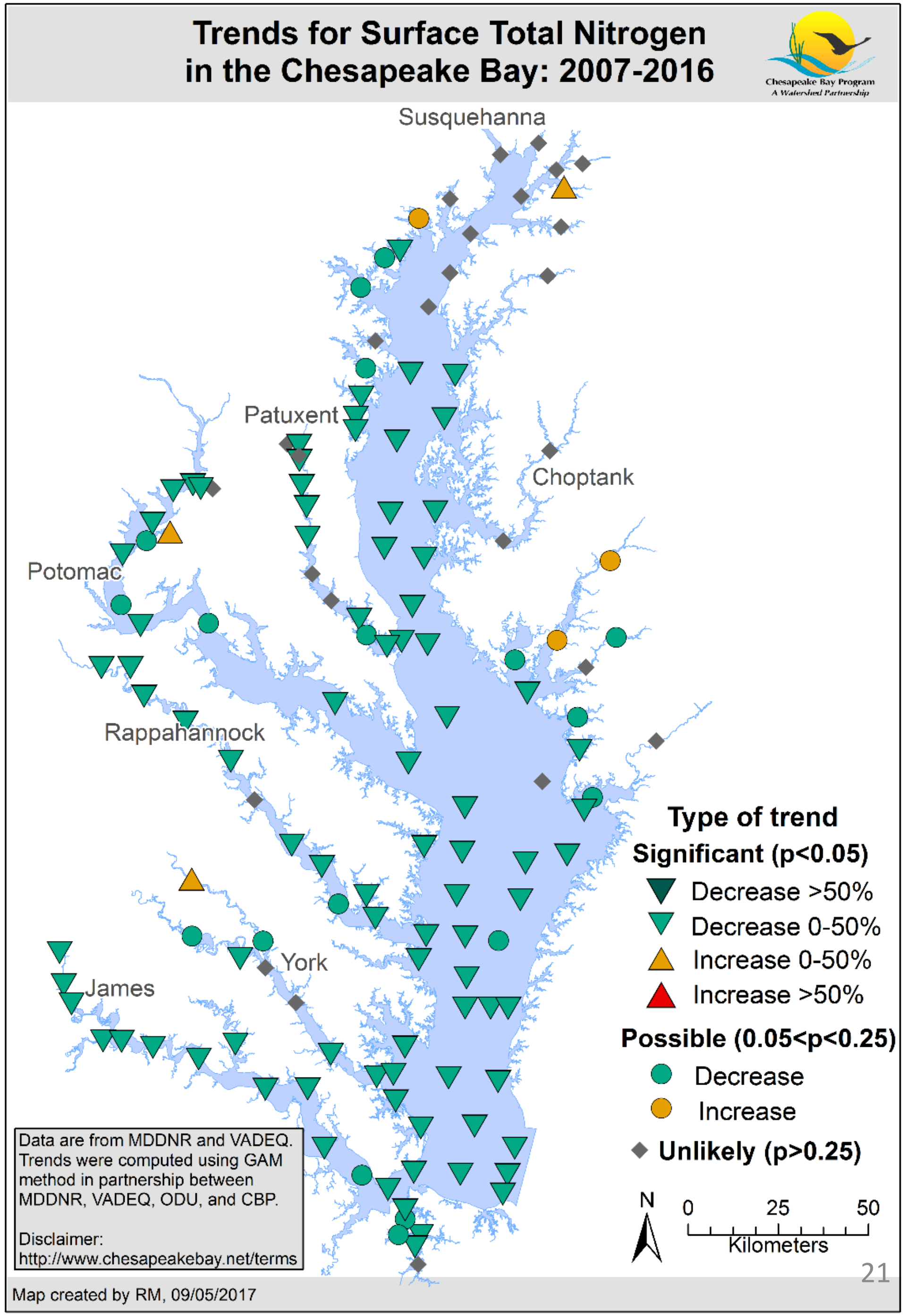
Baywide submerged aquatic vegetation (SAV) abundance has been collected annually since 1984 by VIMS.

https://www.bayjournal.com/article/largescale_sav_restoration_discouraged_until_water_quality_improves

With over 30 years of standardized, high-quality data, we can now use powerful analytics to understand how and why water quality is changing over time

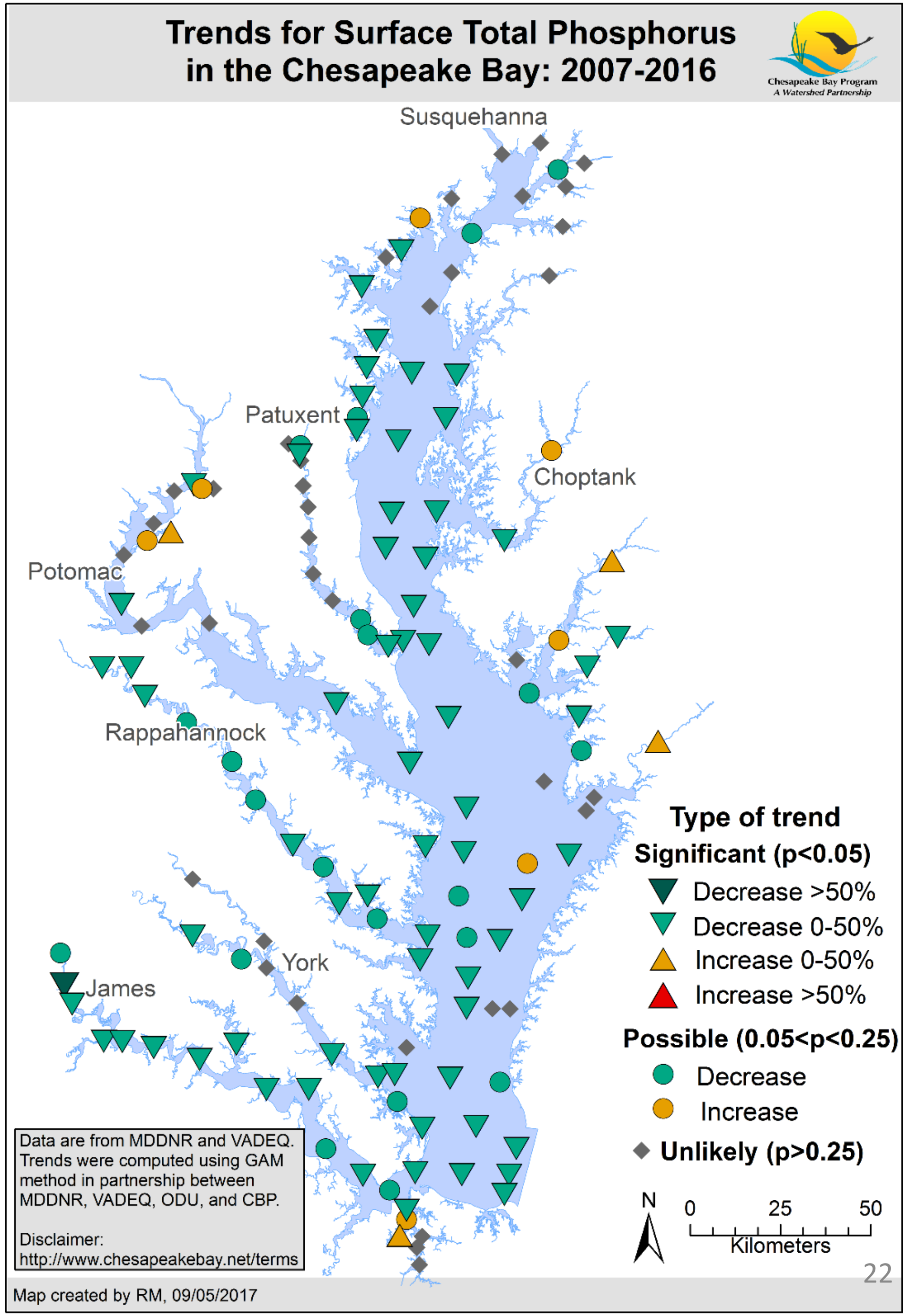
Nutrient Trends: Surface Total Nitrogen

2007-2016 Trends	
Trend in TN concentration	**Percent of Stations**
Significant decrease (improvement)	63%
Significant increase (degradation)	2%
No significant trend	35%



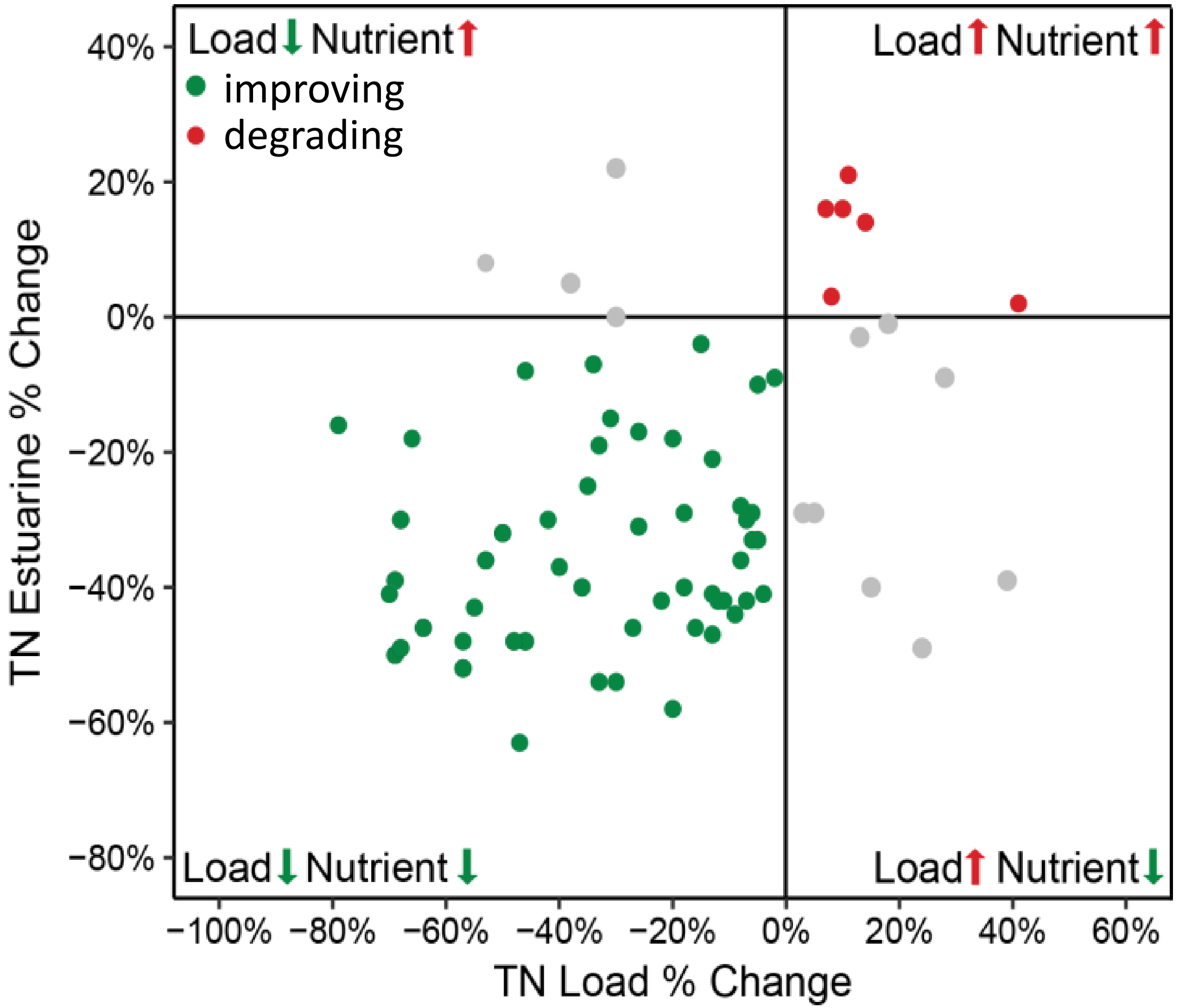
Nutrient Trends: Surface Total Phosphorus

2007-2016 Trends	
Trend in TP concentration	**Percent of Stations**
Significant decrease (improvement)	49%
Significant increase (degradation)	3%
No significant trend	48%



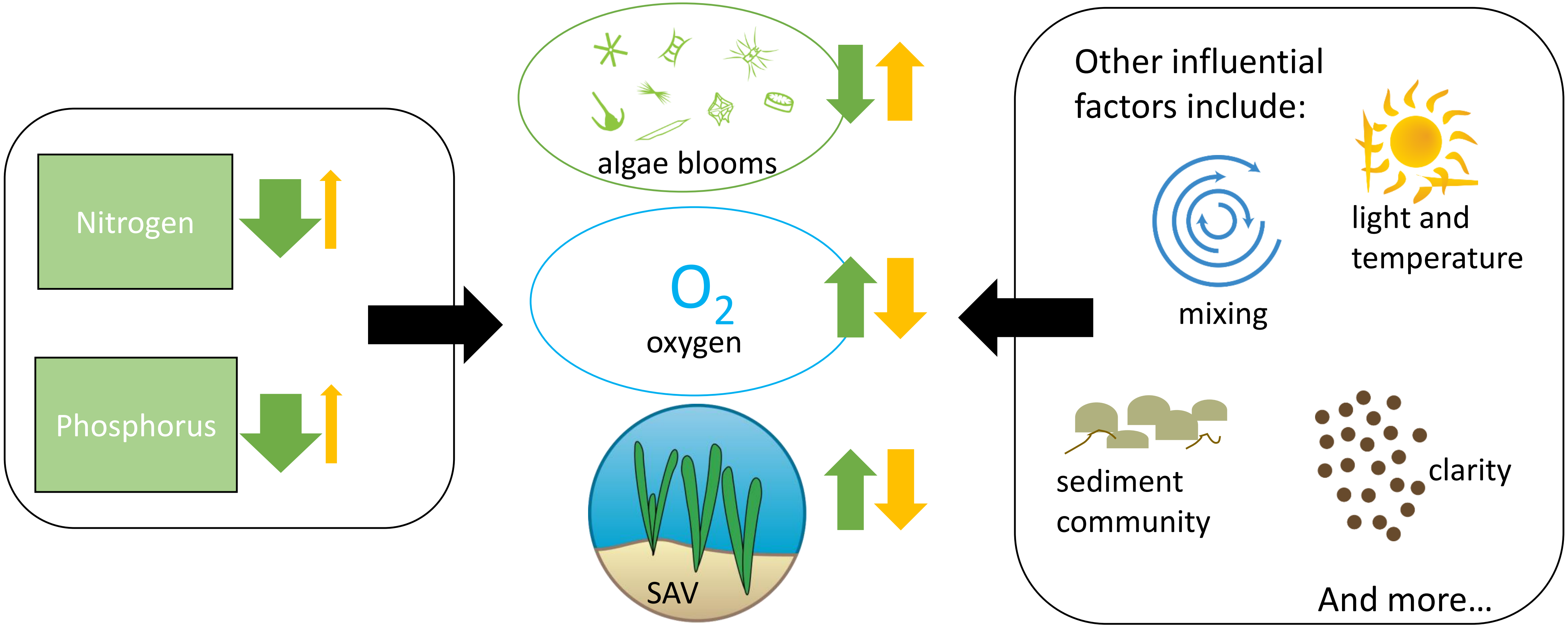
Estuarine nutrient concentrations respond to watershed loads

In the majority of drainage areas, the trends in tidal nutrient concentrations are in the same direction as the trends in watershed inputs.



Change in CBP watershed model loads and tidal nitrogen concentrations from 1989-91 to 2012-14 (Testa et al. 2018a.)

How are other tidal water quality indicators responding?

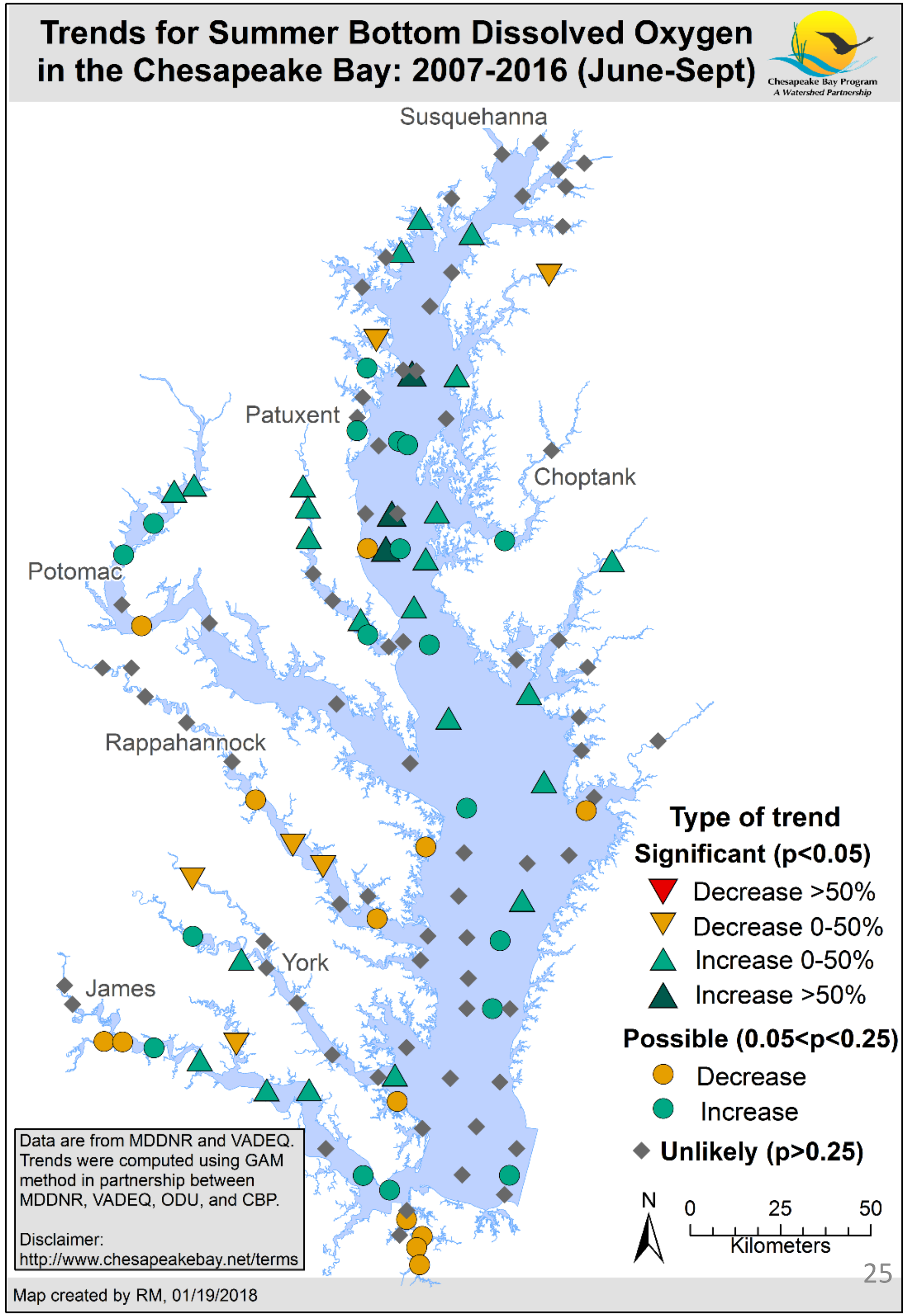


Estuaries are complex environments.
The response to restoration depends on location, season, and physical and biological factors.

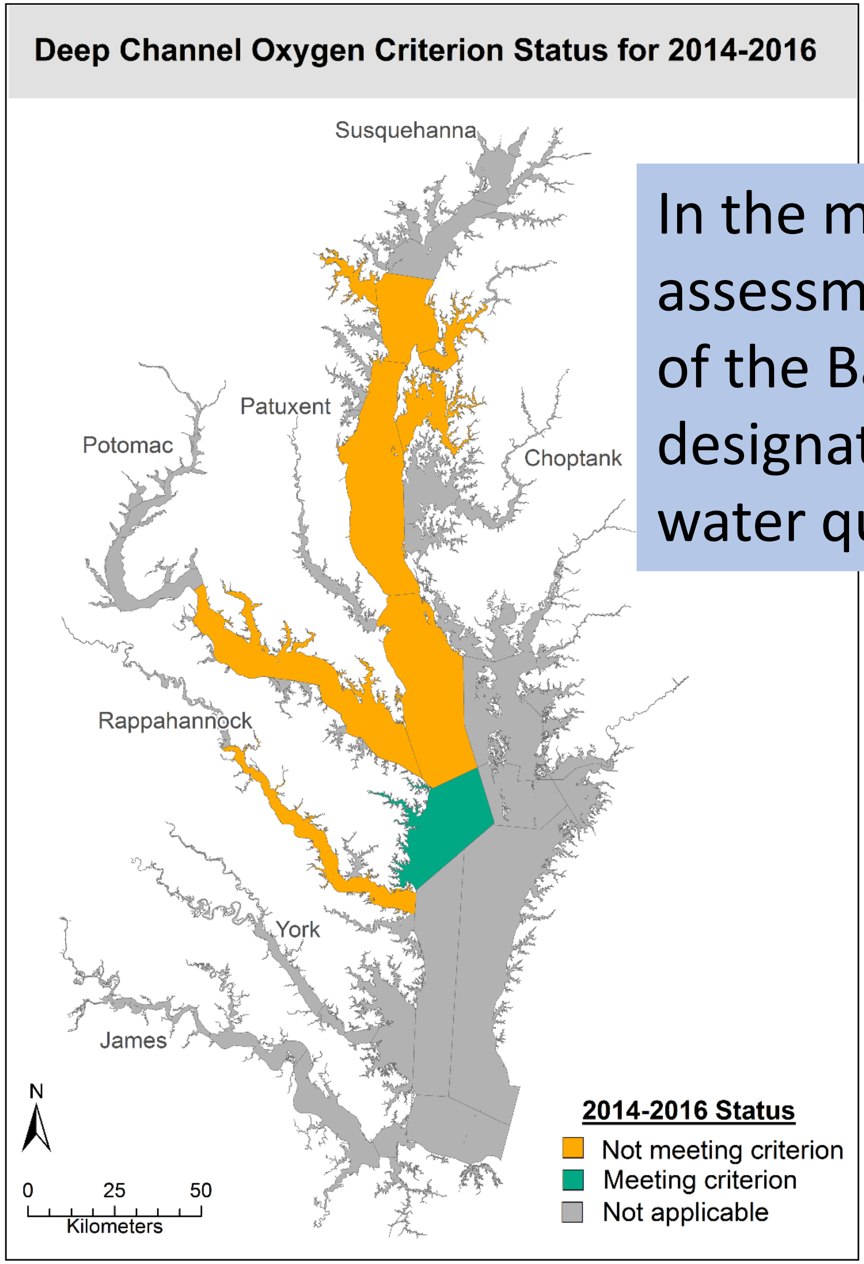
Images from: Tracey Saxby, Jane Thomas and Jane Hawkey, Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/imagelibrary/)

Dissolved Oxygen Trends: Summer; Bottom

2007-2016 Trends	
Trend in DO concentration	Percent of Stations
Significant increase (improvement)	19%
Significant decrease (degradation)	4%
No significant trend	76%

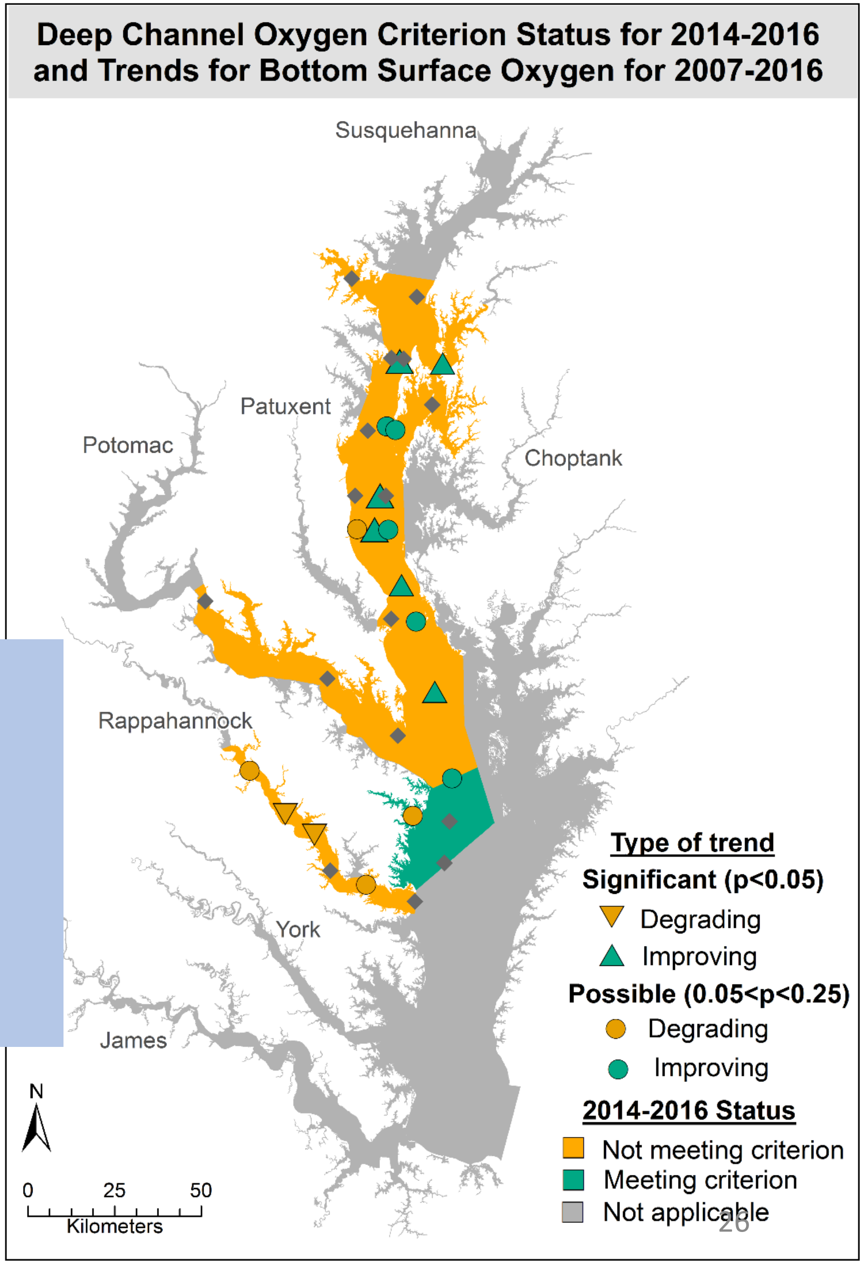


Dissolved Oxygen Status and Trends: Deep Channel

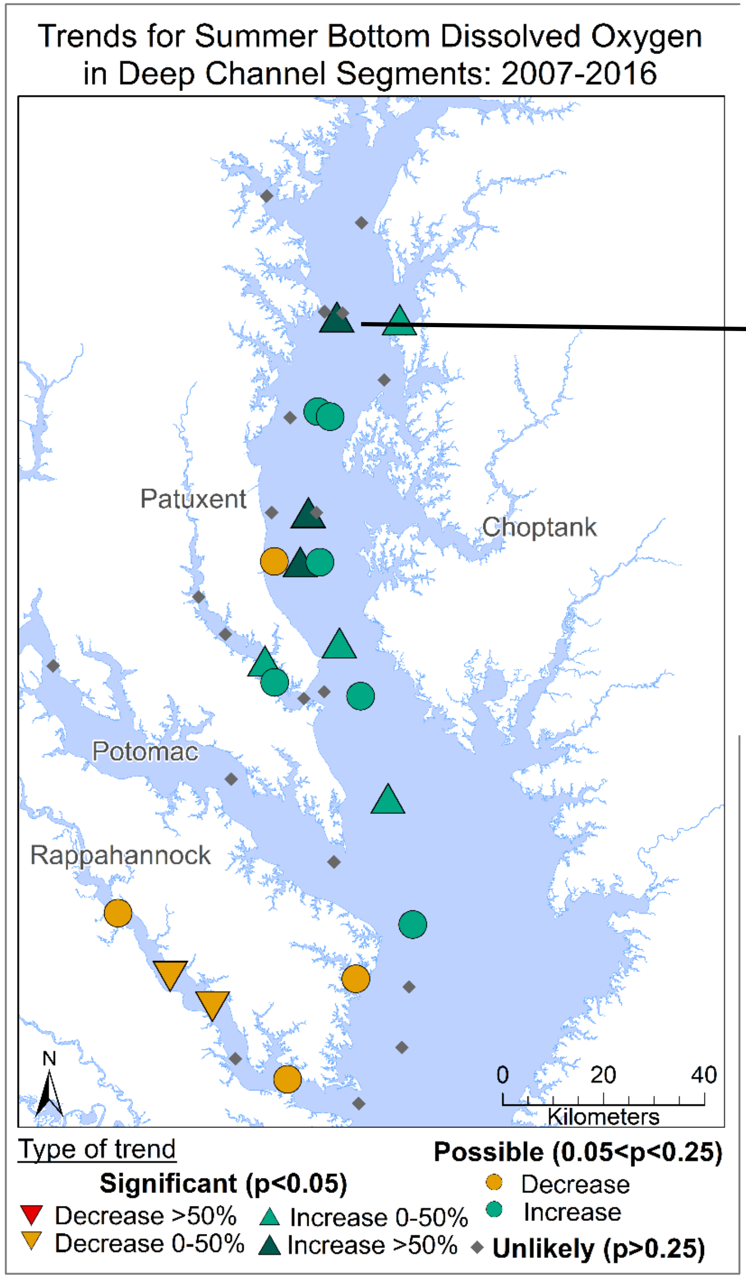


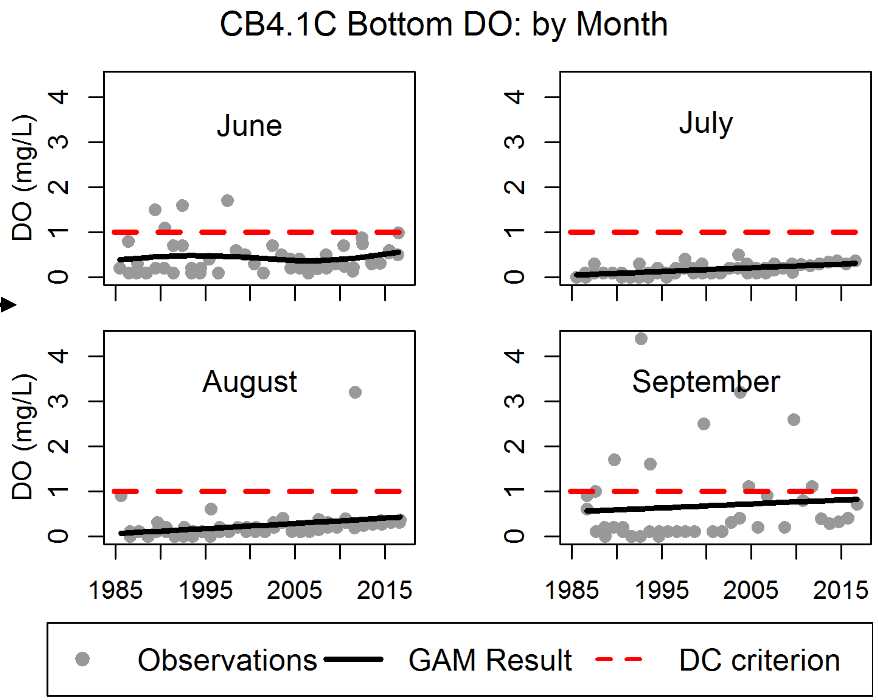
In the most recent assessment, about 12.5% of the Bay's Deep Channel designated use met DO water quality standards.

Trends analysis provides valuable information on the trajectory of conditions



Explaining Deep Channel DO attainment and trends

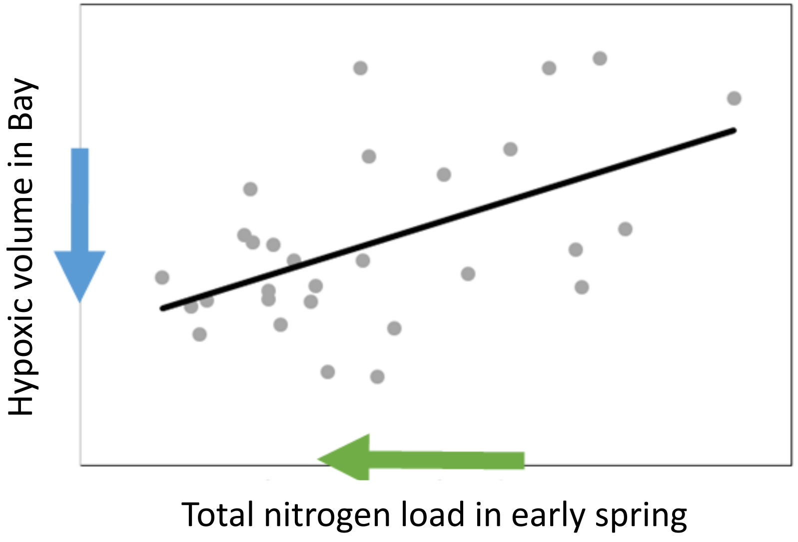




Most measurements are still below the water quality standard, but summer patterns are changing…

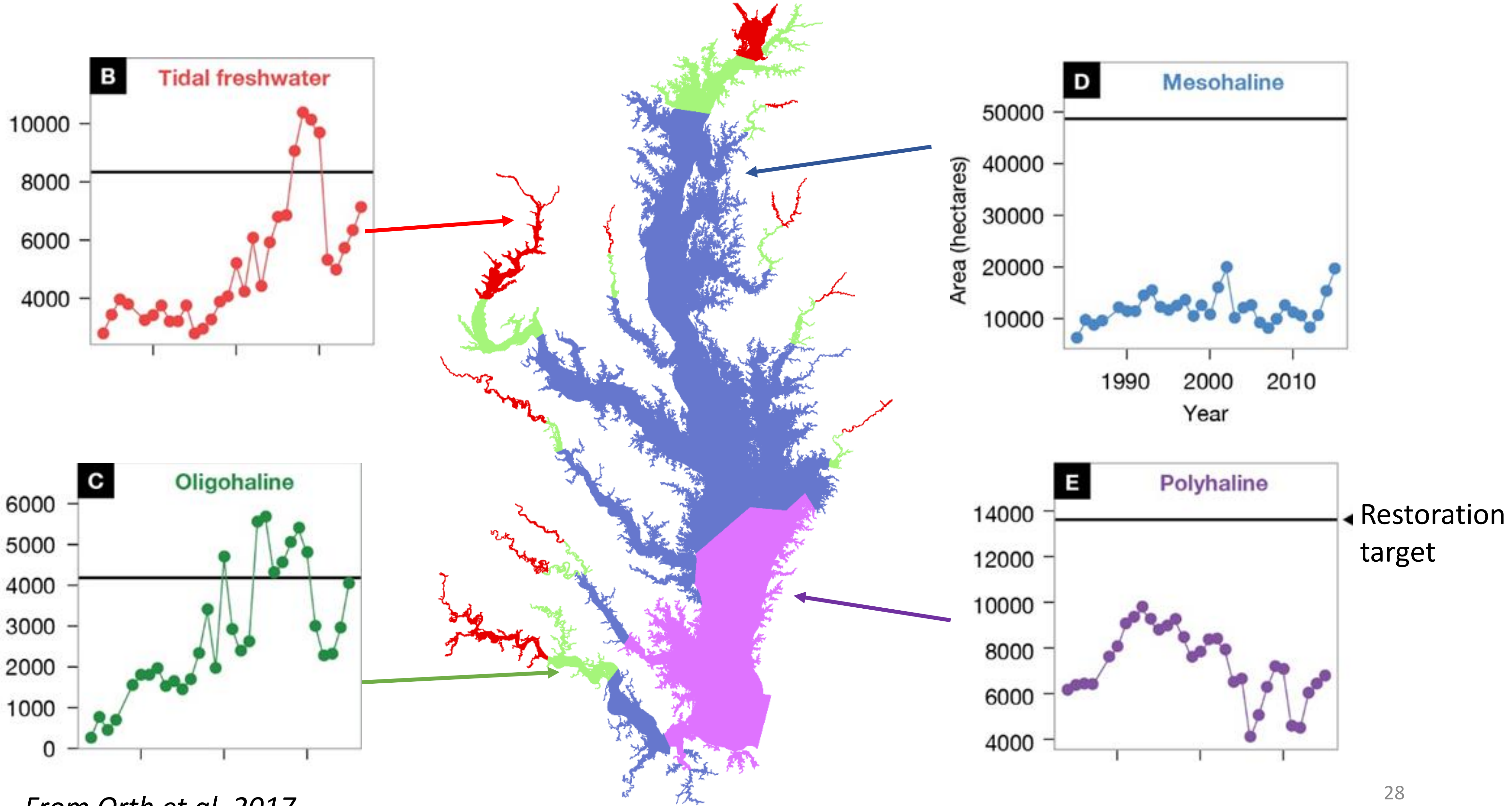
…and hypoxia reduction corresponds to observed nutrient load reductions

Relationship of hypoxia to nitrogen load



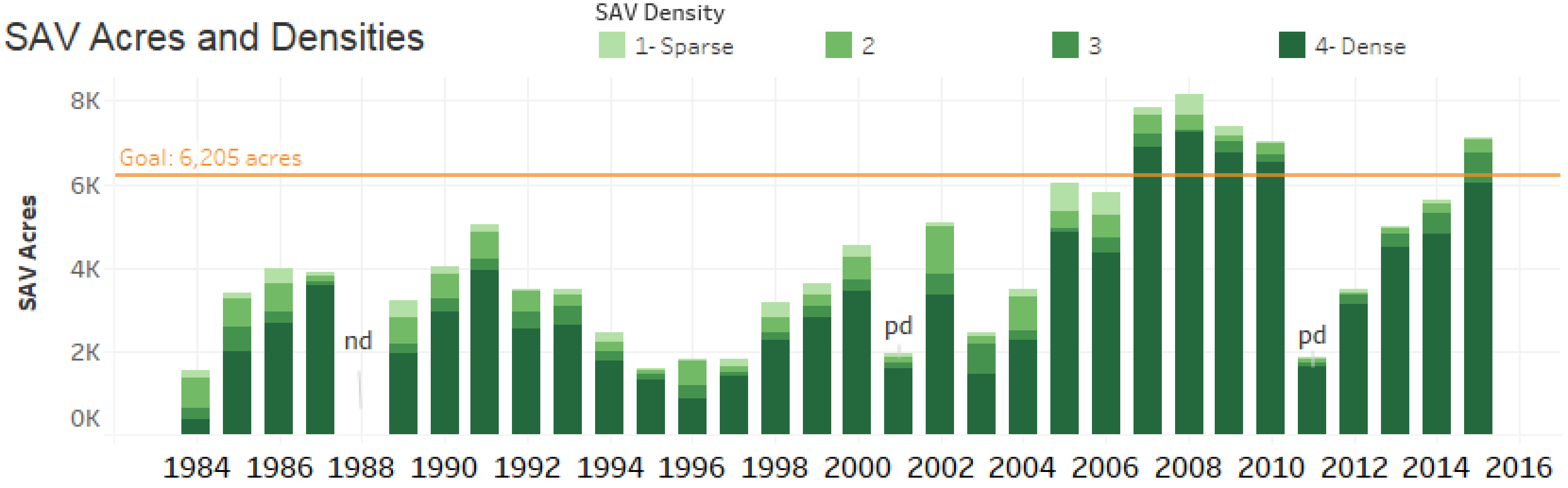
Murphy and Testa, personal communication

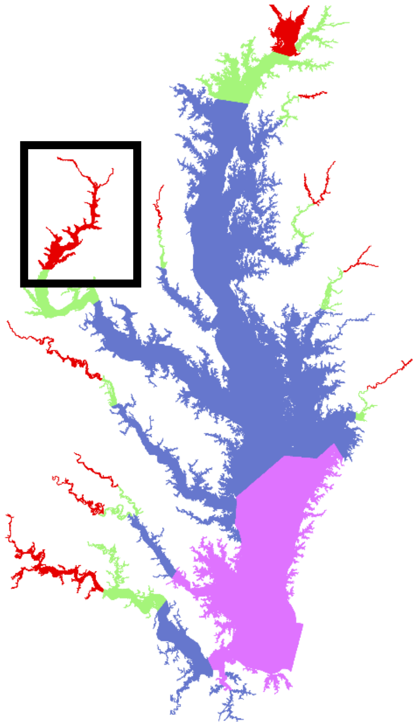
Bay-wide SAV Trends

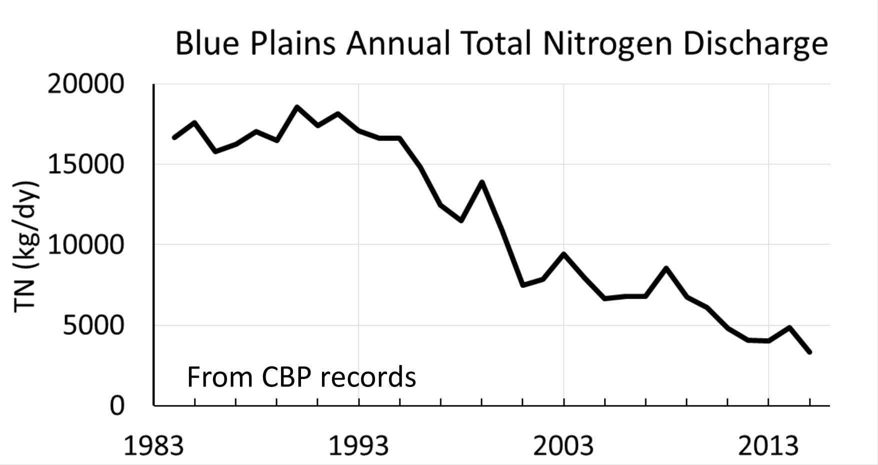


From Orth et al. 2017

SAV Case Study: Upper Tidal Potomac







Research studies find that expansion of SAV from nearly zero in mid-1900s to attaining the goal attributed to:

- Dramatic improvements in nutrient concentrations from WWTP upgrades (Ruhl and Rybicki 2010)
- Enhanced water clarity due to exotic clam (Phelps 1994)
- Non-native plant introduction facilitating recolonization of multiple species (Rybicki and Landwehr 2007)

Summary

- **Tidal nutrient concentrations are improving in most locations.**
  - *Many of these reductions can be directly linked to reductions from point sources or the watershed.*

- **Water quality has improved enough in some locations to support recovery of SAV.**
  - *Once SAV is present, it helps to further improve water quality and supports other important living resources.*

- **In some locations, conditions continue to degrade.**
  - *Degradation has been linked to high nutrient inputs from agriculture, and to urbanization.*

- **Location, season, and biological factors affect how tidal waters respond to management actions.**
  - *We are now applying novel analytical techniques to better trace changes in water quality back to their causes.*

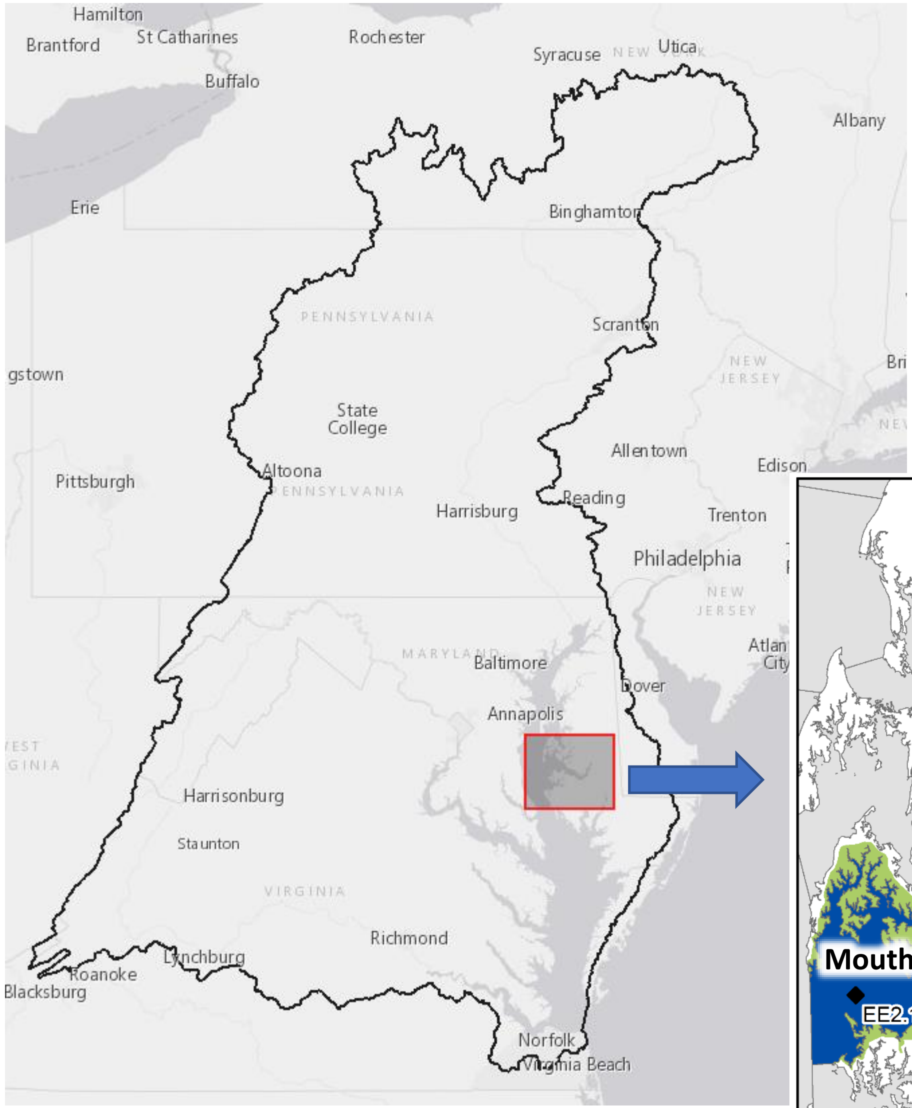
Putting it all together

Integrating monitoring, modeling, and trends analyses to inform management

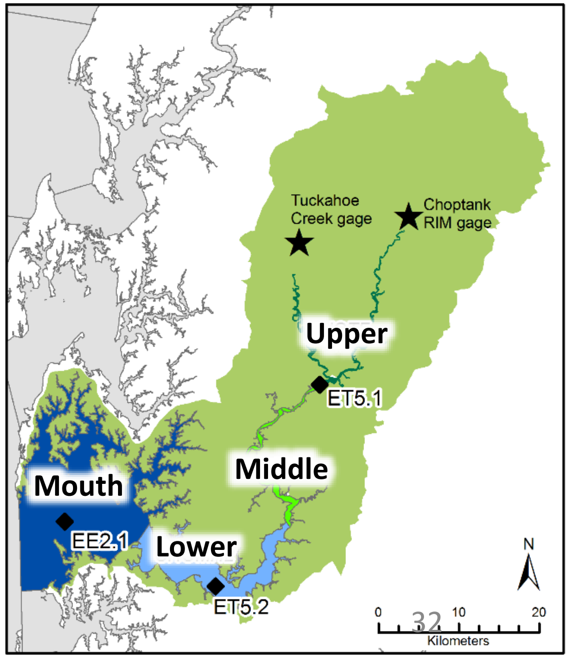
Emily Trentacoste, EPA CBPO, Environmental Scientist, Trends & Implementation Analyst

Developing storylines: A Choptank River example

- Storylines were developed to demonstrate how the information just shown previously can be integrated and provided at smaller scales to inform planning efforts
- Received positive feedback on concept of storylines and their utility
- We've been working with jurisdictions and local groups to develop storylines across the watershed (tidal and non-tidal)

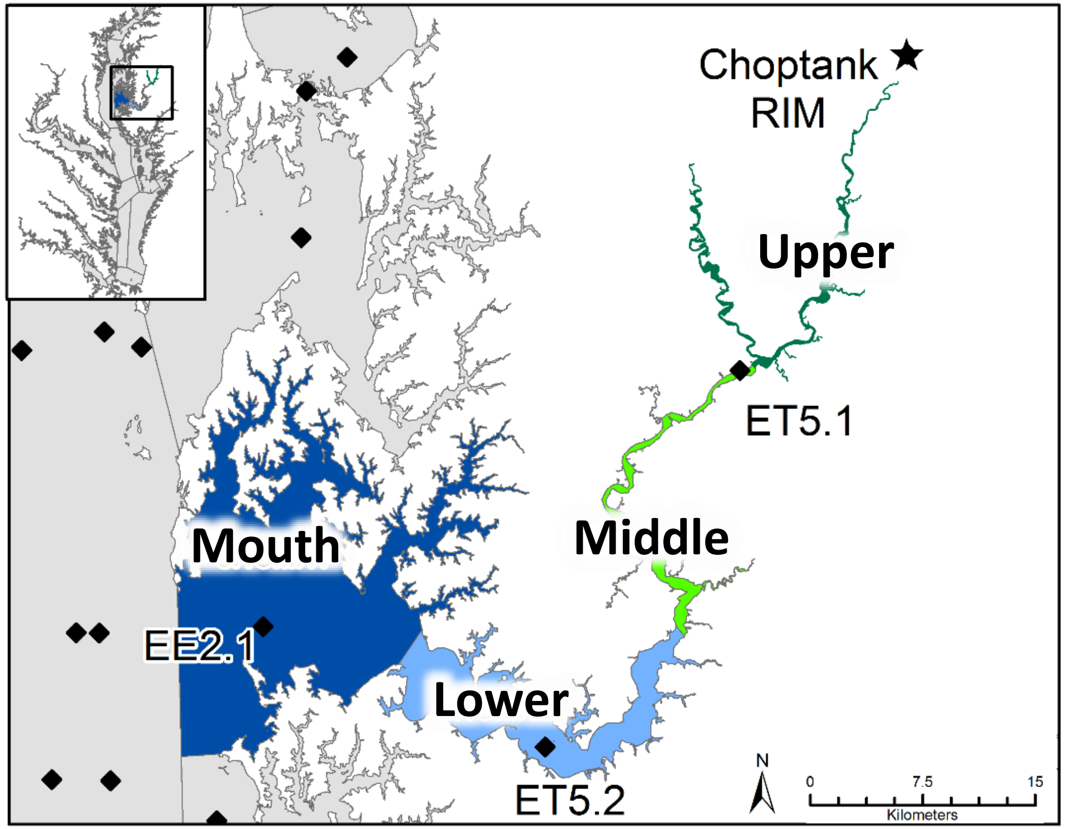


Choptank River



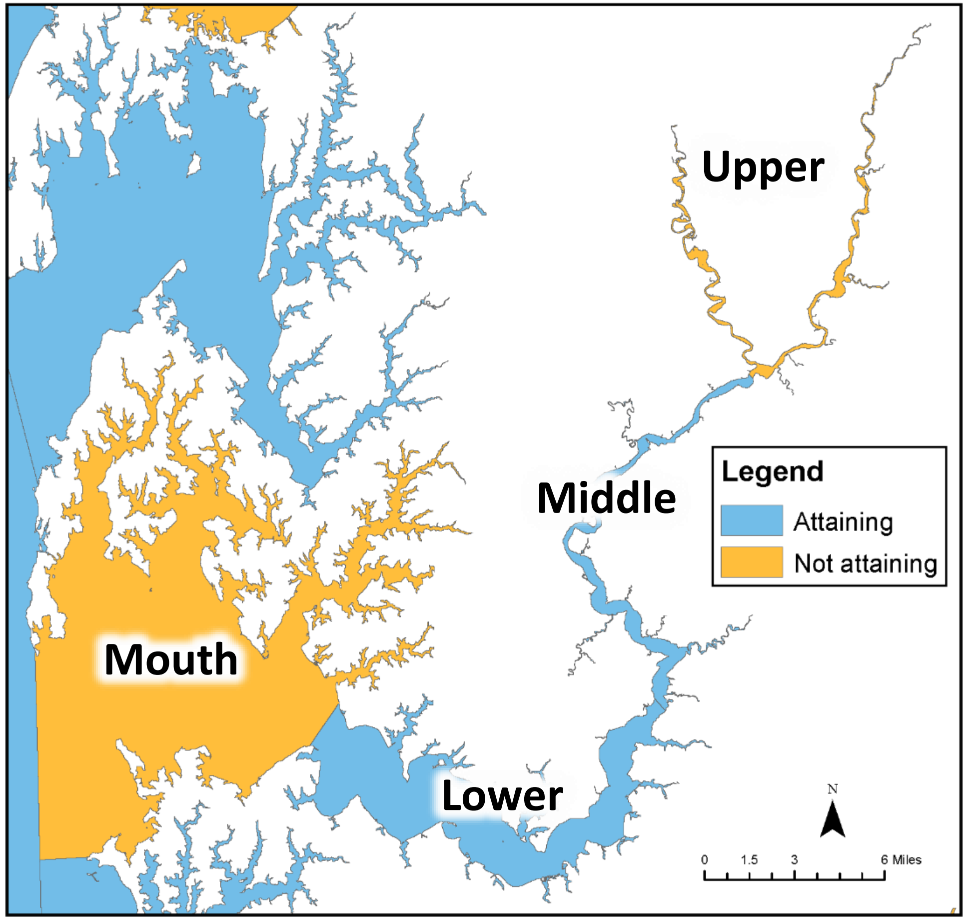
Starting in the tidal waters: water quality standards

Choptank River tidal segments



Map and graph: Rebecca Murphy, UMCES

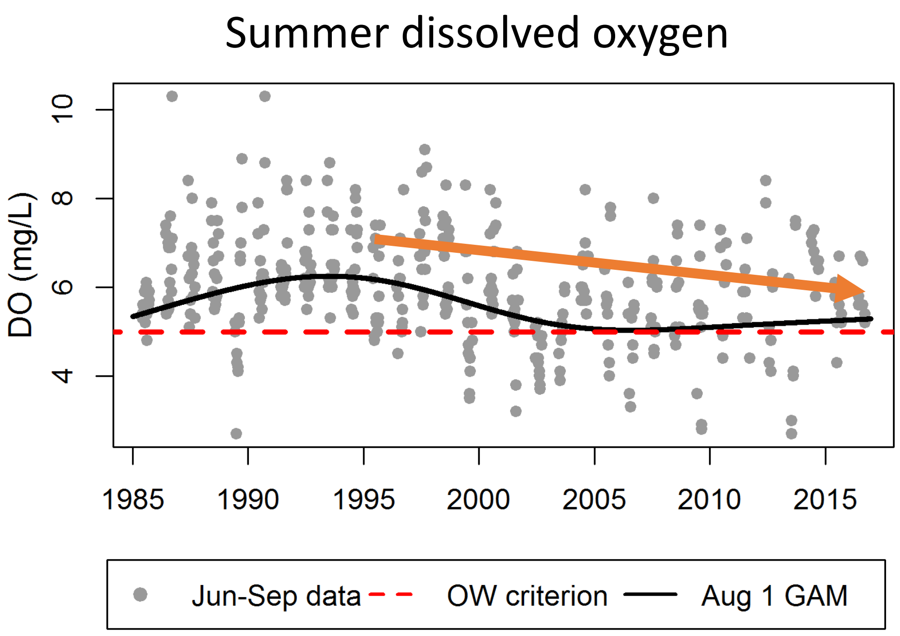
Choptank River attainment of open water dissolved oxygen criterion

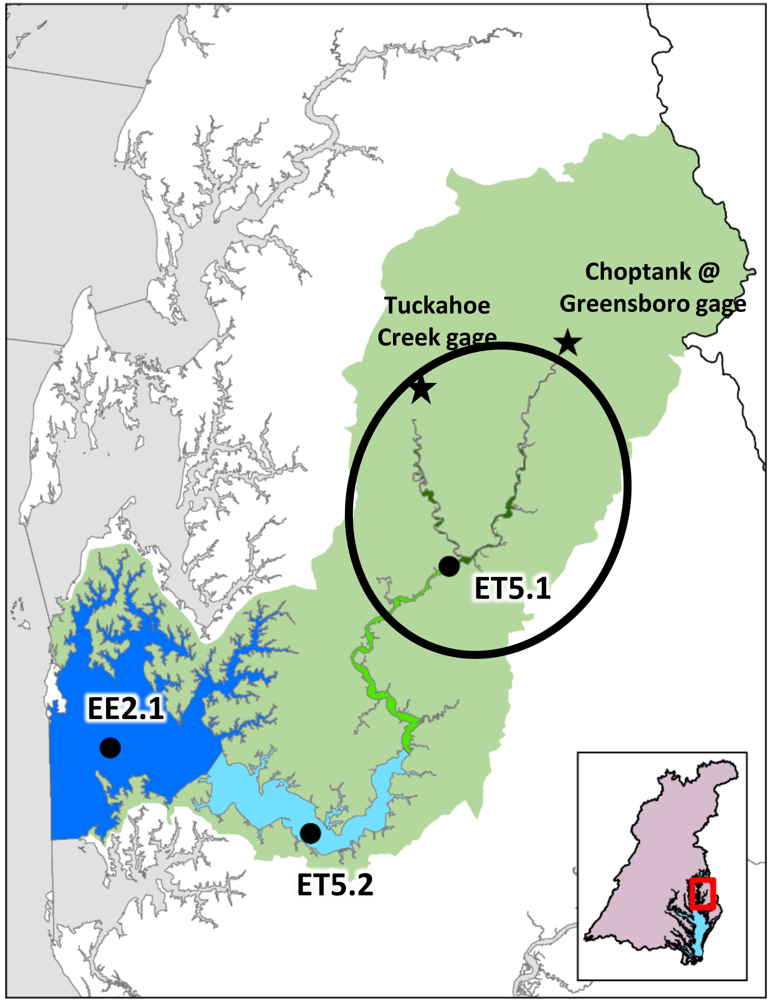


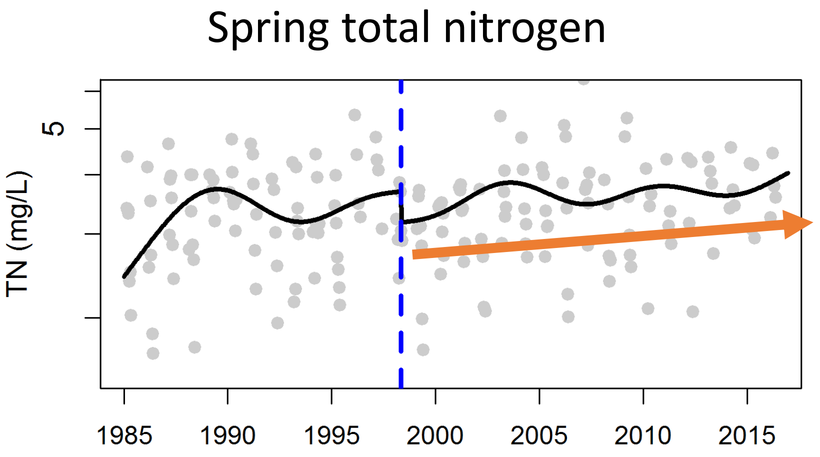
- Portions of the river are not attaining water quality standards
- Sources, drivers, and trends are different along the river

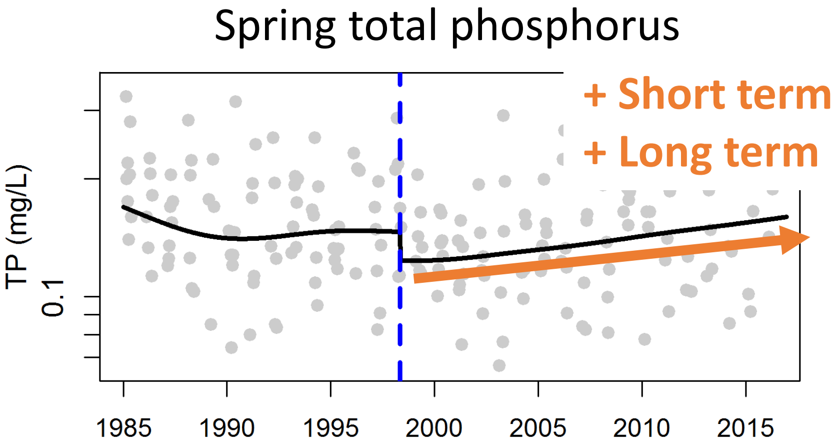
Water quality drivers of attainment

- Upper river has shown long-term decline of summer dissolved oxygen and clarity
- Tidal nutrient concentrations influence DO
- Research has connected decline in water quality to increased nutrients from watershed





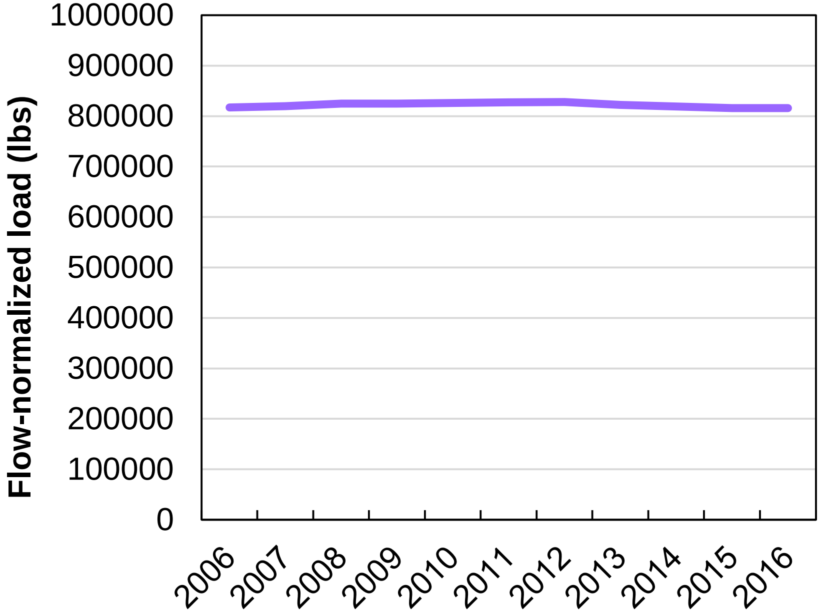


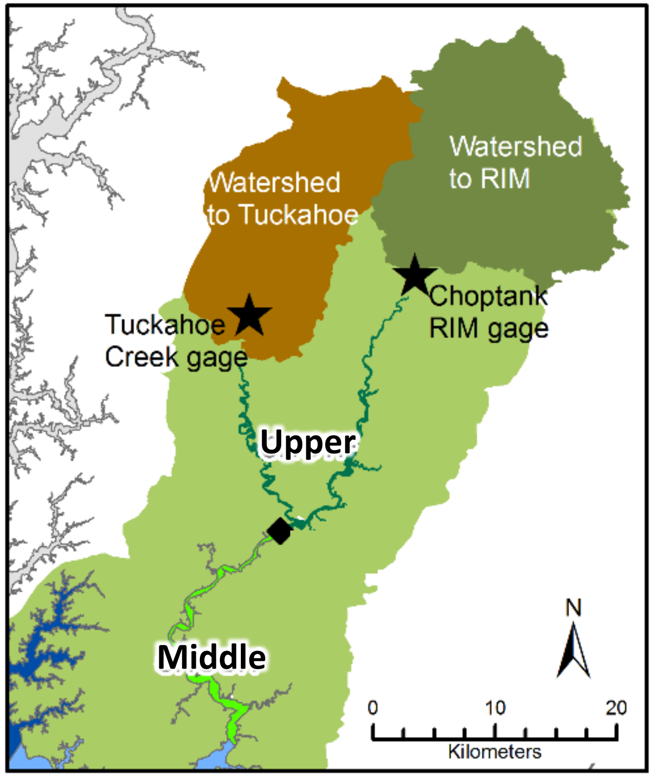


GAMs: Rebecca Murphy, UMCES

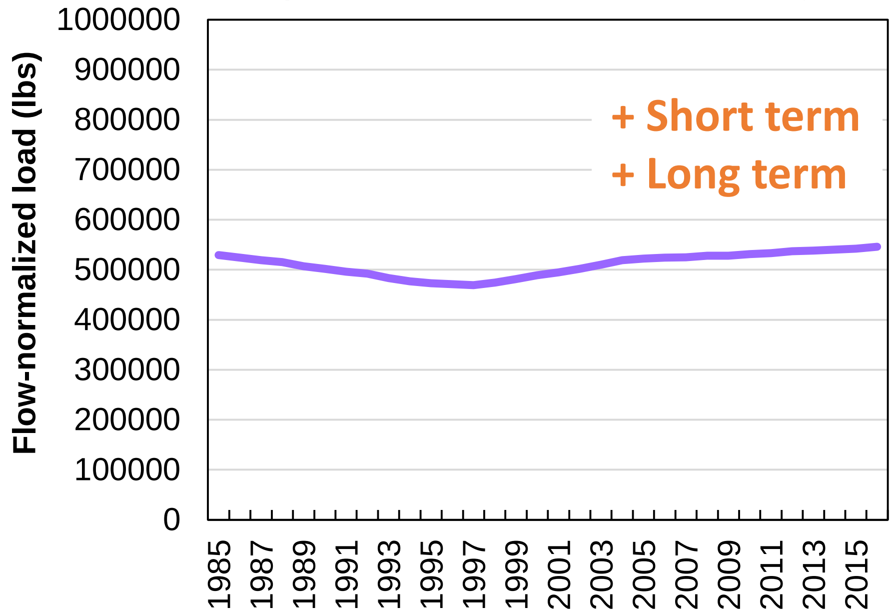
Watershed trends
(flow-normalized)

Tuckahoe Creek: Nitrogen

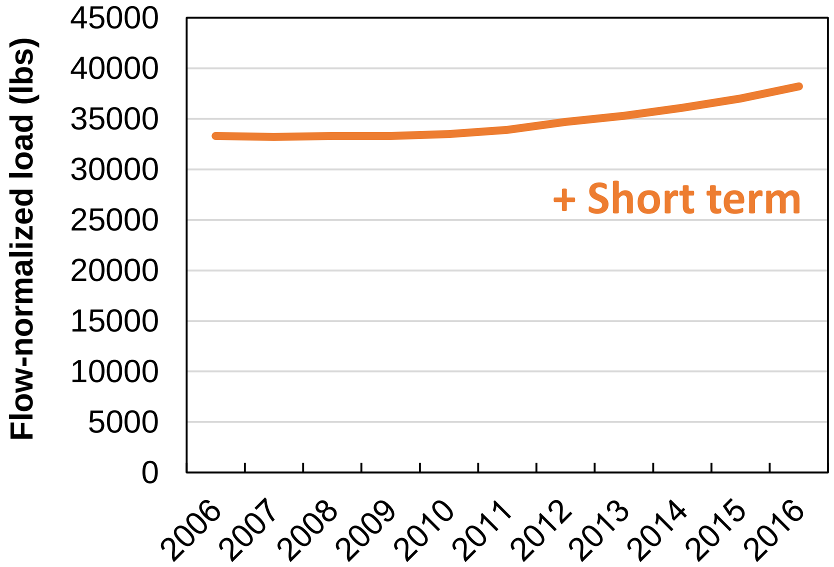




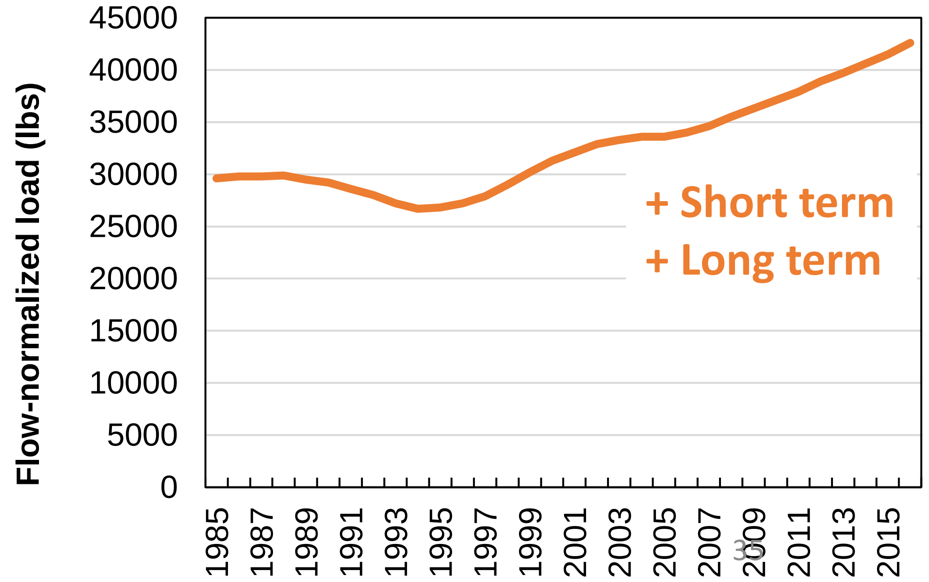
Choptank @ Greensboro: Nitrogen



Tuckahoe Creek: Phosphorus



Choptank @ Greensboro: Phosphorus

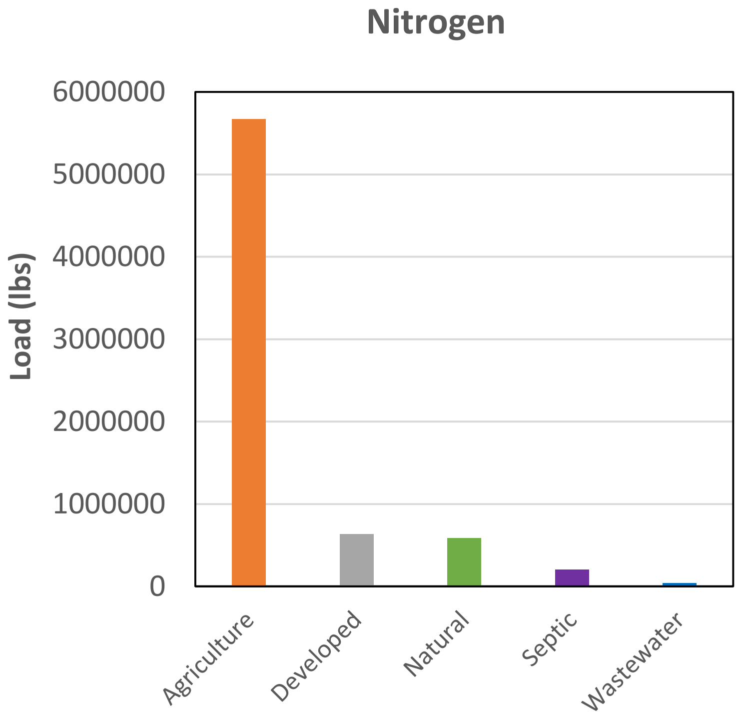


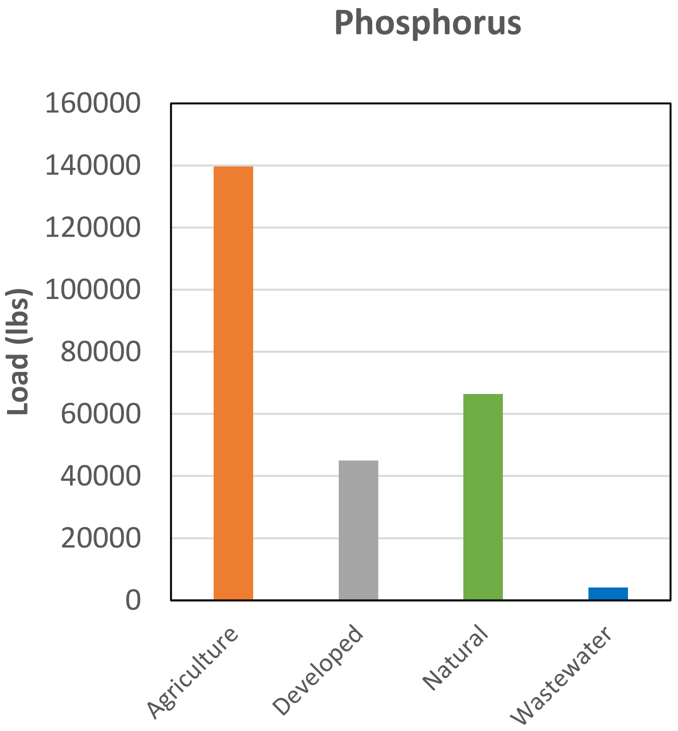
USGS Chesapeake Bay Non-tidal Network:
https://cbrim.er.usgs.gov/

Where do nutrients come from in the watershed?

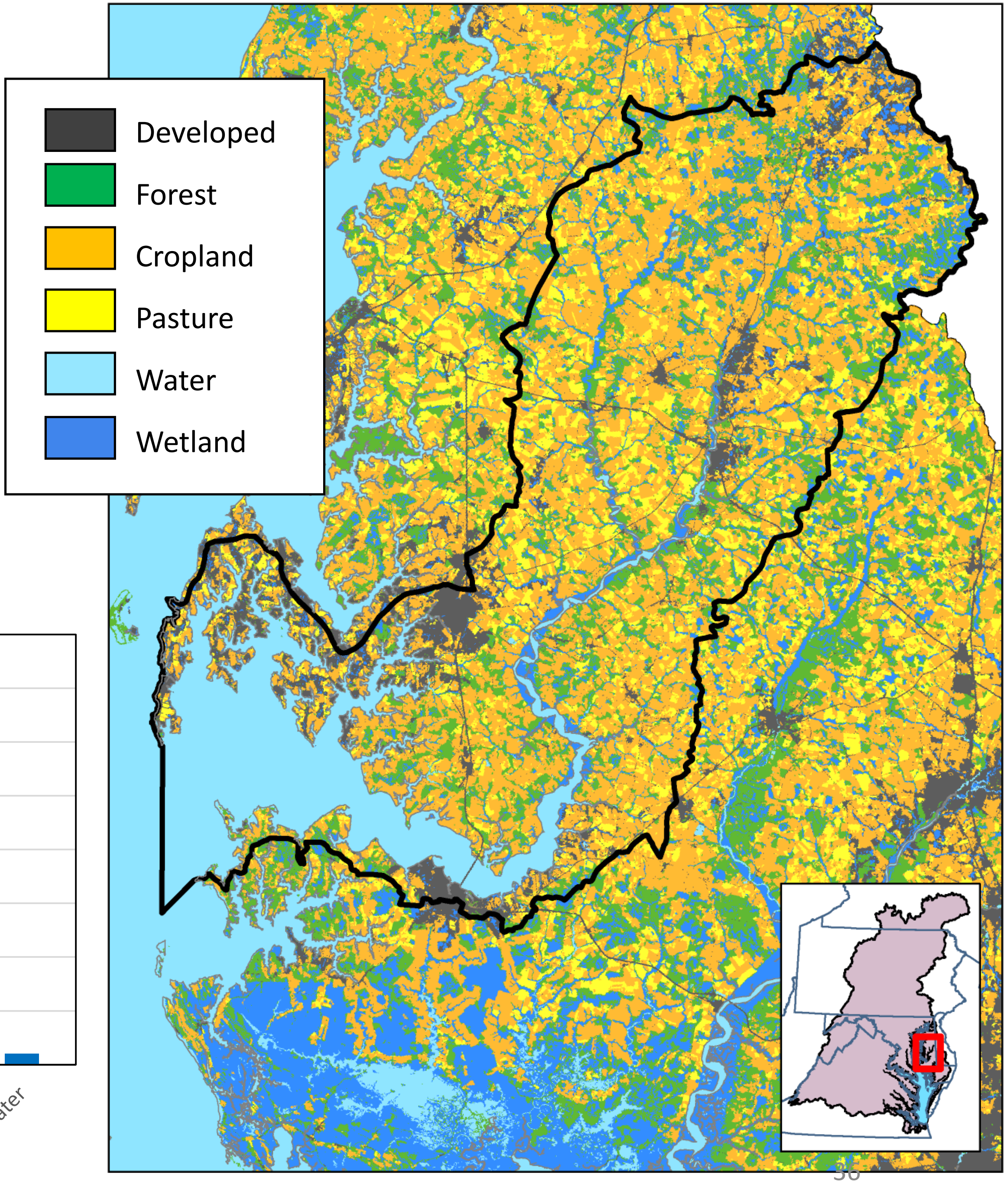
- Nutrient and sediment loads come primarily from agriculture, specifically cropland
- Different localities can have unique issues

Sources of loads





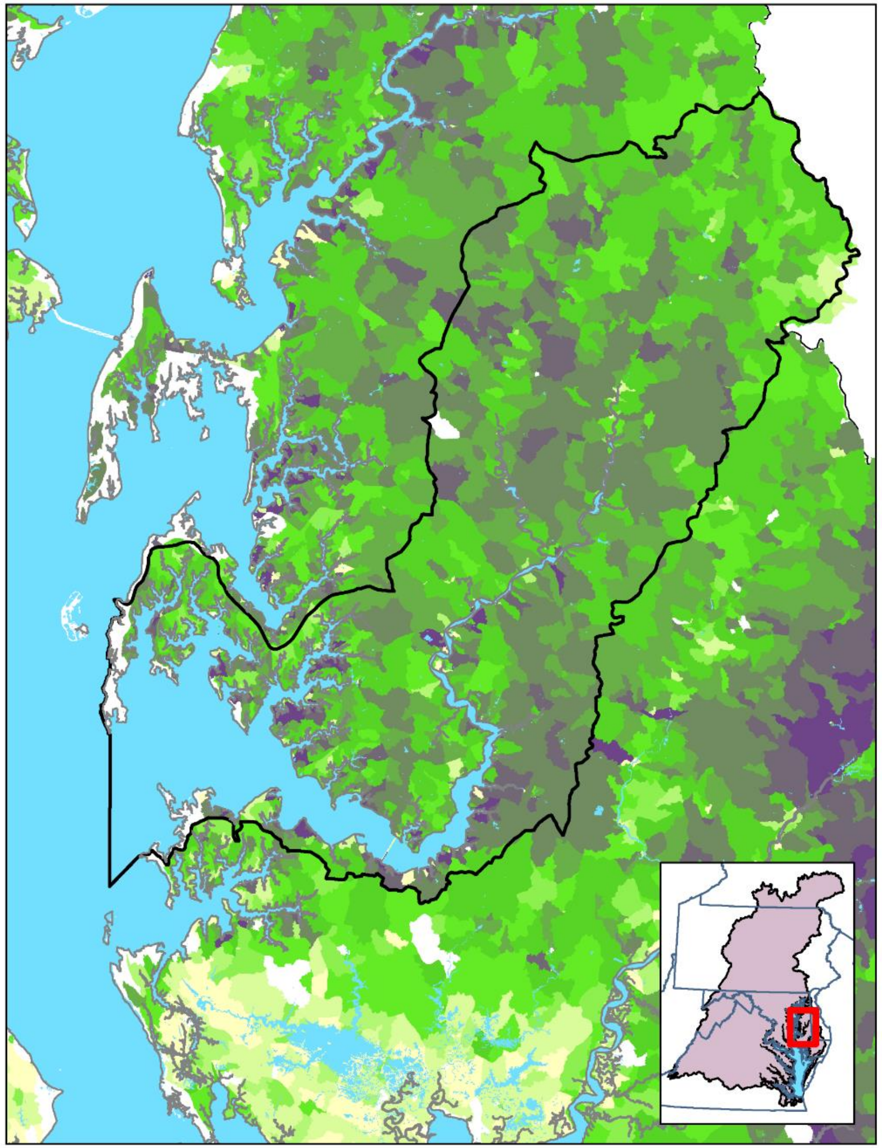
Chesapeake Bay Phase 6 Program Watershed Model. Draft 2016 Progress.



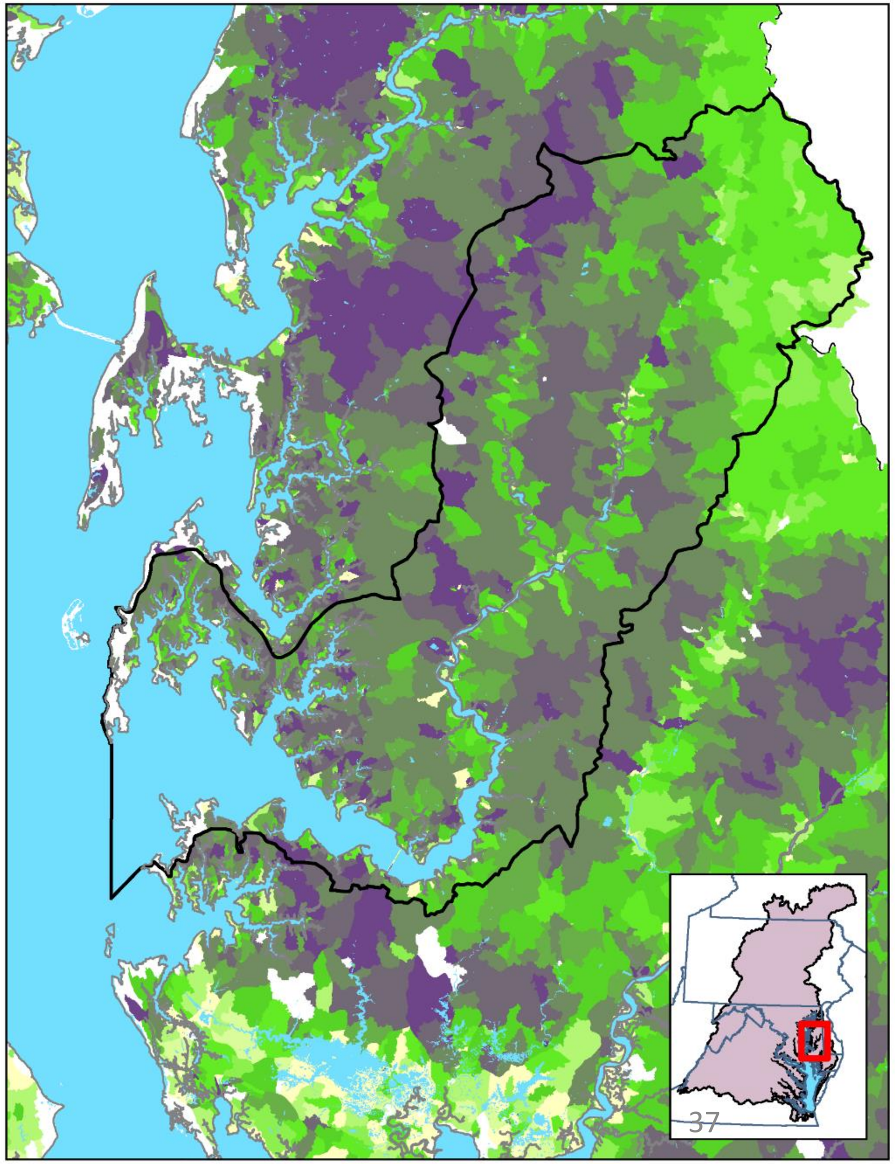
Map data from Falcone, J.A., 2015.

Loads in the watershed are tied to land use and geology

Nitrogen



Phosphorus



USGS Nitrogen SPARROW model

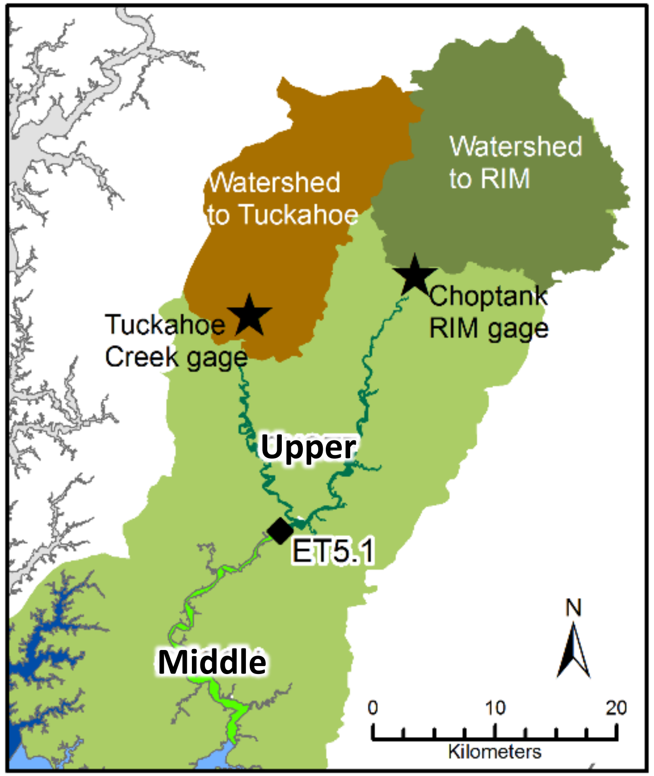
Estimated annual load to local streams (lbs/acre)

Nitrogen	Phosphorus
< 2	< 0.5
2 to 3	0.05 to 0.1
3 to 4	0.1 to 0.2
4 to 5	0.2 to 0.3
5 to 7	0.3 to 0.5
7 to 10	0.5 to 0.8
10 to 14	0.8 to 1
14 to 17	1 to 1.5
17 to 22	1.5 to 2.0
>22	>2.0

Map data from Ator, S.W. et al., 2011. Maps modified from Ator, S.W. & Denver, J.M., 2015.

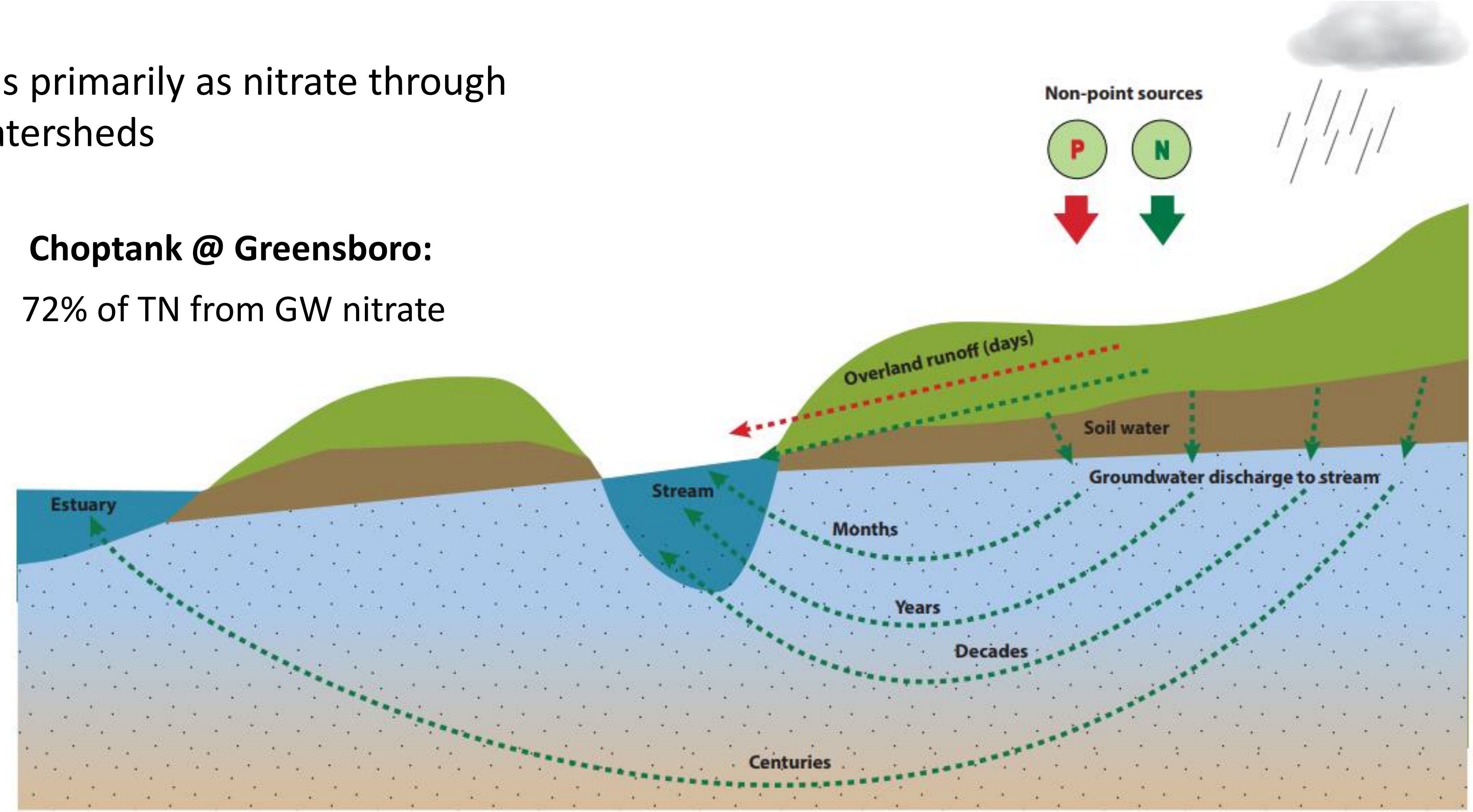
The transport of nutrients matters

- Phosphorus reaches streams primarily from overland runoff during storms
- Nitrogen reaches streams primarily as nitrate through groundwater in some watersheds



Choptank @ Greensboro:

72% of TN from GW nitrate



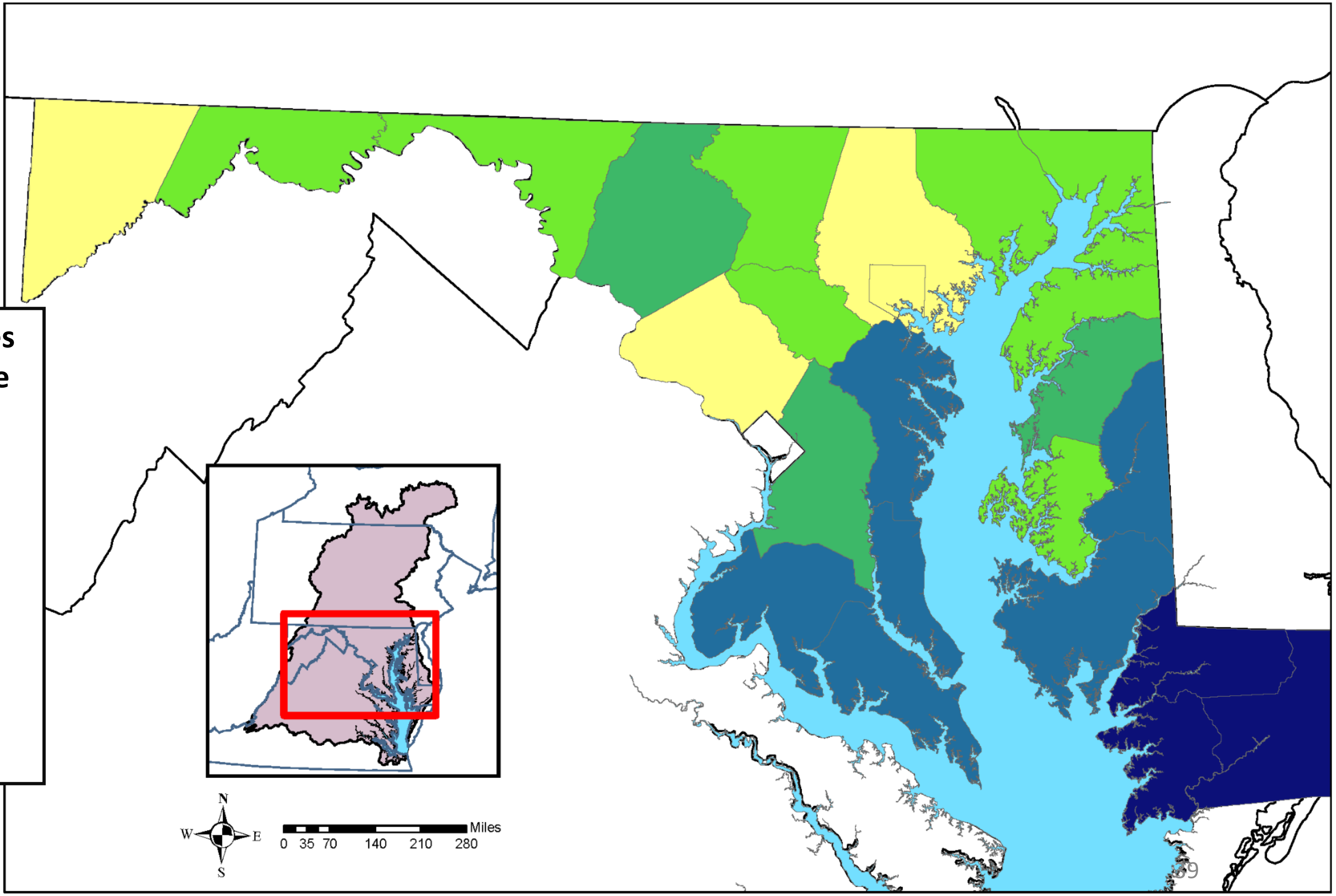
Ator, S.W. & Denver, J.M., 2015.
Bachman, L.J., et al., 1998.

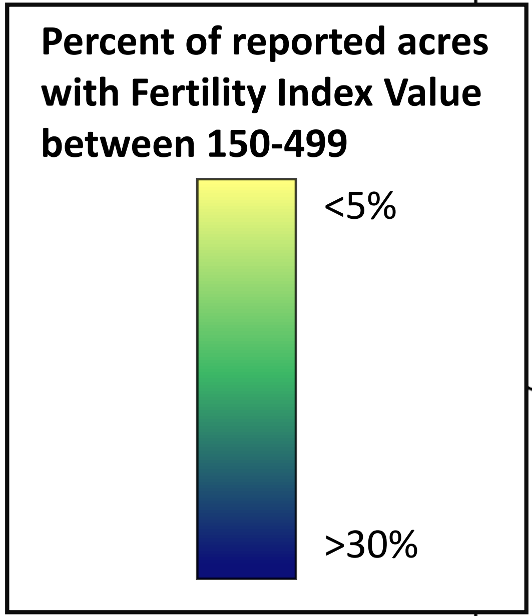
Diagram from Lyerly, A.L. et al., 2014.

Soil phosphorus and water quality are linked

- High soil phosphorus levels can lead to increased loads of phosphorus into streams

Fertility Index Value of Maryland Counties



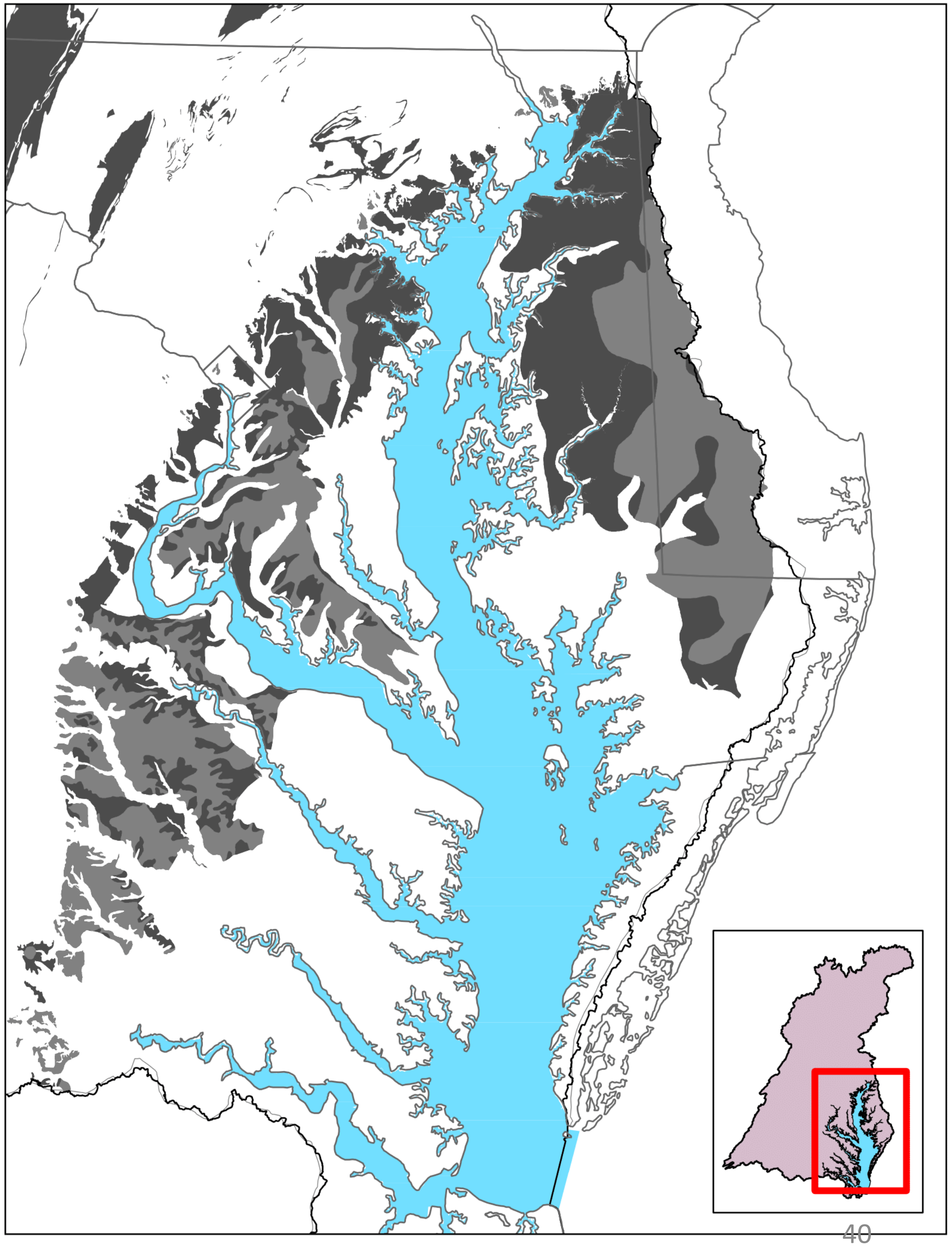


Maryland Department of Agriculture
Phosphorus Management Tool

Certain areas are more vulnerable to movement of nitrate into groundwater

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

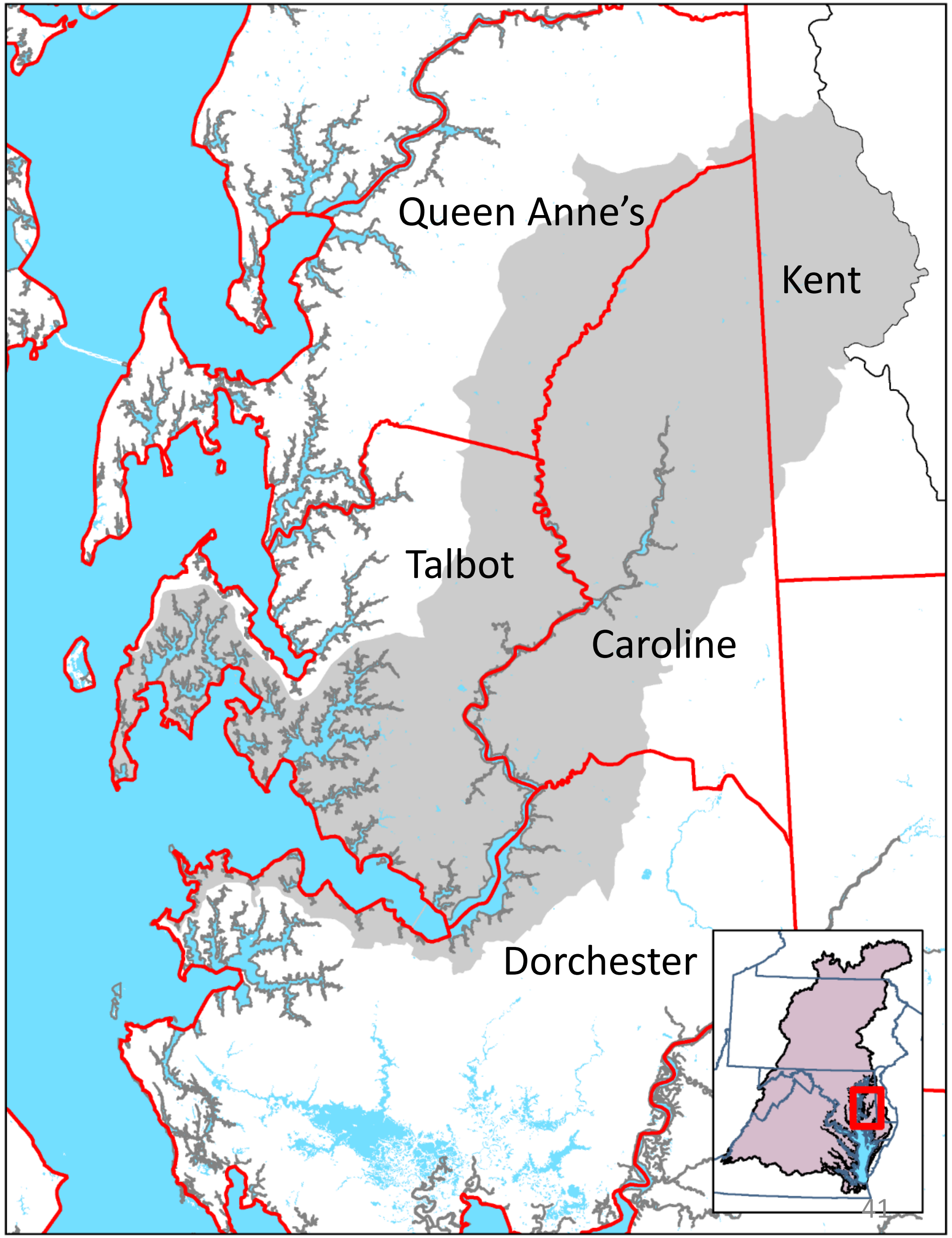
Vulnerable geology



Ator, S.W. & Denver, J.M., 2015.

Map modified from Jimmy Webber, USGS, using Brakebill, JW 2000 and Ator, S. et al. 2005.

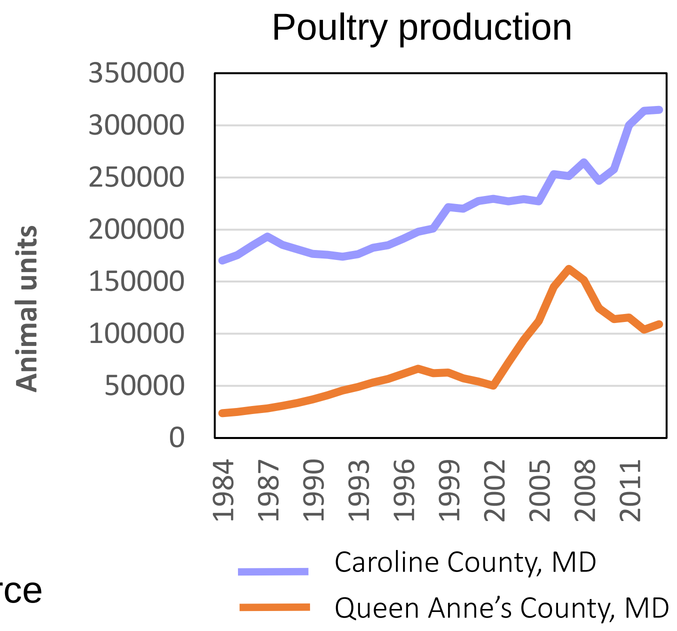
Sources, drivers, and impacts can differ between political boundaries

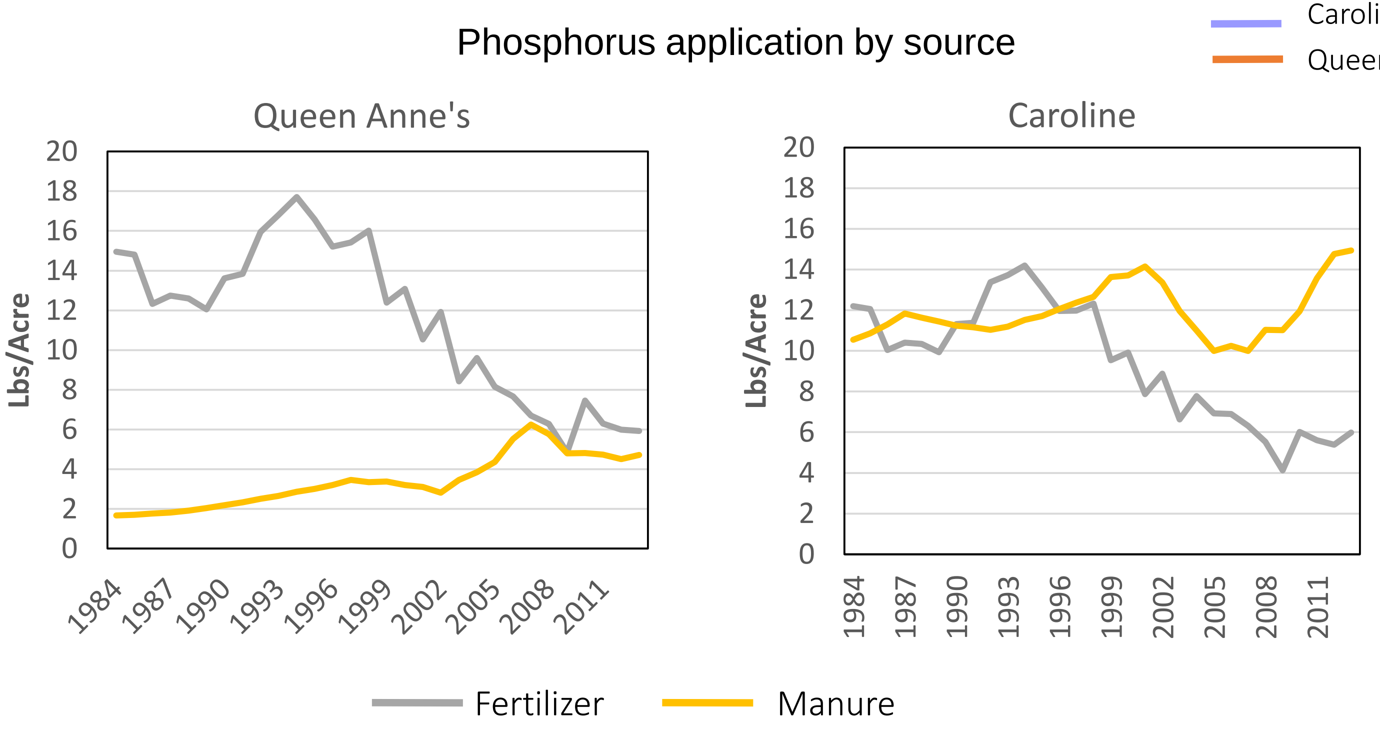


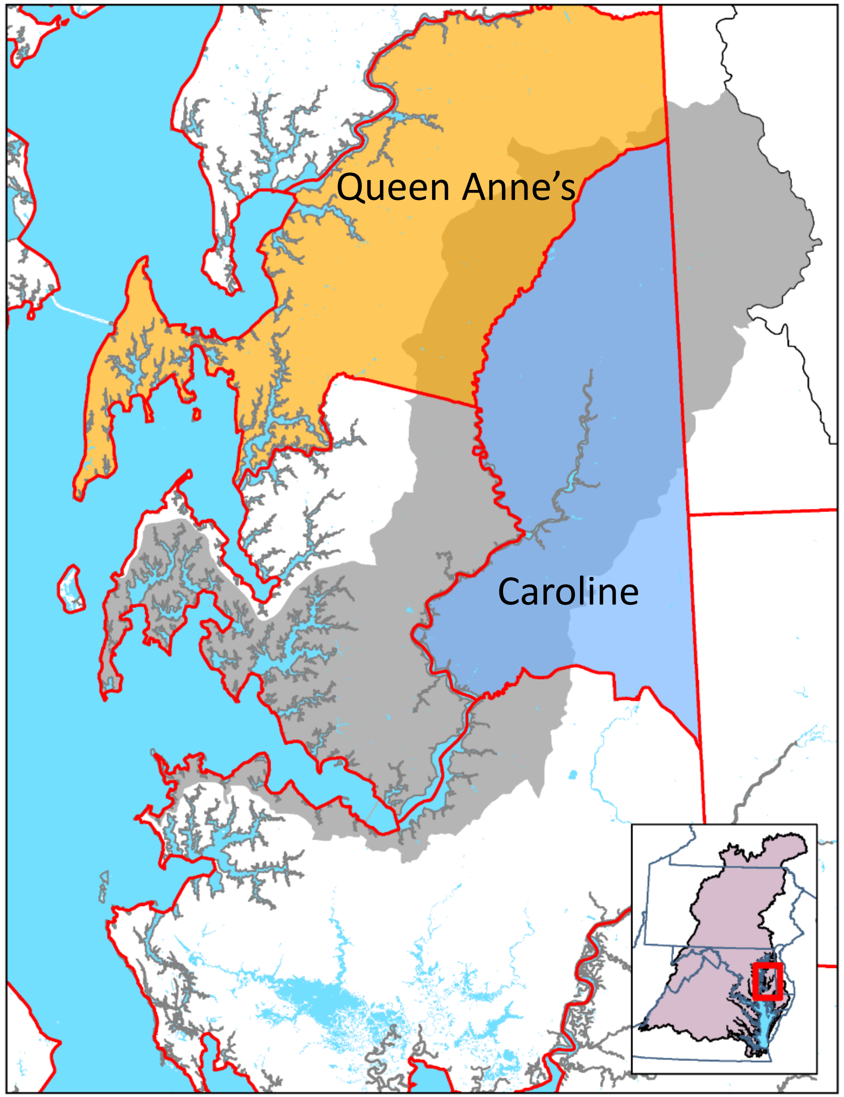
Sources, drivers, and impacts can differ across boundaries

Example: Queen Anne's & Caroline

- Different agricultural production
- Different application practices
- Different impact on soils & streams







Chesapeake Bay Phase 6 Program Watershed Model Calibration Inputs.
http://cast.chesapeakebay.net

Sources, drivers, and impacts can differ across boundaries

Example: Queen Anne’s & Caroline

- Different agricultural production
- Different application practices
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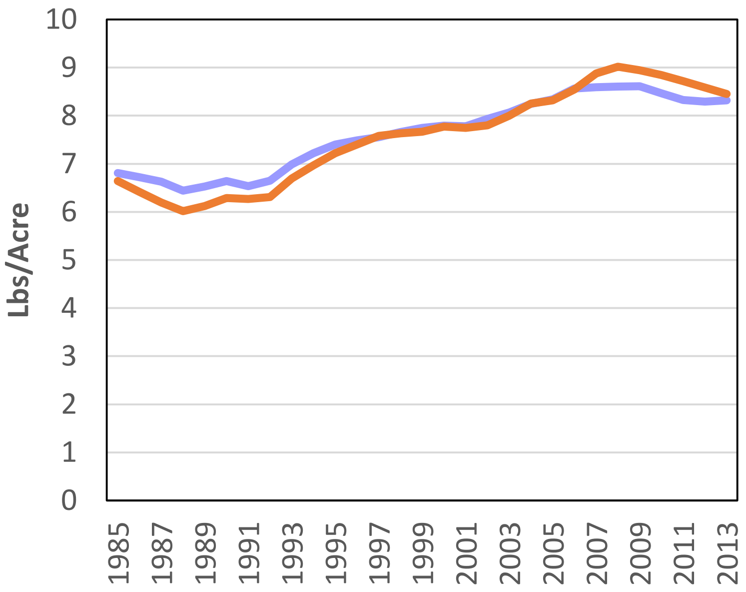
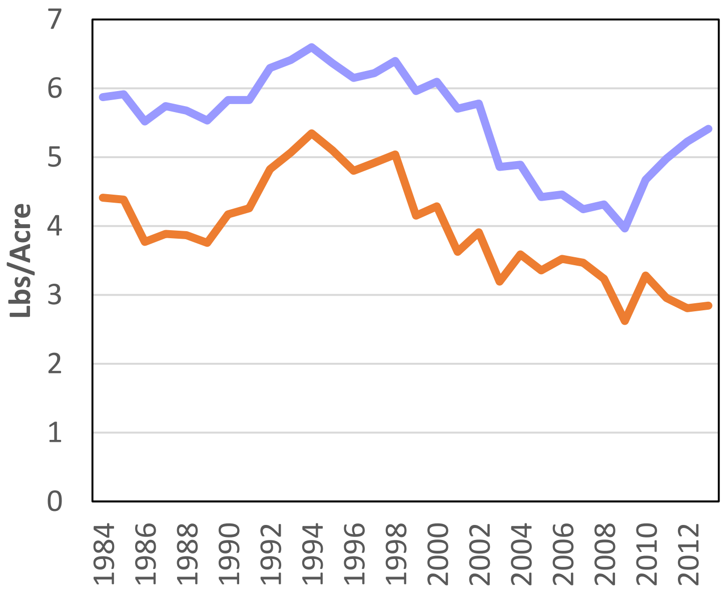
Phosphorus removed in crops

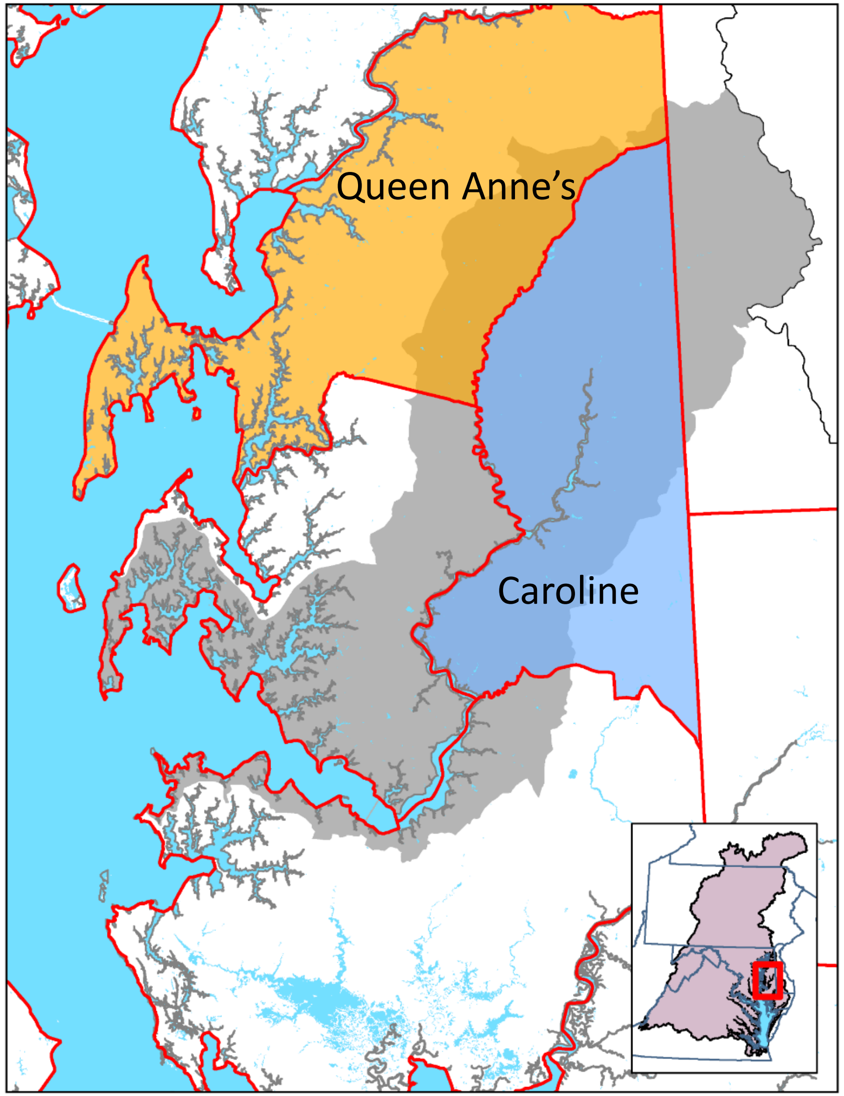


Phosphorus applied to crops



Caroline County, MD

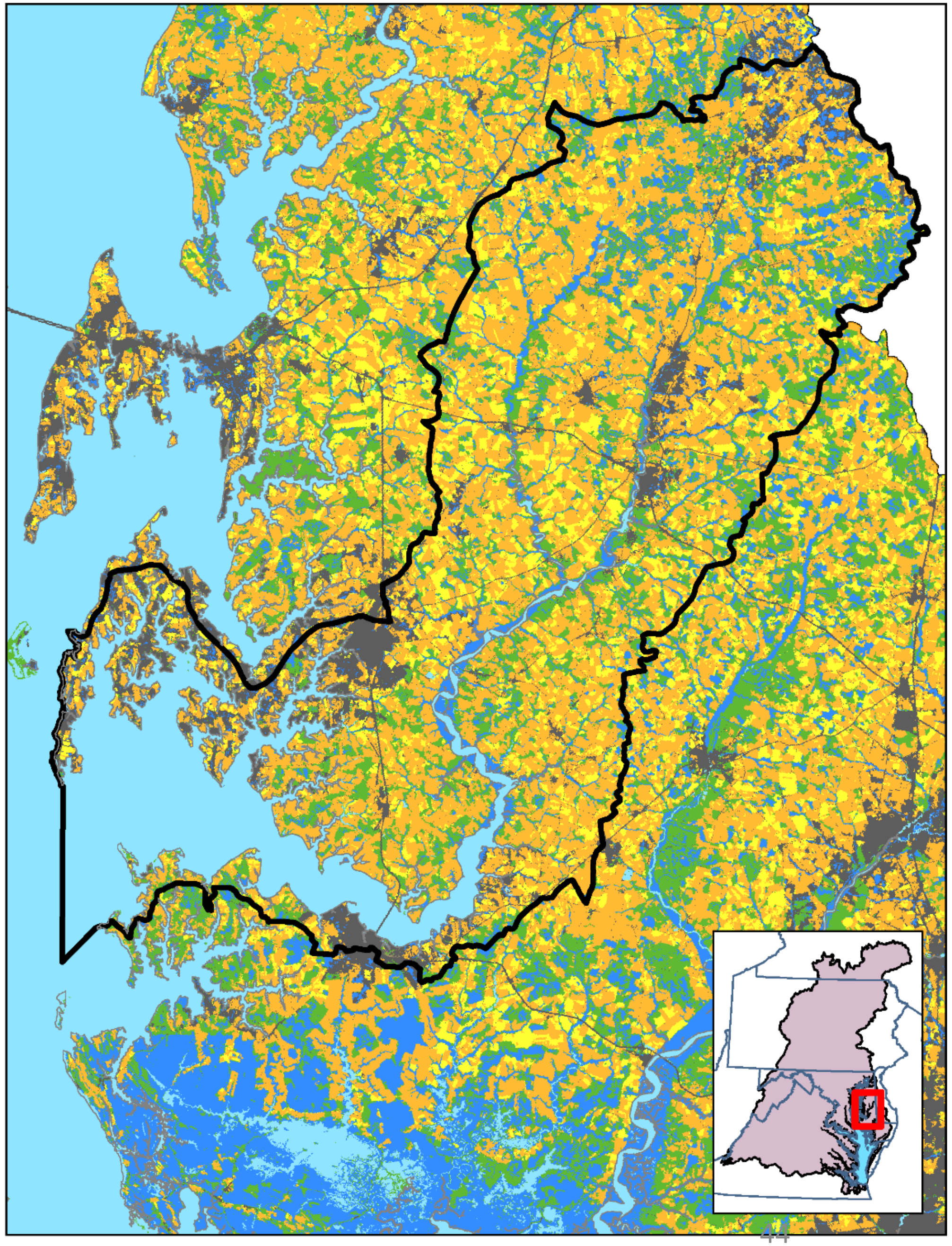
Queen Anne’s County, MD



Chesapeake Bay Phase 6 Program Watershed Model Calibration Inputs. http://cast.chesapeakebay.net

Making the management connection:

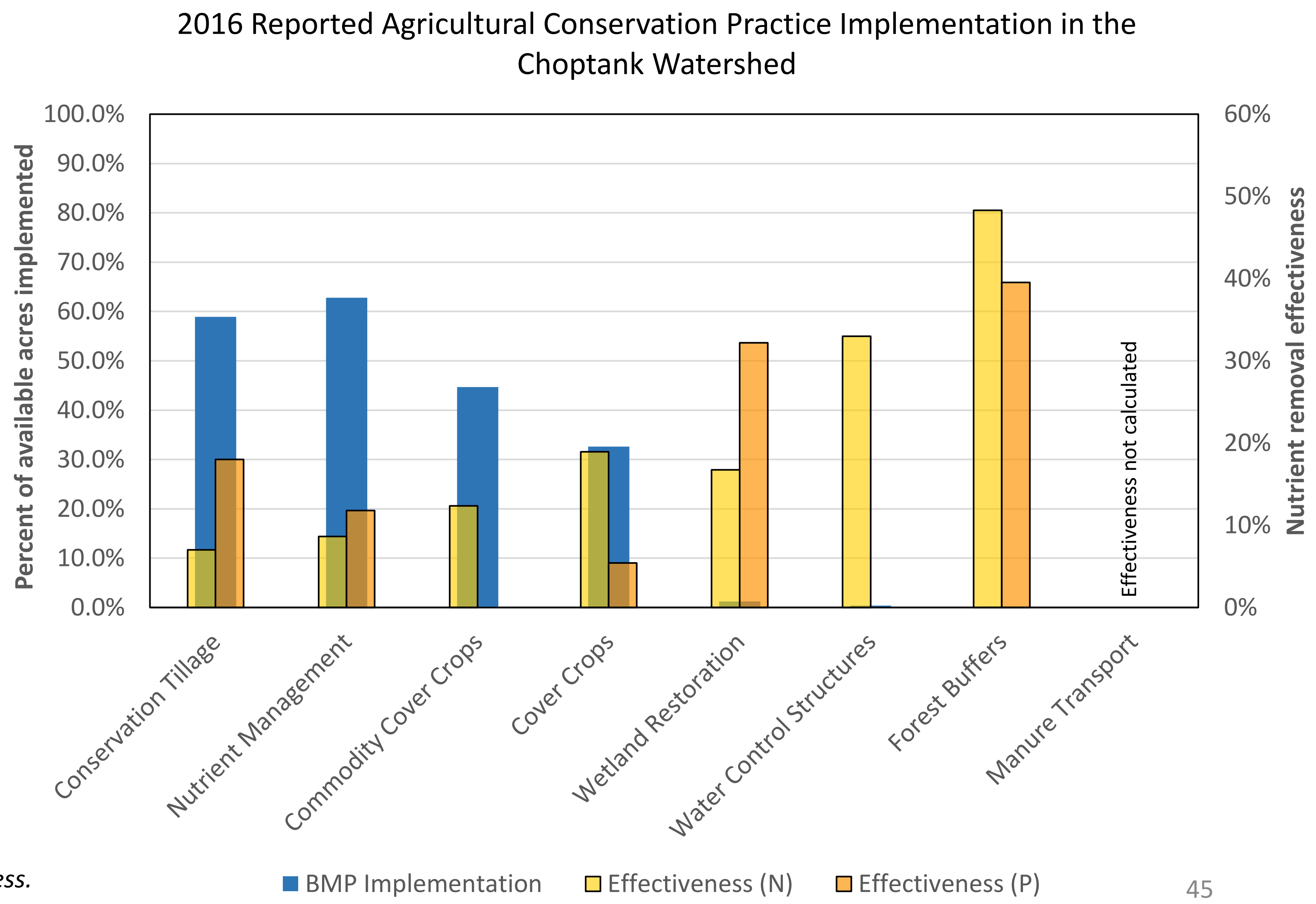
What have we done so far and what are the opportunities moving forward?



Map data from Falcone, J.A., 2015.

What practices address the issues in the Choptank? Have we been implementing them?

- Conservation tillage has been the longest and most widely implemented practice
- Major issues are nitrogen in groundwater, soil phosphorus, and overland runoff of sediment and phosphorus
- Effective practices could be cover crops, forest buffers, water control structures, manure transport, wetland restoration, appropriate nutrient management

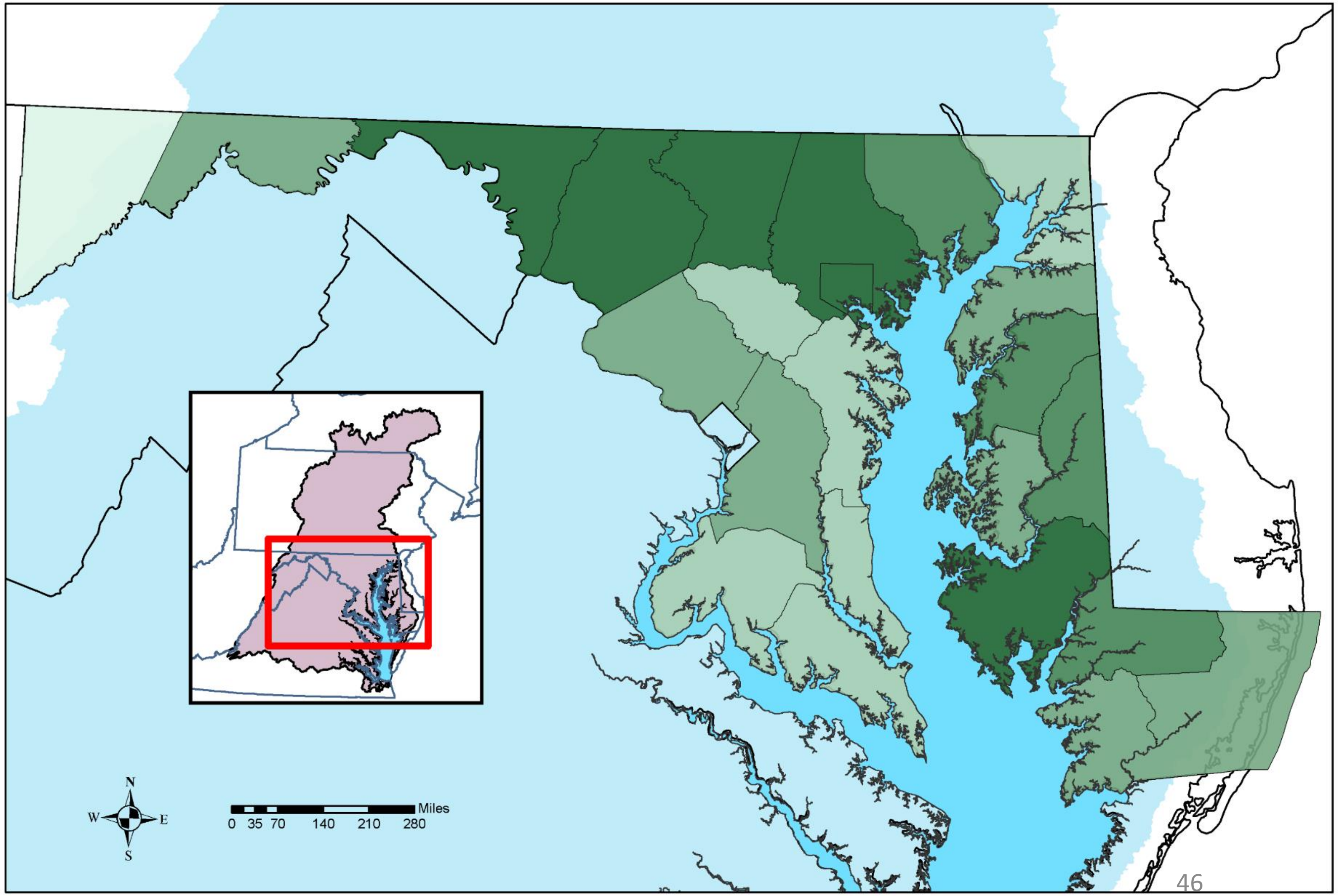


Chesapeake Bay Phase 6 Program Watershed Model Draft 2016 Progress. http://cast.chesapeakebay.net

The low hanging fruit isn't all gone!

- Opportunities exist to focus restoration efforts geographically and by the most cost-effective practices
- We are working with partners to build this information into tools

Acres available for grass or forest buffer implementation



Acres available for buffer implementation

Fewer acres

More acres

Data from Lindsey Gordon, CRC CBP

The low hanging fruit isn't all gone!

- Opportunities exist to focus restoration efforts geographically and by the most cost-effective practices
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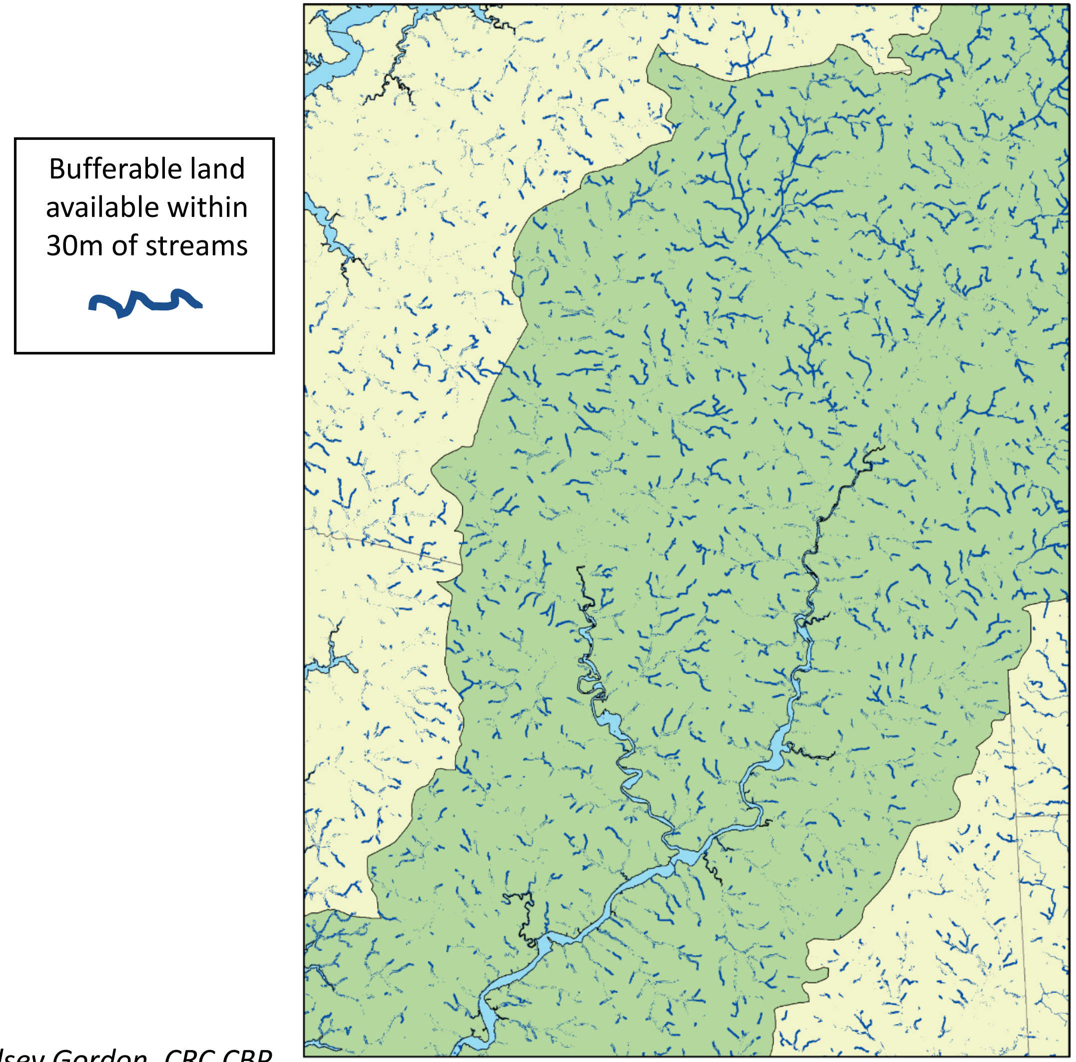
Acres available for grass or forest buffer implementation



Data from Lindsey Gordon, CRC CBP

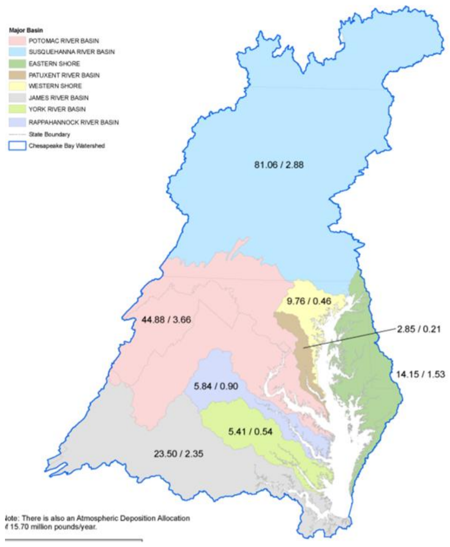
Setting Goals and Designing Plans with the Data

Matt Johnston, UMD at CBPO, Non-Point Source Data Analyst

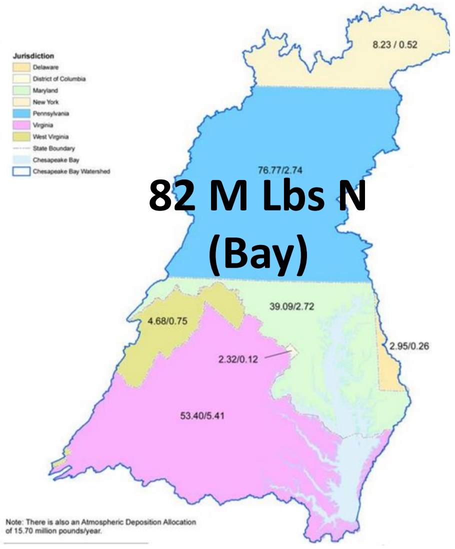
Developing Local Goals (Numbers Hypothetical)

Step 1: Receive Statewide Bay Goal from Partnership

Pollution Diet by River



Pollution Diet by State

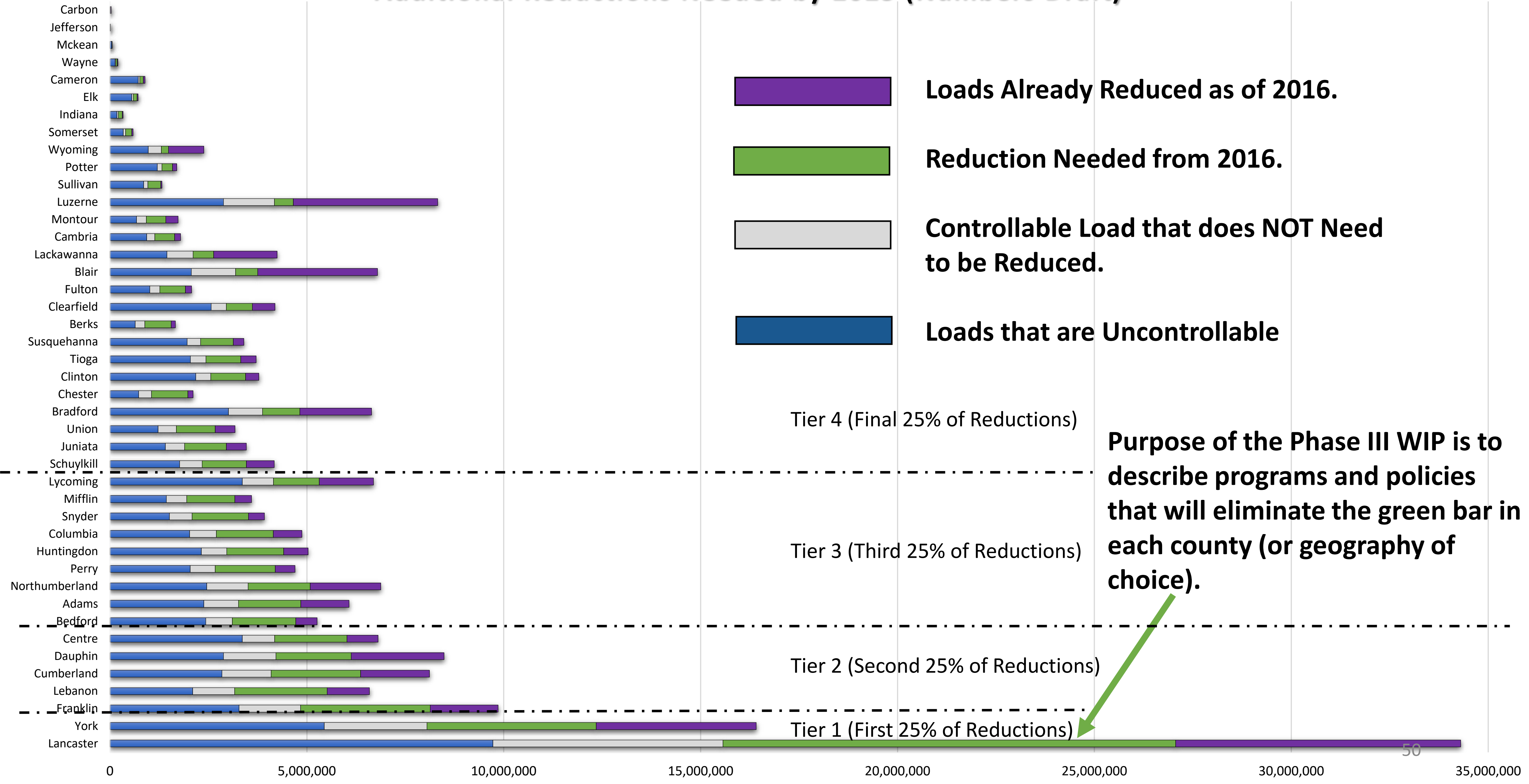


Step 2: Convert Bay Goal to Local Streams Goal for State

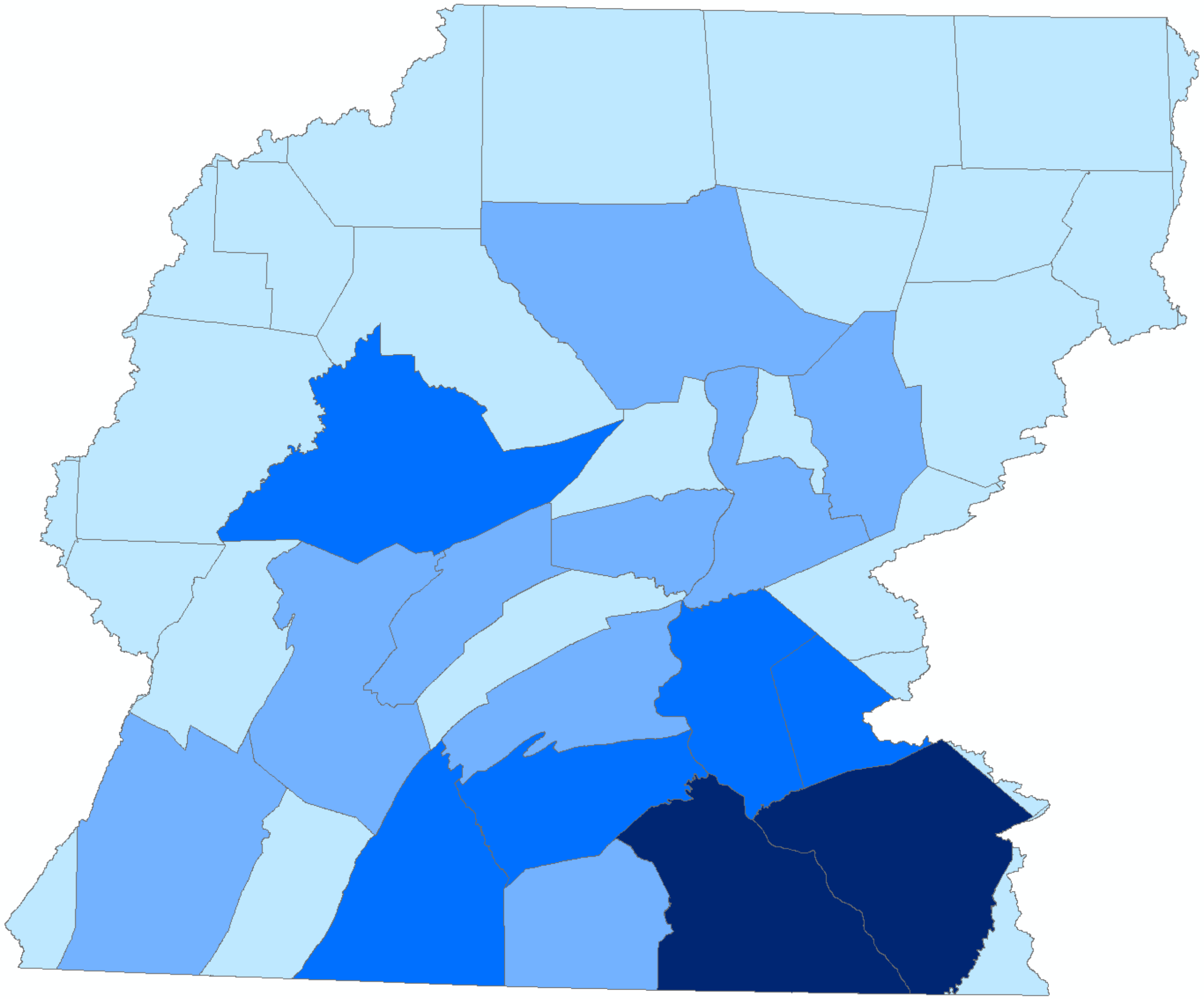
114 M Lbs N (Local Streams)

Step 3: Convert Statewide Local Streams Goal to Goals for Local Geographies

Estimated Reductions in Lbs of Nitrogen Delivered to PA Streams as of 2016, and Additional Reductions Needed by 2025 (Numbers Draft)



Where Should Efforts be Targeted?



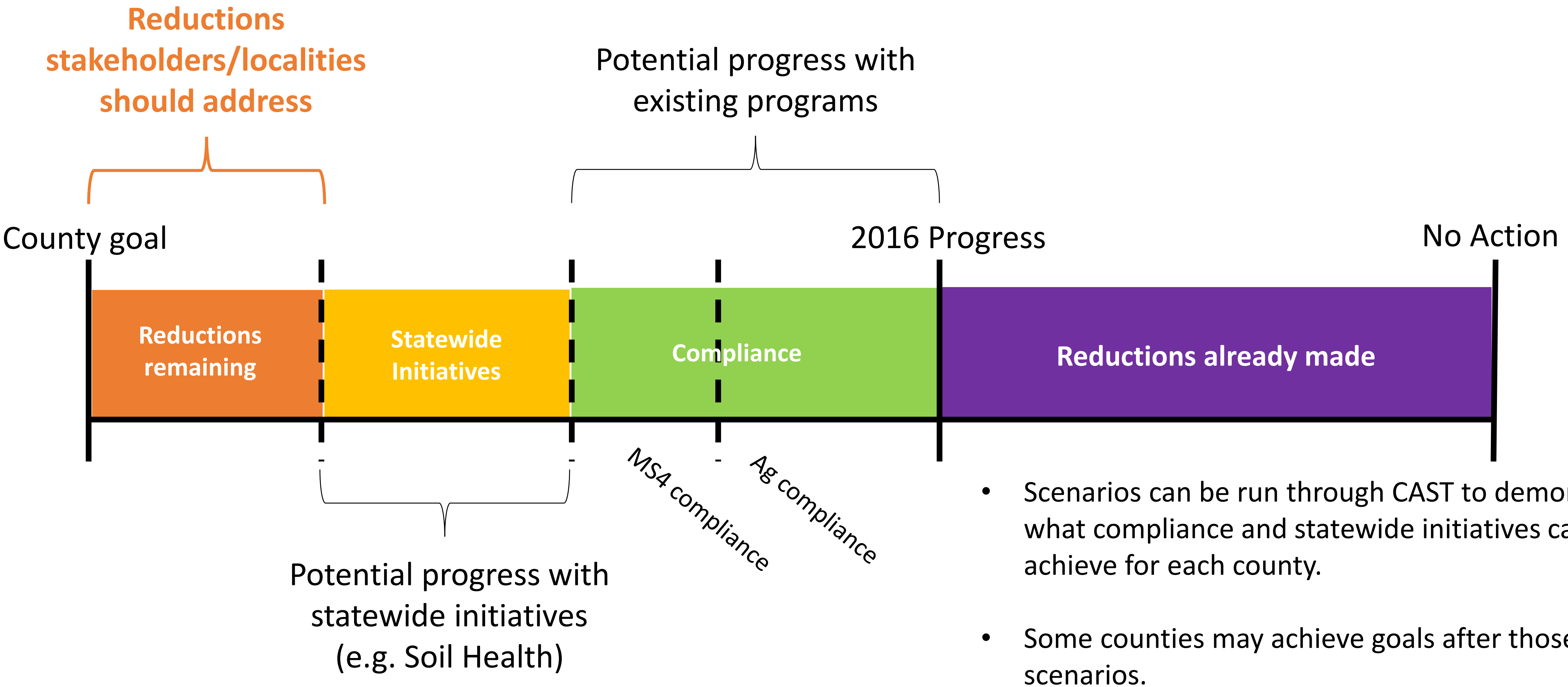
Tier 1 - First 25% of Reductions

Tier 2 - Second 25% of Reductions

Tier 3 - Third 25% of Reductions

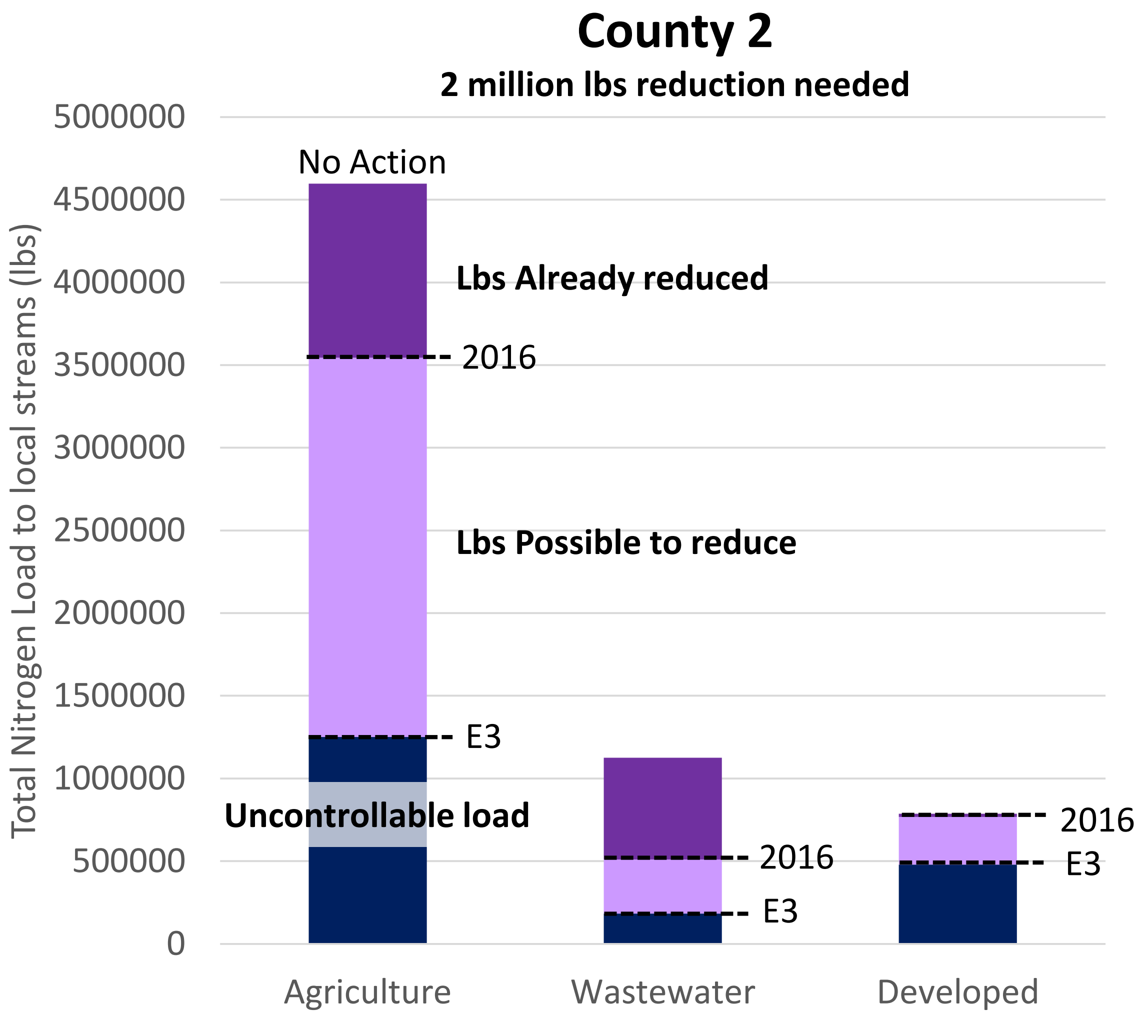
Tier 1 - Last 25% of Reductions

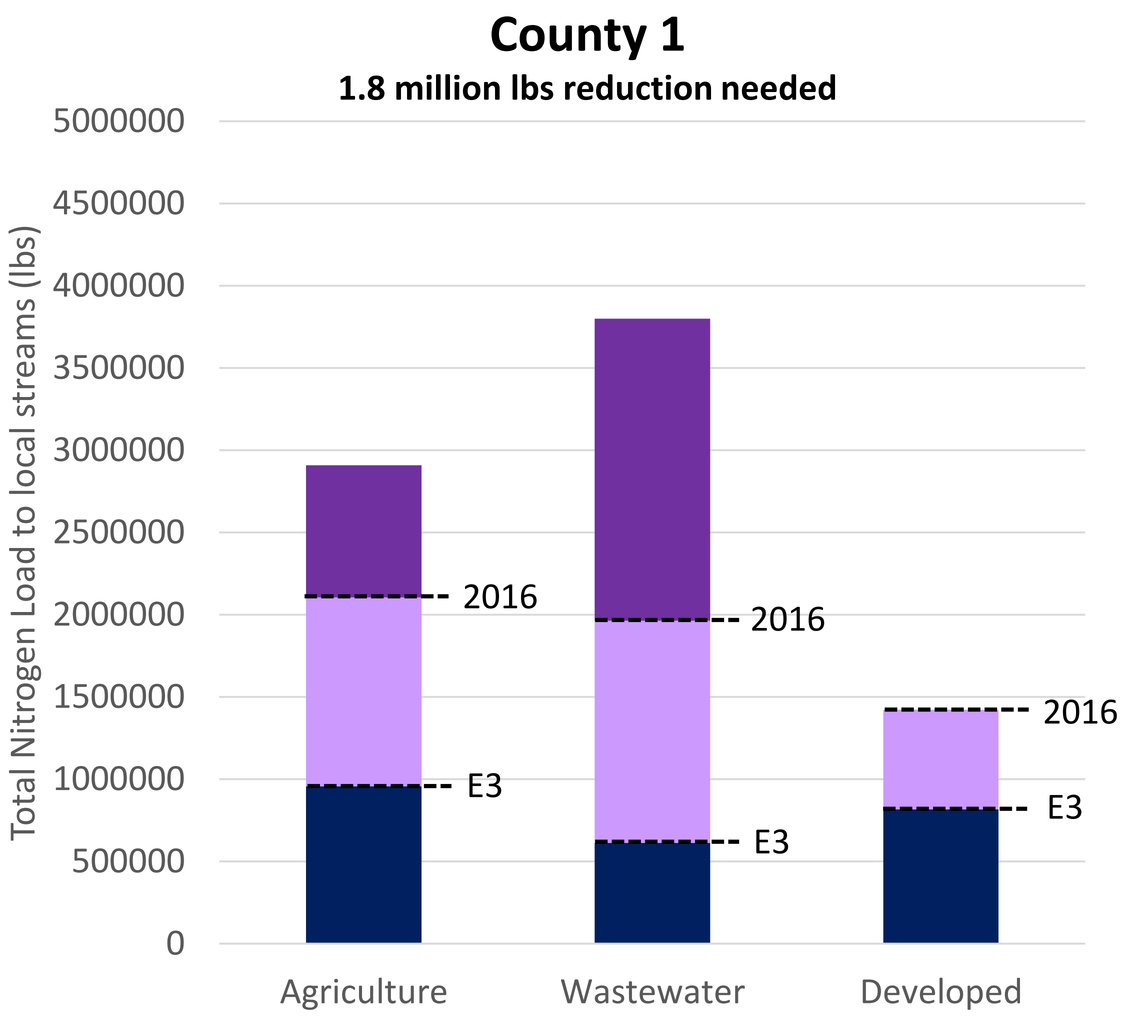
Hypothetical Journey to a County Goal



- Scenarios can be run through CAST to demonstrate what compliance and statewide initiatives can achieve for each county.
- Some counties may achieve goals after those scenarios.
- **Others will have to address remaining reductions needed.**

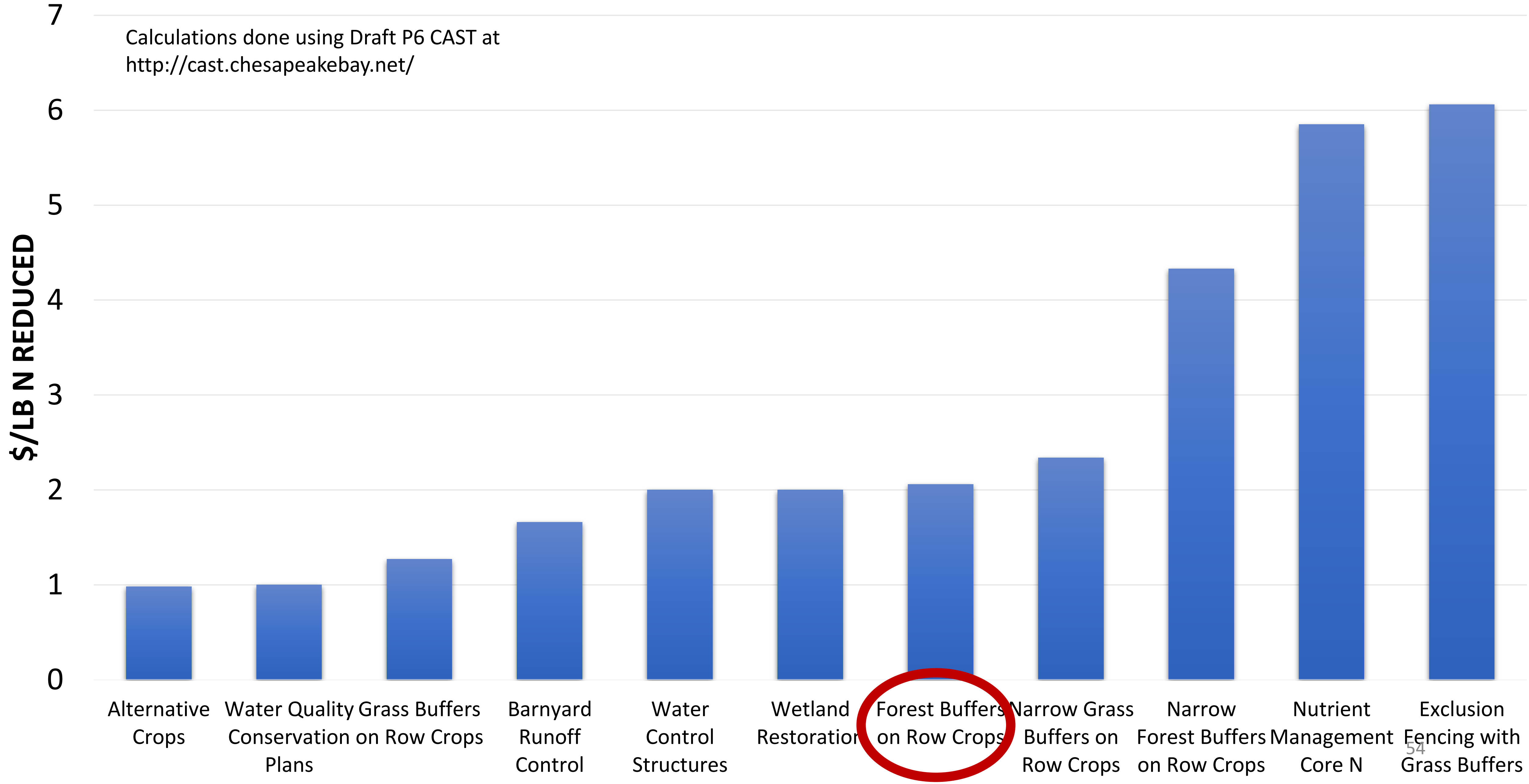
From what sectors are remaining reductions available?



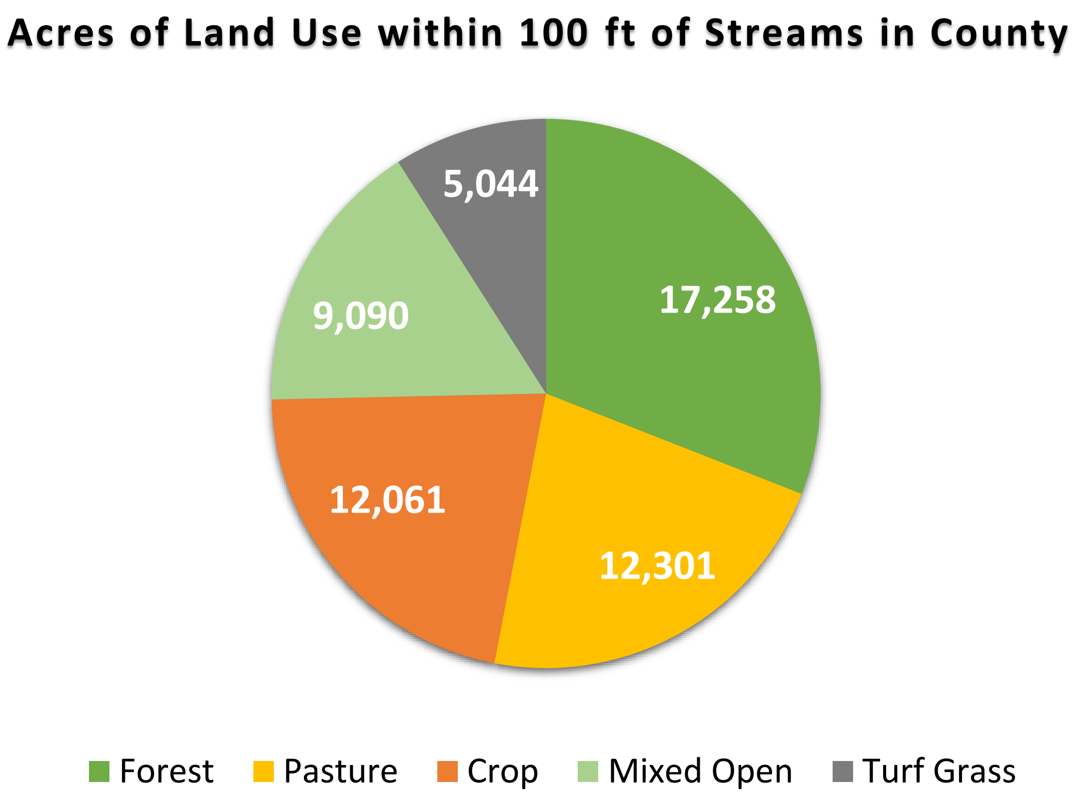


- Jurisdictions and their local areas can determine how to address local area goals across sectors
- Remaining reductions available in each sector before E3 differs between local areas

Most Cost-Effective Practices to Reduce N to Bay



Determining “Opportunity” (Available Acres) for BMP

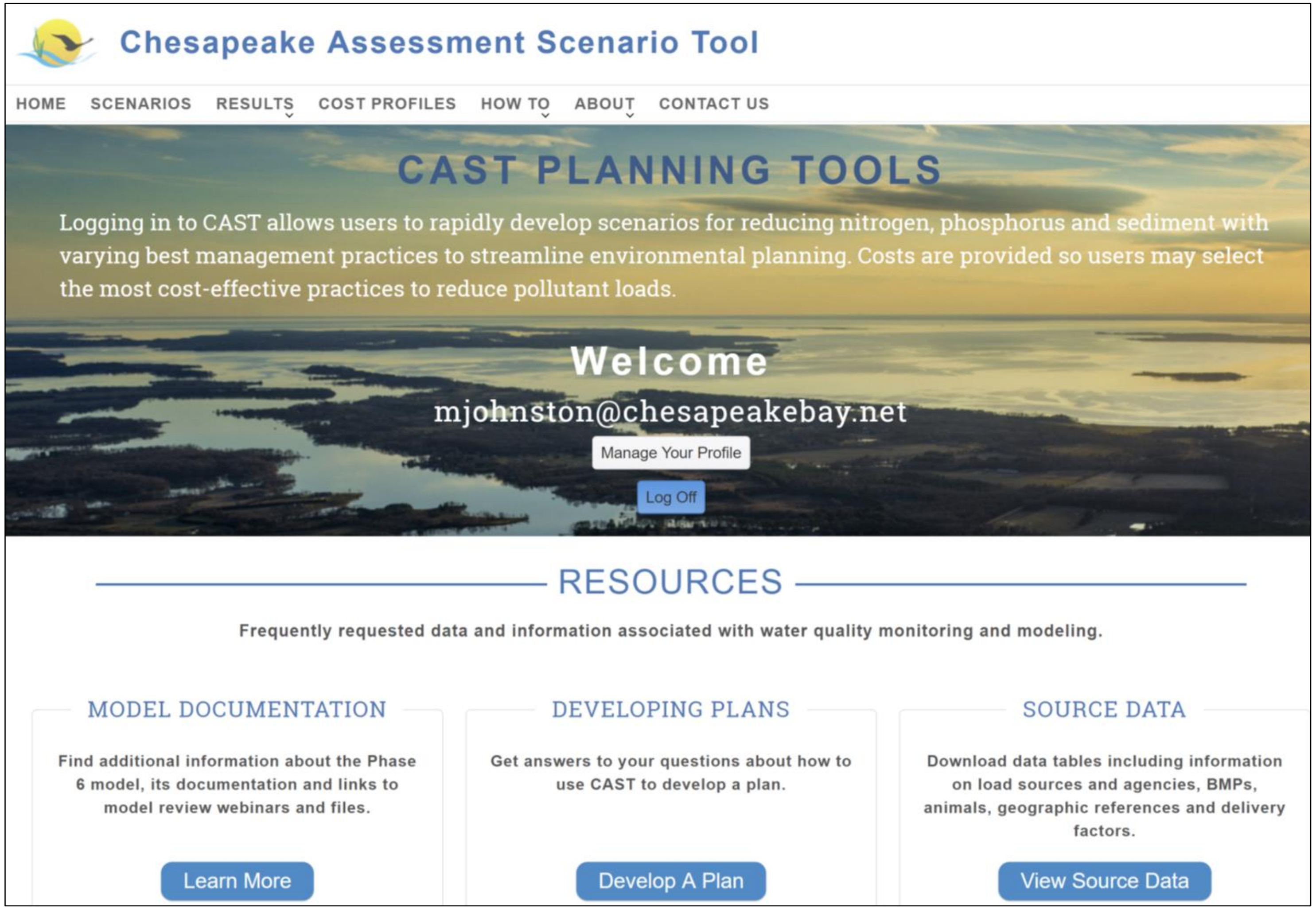


- CBPO used high resolution land use data to estimate acres of land uses within 30 meters of streams everywhere in the watershed.
- This analysis indicates there are approximately 12,000 acres of Cropland within 30 meters of streams in this county.
- Opportunity for Forest Buffers on Cropland = 12,000 acres
- **Phase III WIP efforts should describe how much of opportunity is feasible, and how programs and policies will achieve that goal.**

Where can Buffers be Planted (Targeted)?

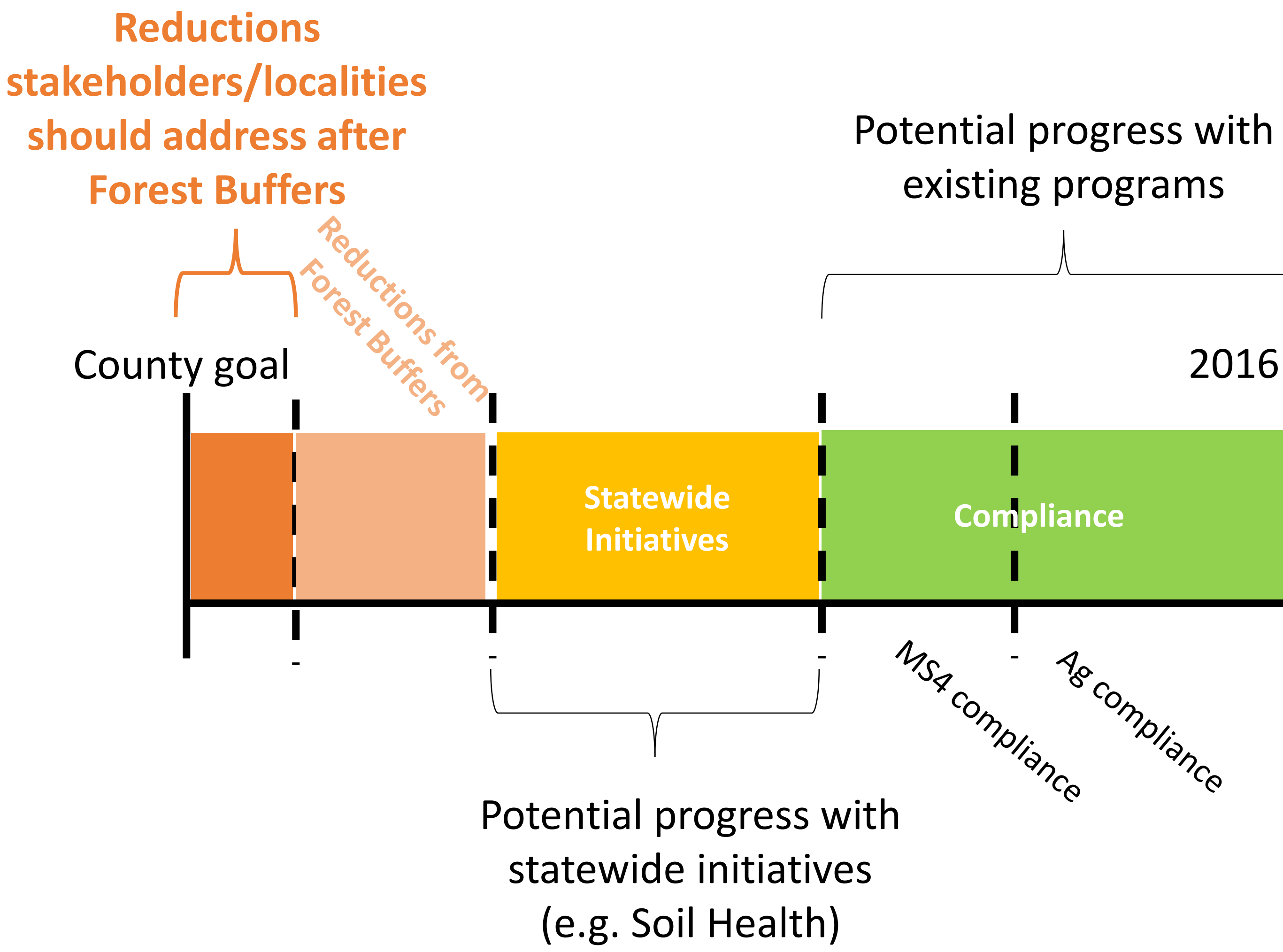
- CBPO is developing a data tool that will allow users to visualize data from the Phase 6 Model, including potential areas for riparian forest buffers.
- Other organizations could use the data as well to develop even more specific targeting tools.
- **Stakeholders determine 5,000 acres out of 12,000 available could be planted.**

Estimating Benefits of Buffer Initiative



- Stakeholders enter 5,000 acres of forest buffers in CAST.
  http://cast.chesapeakebay.net/
- CAST estimates about 1 M lbs reduction in nitrogen from 5,000 acres (-200 lbs/acre)

Hypothetical Journey to a County Goal (with Forest Buffers)



- Scenarios can be run through CAST to demonstrate what compliance and statewide initiatives can achieve for each county.
- Some counties may achieve goals after those scenarios.
- **Others will have to address remaining reductions needed.**

Technical outreach and engagement to jurisdictions and local areas

We are currently working with the jurisdictions and local partners to incorporate this information into their planning efforts…

- Technical support to jurisdictions
  - Explaining trends and science building blocks (e.g. Joel’s & Jeni’s information)
  - Storyline development and training (e.g. Emily’s information)
  - Support with model, scenarios, CAST, sector breakdowns, BMP implementation opportunities, etc. (e.g. Matt’s information)

We are currently working with the jurisdictions and local partners to incorporate this information into their planning efforts…

- Support to local areas
  - Through jurisdictions' local engagement strategies
  - Through LGAC and LGEI
  - Directly with local groups

We are currently working with the jurisdictions and local partners to incorporate this information into their planning efforts…

- Tool development & data accessibility
  - Data layers, guidance and messages being made available
  - Tool development process underway to gather user feedback

We are currently working with the jurisdictions and local partners to incorporate this information into their planning efforts…

February — **June** — **December**

Technical support to jurisdictions

- Initial face-to-face meetings by May
- Identify technical support contacts

Continued support during WIP development

Support to local areas

- Align with jurisdictions' local engagement schedule and events

Continued support

Tool development & data accessibility

- Feedback gathered from jurisdictions and local partners
- Tool scheduled to be available in June

Trainings/webinars on tool

Today's requested decisions from PSC

Approval of presented approach and schedule for developing and sharing explanations and management implications of the trends observed at hundreds of monitoring stations around the watershed and across the Bay's tidal waters with the jurisdictions and their local partners.

Today's requested decisions from PSC

Commitment to work with these explanations of the observed trends and resultant management implications to help inform and guide the jurisdictions' development of their Phase III Watershed Implementation Plans and adaptively manage their implementation in the years ahead.