Using the Tributary Summaries:
Case Studies of the Potomac and York Tributaries

December 6, 2021

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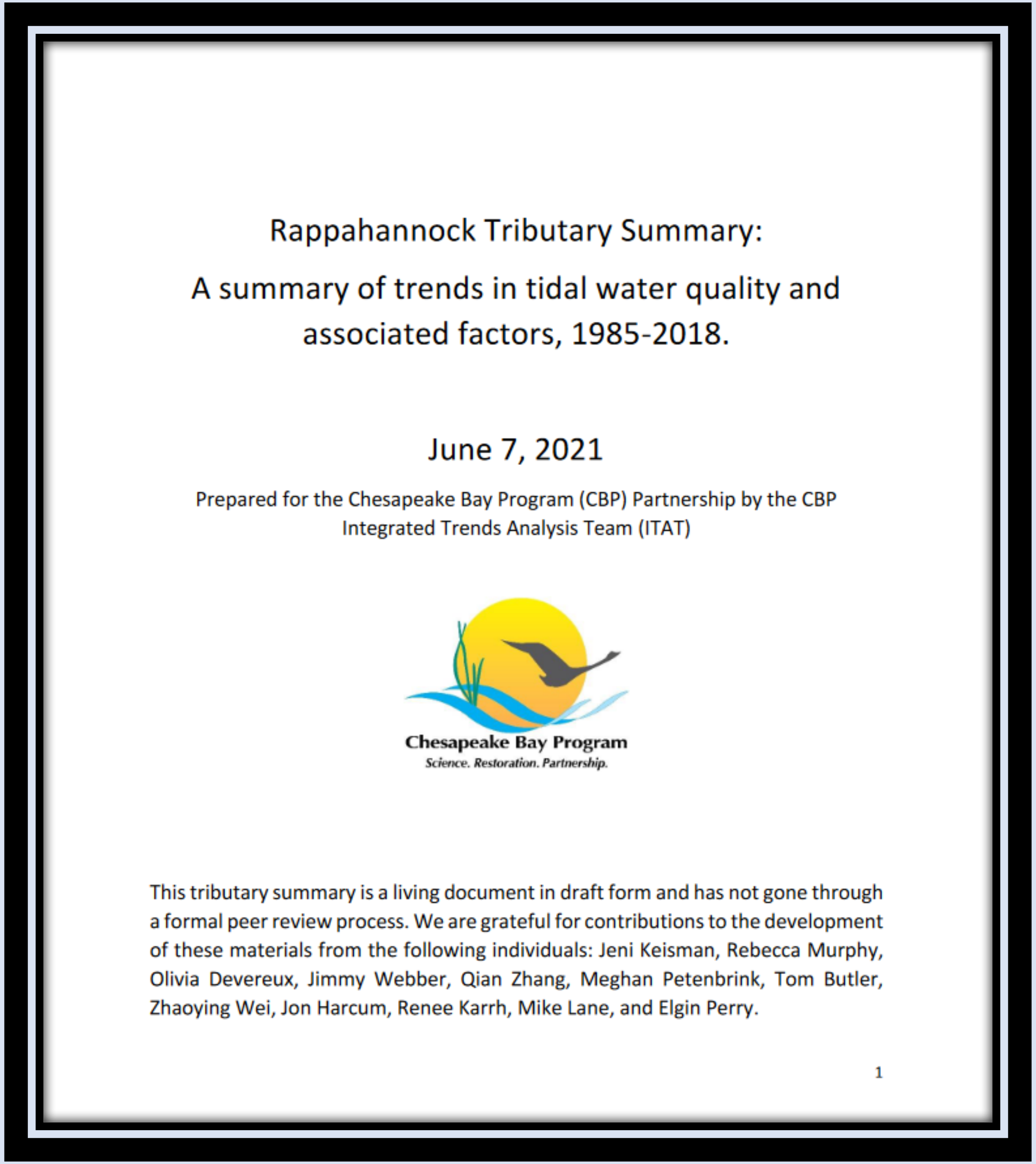

Rappahannock Tributary Summary:

A summary of trends in tidal water quality and associated factors, 1985-2018.

June 7, 2021

Prepared for the Chesapeake Bay Program (CBP) Partnership by the CBP Integrated Trends Analysis Team (ITAT)

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This tributary summary is a living document in draft form and has not gone through a formal peer review process. We are grateful for contributions to the development of these materials from the following individuals: Jeni Keisman, Rebecca Murphy, Olivia Devereux, Jimmy Webber, Qian Zhang, Meghan Petenbrink, Tom Butler, Zhaoying Wei, Jon Harcum, Renee Karrh, Mike Lane, and Elgin Perry.

1

Overview of Presentation

1. *Long Term WQS Attainment Indicator*

2. What are the Tributary Summaries?

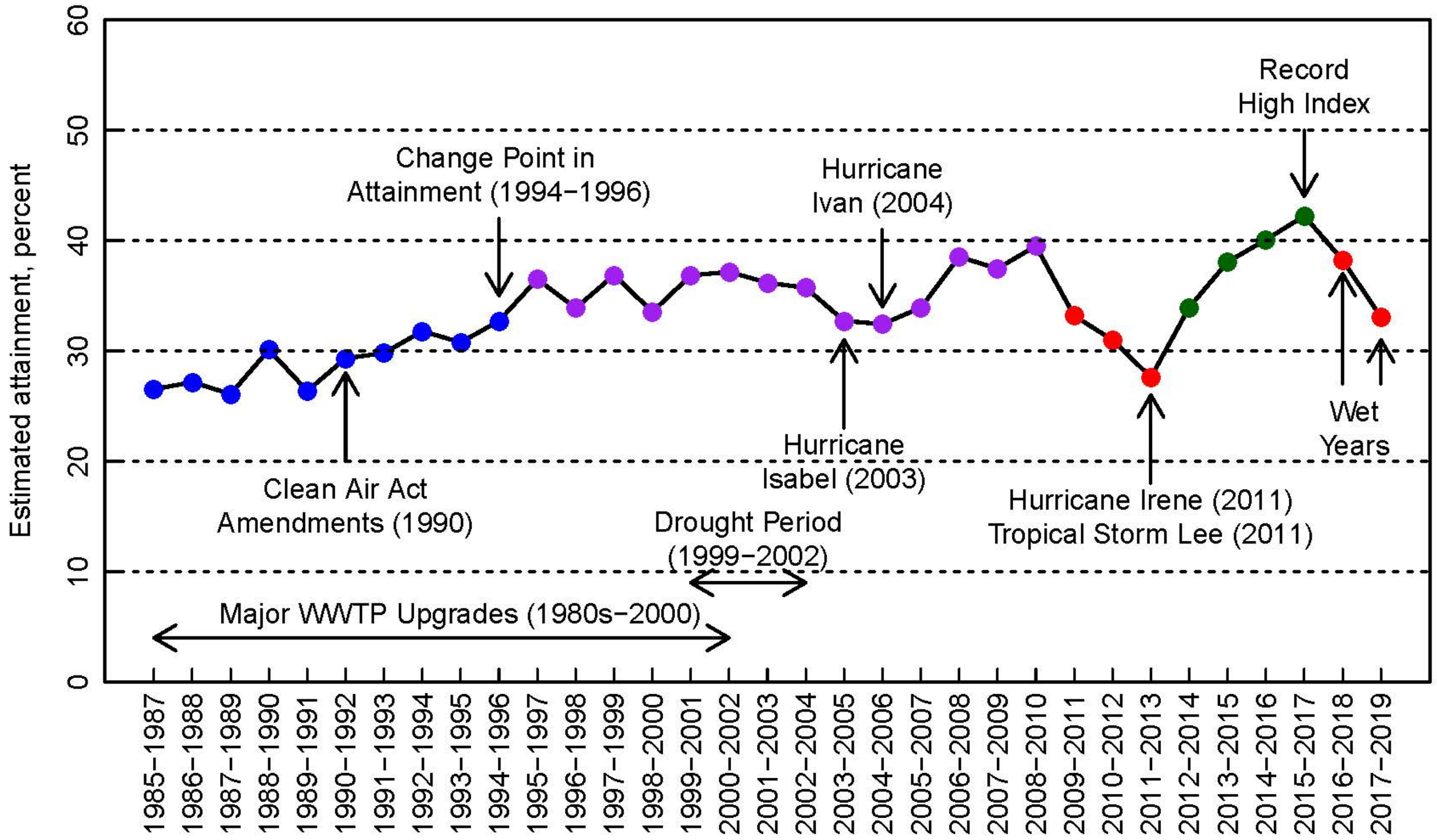
3. Looking at two Tributary Summaries
    - *The Potomac*
    - *The York River*

4. Next Steps for the Tributary Summaries

Water quality standards attainment indicator

Long-term WQS indicator

- Reached its peak (42%) in 2015-2017 but dropped to 33% in 2017-2019.
- It is responsive to extreme weather events but can quickly recover afterwards.
- The indicator has a positive long-term trend ($p < 0.05$) in 1985-2019.

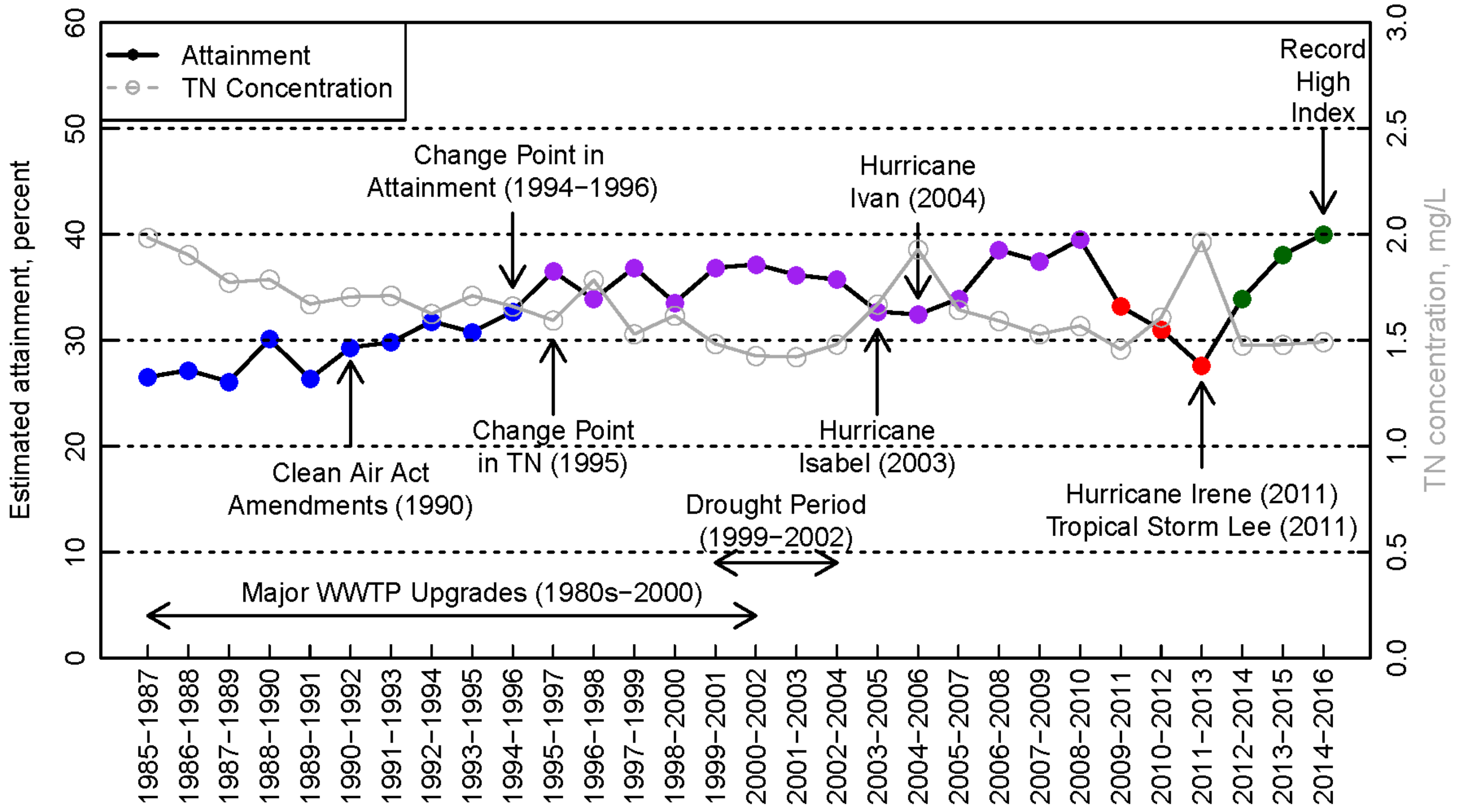


Slide from Qian Zhang (UMCES) and Peter Tango (UGSG)

Factors influencing WQS Attainment

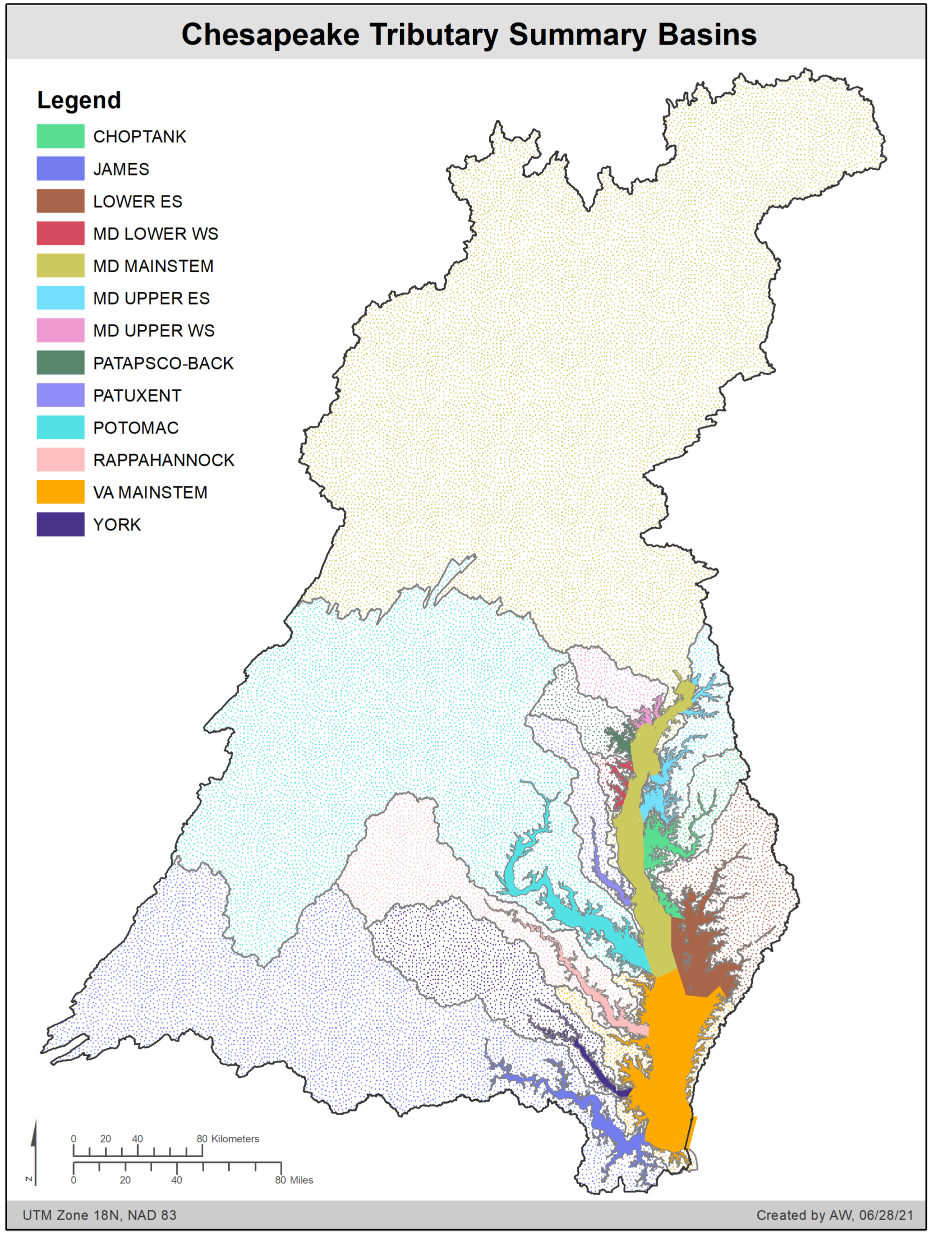
- The improvement in the Baywide attainment was statistically linked to the decline of TN input from the watershed, suggesting the effectiveness of nutrient control actions.

- Additional factors (TP, flow, WTEMP, Secchi, etc.) are under investigation.



Slide from Qian Zhang (UMCES) and Peter Tango (UGSG)

13 Tributary Trend Summaries

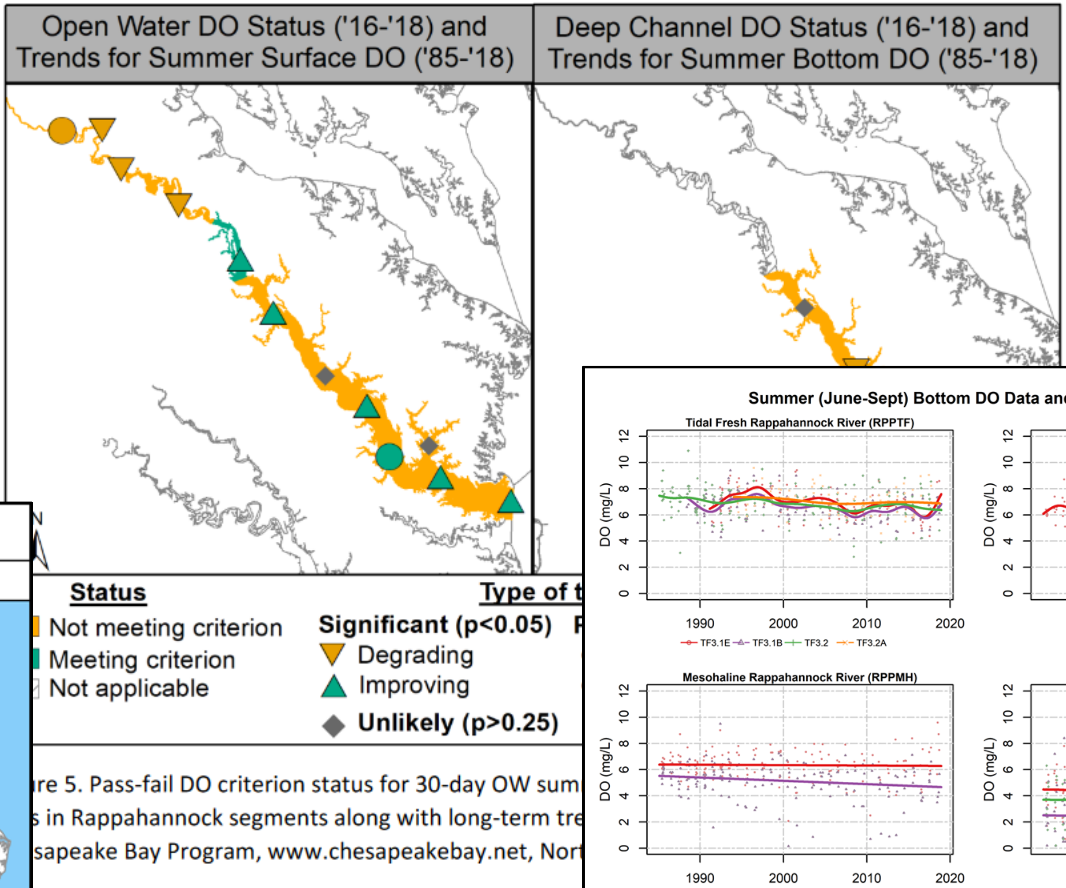


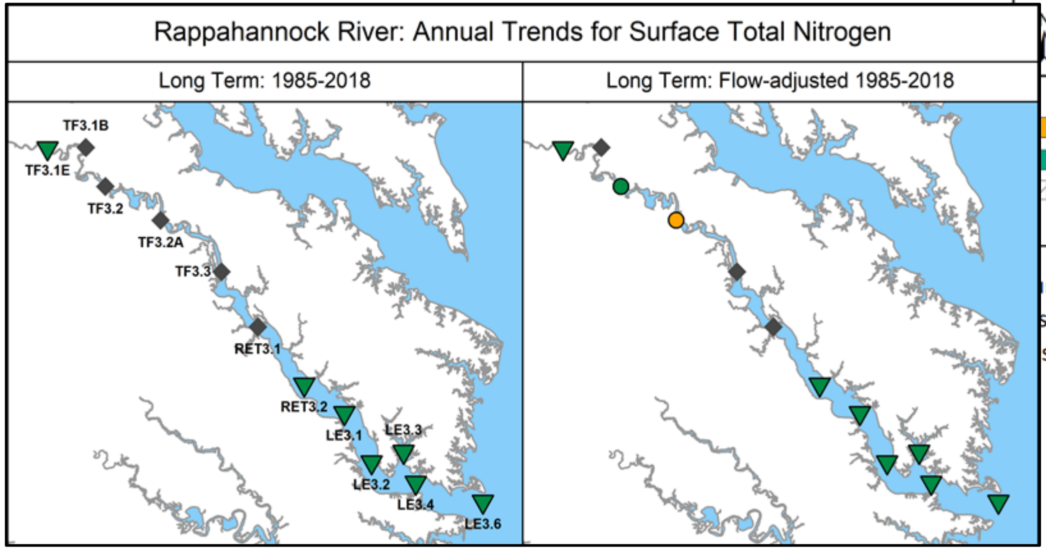
- **Maryland Mainstem** *(The 5 Chesapeake Bay mainstem segments within the MD state boundary. Drainage basins include the Susquehanna River and upper Chesapeake shorelines)*
- **Maryland Upper Eastern Shore** *(The Northeast, Bohemia, Elk, Back Creek, Sassafras, and Chester Rivers, the C&D Canal, and Eastern Bay)*
- **Choptank** *(the Choptank, Little Choptank, and Honga)*
- **Maryland Upper Western Shore** *(Bush, Gunpowder, Middle Rivers)*
- **Maryland Lower Western Shore** *(Magothy, Severn, South, Rhode, and West)*
- **Patapsco & Back Rivers**
- **Patuxent** *(includes the Western Branch tributary)*
- **Potomac**
- **Rappahannock** *(includes the Corrotoman tributary)*
- **York** *(includes the Mattaponi and Pamunkey tributaries)*
- **James** *(includes the Appomattox, Chickahominy, and Elizabeth tributaries)*
- **Lower E. Shore** *(includes the Nanticoke, Manokin, Wicomico, Big Annemessex, and Pocomoke rivers & Tangier Sound)*
- **Virginia Mainstem** *(no summary but Appendices are provided)*

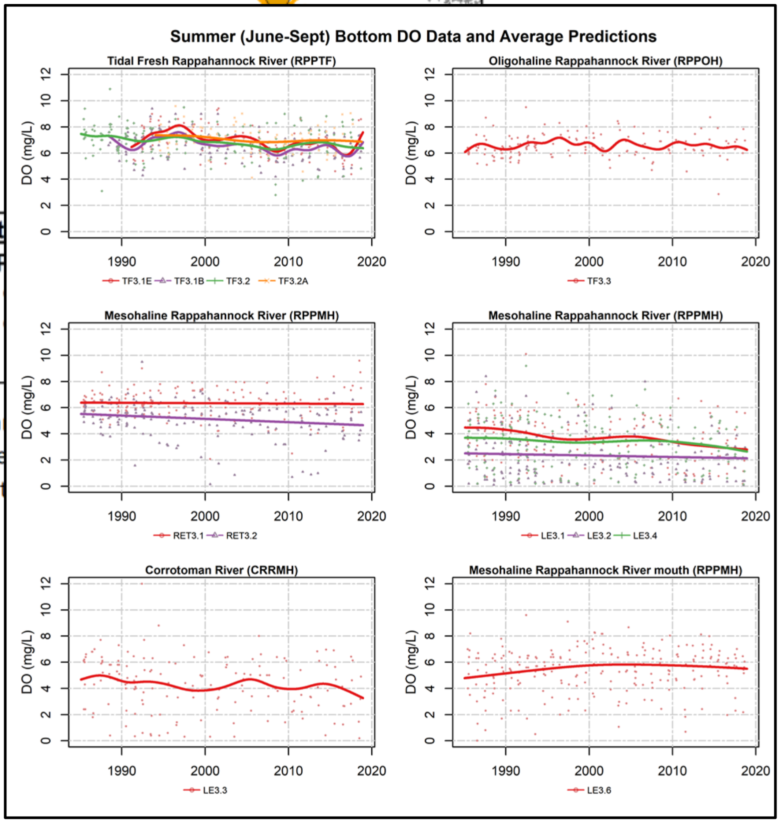
What are the Tributary Summaries?

A compilation of information by tributary or region on:

- **Tidal water quality and trends**



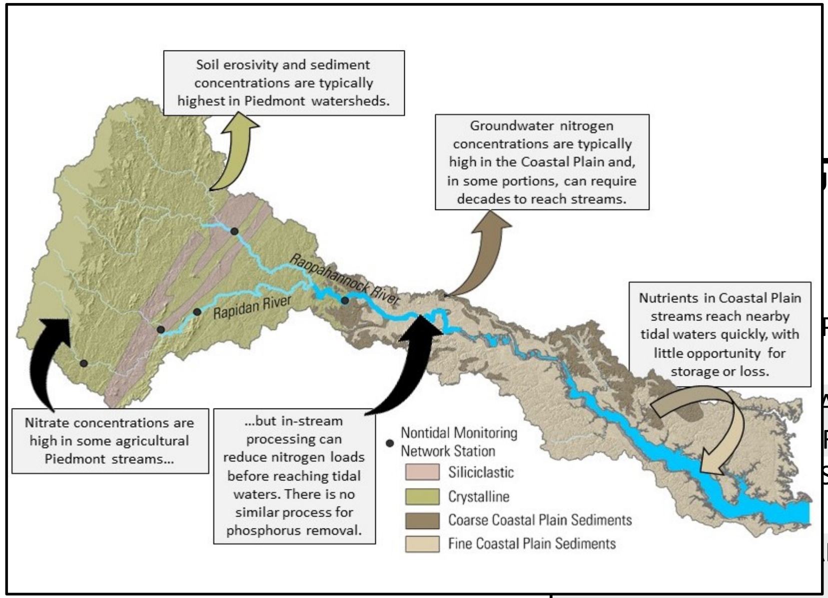


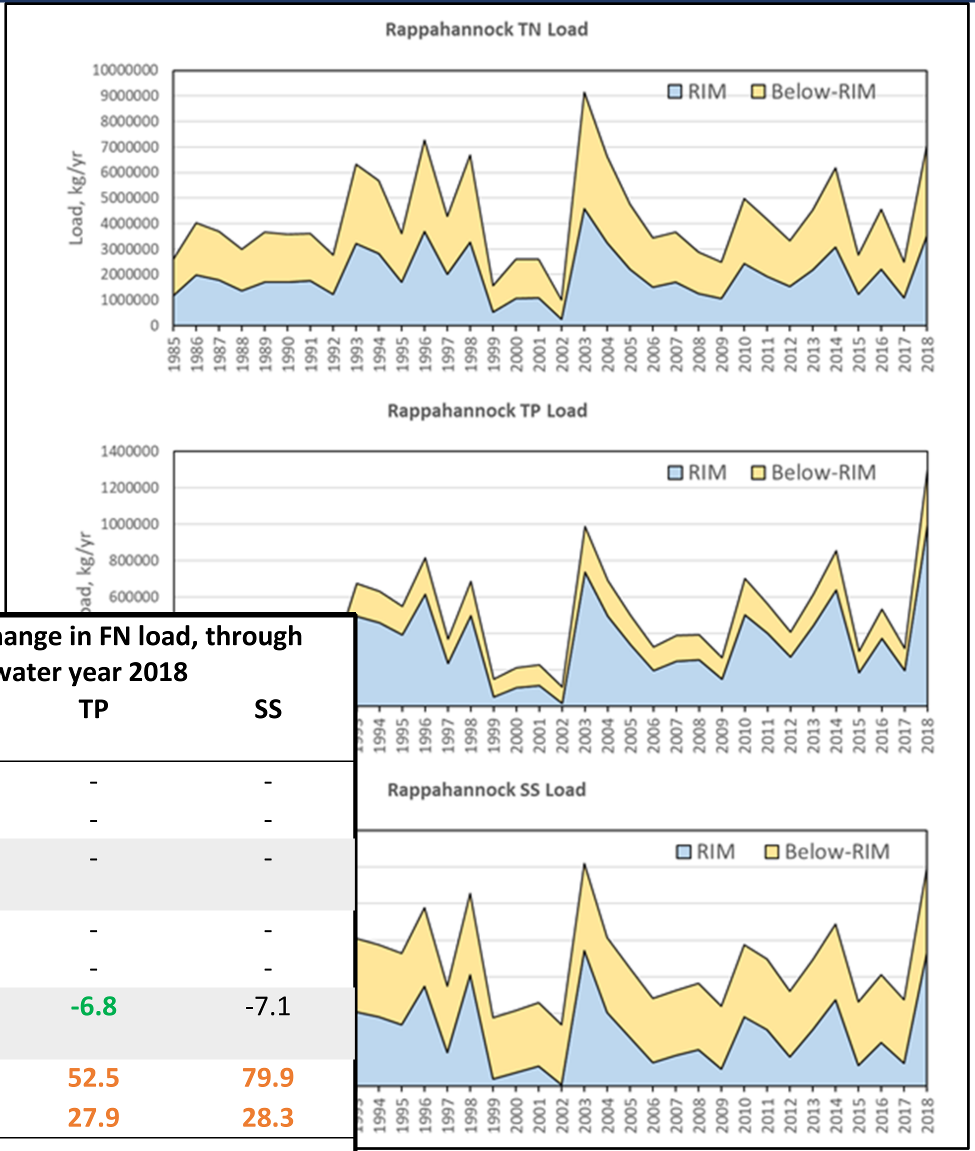


What are the Tributary Summaries?

A compilation of information by tributary or region on:

- Tidal water quality and trends,
- **Watershed characteristics and changes**



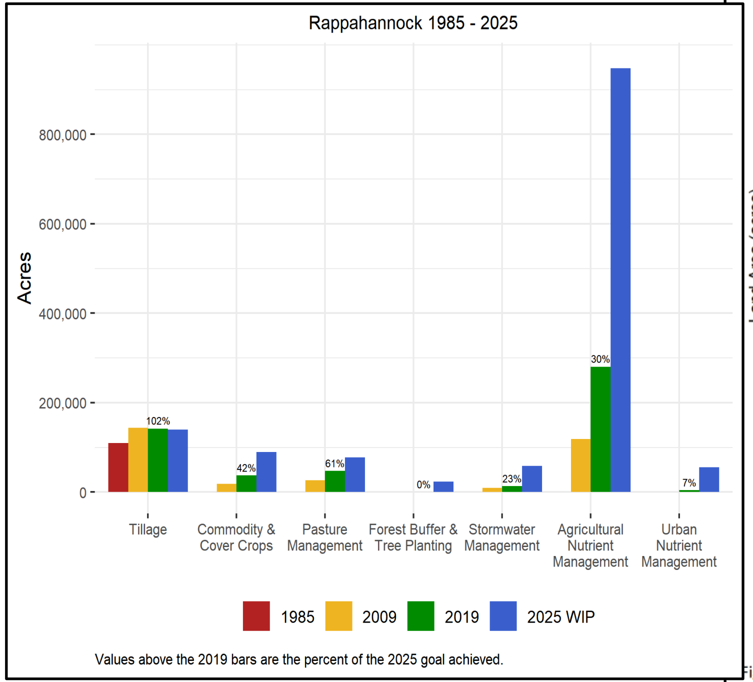


	JSGS Station Name	Trend start water year	Percent change in FN load, through water year 2018		
			TN	TP	SS
	PAHANNOCK RIVER AT REMINGTON, VA	1985	24.4	-	-
		2009	15.4	-	-
	APIDAN RIVER NEAR RUCKERSVILLE, VA	2009	-5.1	-	-
	SON RIVER NEAR LOCUST DALE, VA	1985	2.5	-	-
		2009	3.5	-	-
	N RIVER NEAR CULPEPER, VA	2009	-8.9	-6.8	-7.1
01668000	RAPPAHANNOCK RIVER NEAR FREDERICKSBURG, VA	1985	-12.7	52.5	79.9
		2009	6.3	27.9	28.3

What are the Tributary Summaries?

A compilation of information by tributary or region on:

- Tidal water quality and trends,
- Watershed characteristics and changes,
- **Landscape drivers.**



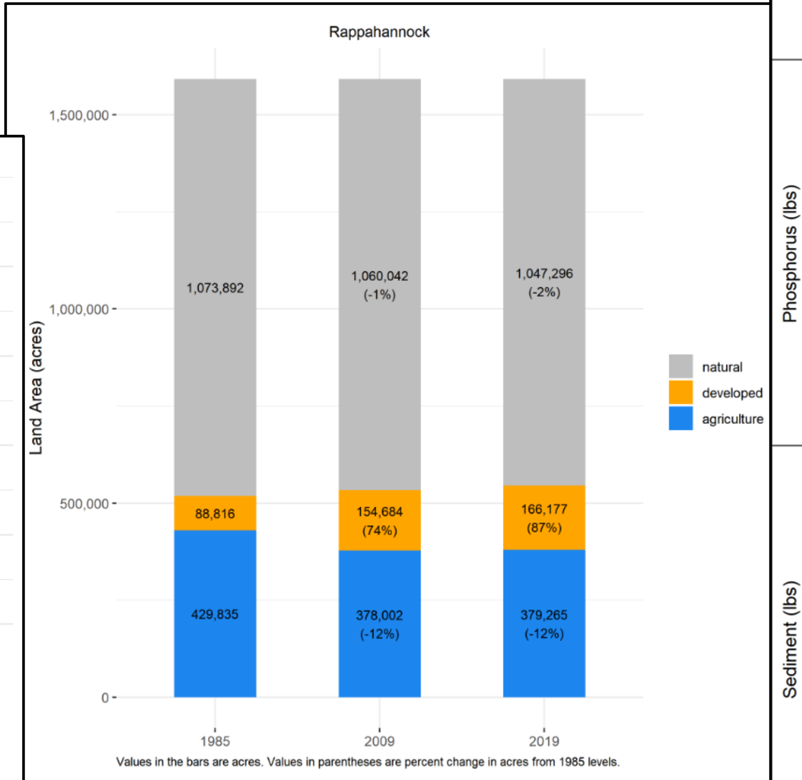
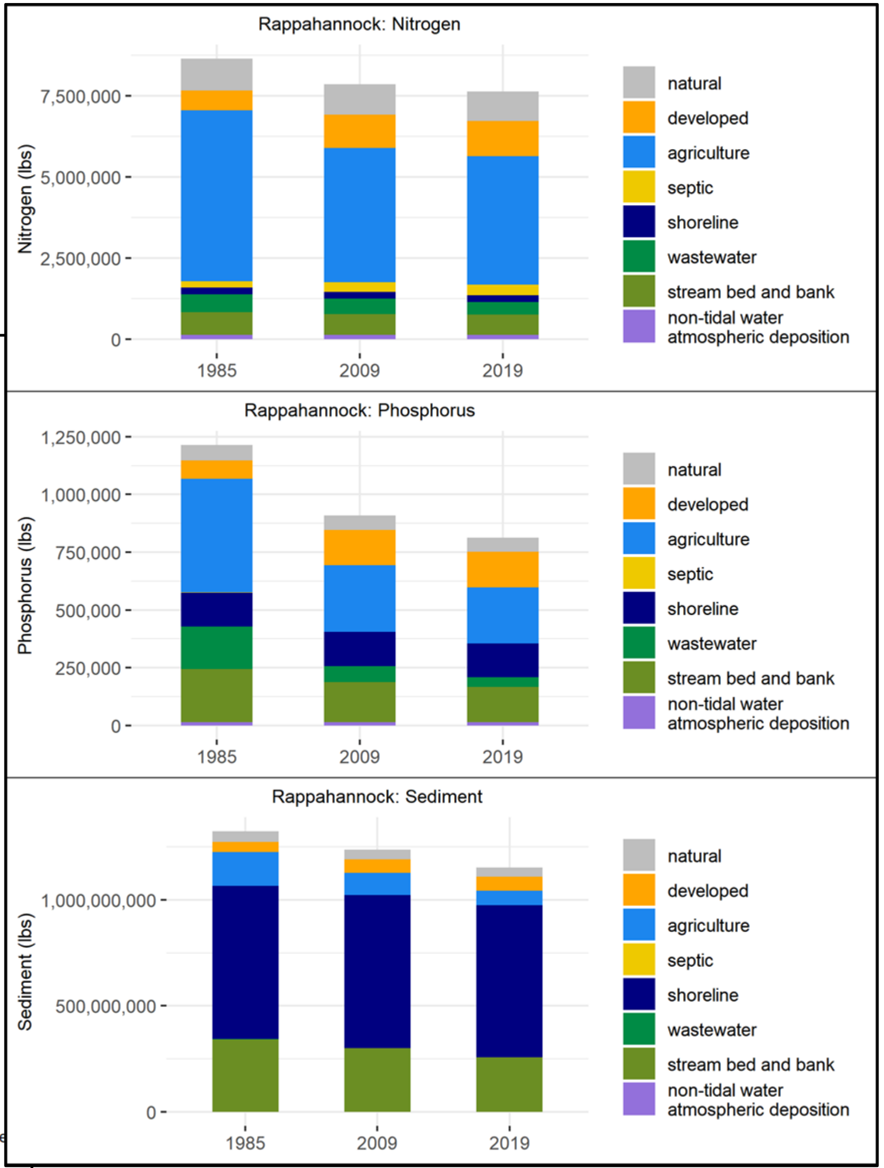


Figure 2. Distribution of land uses in the Rappahannock watershed. Percentages are the percent change from 1985 for each source sector.



Who is the audience for the tributary summaries?

- Technical managers within jurisdiction agencies
- Local watershed organizations
- Federal, state, and academic researchers

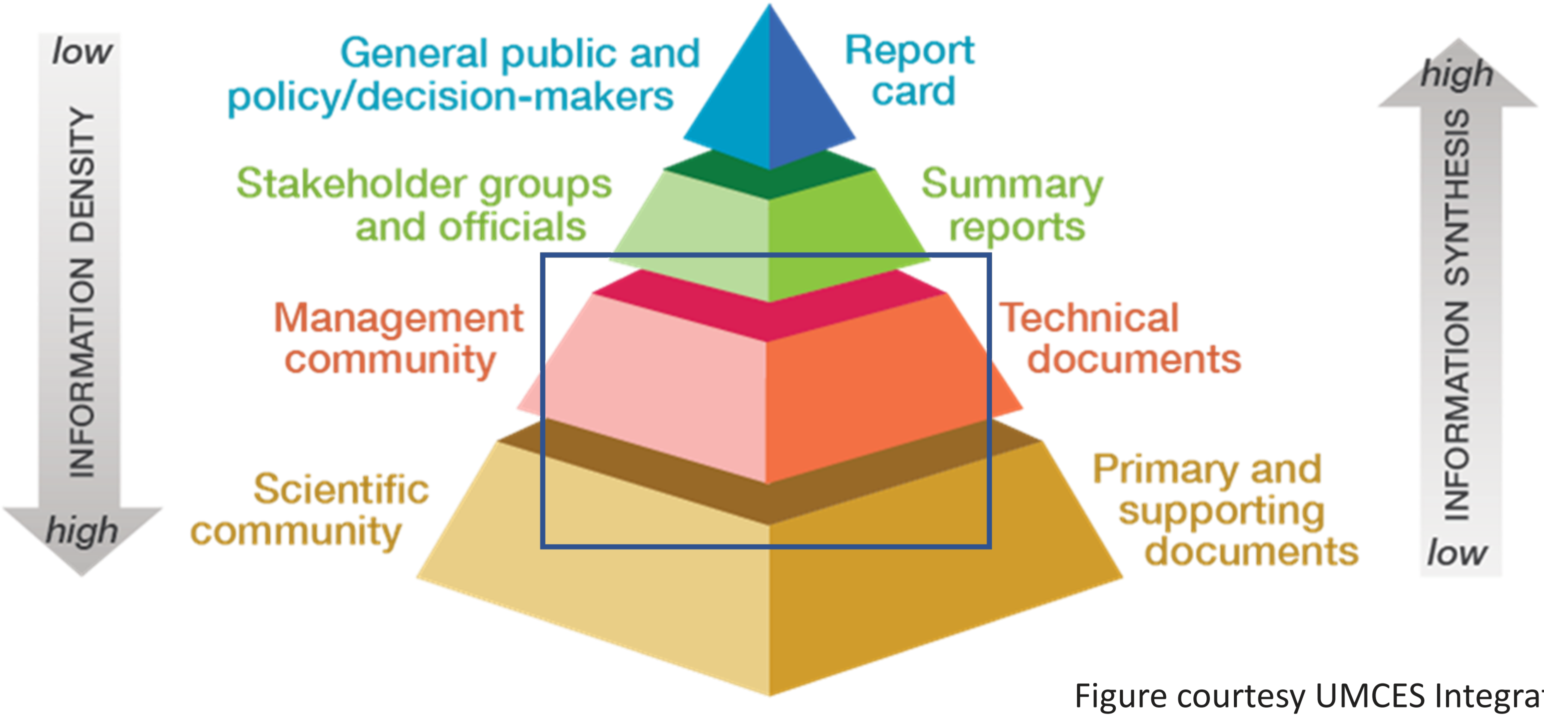
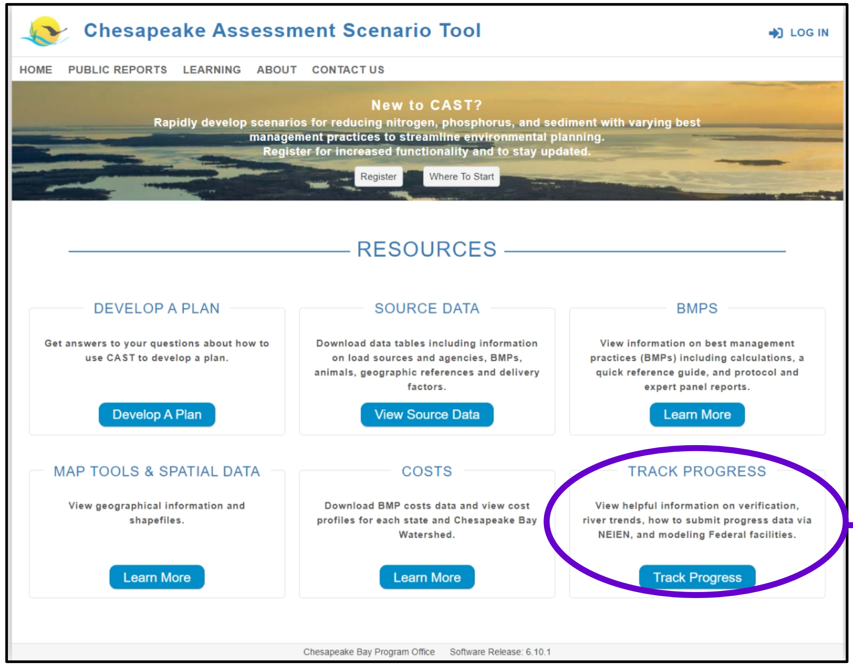
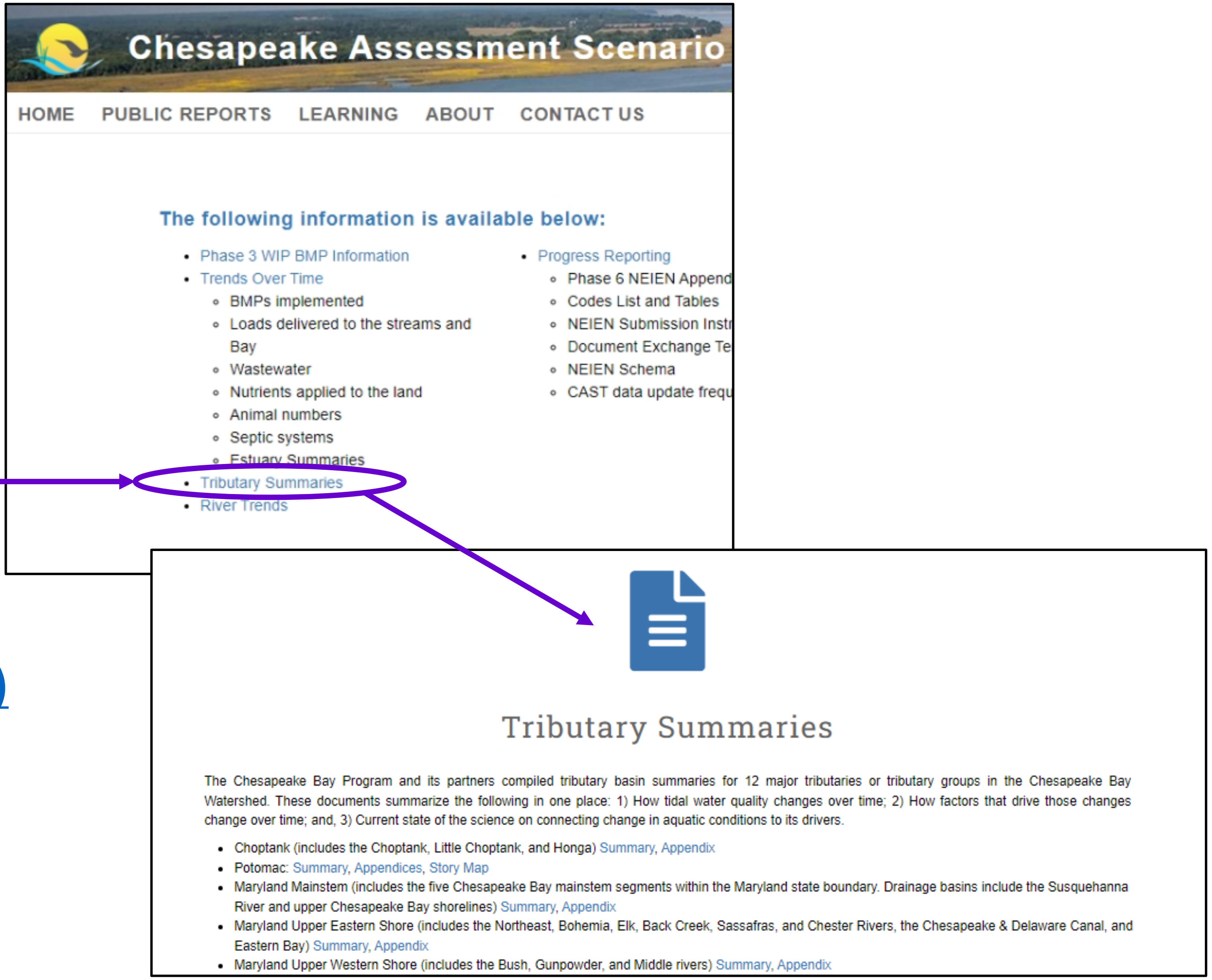


Figure courtesy UMCES Integration and Application Network, ian.umces.edu

Where can I access the tributary summaries?





[CAST - TMDL Tracking (chesapeakebay.net)](#)

Where can I access the tributary summaries?

https://www.chesapeakebay.net/who/group/integrated_trends_analysis_team

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WHO WE ARE > HOW WE'RE ORGANIZED > INTEGRATED TRENDS ANALYSIS TEAM

Integrated Trends Analysis Team

Upcoming Meeting

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Projects and Resources

Tributary Summaries

The Chesapeake Bay Program and its partners produce tributary basin summary reports for the Bay's 12 major tributaries using tidal monitoring data from more than 130 monitoring stations throughout the mainstem and tidal portions of the Bay. These reports use water quality sample data to summarize 1) How tidal water quality (TN, TP, DO, Chlorophyll a, Secchi Depth) has changed over time, 2) How and which factors may influence water quality change over time, and 3) Recent research connecting observed changes in aquatic conditions to its drivers.

These documents can be found here: https://cast.chesapeakebay.net/Home/TMDLTracking#tributaryRptsSection

How do we use this information?

- As readily-available ***background*** for change over time observed with monitoring data.

- To answer questions such as:
  - *Have water quality indicators in my river been improving or degrading over time?*
  - *How have landscape factors that drive water quality change in my watershed changed over time?*
  - *What clues do they provide that might explain observed water quality change (or lack of change)?*
  - *What should I target to turn a degrading trend around or maintain improvements for future water quality and living resource conditions?*
  - *What should scientists focus our analyses on to provide better answers in the future?*

Case Studies today:

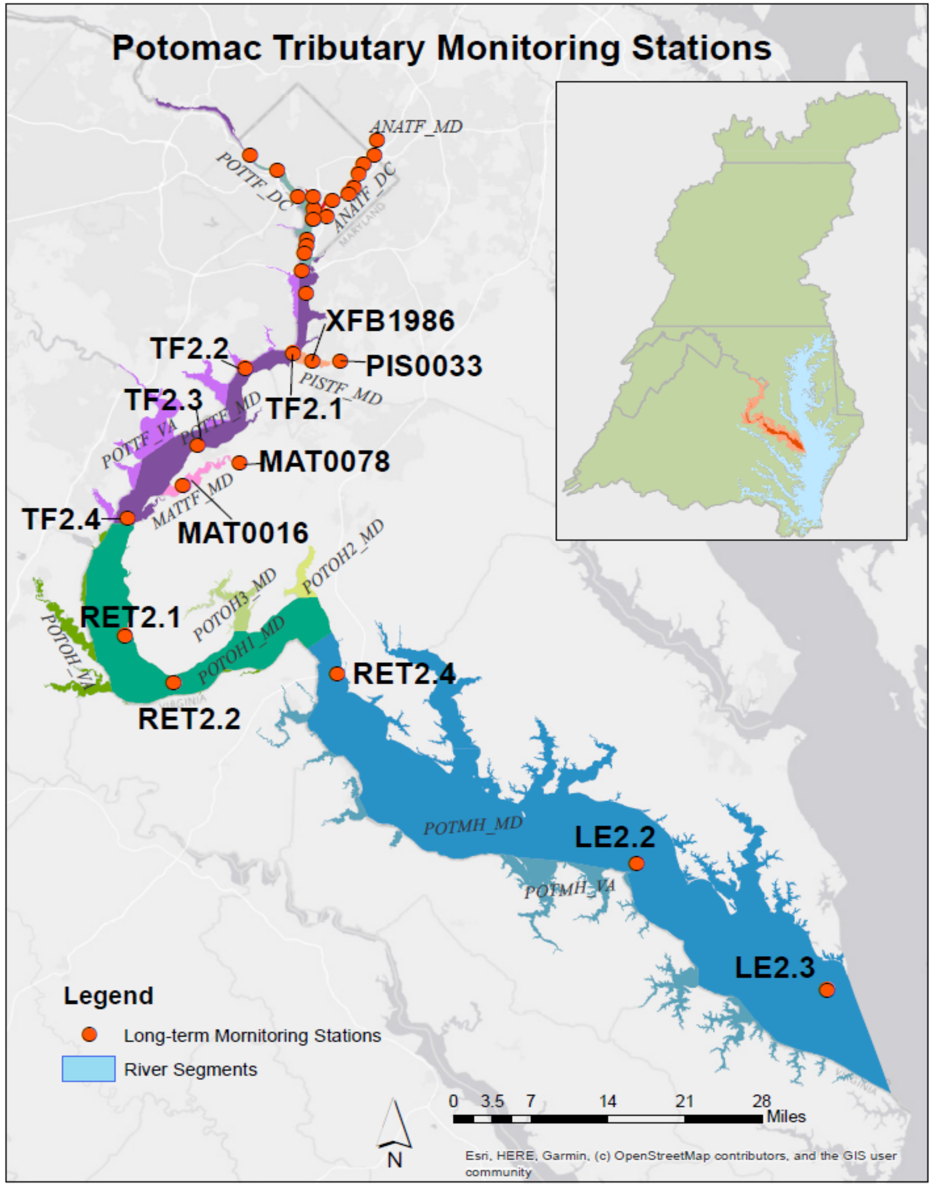
1) Potomac Tributary Summary
2) York Tributary Summary

Case Study 1: Potomac Tributary Summary

- Completed Dec, 2020.
- Uses data from 1985-2018.

Keisman, J., Murphy, R. R., Devereux, O.H., Harcum, J., Karrh, R., Lane, M., Perry, E., Webber, J., Wei, Z., Zhang, Q., Petenbrink, M. 2020. Potomac Tributary Report: A summary of trends in tidal water quality and associated factors. Chesapeake Bay Program, Annapolis MD.

- Story Map produced by USGS: https://wim.usgs.gov/geonarrative/potomactrib/

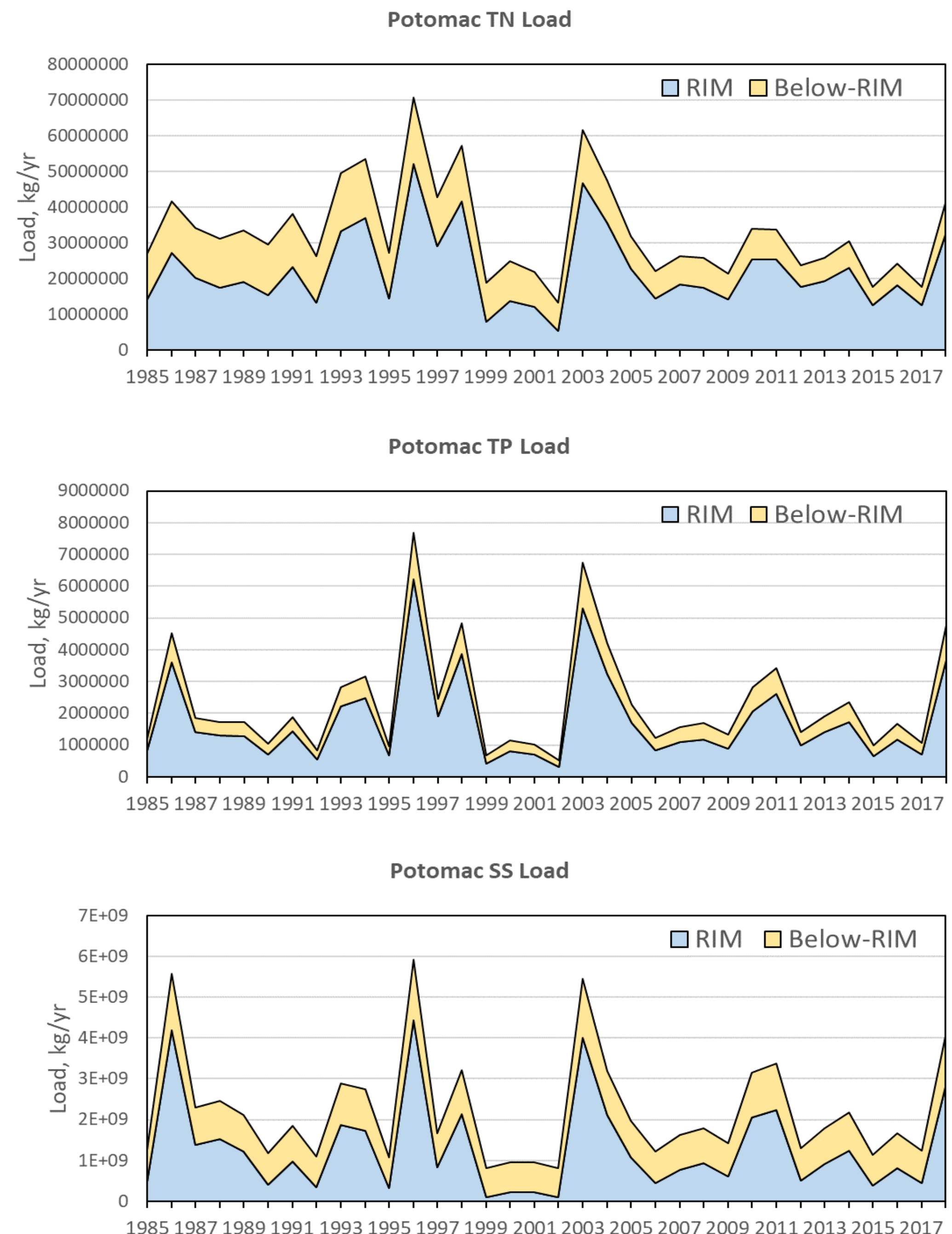


Case Study 1: **Estimated Loads**

Estimated loads to tidal portions from USGS RIM Stations at the tidal-nontidal interface.

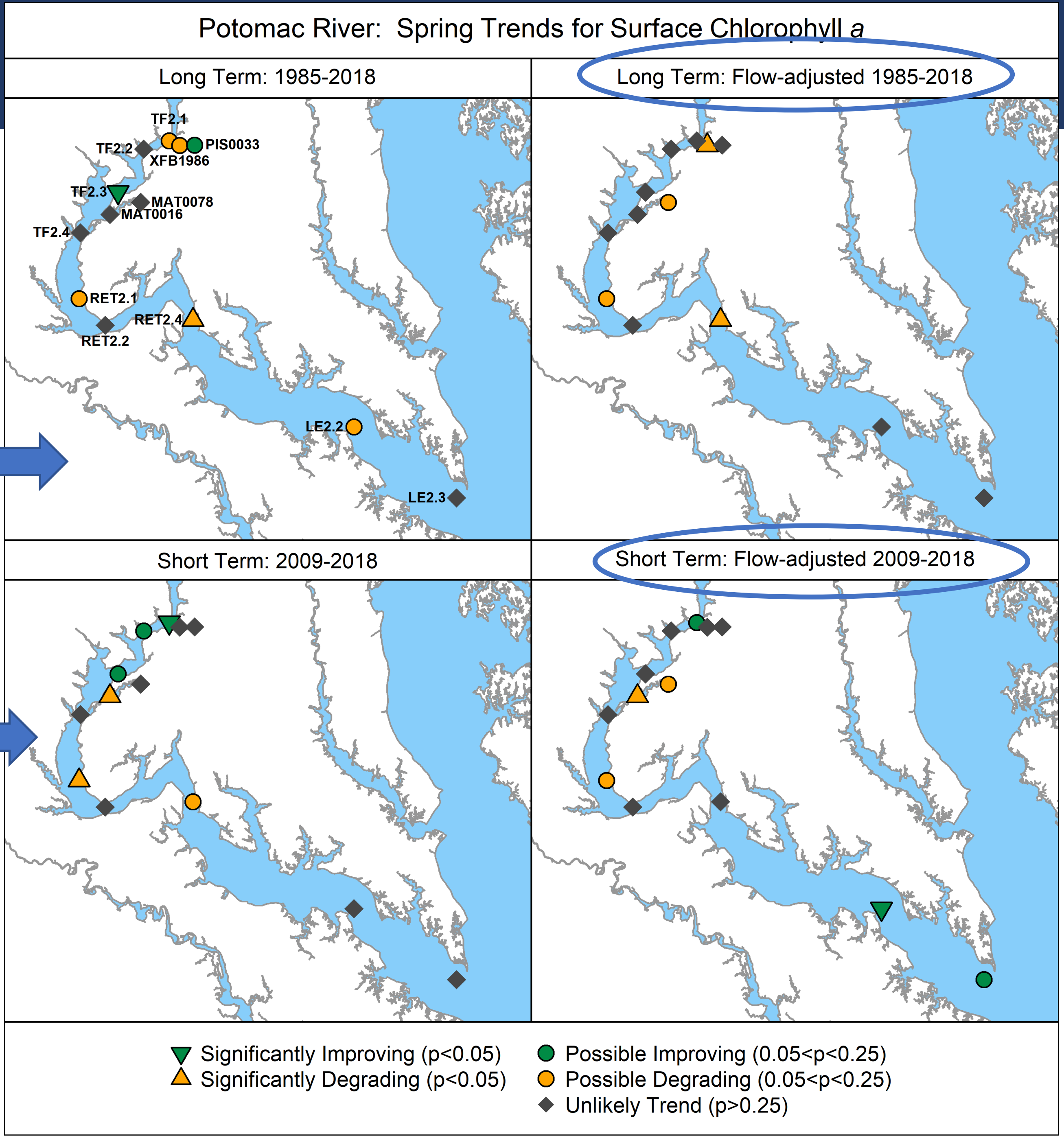
- True condition loads are highly variable due to freshwater flow, but "flow-normalized" loads are mostly decreasing in the Potomac.
  - TN has an overall decline that is significant due to substantial efforts to reduce Nitrogen loads from WWTPs and the introduction of the Clean Air Act..
  - TP has an overall increase that is not significant.
  - SS has an overall decline that is not significant.
- Point source loads have decreased for TN and TP.

Total estimate of observed loads to tidal Potomac



Case Study 1: Chlorophyll *a*

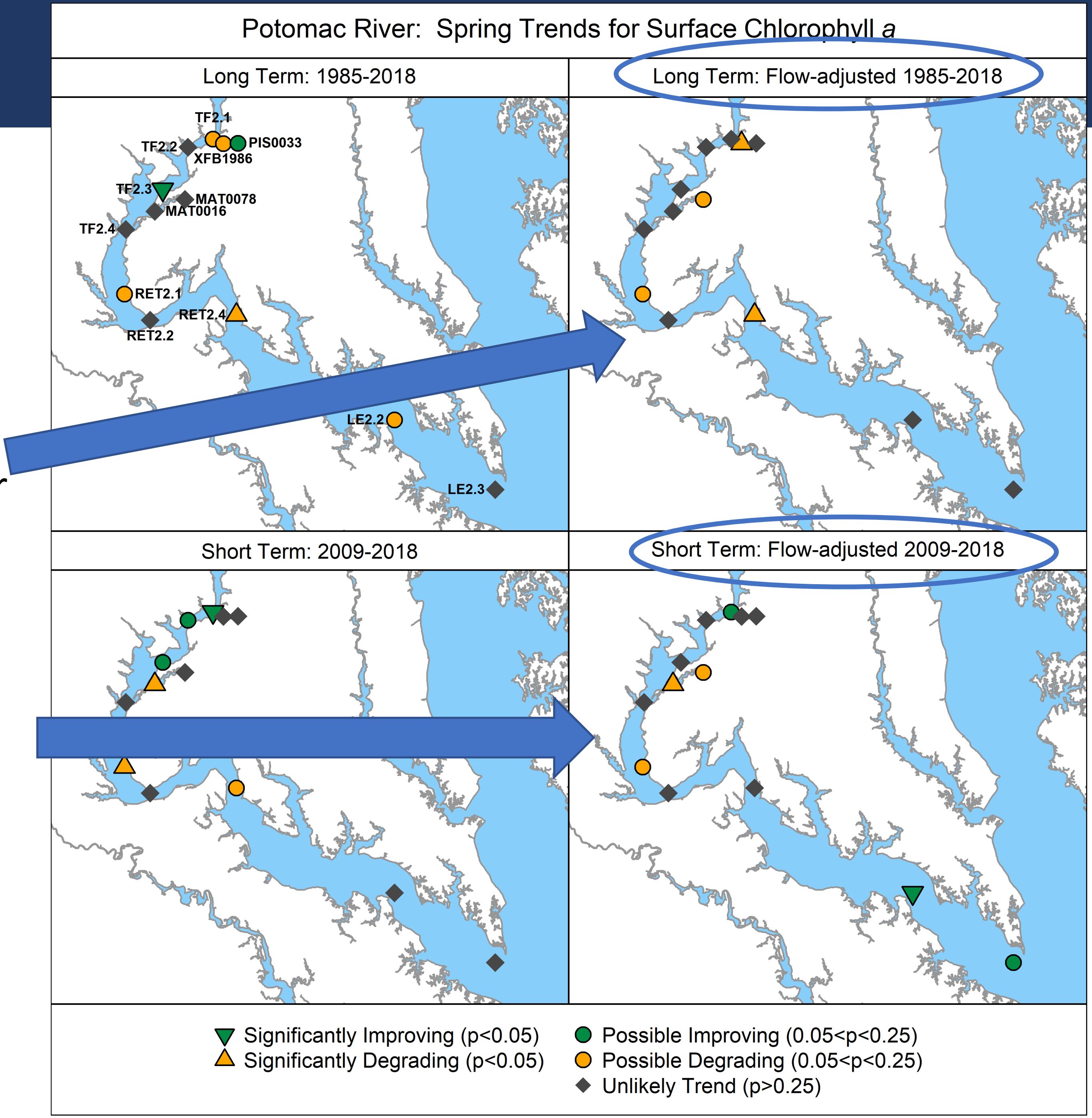
- Long Term vs Short Term Trends:
  - Long term observed change
  - Long term flow-adjusted change (i.e., if flow had been average)
  - Recent 10-year observed change
  - 10-year flow-adjusted



Case Study 1: Chlorophyll *a*

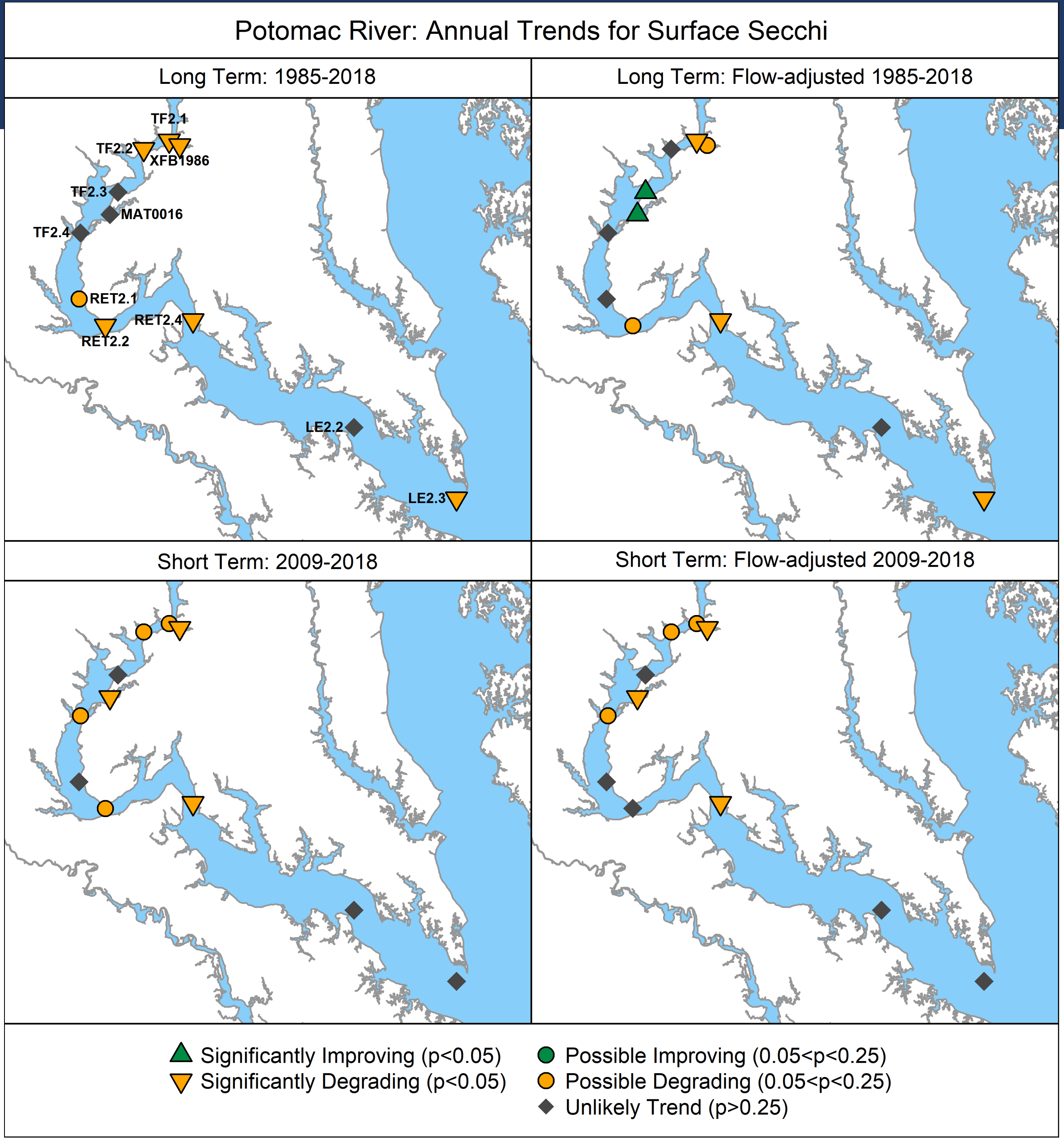
- Trends for chlorophyll *a* are **split into spring and summer** to analyze chlorophyll *a* during the two seasons when phytoplankton blooms are commonly observed.

- **Mixed Trends**: Long Term mostly degrading or showing no trend.
  - Short Term *possible improvements* or *no trends* in the upper tidal fresh stations, *degrading trends* in the middle of the river, *and improving trends* after flow adjustment in the mesohaline stations.



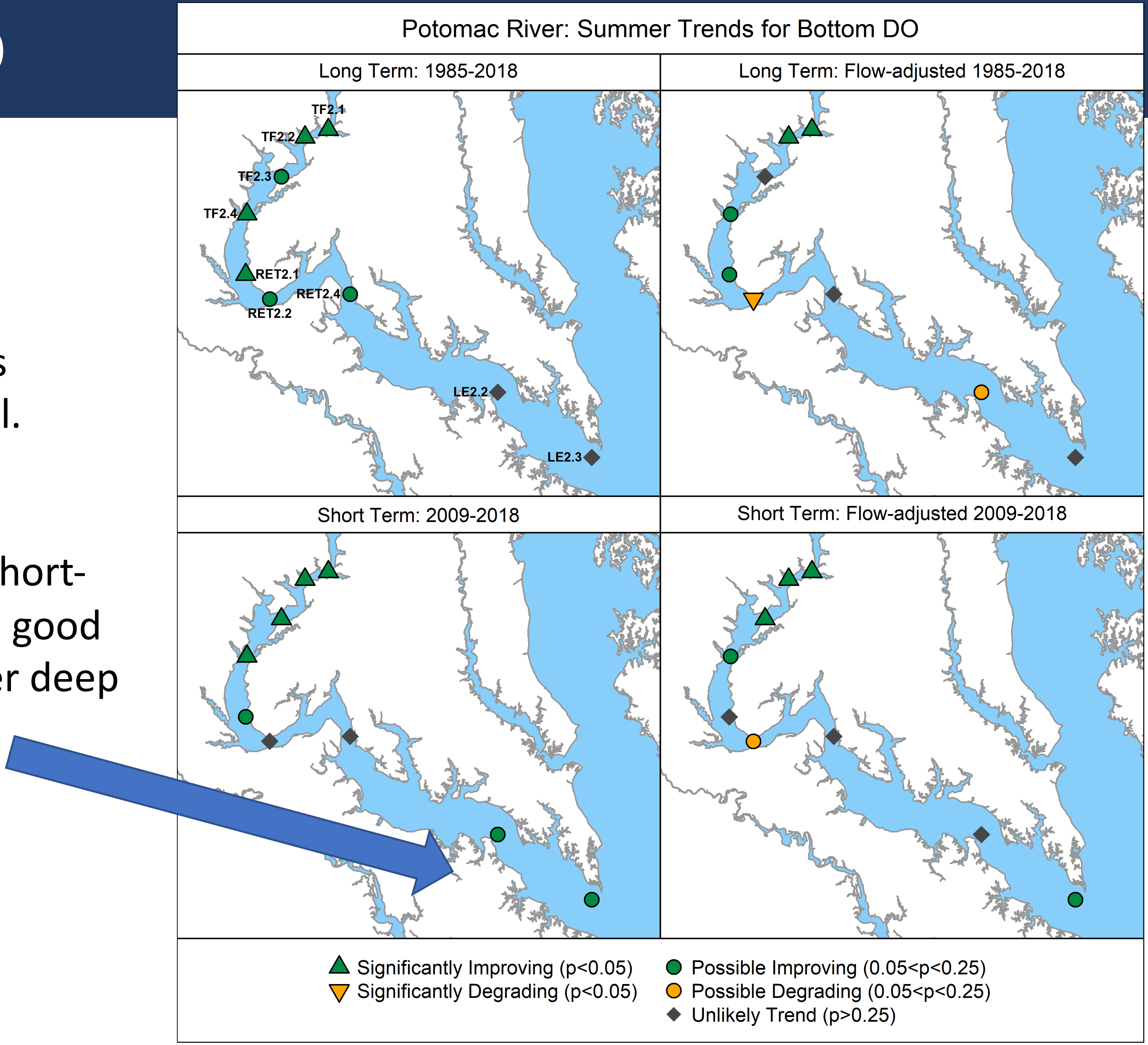
Case Study 1: Secchi

- A measure of visibility through the water
- Shows mostly degradation or no trend.
- Fairly consistent with chlorophyll *a.*



Case Study 1: Bottom DO

- Summer (June-Sept) bottom DO is improving at many stations overall.
- Possible improvements over the short-term at the deepest stations are a good sign too (and consistent with other deep areas of the Bay).



Case Study 1: WQ Status

- Tracking Open Water, Deep Water and Deep Channel DO Criteria.

- We include a record of the evaluation results indicating whether different Potomac segments have met or not met specific WQ criteria for DO.

Open Water Summer Criteria Status

time period	ANATF_DC	ANATF_MD	PISTF	MATTF	POTTF_DC	POTTF_MD	POTTF_VA	POTOH1_MD	POTOH2_MD	POTOH3_MD	POTOH_VA	POTMH_MD	POTMH_VA
1985-1987							ND		ND	ND	ND		ND
1986-1988							ND		ND	ND	ND		ND
1987-1989							ND		ND	ND	ND		ND
1988-1990							ND		ND	ND	ND		ND
1989-1991							ND		ND	ND	ND		ND
1990-1992							ND		ND	ND	ND		ND
1991-1993							ND		ND	ND	ND		ND
1992-1994							ND		ND	ND	ND		ND
1993-1995							ND		ND	ND	ND		ND
1994-1996							ND		ND	ND	ND		ND
1995-1997							ND		ND	ND	ND		ND
1996-1998							ND		ND	ND	ND		ND
[illegible]99							ND		ND	ND	ND		ND
[illegible]00							ND		ND	ND	ND		ND
199[illegible]-2001							ND		ND	ND	ND		ND
2000-2002							ND		ND	ND	ND		ND
2001-2003							ND		ND	ND	ND		ND
2002-2004									ND	ND			
2003-2005									ND	ND			
2004-2006													
2005-2007													
2006-2008													
2007-2009													
2008-2010													
2009-2011									ND	ND			
2010-2012									ND	ND			
2011-2013									ND	ND			
2012-2014									ND	ND			
2013-2015									ND	ND			
2014-2016									ND	ND			
2015-2017									ND	ND			
2016-2018									ND	ND			

Case Study 1: WQ Status

- Tracking Open Water, Deep Water and Deep Channel DO Criteria.

- We include a record of the evaluation results indicating whether different Potomac segments have met or not met specific WQ criteria for DO.

Deep Water and Channel Status

time period	Deep Water		Deep Channel	
	POTMH_MD	POTMH_VA	POTMH_MD	POTMH_VA
1985-1987		ND		ND
1986-1988		ND		ND
1987-1989		ND		ND
1988-1990		ND		ND
1989-1991		ND		ND
1990-1992		ND		ND
1991-1993		ND		ND
1992-1994		ND		ND
1993-1995		ND		ND
1994-1996		ND		ND
1995-1997		ND		ND
1996-1998		ND		ND
1997-1999		ND		ND
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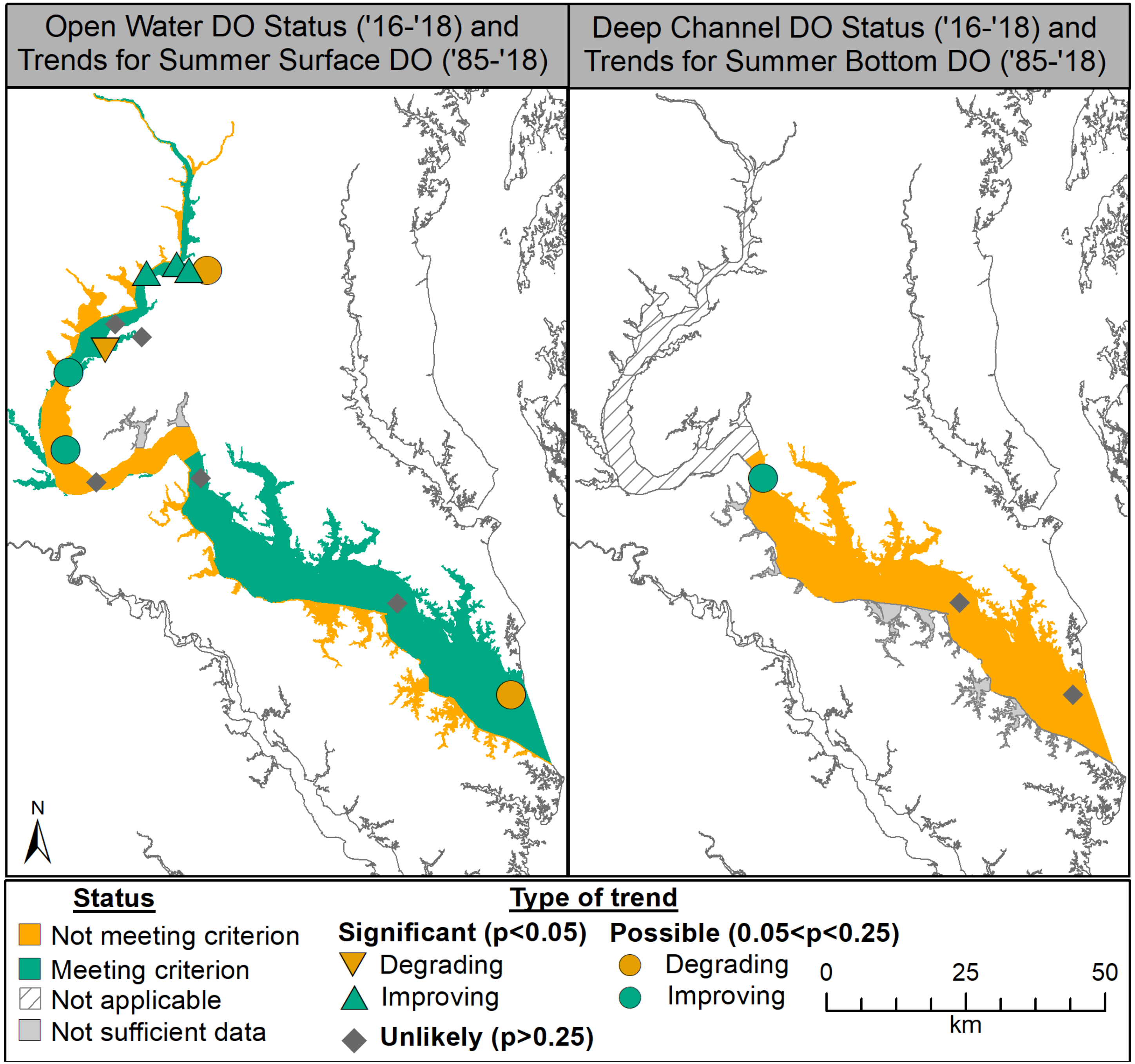
2000-2002		ND		ND
2001-2003		ND		ND
2002-2004				ND
2003-2005				ND
2004-2006				
2005-2007				
2006-2008				
2007-2009				
2008-2010				
2009-2011				
2010-2012		ND		ND
2011-2013				ND
2012-2014				ND
2013-2015				ND
2014-2016				ND
2015-2017				ND
2016-2018				ND

Case Study 1: WQ Status

- <u>Comparing trends in station-level DO concentrations to the computed DO criterion status for a recent assessment period can reveal valuable information:</u>
  - Whether **progress is being made towards attainment in a segment that is not meeting the water quality criteria,**
  - or conversely the possibility that **conditions are degrading even if the criteria are currently being met**.



Case Study 1: Potomac Tributary Report

- The Potomac Tributary Report is the only finished summary *meaning*,
  - The report contains an **"Insights on Changes"** section, which pulls in additional research to provide further context for the WQ trends and changes in the watershed.

To answer questions like:

→ ***How do tidal waters respond to actions in the watershed?*** *(Actions may include WWTP upgrades, implementation of agricultural best management practices to reduce nutrient pollution, etc.*

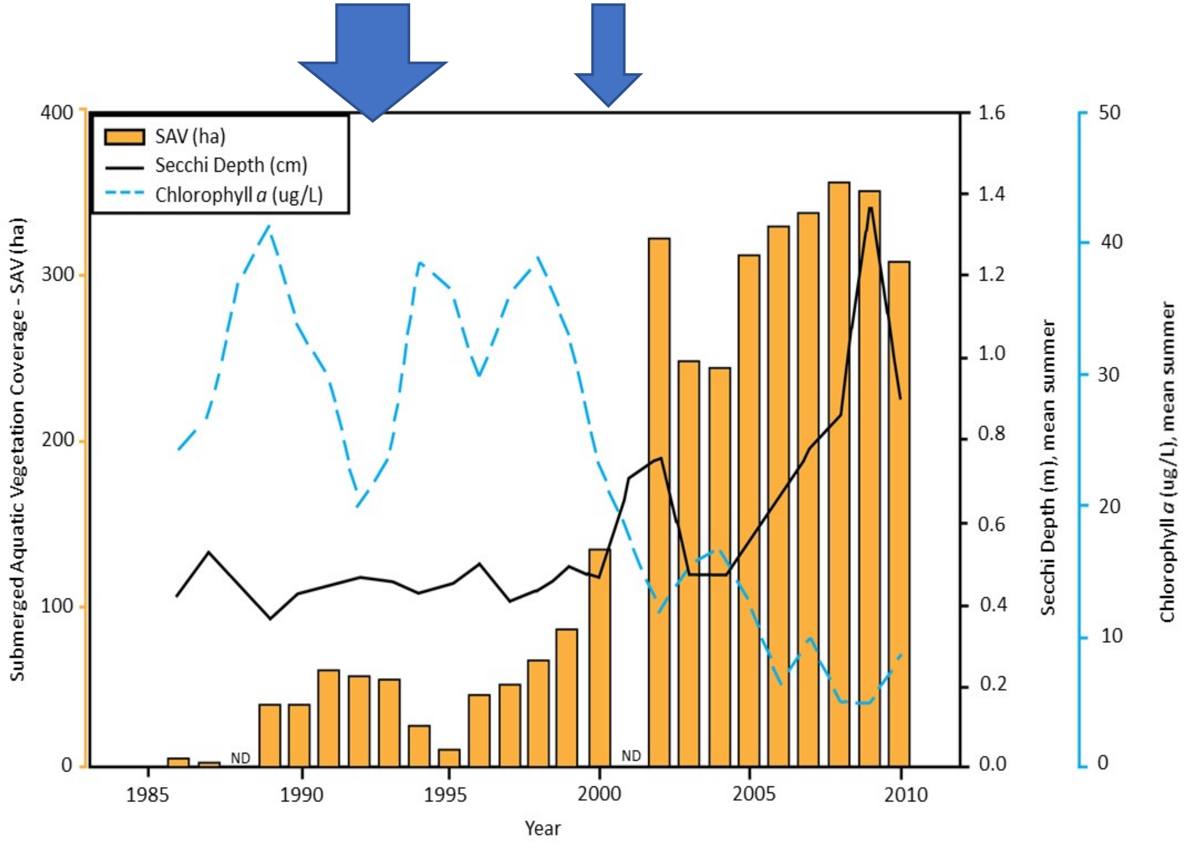
Two important findings from the Potomac Tributary Report:

1. Local response to large nutrient reductions happens and is clearly shown with the data.

2. Long-term response to watershed-wide nutrient reductions is happening in the tidal waters.

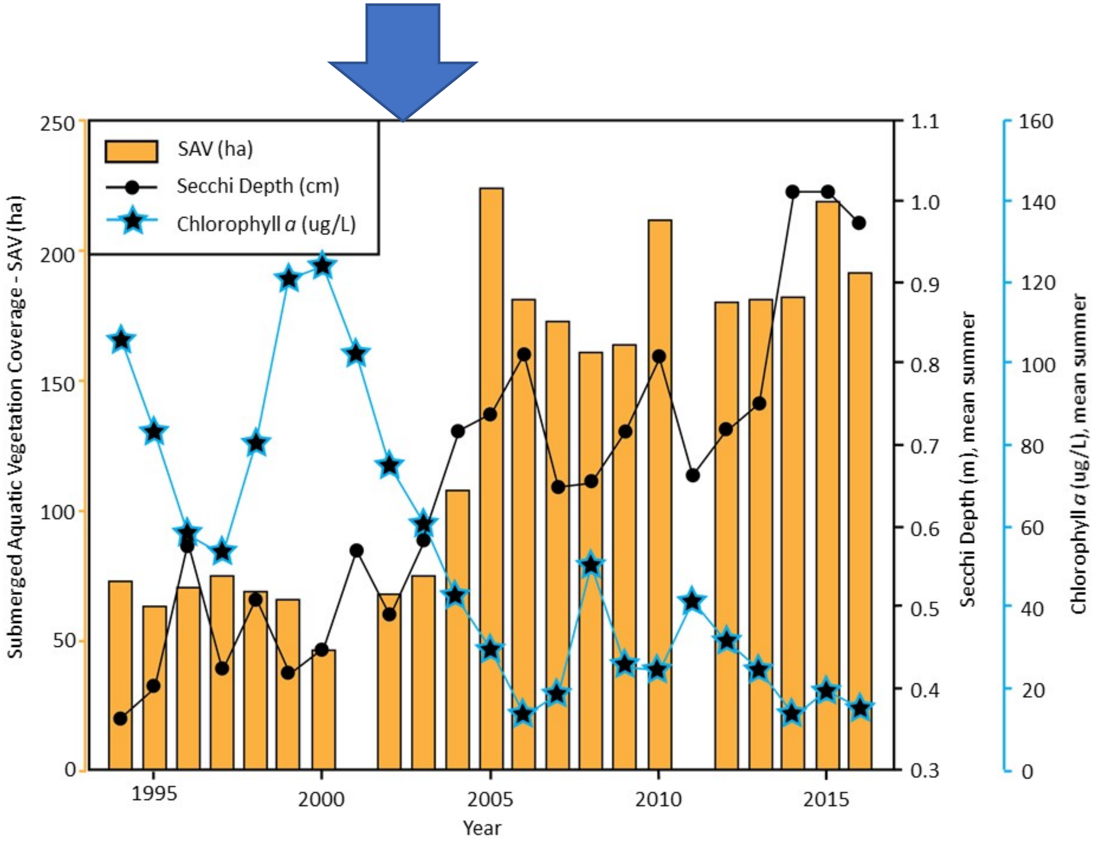
Tidal water response: 1) *Local response to large nutrient reductions happens*

Mattawoman Creek: Very large WW load reductions



SAV coverage (ha), water clarity (Secchi disk depth), and algal biomass (chlorophyll *a* concentration) in Mattawoman Creek. From Boynton *et al.* (2014).

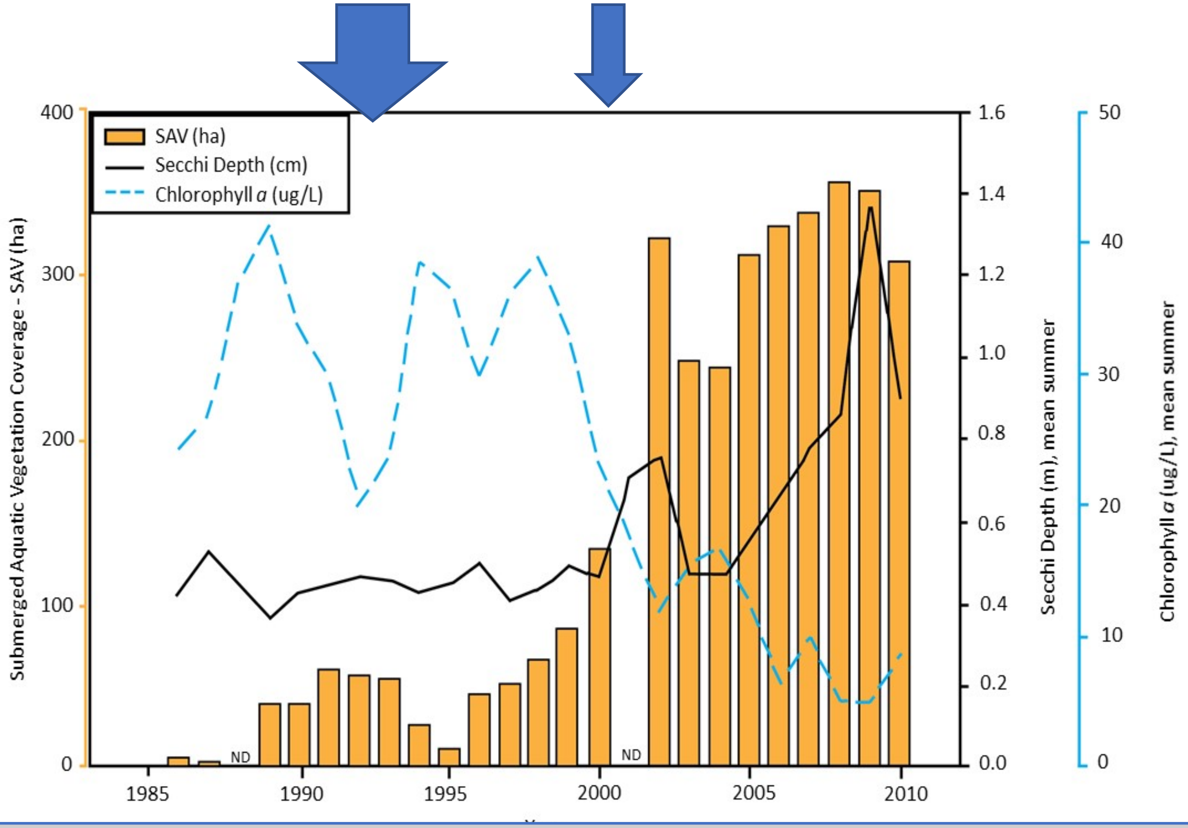
Gunston Cove: Very large WW load reduction



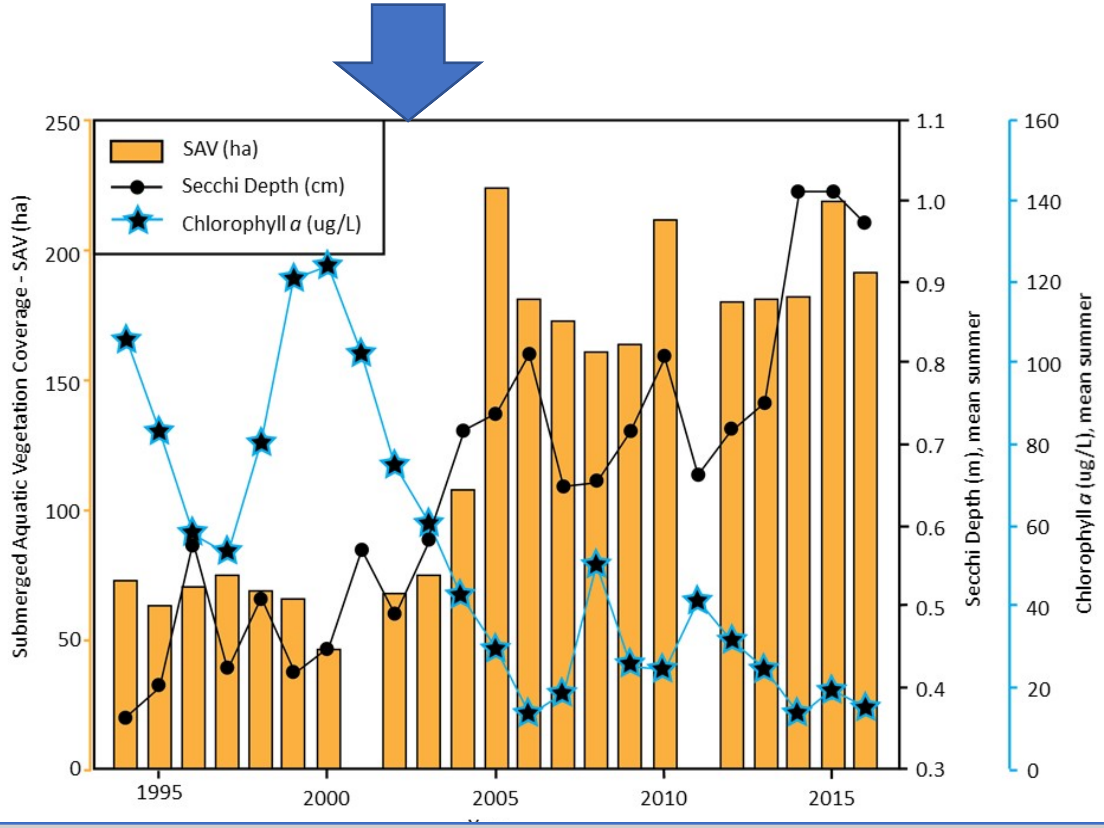
Algal biomass (as chlorophyll *a*), Secchi depth, and SAV acreage for the period 1994 – 2016 in Gunston Cove. From Jones *et al.* (2017).

Tidal water response: 1) *Local response to large nutrient reductions happens*

Mattawoman Creek: Very large WW load reductions



Gunston Cove: Very large WW load reduction



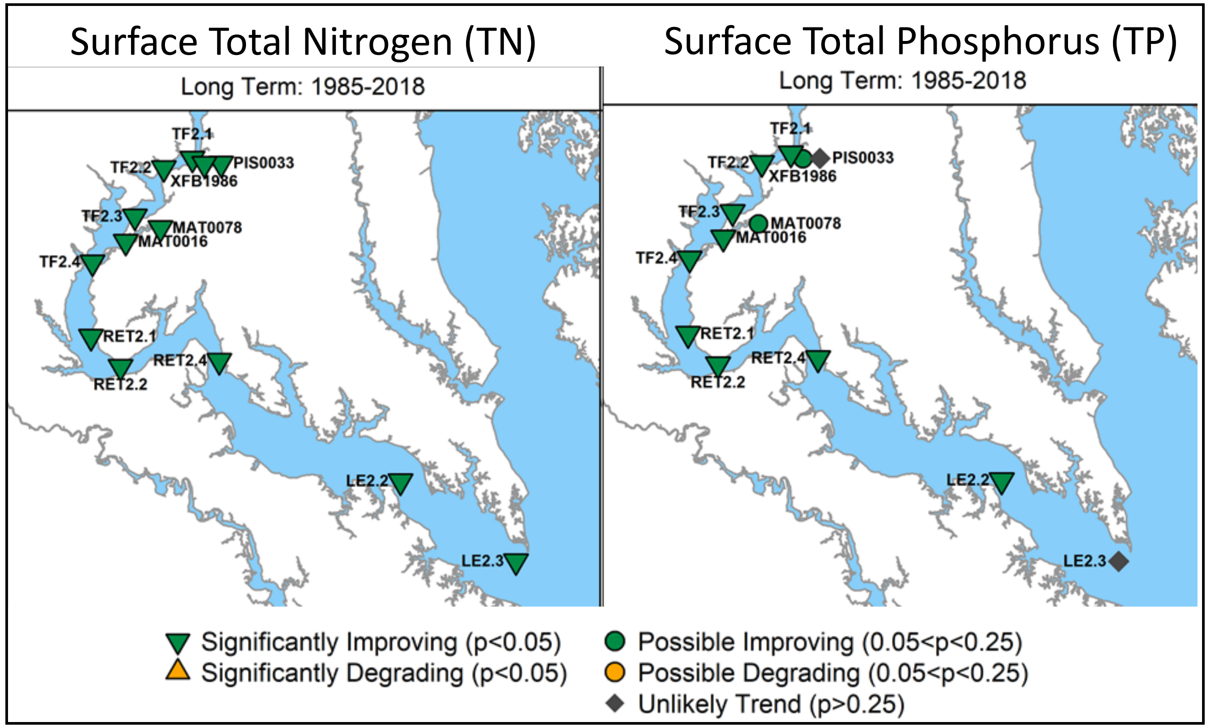
<u>What this tells us:</u> This data clearly shows that investment in large-scale nutrient reductions is successful for improving water quality dramatically in local systems.

Tidal water response: *2) Long-term response to watershed changes is happening*

- Over the long-term, nutrient loads have decreased across the Potomac watershed.
- Tidal nutrient concentrations have decreased at almost all tidal stations.

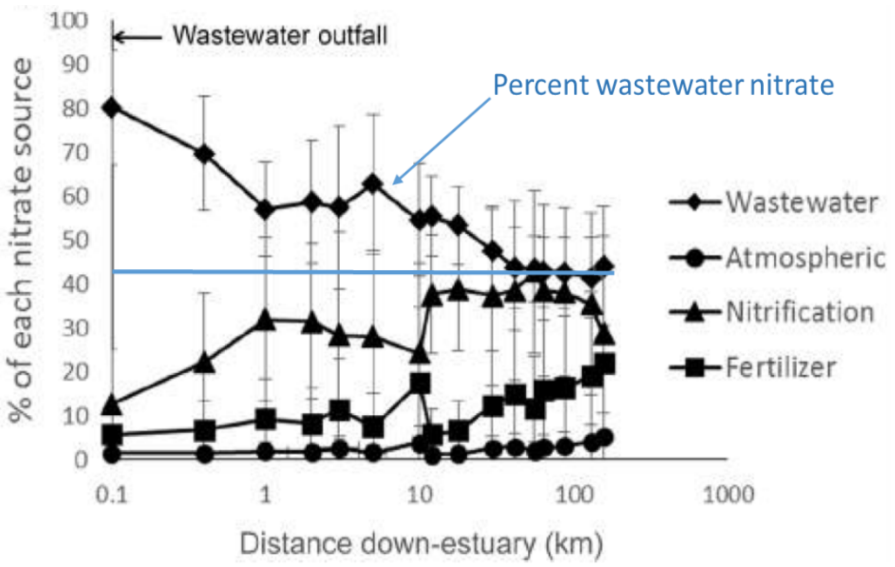
Table 3. Trends (2009 – 2018) in flow normalized total nitrogen (TN), total phosphorus (TP), and suspended sediment (SS) for nontidal network monitoring locations in the Potomac River watershed.

Parameter	No. of stations	Value	Trend direction degrading	Trend direction improving	Trend direction no trend
TN	28	n	7	14	7
		median %	15.4%	-5.8%	1.1%
TP	18	n	0	12	6
		median %	-	-28.9%	8.5%
SSC	18	n	5	5	8
		median %	23.7%	-24.4%	5.2%

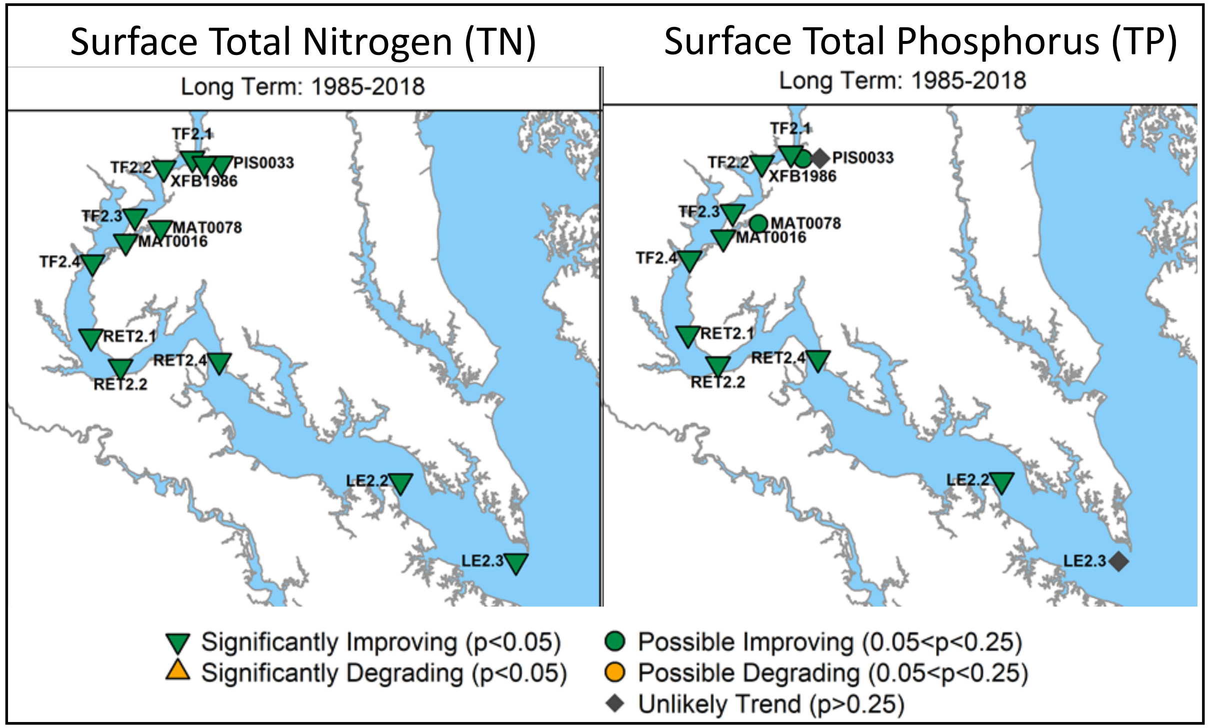


Tidal water response: *2) Long-term response to watershed changes is happening*

- These tidal trends are **not just local response**, but have been shown to be impacted by loads from many types of sources.

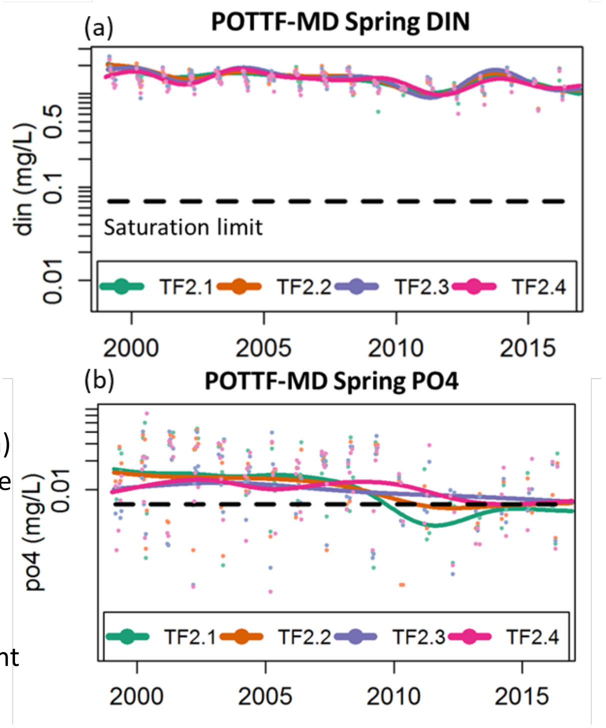


Mean annual change in the percent contribution of nitrate from wastewater, fertilizer, atmospheric deposition, and nitrification, based on an isotope mixing model, with distance down-estuary from wastewater treatment plant output. Adapted from Pennino *et al.* (2016).

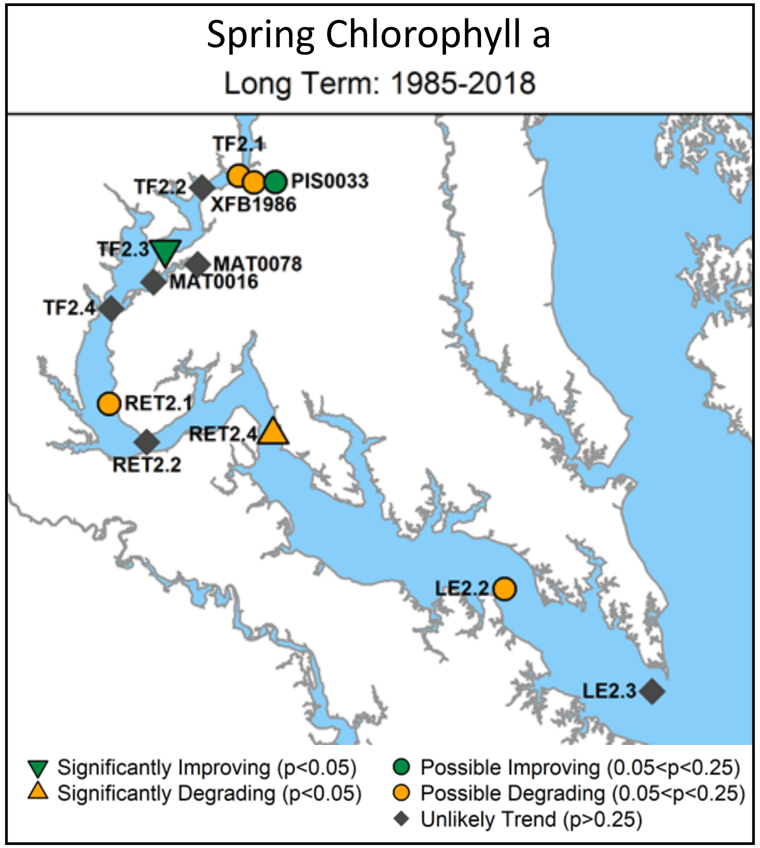


Tidal water response: *2) Large-scale, long-term response is happening*

- Other water quality responses are not as clear
- But research shows there may be a reason: **Nutrients have improved, but still need to be lower to limit phytoplankton growth in most places.**



Spring dissolved inorganic nitrogen (a) and spring phosphate (b) at monitoring stations in the tidal Potomac River from 1999 to 2018. Black dotted lines represent nutrient saturation thresholds.



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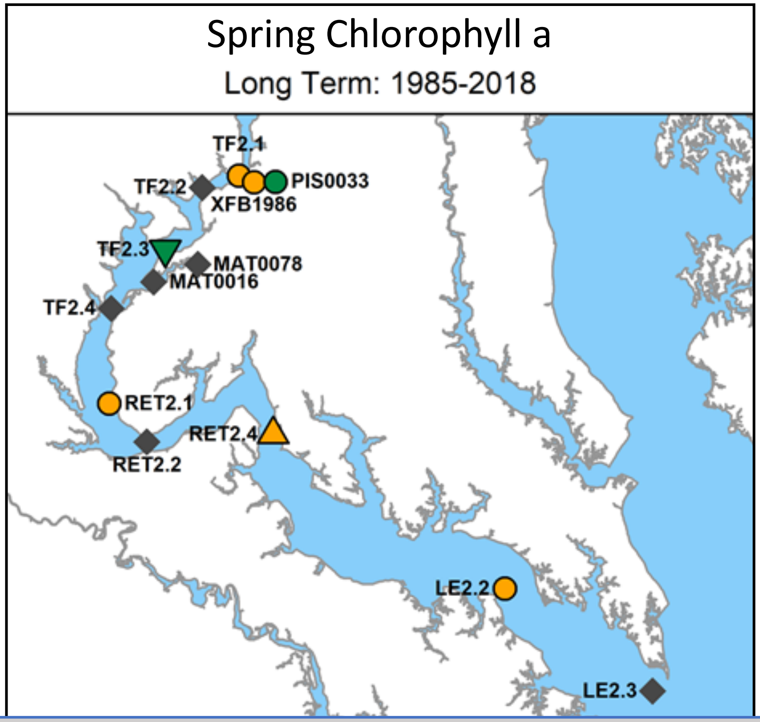
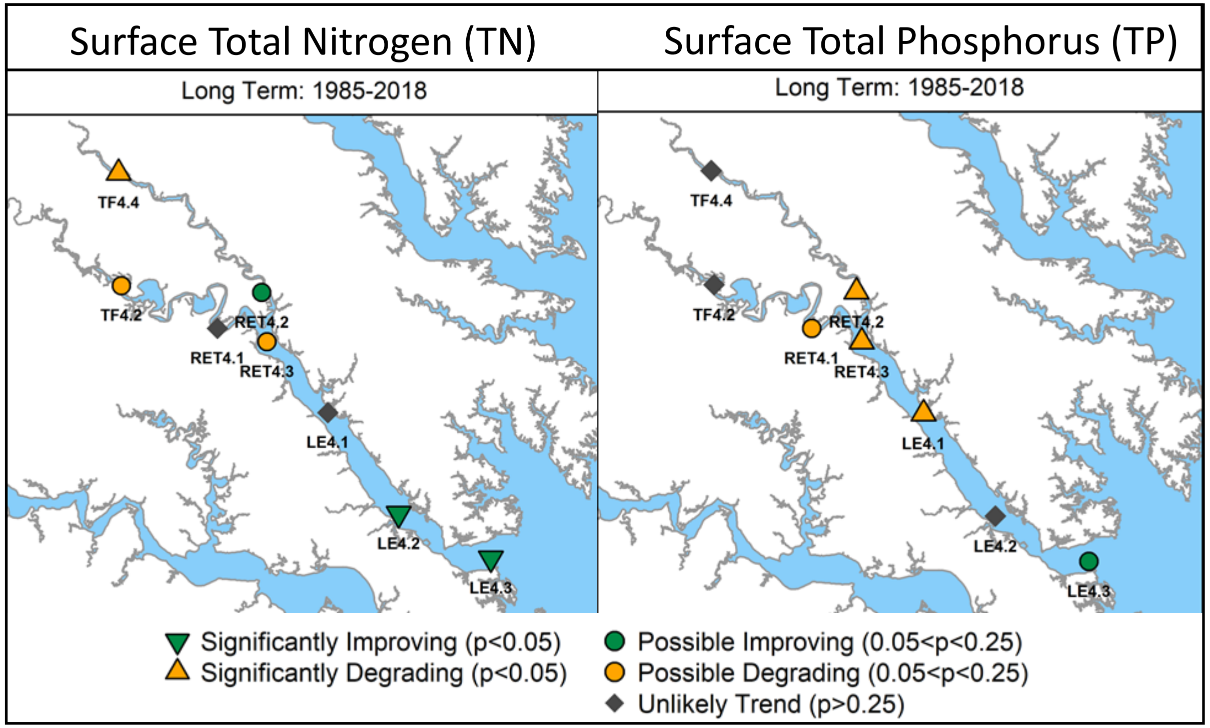


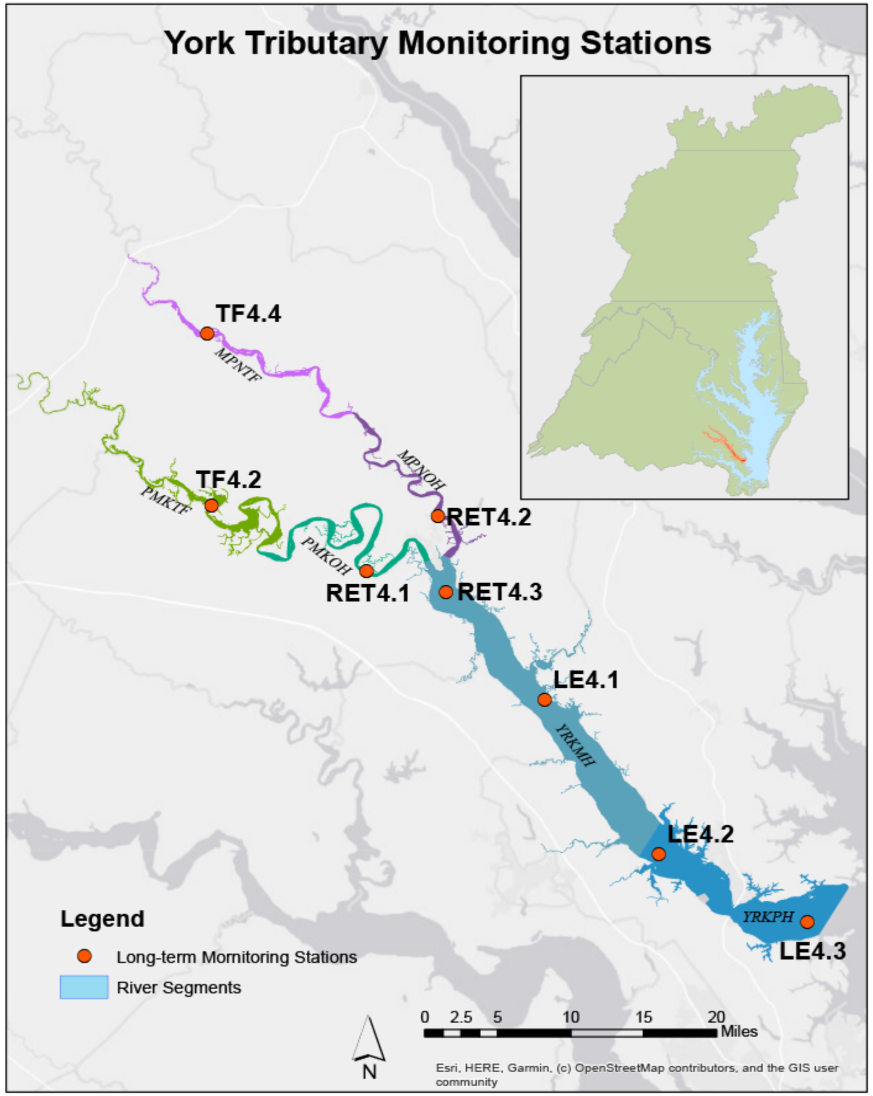
<u>What this tells us:</u> The data shows that watershed-wide nutrient reductions have improved nutrients in the Potomac. The science supports the conclusion that with more reductions, improvements will continue.

Case Study 2: York River

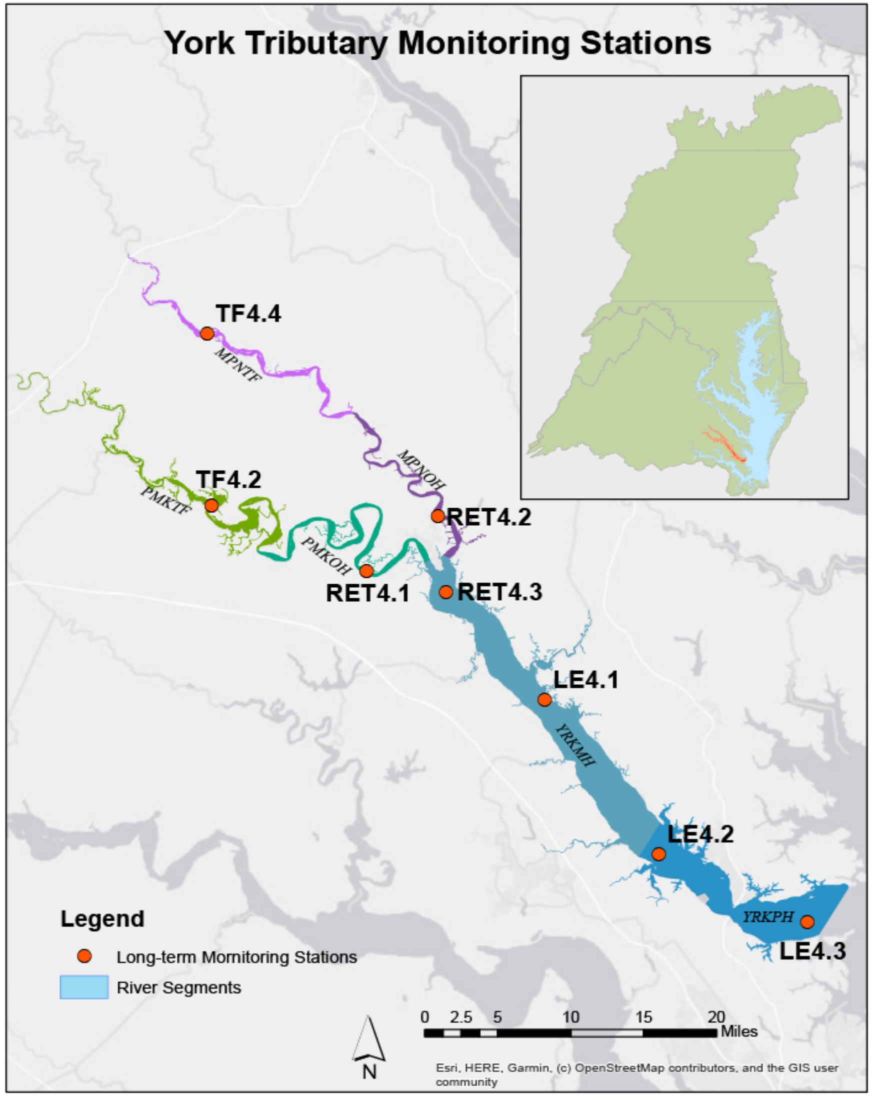
- Watershed stations: Mostly increasing flow-normalized nutrient loads
- Tidal: Long-term TN and TP trends are mixed, but more increasing than decreasing

→ Patterns are relatively consistent watershed-to-estuary





Case Study 2: Example York River



- The history of meeting the assessed water quality criteria

→ ***Mixed: Clearly it is possible to meet the criteria, but isn't consistently happening***

Open Water Summer DO

time period	MPNOH	MPNTF	PMKOH	PMKTF	YRKMH	YRKPH
1985-1987						
1986-1988						
1987-1989						
1988-1990						
1989-1991						
1990-1992						
1991-1993						
1992-1994						
1993-1995						
1994-1996						
1995-1997						
1996-1998						
1997-1999						
1998-2000						
1999-2001						
2000-2002						
2001-2003						
2002-2004						
2003-2005						
2004-2006						
2005-2007						
2006-2008						
2007-2009						
2008-2010						
2009-2011						
2010-2012						
2011-2013						
2012-2014						
2013-2015						
2014-2016						
2015-2017						
2016-2018						
2017-2019						

Deep Water Summer DO

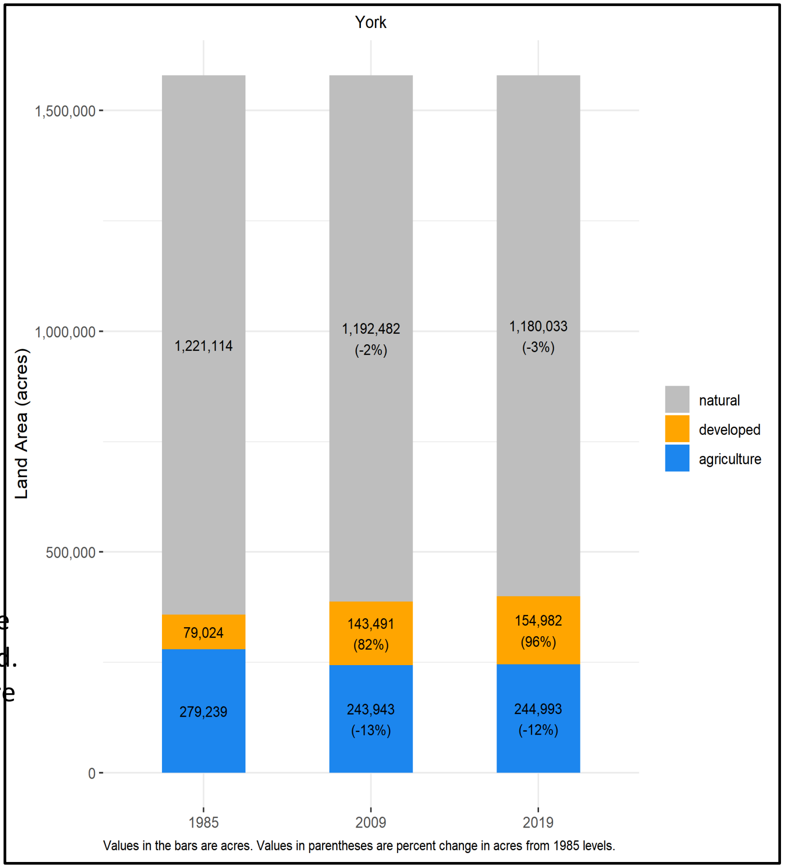
time period	YRKPH
1985-1987	
1986-1988	
1987-1989	
1988-1990	
1989-1991	
1990-1992	
1991-1993	
1992-1994	
1993-1995	
1994-1996	
1995-1997	
1996-1998	
1997-1999	
1998-2000	
1999-2001	
2000-2002	
2001-2003	
2002-2004	
2003-2005	
2004-2006	
2005-2007	
2006-2008	
2007-2009	
2008-2010	
2009-2011	
2010-2012	
2011-2013	
2012-2014	
2013-2015	
2014-2016	
2015-2017	
2016-2018	
2017-2019	

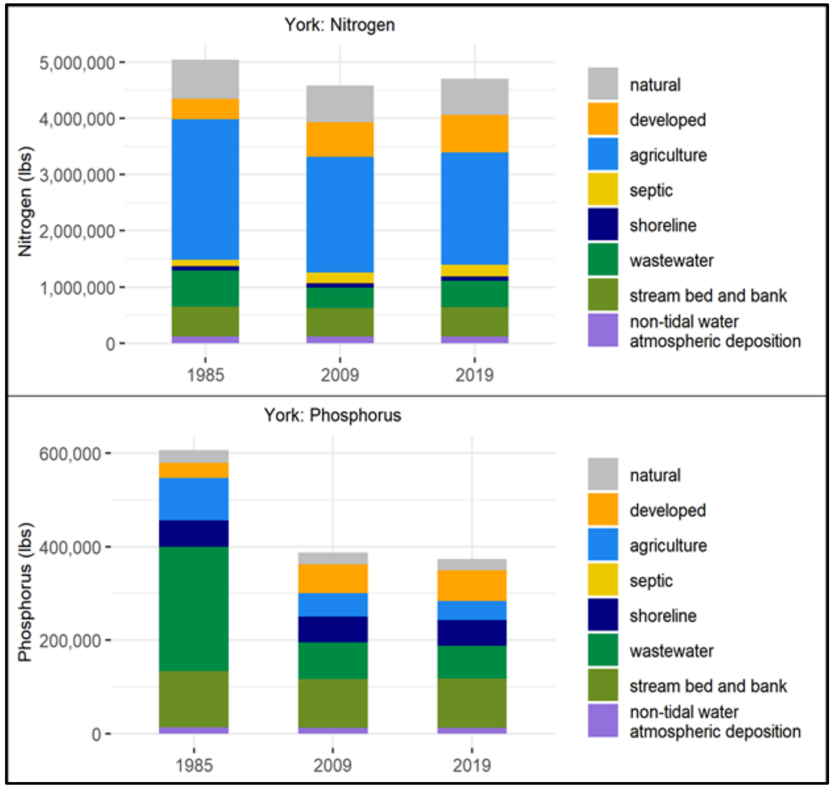
Case Study 2: Example York River

- Increasing development and fairly consistent agricultural land use in the last decade
- Expected long-term loads have plateaued, or increased

→ ***This and similar information can help understand why nutrients are not decreasing and help target actions***

Distribution of land uses in the York watershed. Percentages are the percent change from 1985 for each source sector.





Expected long-term average loads to the tidal York, as obtained from the Chesapeake Assessment Scenario Tool (CAST-19). Data shown are time-average, steady-state (Not true conditions).

Case Study 2: Example York River

How do tidal waters respond to actions in the watershed?

Consider findings from Potomac:

1. Local response to large nutrient reductions is clear from the data.
2. Long-term responses to system-wide changes are happening.

Next steps to add to York tributary summary:

1. Identify other data available for the York system (continuous monitoring, SAV coverage, etc). Talk to local partners and researchers to find:
   - Shallow-water monitoring near large recent development.
   - Areas near wastewater discharges which have changed.
   - Possibly get insights from these findings to provide support for continued, targeted actions.
2. This is clear from the Trib Summary already. Nutrient loads have increased, and tidal concentrations are similar. To support decisions, perhaps:
   - Look at the expected loads by source and recent land change.
   - Know that any nutrient reductions that reach the tidal waters will reduce tidal nutrients.

Next Steps for the Tributary Summaries

- Discussing priority for updating tributary summaries
- Introducing “Insights on Changes” section to other tributary summaries.
- Considering addressing climate change in the reports.
  - Ex. Rainfall duration and intensity

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Please Check out the 2020 Tidal Trends!

Long-Term and Short-Term Changes on the ITAT Webpage for:

- TN
- TP
- TSS
- Chlorophyll-a
- Secchi Depth
- DO
- Water Temperature

Maps of 2020 Tidal Water Quality Change

1. Long-Term Change

Observed change in water quality by station from the beginning of the period to 2020.

Surface Total Nitrogen, Annual 1985-2020 (462.47 KB)
Surface Total Phosphorus, Annual 1985-2020 (470.11 KB)
Surface Chlorophyll-a, Spring 1985-2020 (466.4 KB)
Surface Chlorophyll-a, Summer 1985-2020 (488.69 KB)
Secchi Depth, Annual 1985-2020 (449.67 KB)
Surface Total Suspended Solids, Annual 1999-2020 (444.54 KB)
Surface Water Temperature, Annual 1985-2020 (482.07 KB)
Bottom Dissolved Oxygen, Summer 1985-2020 (467.25 KB)

Overview of Findings:
https://www.chesapeakebay.net/channel_files/44102/2020_tidal_trends_-_itat_11-19-21.pdf

Requested Feedback

1) Which Tributary Summary is the priority to update?

2) What additional content should we include in the tributary summaries to better contextualize and understand the monitoring data?

Menti: https://www.menti.com/y9acmcksa5

Code: **6071 7089**

Links and References

CAST/Tributary Summaries: https://cast.chesapeakebay.net/Home/TMDLTracking#tributaryRptsSection

Potomac Story Map: https://wim.usgs.gov/geonarrative/potomactrib/

References:

Boynton, W. R., C. L. S. Hodgkins, C. A. O'Leary, E. M. Bailey, A. R. Bayard and L. A. Wainger, 2014. Multi-decade responses of a tidal creek system to nutrient load reductions: Mattawoman Creek, Maryland USA. Estuaries Coasts 37:111-127, DOI: 10.1007/s12237-013-9690-4.

Jones, R. C., K. Mutsert and A. Fowler, 2017. An ecological study of Gunston Cove: Final report. Provided to the Department of Public Works and Environmental Services, Fairfax County, VA, p. 181. https://www.fairfaxcounty.gov/publicworks/sites/publicworks/files/assets/documents/gunston-cove_2.pdf.

Keisman, J., Murphy, R. R., Devereux, O.H., Harcum, J., Karrh, R., Lane, M., Perry, E., Webber, J., Wei, Z., Zhang, Q., Petenbrink, M. 2020. Potomac Tributary Report: A summary of trends in tidal water quality and associated factors. Chesapeake Bay Program, Annapolis MD. https://cast.chesapeakebay.net/Home/TMDLTracking#tributaryRptsSection

Pennino, M. J., S. S. Kaushal, S. N. Murthy, J. D. Blomquist, J. C. Cornwell and L. A. Harris, 2016. Sources and transformations of anthropogenic nitrogen along an urban river–estuarine continuum. Biogeosciences 13:6211-6228, DOI: 10.5194/bg-13-6211-2016.