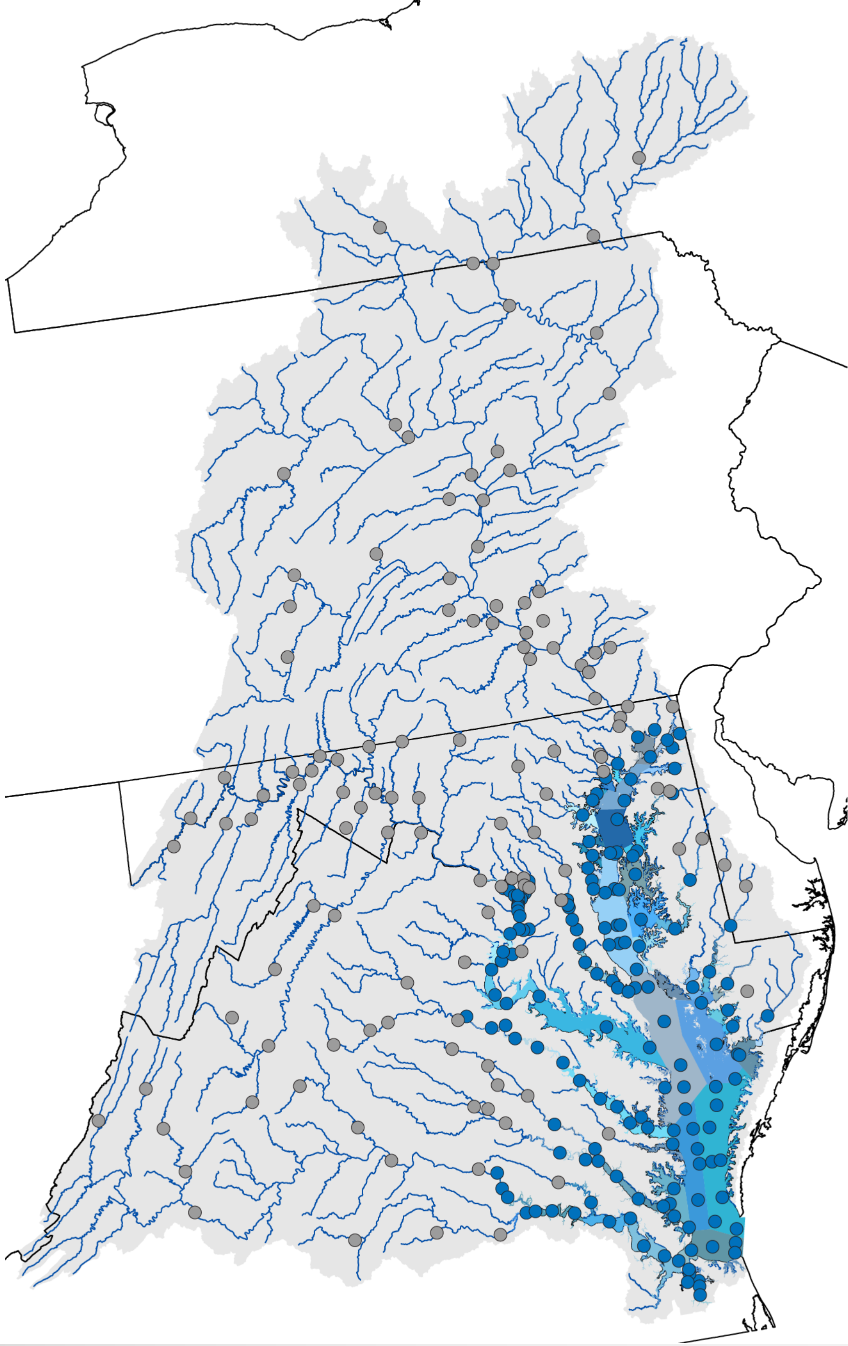
Nontidal and Tidal Nutrient Trends:
An exploration of monitoring data

December 7, 2022

Objective: to compare long-term monitored total nitrogen and total phosphorus changes in tidal and nontidal Chesapeake Bay stations.



A collaborative analysis team:

- Chris Mason, James Colgin, Alex Soroka, and Doug Moyer (USGS):
  NTN load & trend computation and analysis
- Rebecca Murphy and Qian Zhang (UMCES/CBP), Mukhtar Ibrahim (MWCOG), Renee Karrh (MDDNR), and Mike Lane (ODU)
  Tidal trend computation and analysis
- Kaylyn Gootman (EPA), Breck Sullivan (USGS), and Alex Gunnerson (CRC):
  ITAT leadership
- Jimmy Webber, John Clune, and Alex Soroka (USGS):
  SIMPLE team

All are welcome to join a follow up discussion about this topic on January 4th from 12:00 – 1:00 PM

SIMPLE: Science to Inform Management Priorities, from Loads to Endpoints

SIMPLE is a collaborative effort by the USGS Chesapeake Bay research community to share scientific information with stakeholders that helps inform nutrient-reducing management activities. This objective is met by communicating existing research and investigating new science activities that address priority stakeholder questions.

Identify priority science questions from stakeholder feedback.

Address questions with insights from existing and new science activities.

Share technical information with stakeholders and science partners.

Use feedback to guide ongoing science activities.

SIMPLE is co-led by Jimmy Webber (VA/WV), John Clune (PA), and Alex Soroka (MD/DE/DC)

There are common themes across the watershed where scientific insights can inform management activities

Strengthening Decision Making with Modeling and Monitoring

Practices to Reduce Nutrients and Sediment: Placement, Changes, and Implications for Targeting

Water-Quality Benefits to Biological Conditions and Human Health

Nutrient and Sediment Responses in Nontidal Streams

Legacy Nutrients and Lag Times

Sediment Dynamics and Reservoir Infilling

Drivers of Nutrient Responses in Nontidal Streams

Nontidal Influences on Estuarine Response and Standards Attainment

Climatic Influences on Water Quality

Summarizing Scientific Findings for Common Stakeholder Questions to Inform Nutrient and Sediment Management Activities in the Chesapeake Bay Watershed

https://www.usgs.gov/centers/chesapeake-bay-activities/science/summarizing-scientific-findings-common-stakeholder

Nontidal Influences on Estuarine Response and Standards Attainment

Management Implications

1. Water quality in the Bay has improved slightly over the past 30 years, with 33% of tidal water segments meeting attainment thresholds of their criteria for the 2017 – 2019 assessment period compared to 27% attainment in the mid-1980's.
2. Attainment levels vary over time, with the highest value of 42% observed in 2015 – 2017, and lower values occurring during times of high river flow when more nutrients are delivered to the Bay.
3. Dissolved oxygen (DO) attainment varies throughout the Bay and generally gets worse with depth, with most segments meeting DO standards for open water and migratory fish spawning designated uses, but not meeting DO standards for deep water and deep channel designated uses in the 2017 – 2019 assessment period.
4. There are numerous physical, chemical, and biological factors influencing Bay water quality, including impacts from extreme weather events, but overall attainment has been statistically associated with nitrogen inputs to the Bay.

USGS science for a changing world

Background photo courtesy of Chesapeake Bay Program

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Nontidal Influences on Estuarine Response and Standards Attainment

Priority Stakeholder Questions

Clicking a "launch" button will jump to content for a specific priority question.

What is the current attainment of water-quality standards in the Bay?

How have attainment patterns and water-quality parameters changed over time?

What factors are affecting water-quality responses in the Bay?

A "return" button is included throughout this theme that will return you to this slide.

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Background photo courtesy of Chesapeake Bay Program

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A comparison of nontidal nutrient trends and tidal responses can help inform management activities

There are numerous factors physical, chemical, and biological factors that influence Bay water quality, including effects of river flows, extreme weather events, and watershed nutrient loads.

After accounting for variation in freshwater flow, nutrient improvements in the Bay were explained by reductions in watershed river load and point source nutrient discharges (Murphy and others, 2022).

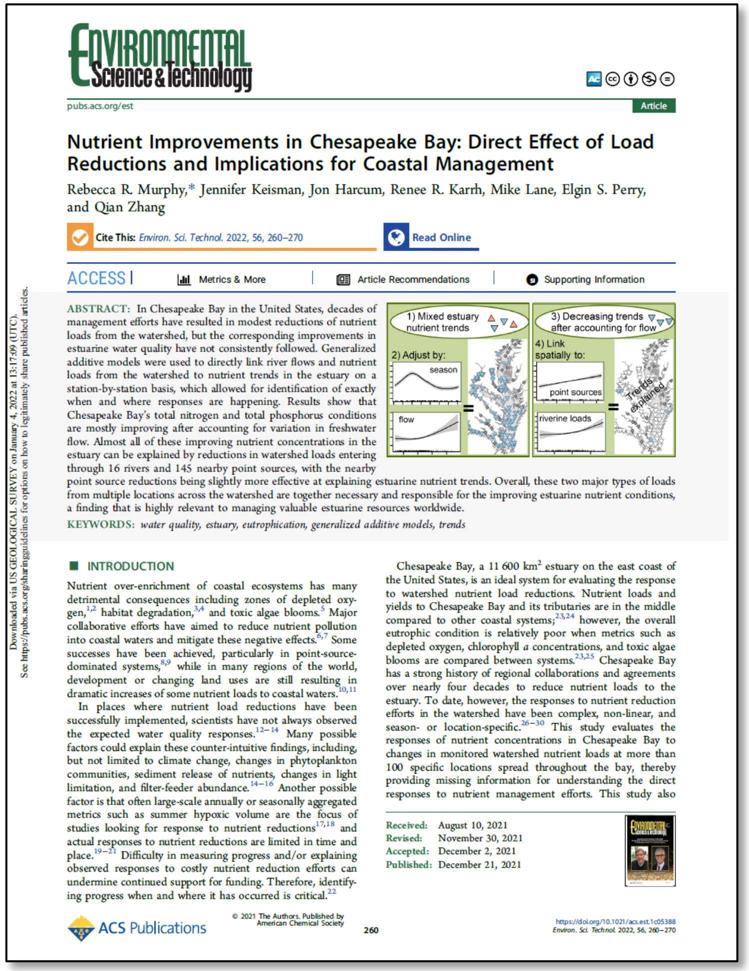
A continued evaluation of nontidal nutrient trends and tidal responses can help inform watershed management activities and evaluate their effects.

How do tidal and nontidal trends differ…

...by region/tributary?

...by constituent (N v P, total v dissolved)?

…over time (long-term vs short-term changes)?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Article

Nutrient Improvements in Chesapeake Bay: Direct Effect of Load Reductions and Implications for Coastal Management

Rebecca R. Murphy,* Jennifer Keisman, Jon Harcum, Renee R. Karrh, Mike Lane, Elgin S. Perry, and Qian Zhang

Cite This: Environ. Sci. Technol. 2022, 56, 260−270 Read Online

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ABSTRACT: In Chesapeake Bay in the United States, decades of management efforts have resulted in modest reductions of nutrient loads from the watershed, but the corresponding improvements in estuarine water quality have not consistently followed. Generalized additive models were used to directly link river flows and nutrient loads from the watershed to nutrient trends in the estuary on a station-by-station basis, which allowed for identification of exactly when and where responses are happening. Results show that Chesapeake Bay's total nitrogen and total phosphorus conditions are mostly improving after accounting for variation in freshwater flow. Almost all of these improving nutrient concentrations in the estuary can be explained by reductions in watershed loads entering through 16 rivers and 145 nearby point sources, with the nearby point source reductions being slightly more effective at explaining estuarine nutrient trends. Overall, these two major types of loads from multiple locations across the watershed are together necessary and responsible for the improving estuarine nutrient conditions, a finding that is highly relevant to managing valuable estuarine resources worldwide.

KEYWORDS: water quality, estuary, eutrophication, generalized additive models, trends

INTRODUCTION

Nutrient over-enrichment of coastal ecosystems has many detrimental consequences including zones of depleted oxygen,[1,2] habitat degradation,[3,4] and toxic algae blooms.[5] Major collaborative efforts have aimed to reduce nutrient pollution into coastal waters and mitigate these negative effects.[6,7] Some successes have been achieved, particularly in point-source-dominated systems,[8,9] while in many regions of the world, development or changing land uses are still resulting in dramatic increases of some nutrient loads to coastal waters.[10,11]

In places where nutrient load reductions have been successfully implemented, scientists have not always observed the expected water quality responses.[12−14] Many possible factors could explain these counter-intuitive findings, including, but not limited to climate change, changes in phytoplankton communities, sediment release of nutrients, changes in light limitation, and filter-feeder abundance.[14−16] Another possible factor is that often large-scale annually or seasonally aggregated metrics such as summer hypoxic volume are the focus of studies looking for response to nutrient reductions[17,18] and actual responses to nutrient reductions are limited in time and place.[19−21] Difficulty in measuring progress and/or explaining observed responses to costly nutrient reduction efforts can undermine continued support for funding. Therefore, identifying progress when and where it has occurred is critical.[22]

Chesapeake Bay, a 11 600 km^2 estuary on the east coast of the United States, is an ideal system for evaluating the response to watershed nutrient load reductions. Nutrient loads and yields to Chesapeake Bay and its tributaries are in the middle compared to other coastal systems;[23,24] however, the overall eutrophic condition is relatively poor when metrics such as depleted oxygen, chlorophyll *a* concentrations, and toxic algae blooms are compared between systems.[23,25] Chesapeake Bay has a strong history of regional collaborations and agreements over nearly four decades to reduce nutrient loads to the estuary. To date, however, the responses to nutrient reduction efforts in the watershed have been complex, non-linear, and season- or location-specific.[26−30] This study evaluates the responses of nutrient concentrations in Chesapeake Bay to changes in monitored watershed nutrient loads at more than 100 specific locations spread throughout the bay, thereby providing missing information for understanding the direct responses to nutrient management efforts. This study also

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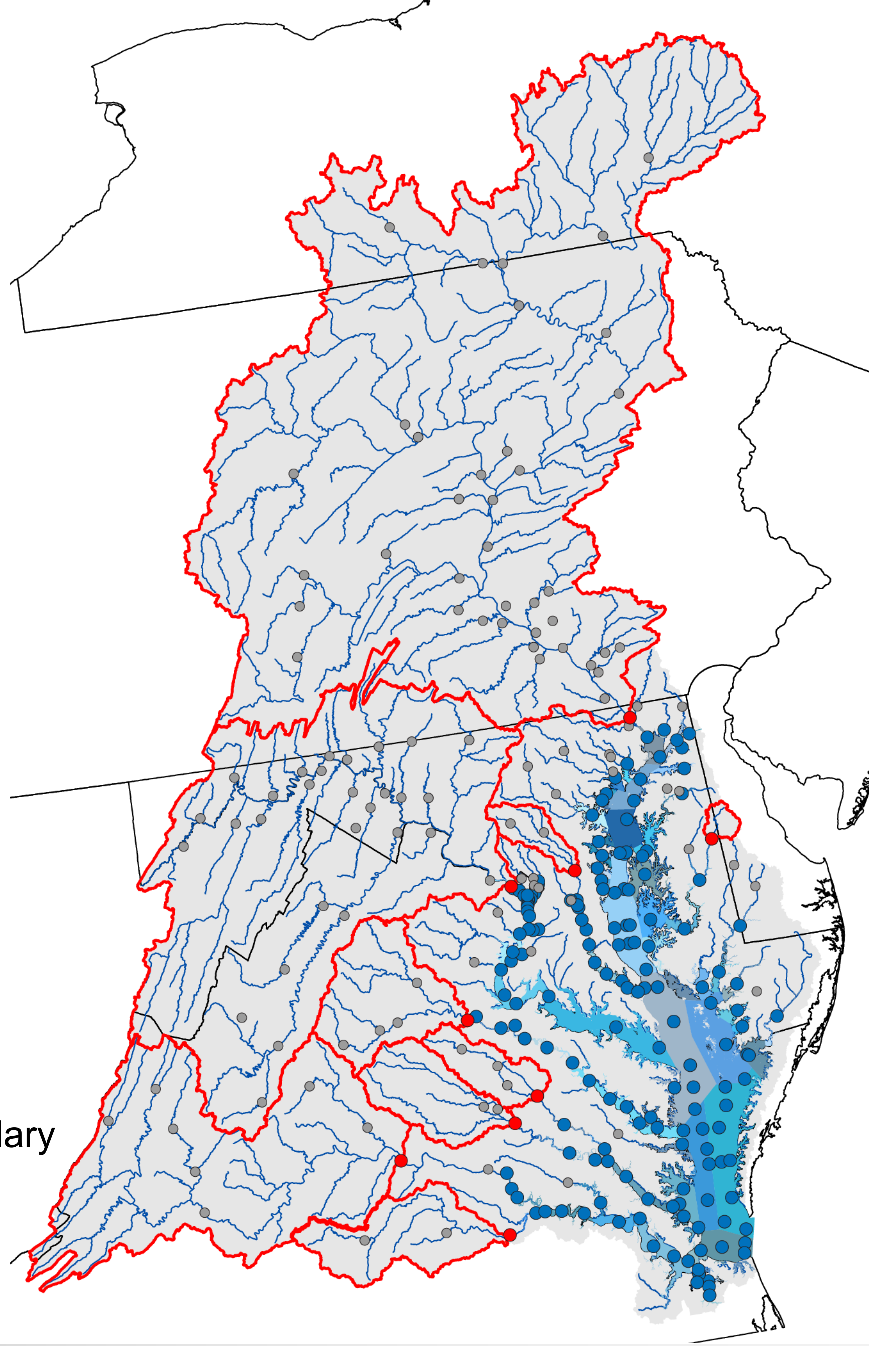
Murphy, R.R., Keisman, J., Harcum, J., Karrh, R.R., Lane, M., Perry, E.S., and Zhang, Q., 2022, Nutrient Improvements in Chesapeake Bay: Direct Effect of Load Reductions and Implications for Coastal Management: Environmental Science & Technology, v. 56, no. 1, p. 260–270.

Nontidal Monitoring Network

Chris Mason, James Colgin, Alex Soroka, and Doug Moyer, (USGS)

- Nutrient and sediment concentrations, loads, and trends are computed biennially at the 123 station NTN.
- Computations are based on monthly and, for many stations, storm-targeted water-quality samples.
- Data are computed annually at 9 River Input Monitoring (RIM) stations, which have been monitored since 1985 and represent 78 percent of the Bay watershed.
- Concentrations, loads, and trends in flow-normalized data are computed using **Weighted Regressions on Time, Discharge, and Season (WRTDS)**.
- NTN loads and trends are computed through water year 2020 and will be available online soon.
- RIM loads and trends are computed through water year 2021 and are available online:
  - www.sciencebase.gov/catalog/item/633b14b5d34e900e86cf13d0



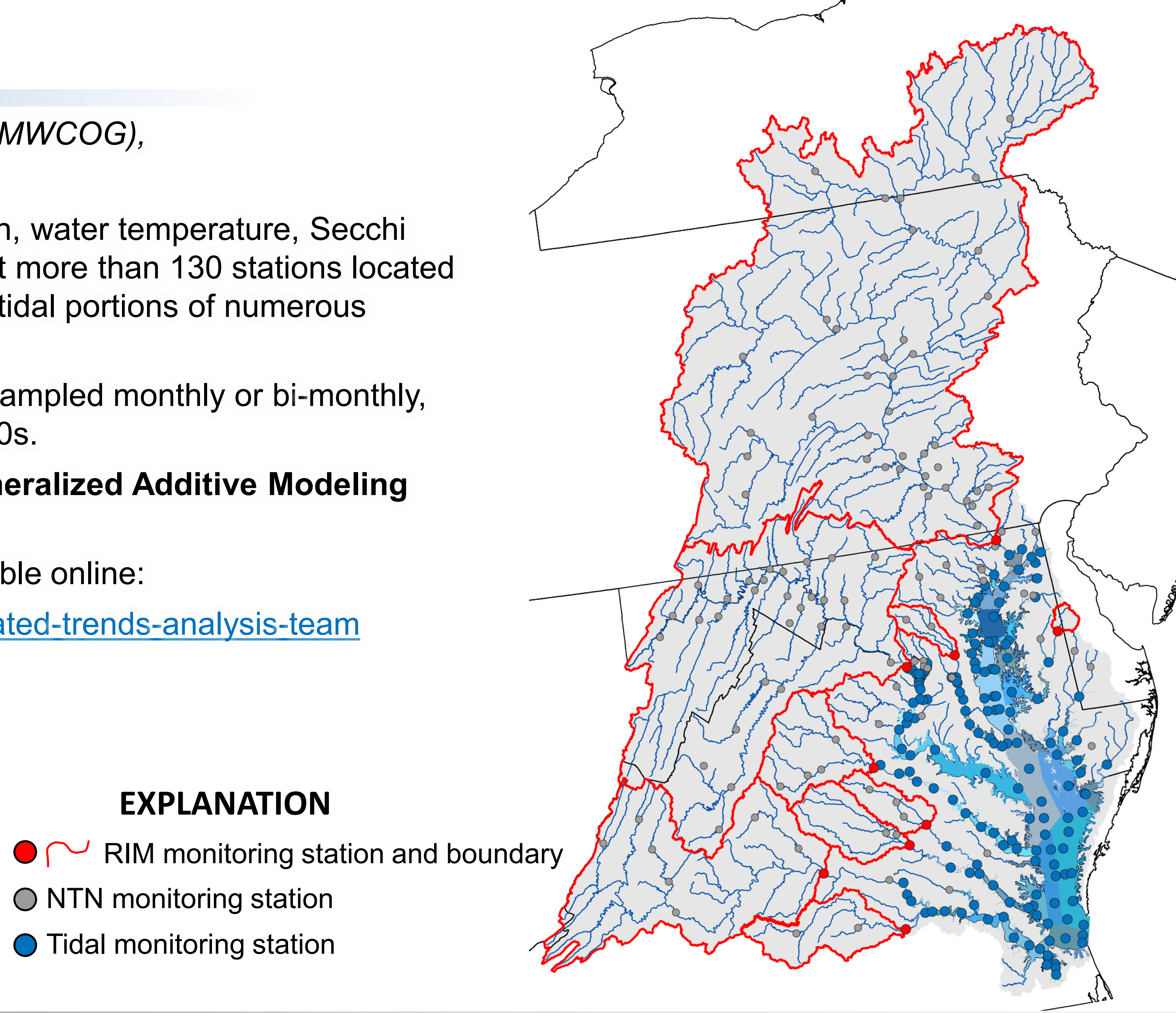
EXPLANATION

- RIM monitoring station and boundary
- NTN monitoring station
- Tidal monitoring station

Tidal Monitoring Network

Rebecca Murphy (UMCES/CBP), Mukhtar Ibrahim (MWCOG),
Renee Karrh (MDDNR, and Mike Lane (ODU)

- Nutrient, total suspended solid, dissolved oxygen, water temperature, Secchi depth, and chlorophyll a, trends are computed at more than 130 stations located throughout the Chesapeake Bay mainstem and tidal portions of numerous tributaries.
- Computations are based on water-quality data sampled monthly or bi-monthly, with many stations monitored since the mid-1980s.
- Flow-adjusted trends are computed using a **Generalized Additive Modeling (GAM)**.
- Data are computed through 2021 and are available online:
  - www.chesapeakebay.net/who/group/integrated-trends-analysis-team
  - cast.chesapeakebay.net/TrendsOverTime

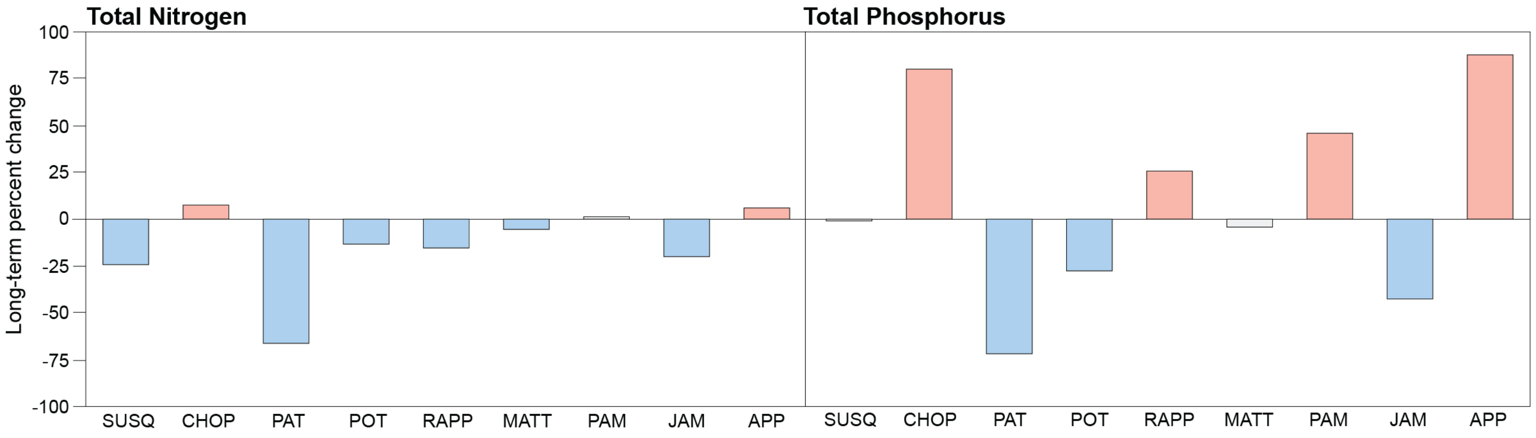


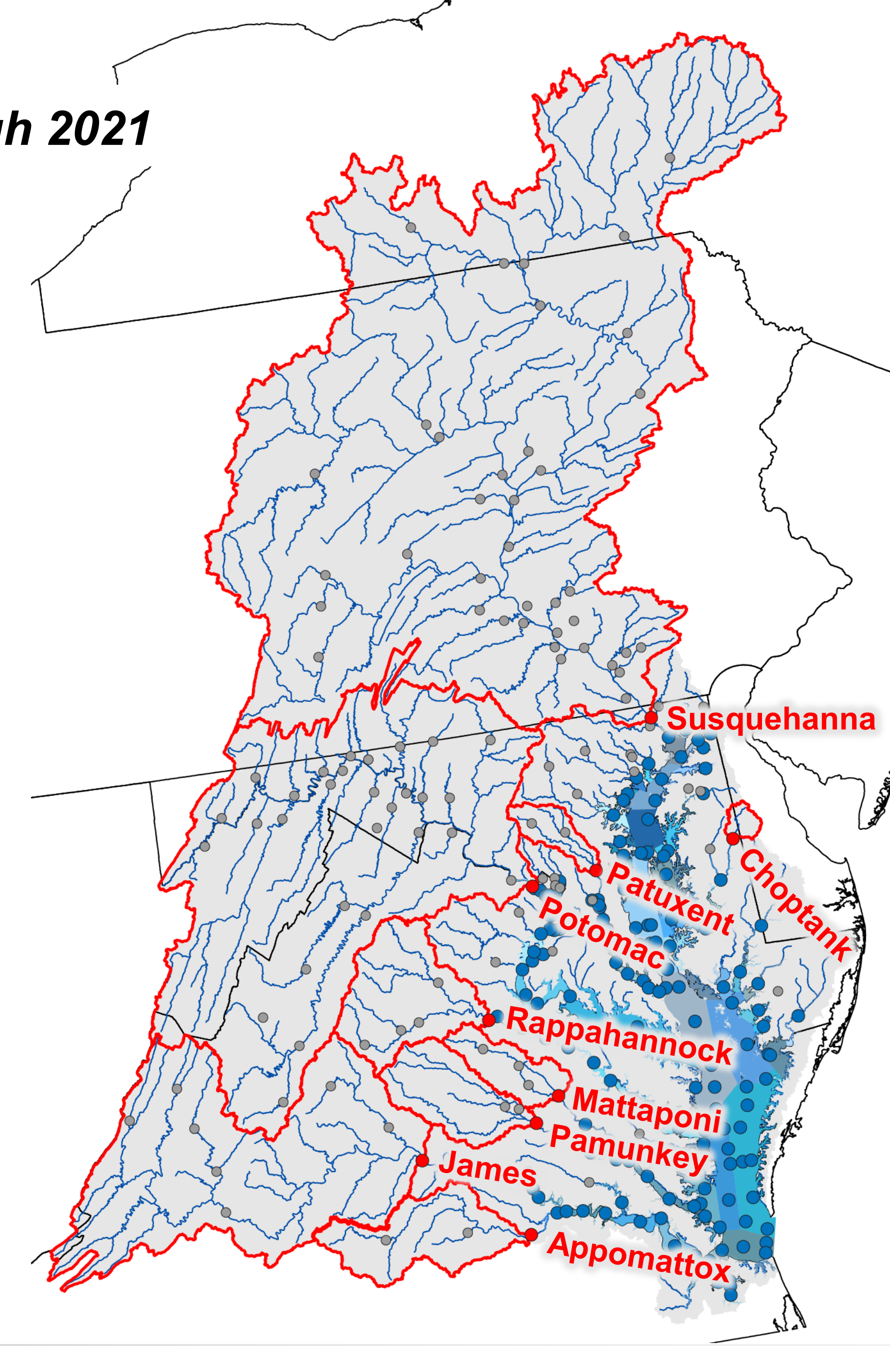
Nontidal Network

Long-Term Flow-Normalized Nutrient Load Trends, RIM Stations, Through 2021

Long-term trends improved for TN at 6 stations and for TP at 3 stations

RIM Station	TN Trend Direction	TP Trend Direction
Susquehanna	Improved	No Change
Choptank	Degraded	Degraded
Patuxent	Improved	Improved
Potomac	Improved	Improved
Rappahannock	Improved	Degraded
Mattaponi	Improved	No Change
Pamunkey	No Change	Degraded
James	Improved	Improved
Appomattox	Degraded	Degraded



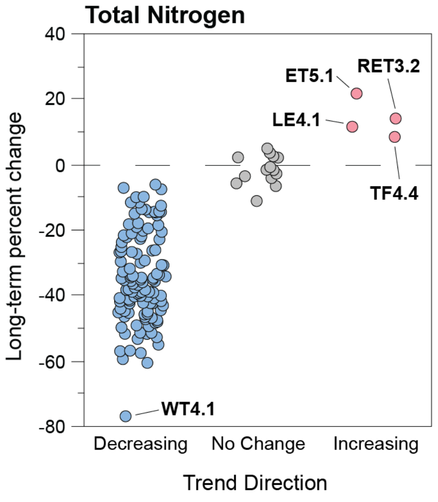


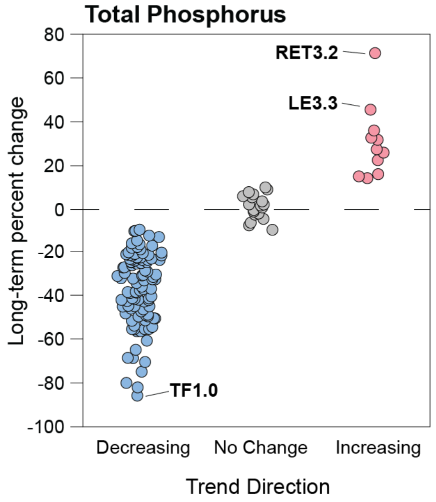
Tidal Network

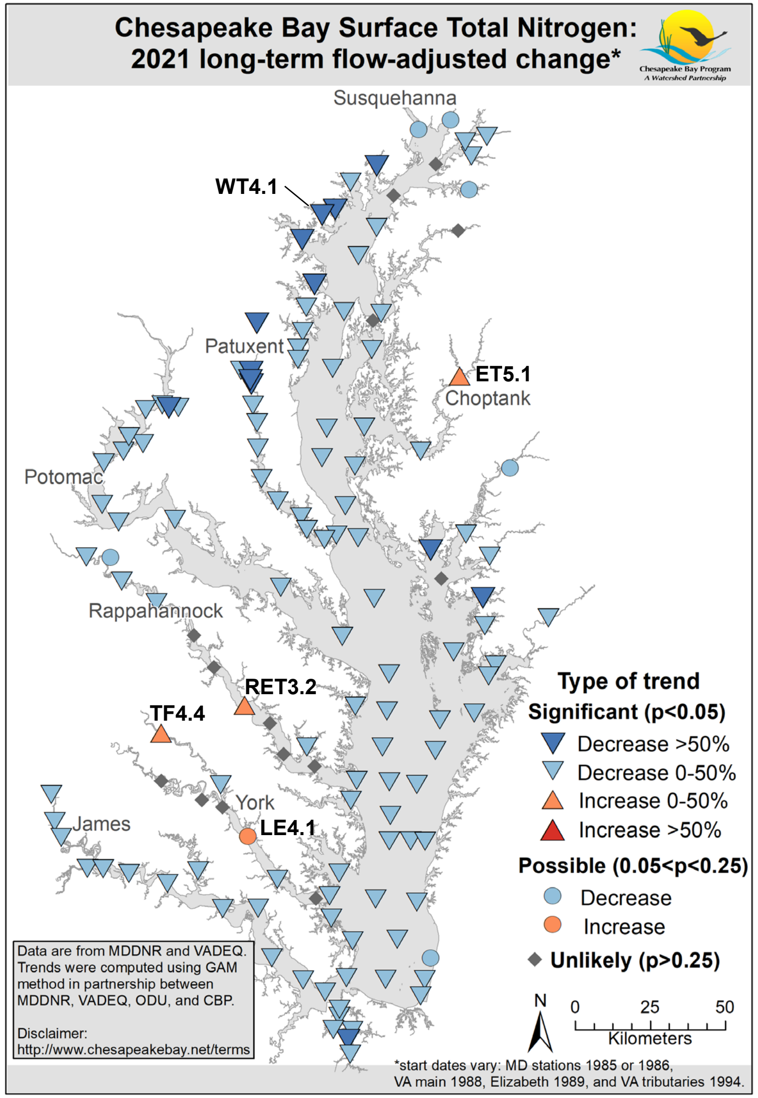
Long-Term Flow-Adjusted Surface Nutrient Concentration Trends, Through 2021

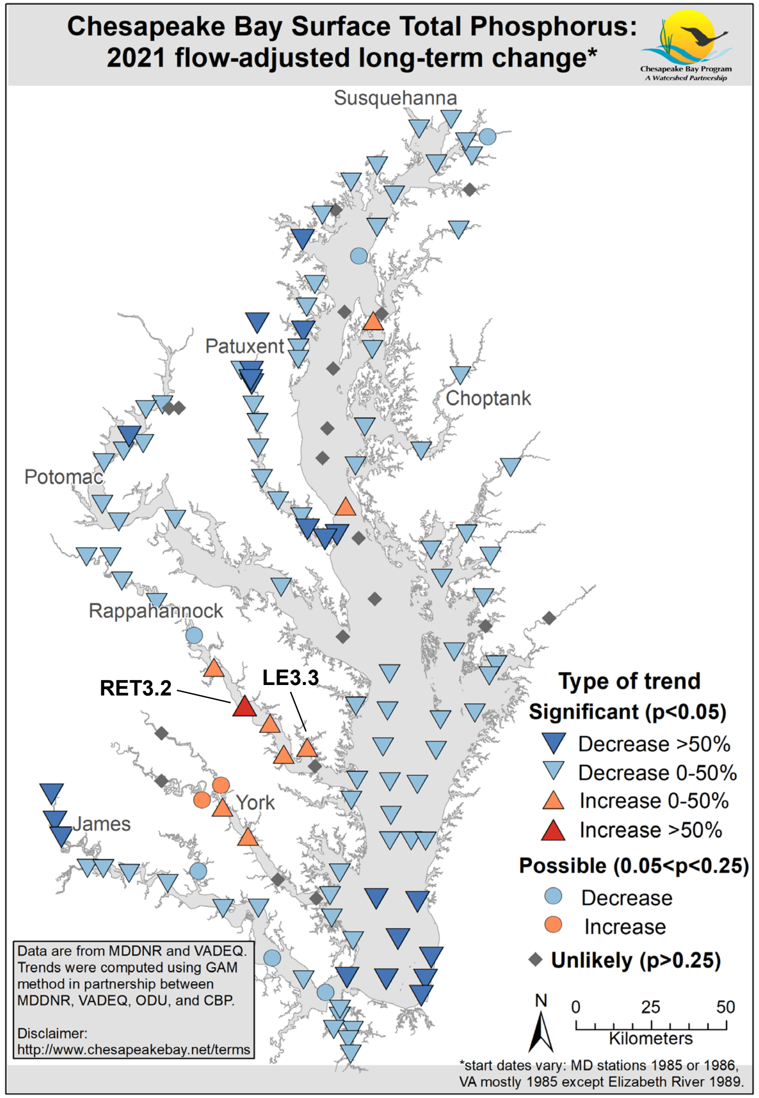
Flow-adjusted TN and TP concentrations improved over a long-term period at most stations.

Parameter	Trend Direction	Percent
Flow-Adjusted Surface TN Concentration, n = 138	Improved	87
	No Change	10
	Degraded	3
Flow-Adjusted Surface TP Concentration, n = 138	Improved	78
	No Change	14
	Degraded	8

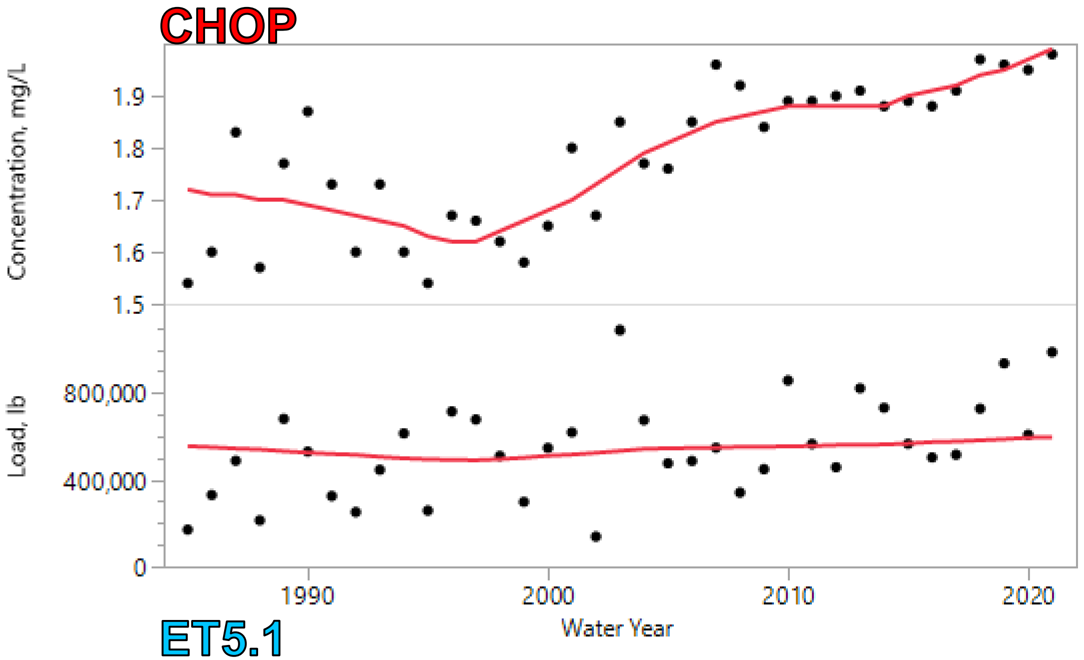


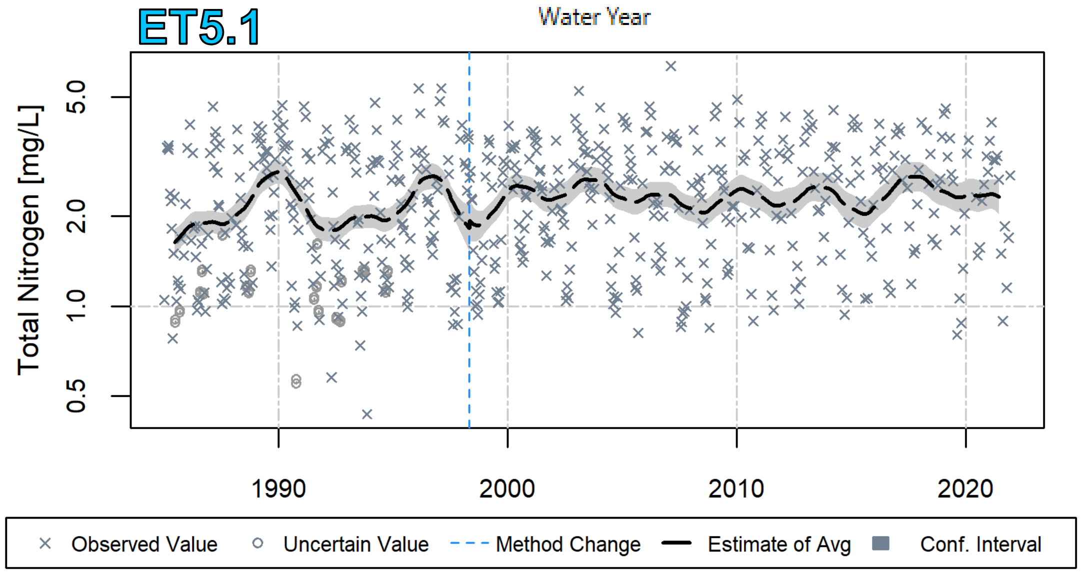


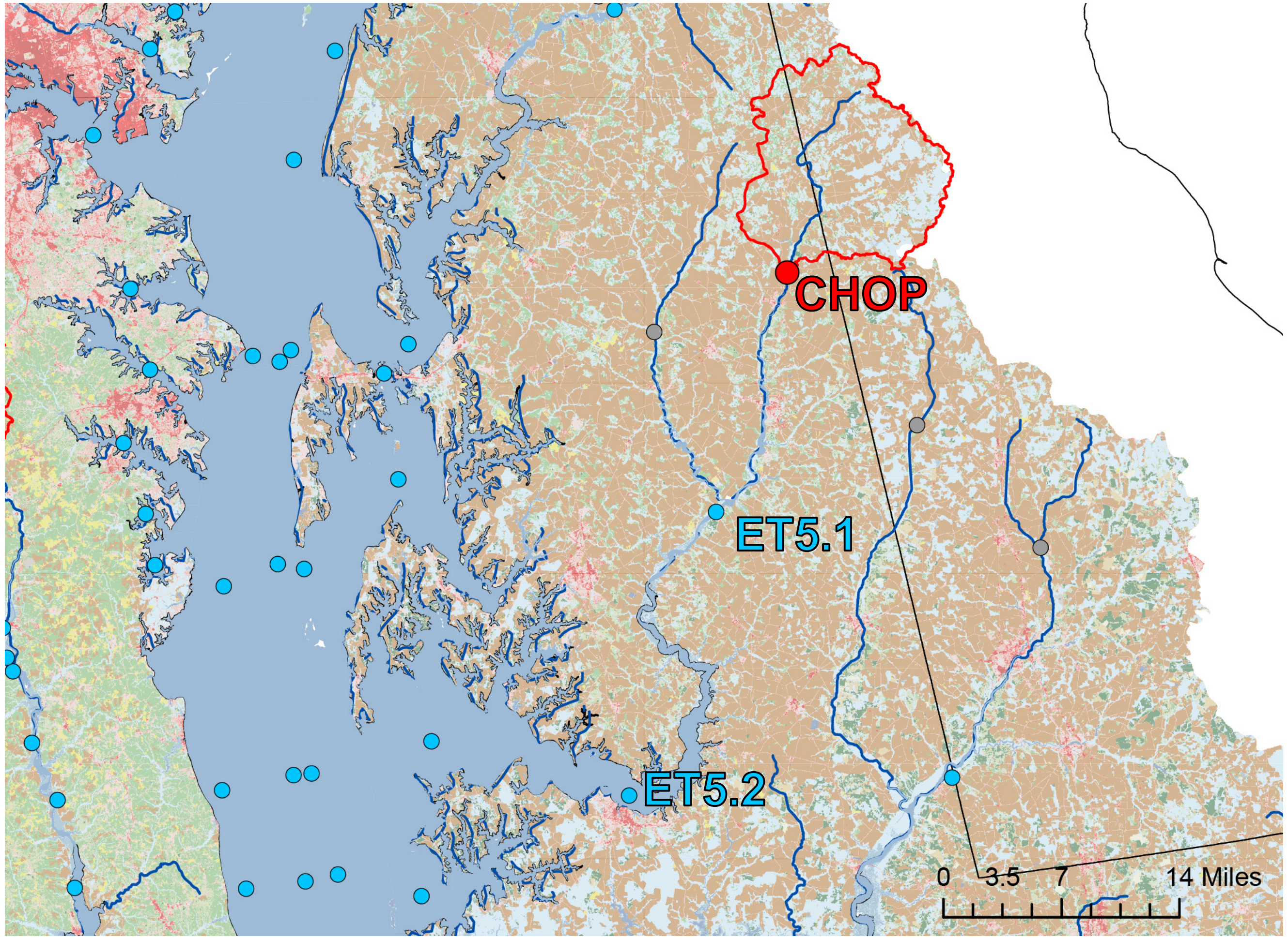




Choptank TN: RIM Increasing, Tidal Increasing



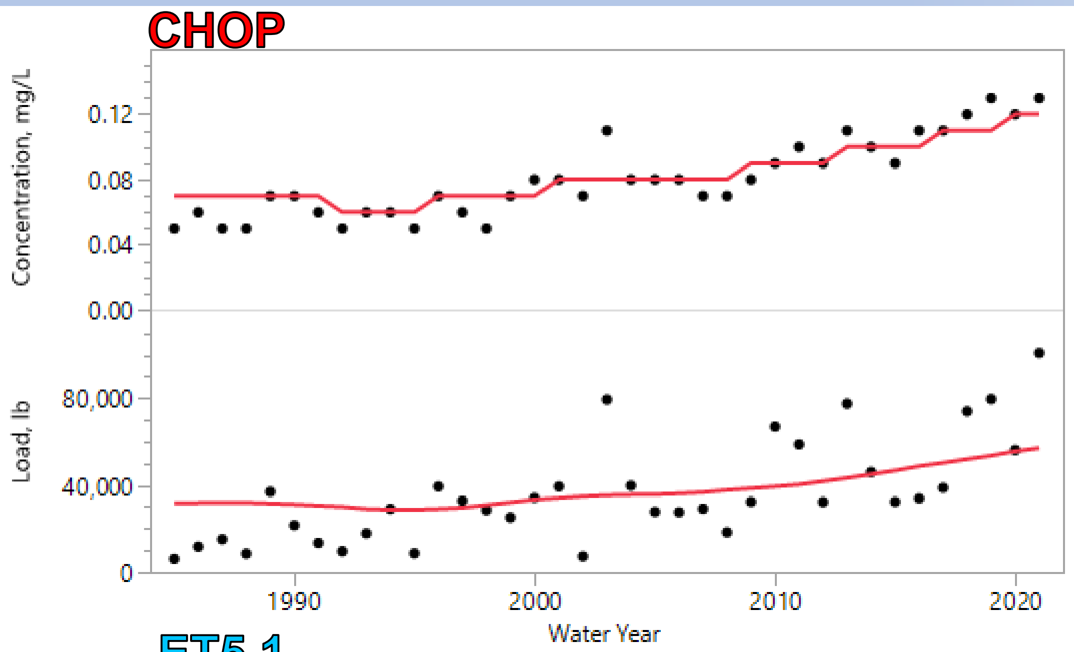


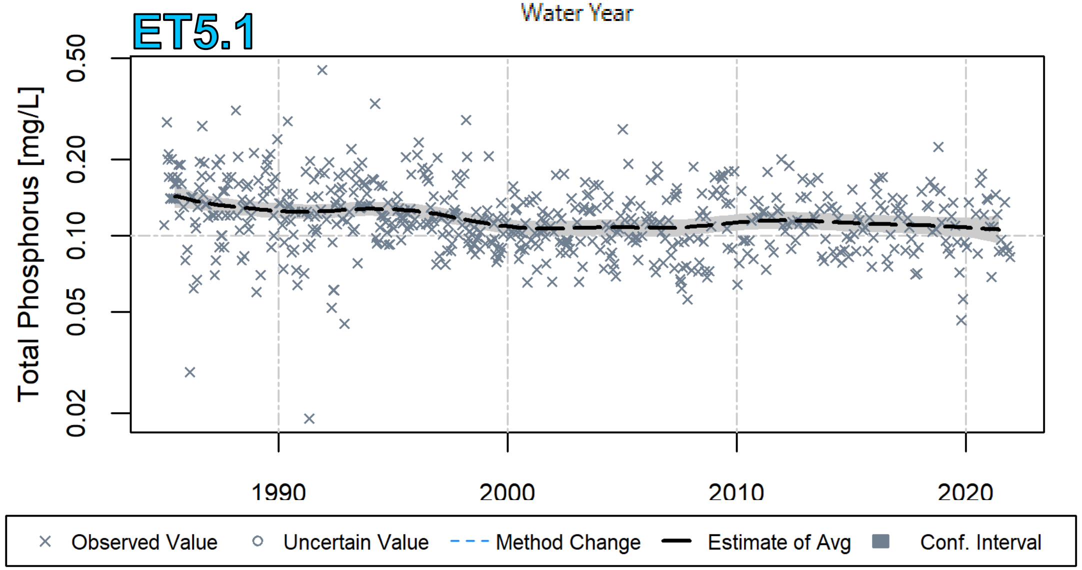


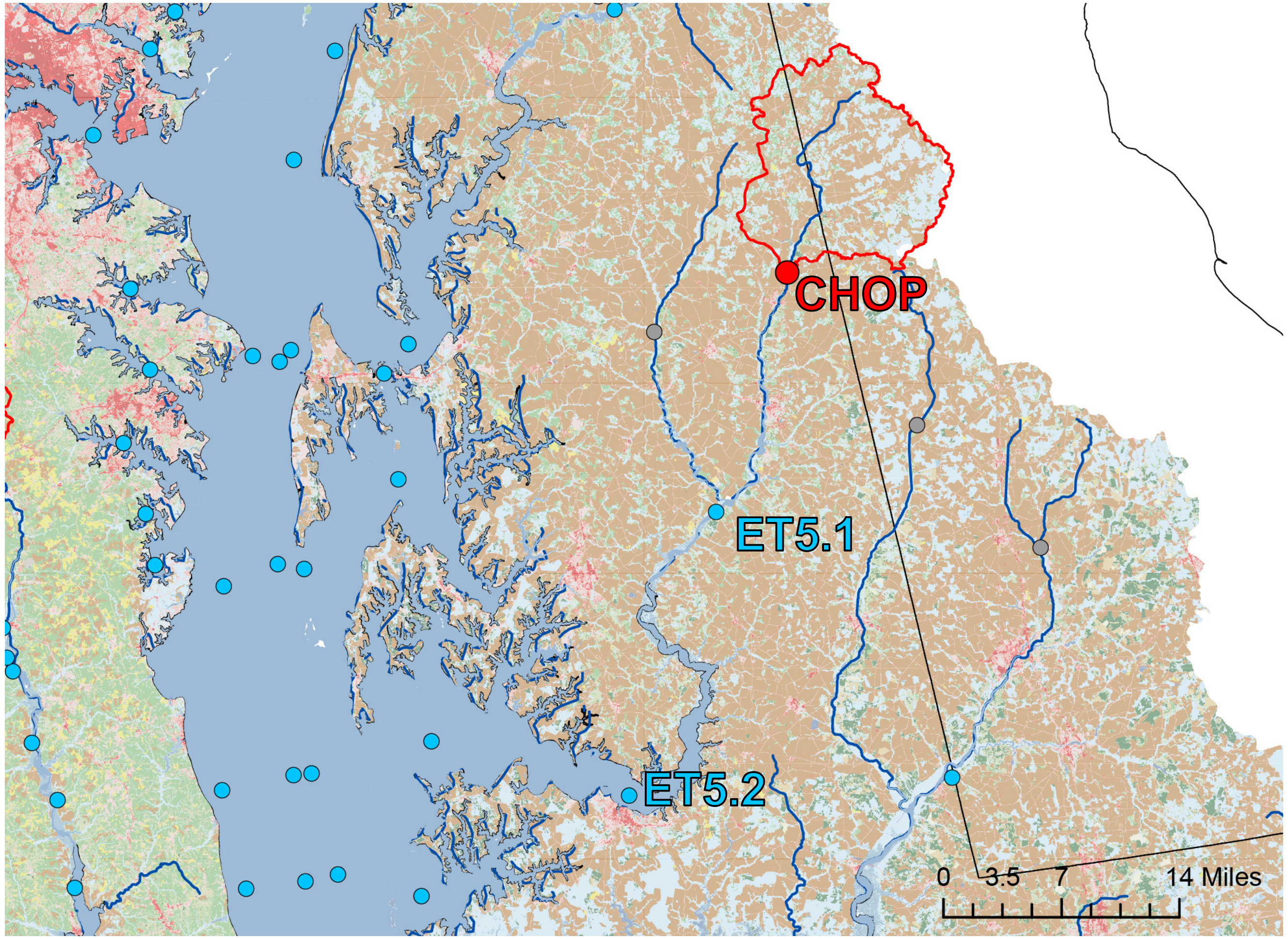
CHOP: +0.3 mg/L* (increasing) +41,900 lb** (increasing)
ET5.1: +0.2 mg/L*** (increasing)
ET 5.2: -0.5 mg/L*** (decreasing)

*Flow-normalized concentration (1985 – 2021) **Flow-normalized load (1985 – 2021)
***Surface flow-adjusted concentration (1985 – 2021)

Choptank TP: RIM Increasing, Tidal Decreasing



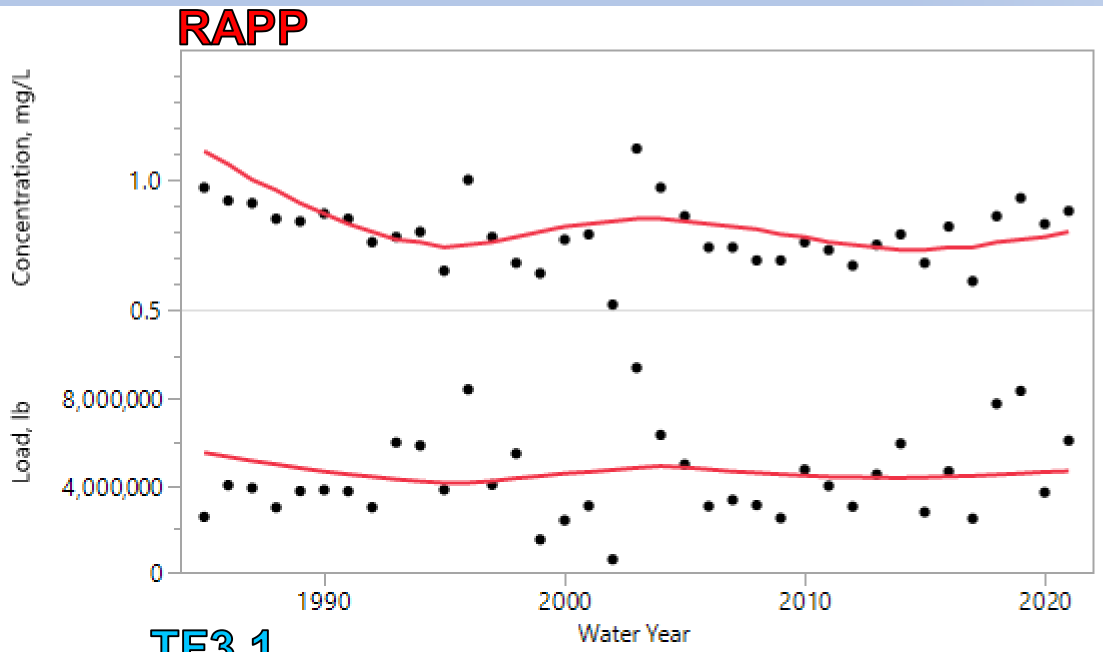


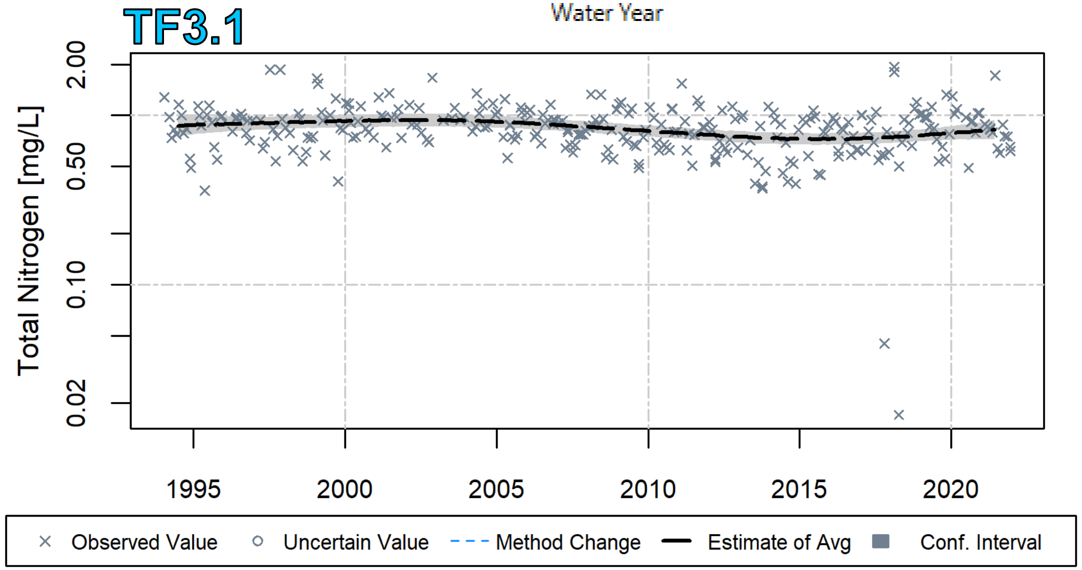


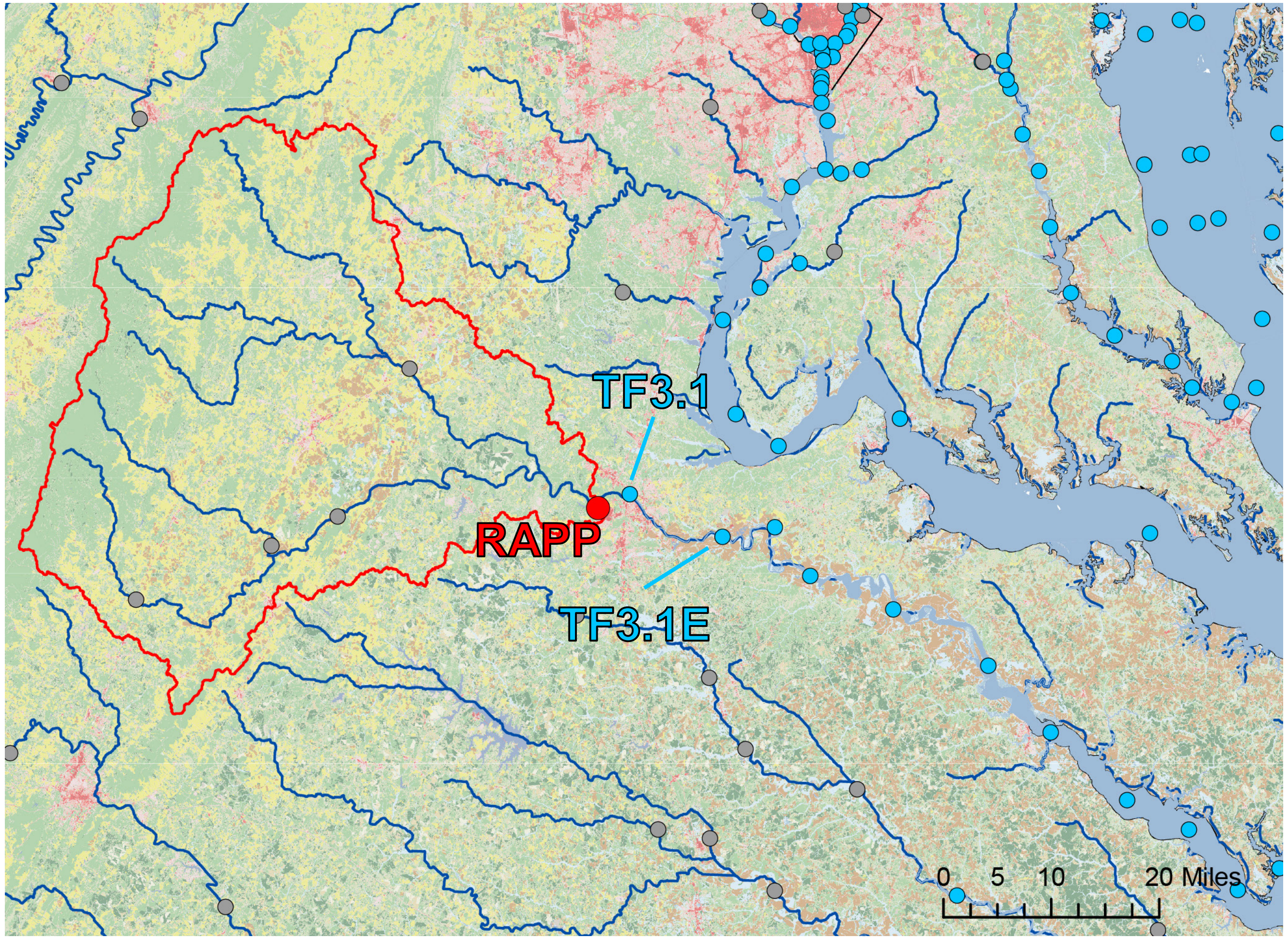
CHOP: +0.05 mg/L* (increasing) +25,400 lb** (increasing)
ET5.1: -0.3 mg/L*** (decreasing)
ET 5.2: -0.5 mg/L*** (decreasing)

*Flow-normalized concentration (1985 – 2021) **Flow-normalized load (1985 – 2021)
***Surface flow-adjusted concentration (1985 – 2021)

Rappahannock TN: RIM Decreasing, Tidal Decreasing







RAPP: -0.3 mg/L* (decreasing) -850,000 lb** (decreasing)

TF3.1: -0.2 mg/L*** (decreasing)

TF3.1E: -0.4 mg/L*** (decreasing)

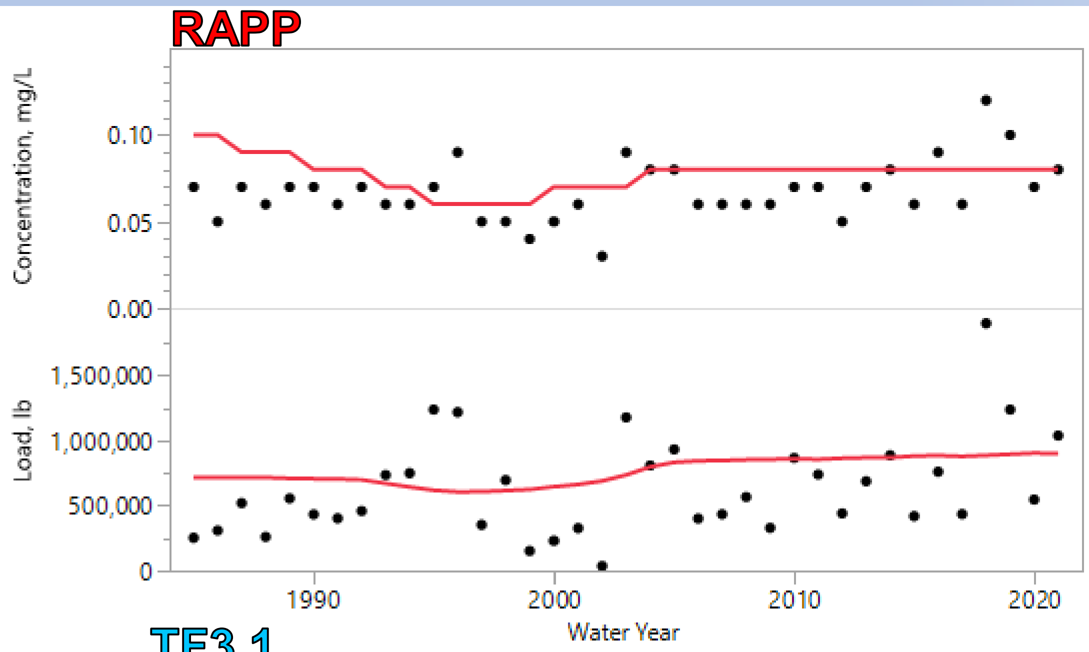
USGS science for a changing world

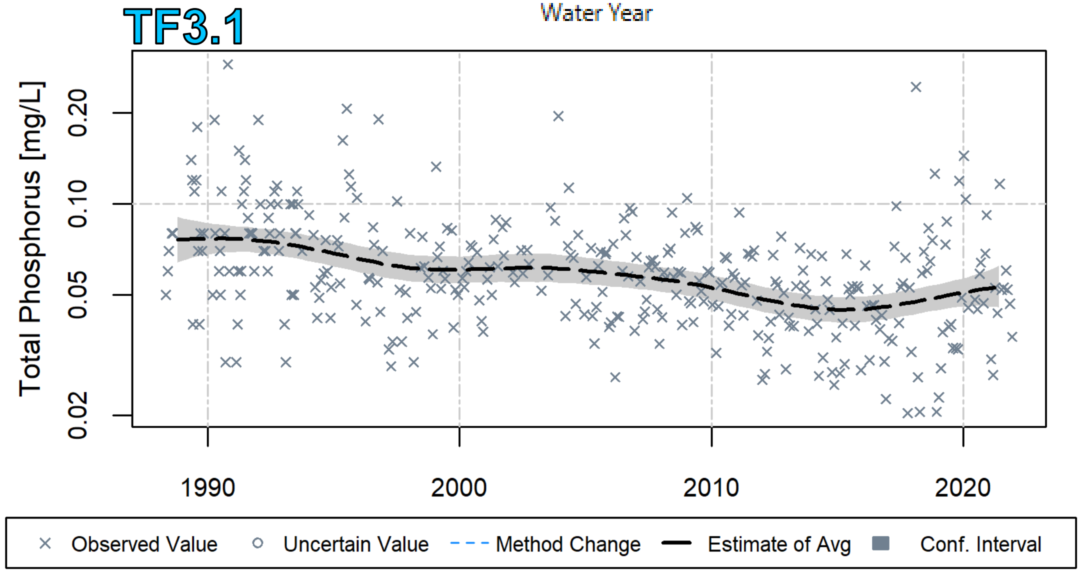
Chesapeake Bay Program Science. Restoration. Partnership.

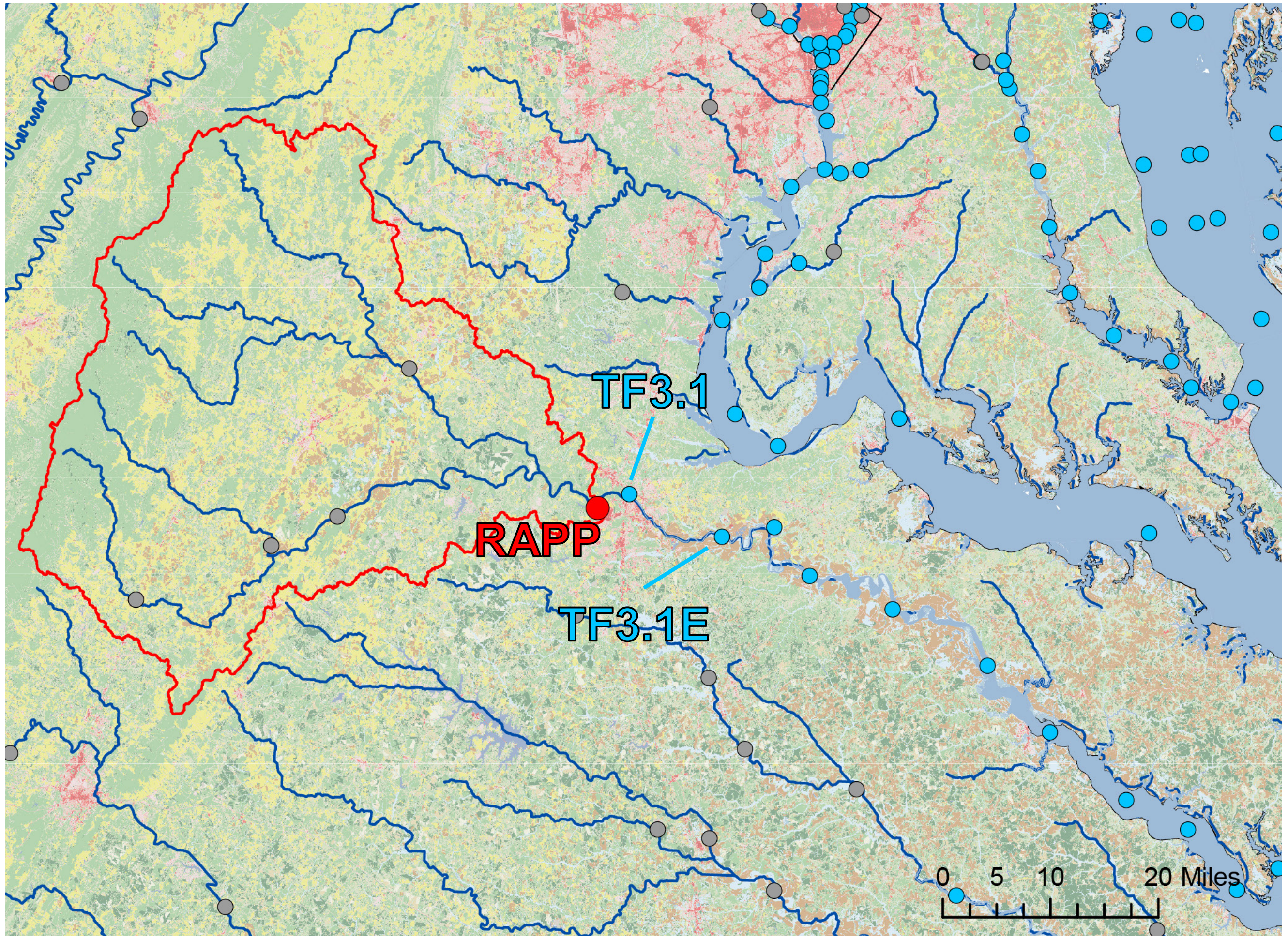
*Flow-normalized concentration (1985 – 2021) **Flow-normalized load (1985 – 2021)

***Surface flow-adjusted concentration (1994 – 2021)

Rappahannock TP: RIM Decreasing, Tidal Decreasing







RAPP: -0.02 mg/L* (decreasing) +184,000 lb** (decreasing)

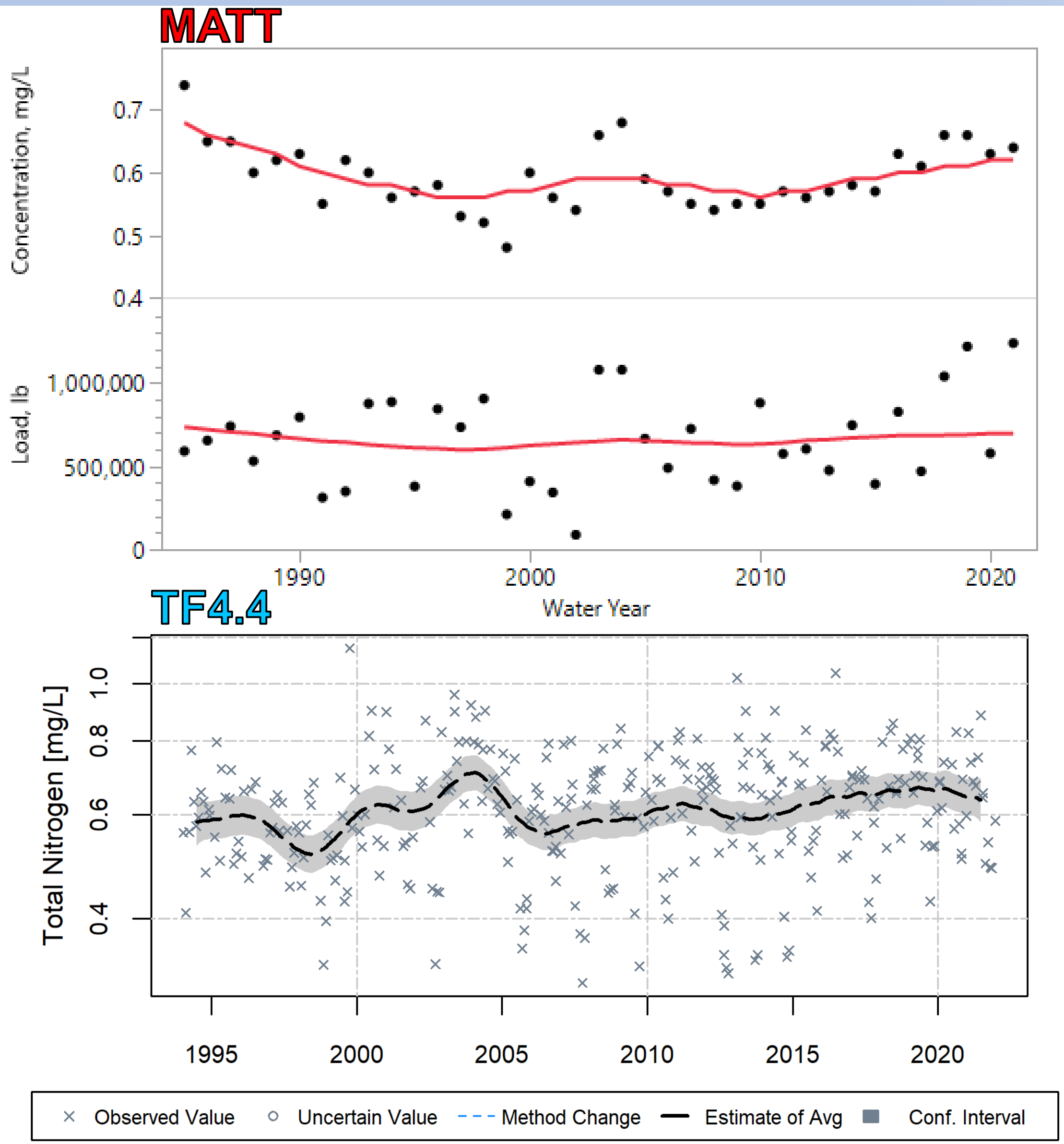
TF3.1: -0.4 mg/L*** (decreasing)

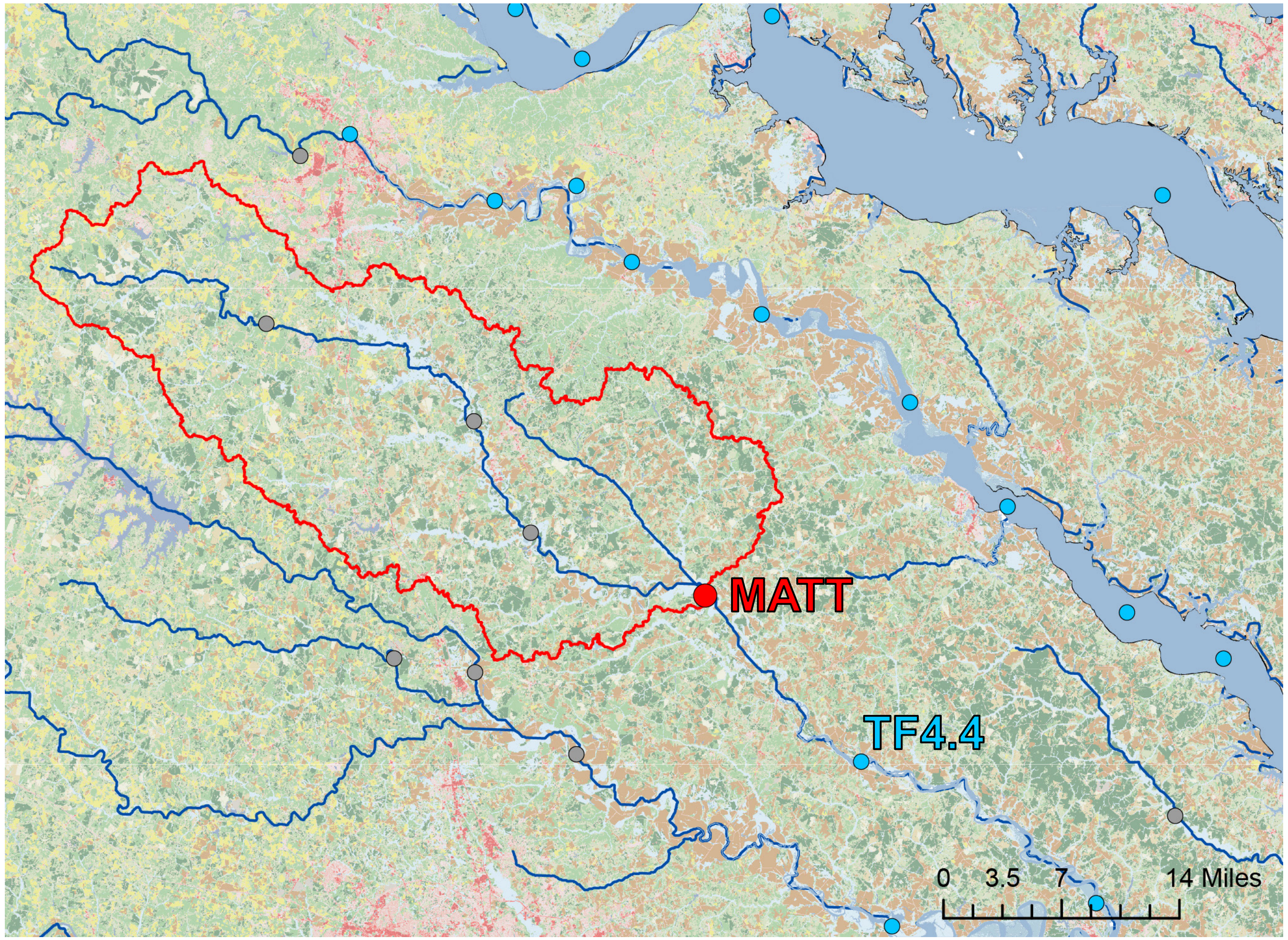
TF3.1E: -0.5 mg/L*** (decreasing)

*Flow-normalized concentration (1985 – 2021) **Flow-normalized load (1985 – 2021)

***Surface flow-adjusted concentration (1988 – 2021)

Mattaponi TN: RIM Decreasing, Tidal Increasing

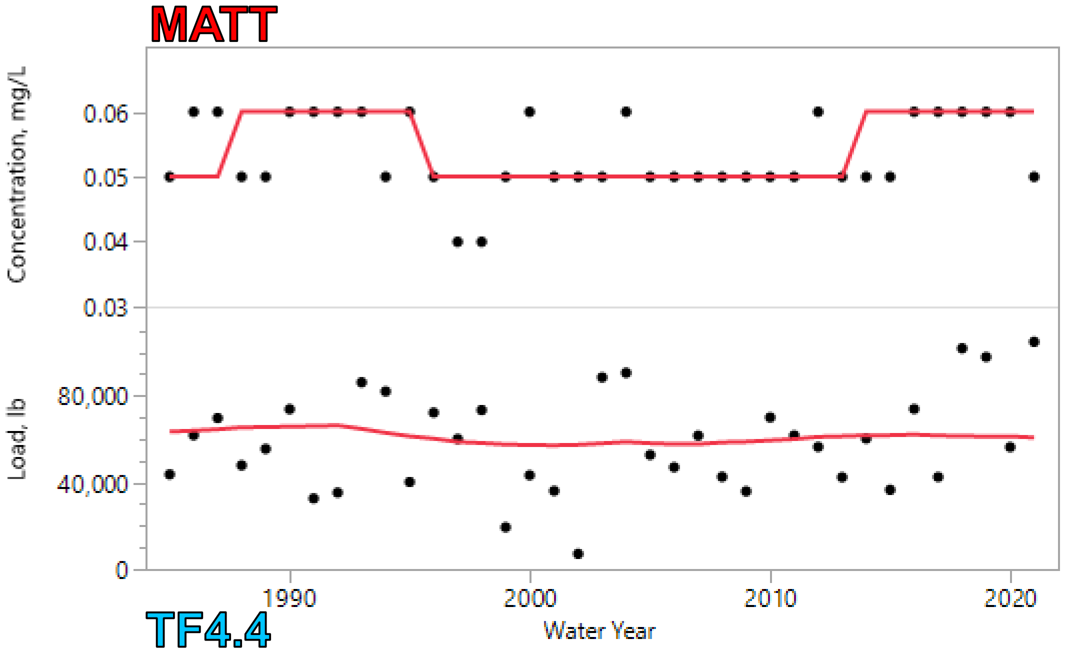


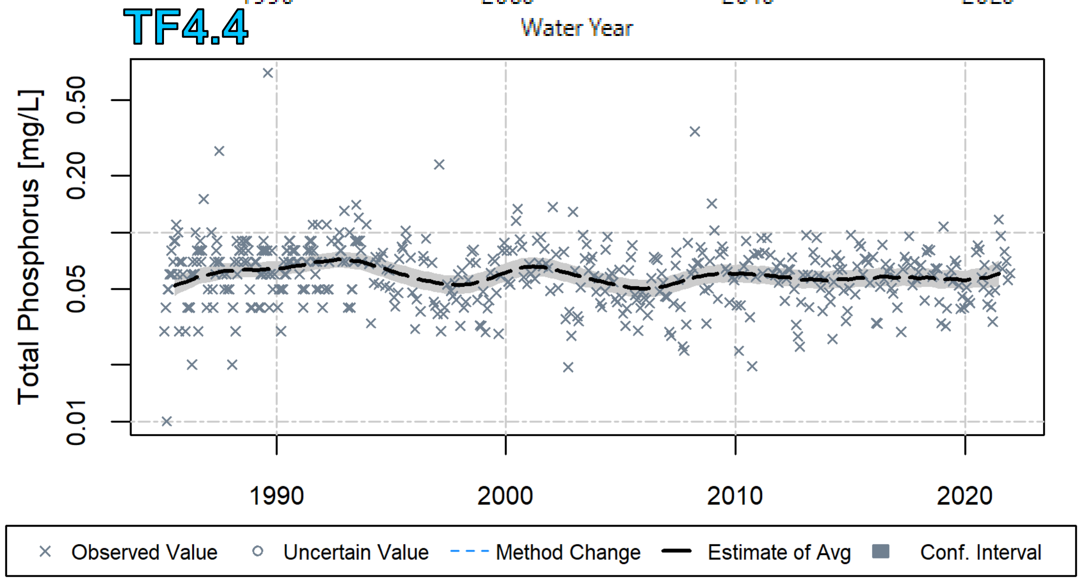


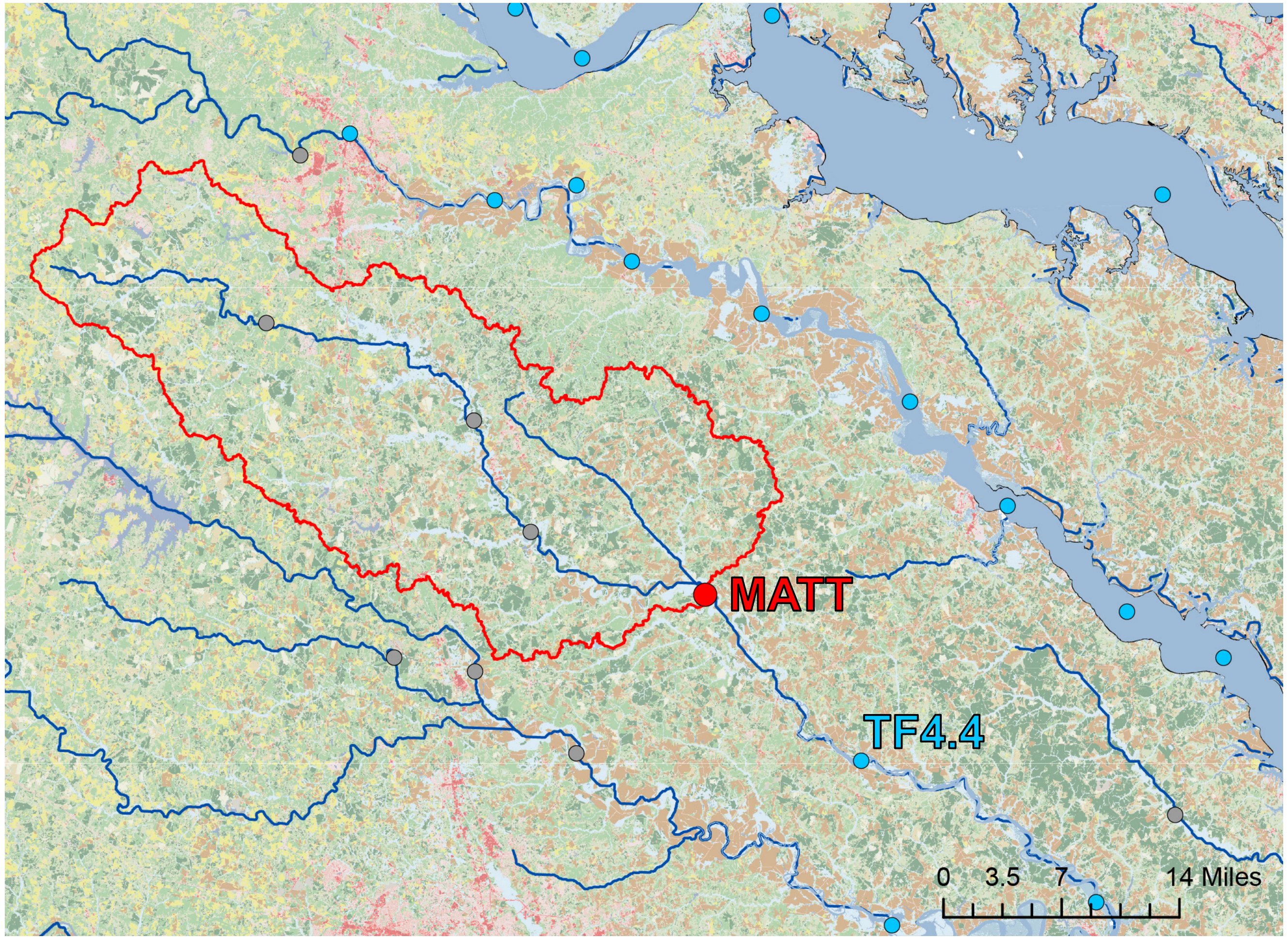
MATT: -0.05 mg/L* (decreasing) -40,000 lb** (decreasing)
TF4.4: +0.08 mg/L*** (increasing)

*Flow-normalized concentration (1985 – 2021) **Flow-normalized load (1985 – 2021)
***Surface flow-adjusted concentration (1994 – 2021)

Mattaponi TP: NTN No Change, Tidal No Change







MATT: +0.00 mg/L* (no change) -2,700 lb** (no change)

TF4.4: +0.08 mg/L*** (no change)

*Flow-normalized concentration (1985 – 2021) **Flow-normalized load (1985 – 2021)

***Surface flow-adjusted concentration (1985 – 2021)

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