Identifying and evaluating water chemistry trends in urban waters

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Objective: To compute trends for a suite of water-quality constituents collected from 14 Fairfax County watersheds between 2008-2018.

Castle Creek, April 2008

Castle Creek, April 2018

In cooperation with Fairfax County, VA

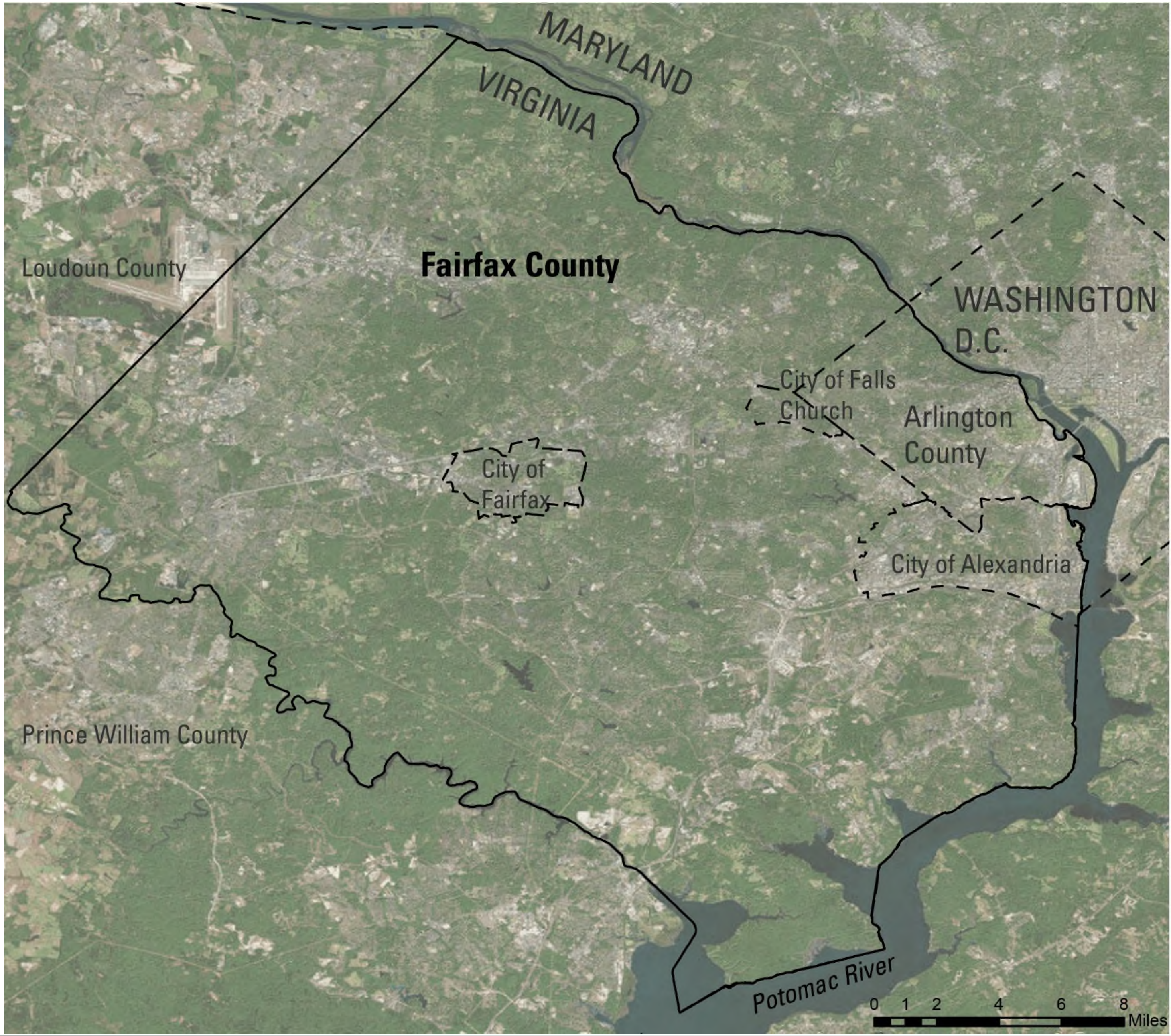
Fairfax County streams are affected by urbanization

Fairfax County (395 mi^2) is adjacent to Washington DC and with **more than 1.1 million residents**, is one of the most populous jurisdictions in Virginia.

There are over **1,600 miles of streams** in Fairfax County that are subject to effects of urbanization, which include altered hydrology, increased nutrient transport, increased stream erosion, and reduced biotic richness[1].

Fairfax County uses a probabilistic monitoring design to assess water quality through biological and chemical data collection, which indicated in 2017 that approximately **75% of streams are in fair, poor, or very poor condition**[2].

To reverse these effects, Fairfax County primarily uses **stream restoration** practices. To date, over 9 miles of streams have been restored and investments have exceeded 100 million dollars[3].



[1]Walsh and others, 2005 [2]Fairfax County Stormwater Status Report, 2017 [3]Shannon Curtis, written commun.

Fairfax County streams have been assessed through a cooperative USGS monitoring program since 2008

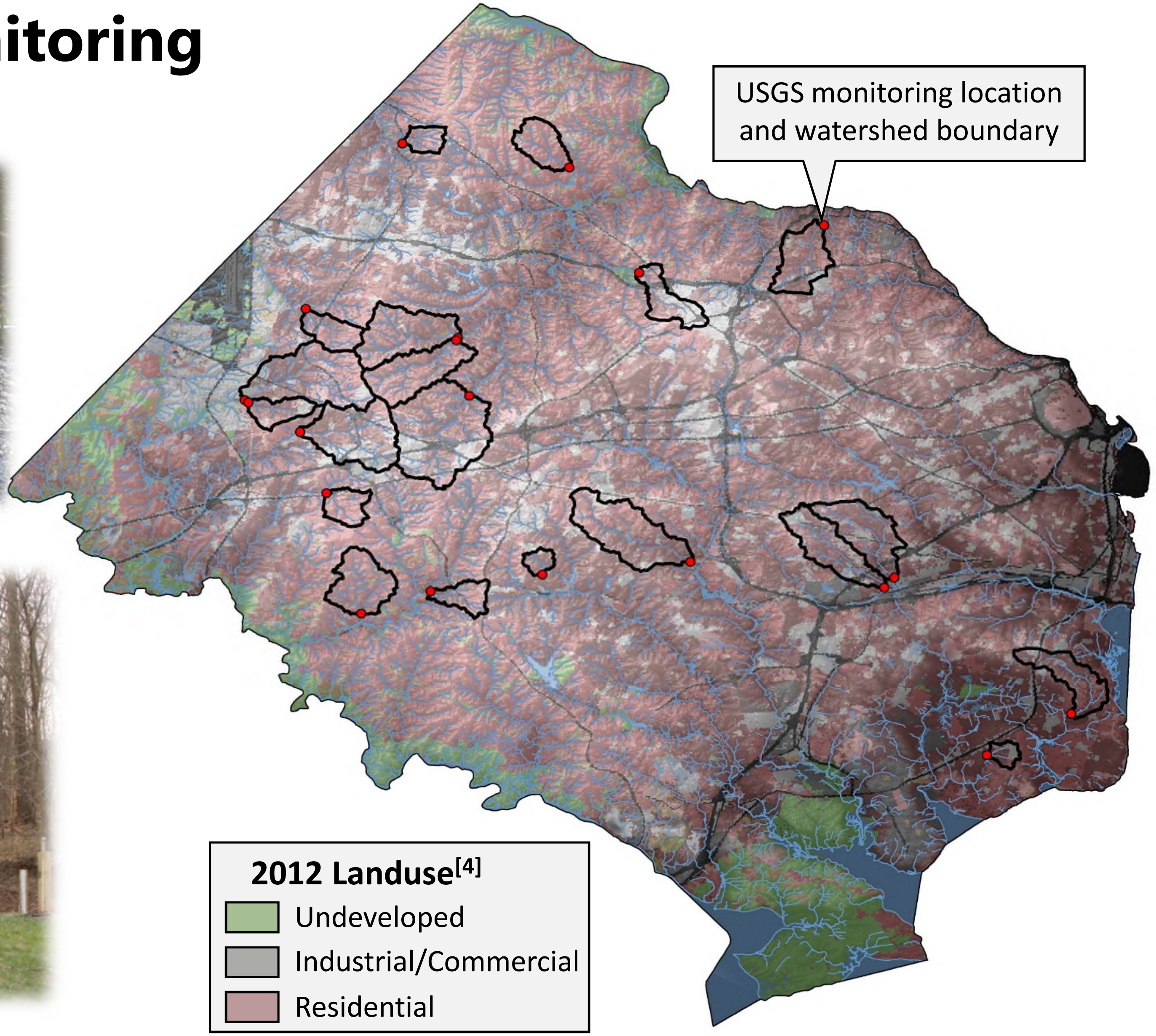
Monthly water-quality samples are collected at 20 stream locations that represent a range of county land use and typically drain watersheds < 5 square miles.

Sampled constituents include:

- Nitrogen (TN and major forms of N)
- Phosphorus (TP and major forms of P)
- Suspended sediment concentration
- Water temp., sp. cond., pH, DO, and turbidity

Benthic macroinvertebrates are sampled annually at each location.

Continuous water-chemistry and streamflow data are collected from 5 monitoring locations and reported online in near real-time.



[4]Falcone, 2015

Water-chemistry trends are computed from ten years of monitoring data

Monotonic water-chemistry trends were determined using a Seasonal Kendall test and are reported for 14 stations that have been sampled each month for 10 years.

Trends in nitrogen, phosphorus, and sediment load were determined using Weighted Regressions on Time, Discharge, and Season (WRTDS) and are reported for 4 stations that have continuous streamflow, monthly samples, and high-flow samples.

Flow-normalized (FN) trends are reported with all results to remove water-chemistry variability associated with interannual streamflow fluctuations.

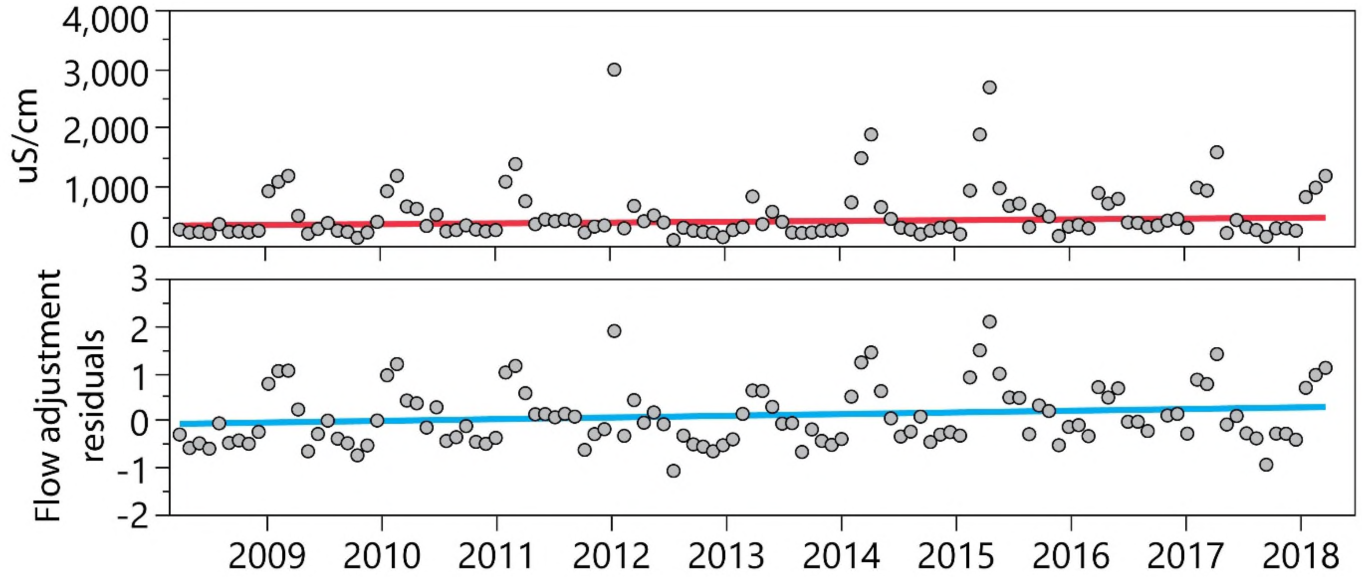
FN trends are important for understanding water-chemistry responses associated with watershed changes other than streamflow. ***FN results are reported in this presentation***.

Big Rocky Run, specific conductance

Significant trend: p-value <=0.10

Significant increasing trend of **+3.1%** per year

Significant increasing FN trend of **+3.3%** per year

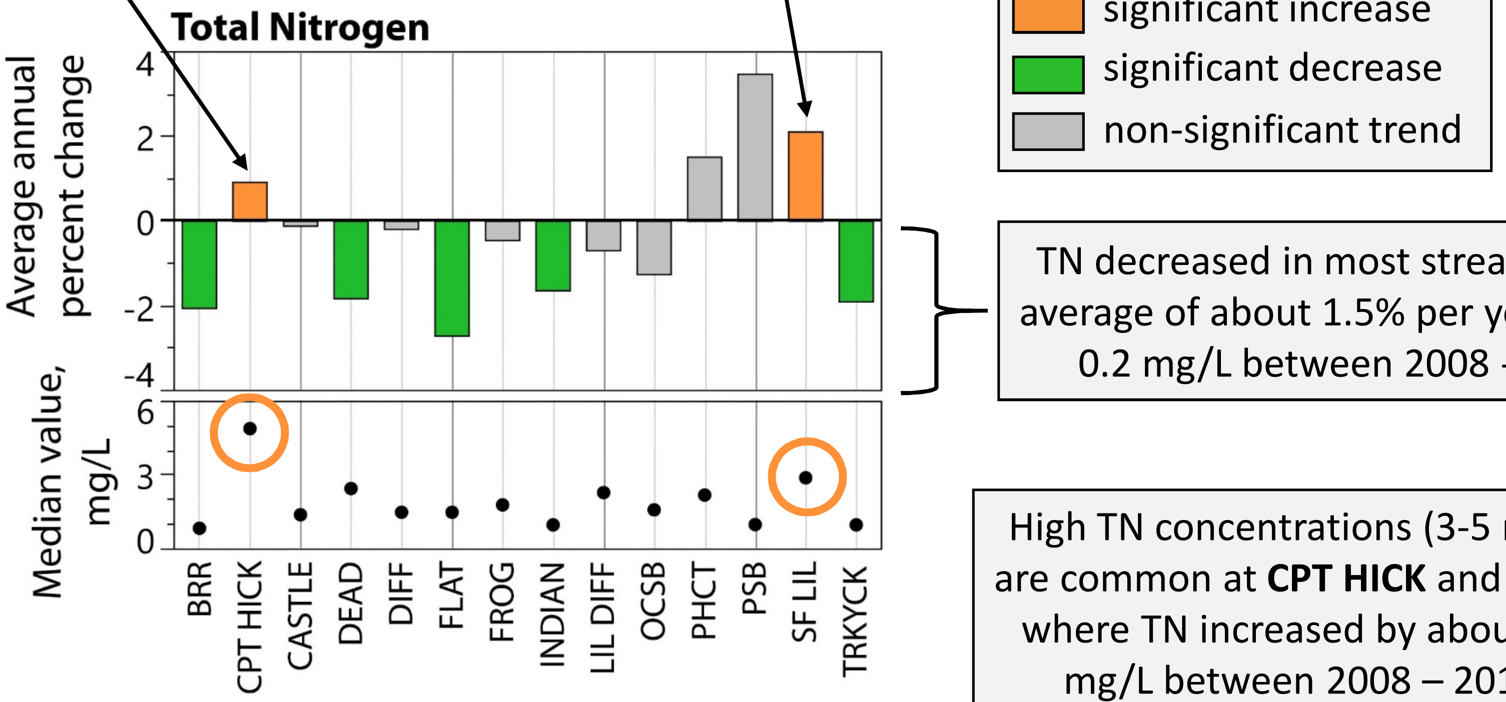


Nitrogen decreased in most streams, but increased in two monitoring locations with the highest concentrations

Significant increases in TN concentrations occurred at Captain Hickory Run (**CPT HICK**) and South Fork Little Difficult Run (**SF LIL**)

Average annual percent change in TN

Median 10-year TN concentration



TN decreased in most streams by an average of about 1.5% per year, about 0.2 mg/L between 2008 - 2018.

High TN concentrations (3-5 mg/L) are common at **CPT HICK** and **SF LIL**, where TN increased by about 0.5 mg/L between 2008 – 2018.

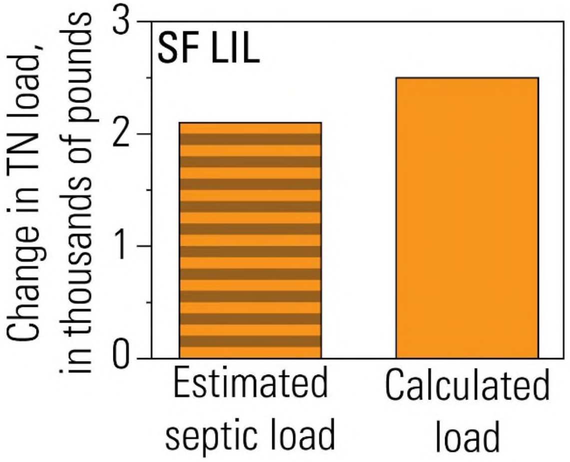
14 monitoring locations

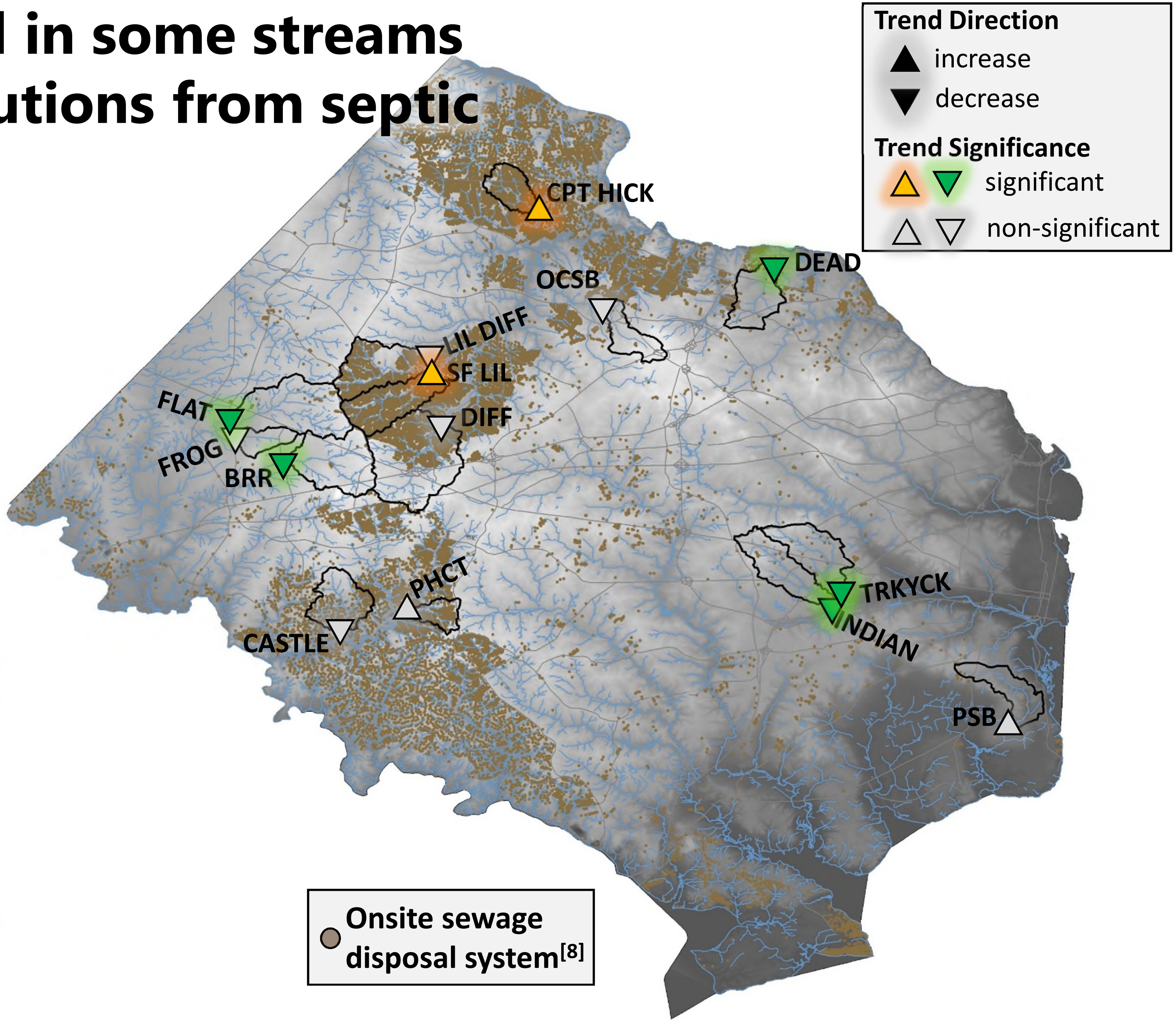
Nitrogen may have increased in some streams because of changing contributions from septic system effluent

Septic system effluent has been identified as a major source of nitrogen in some Fairfax County streams, with high TN concentrations found in streams draining watersheds with high septic system densities (up to 500 systems / mi^2)[5].

The number of septic systems increased in **CPT HICK** and **SF LIL** by about 7% between 2007 – 2017[6], an increase of about 30 systems / mi^2

The estimated mass of TN contributed by the additional septic systems in **SF LIL** is about 2,100 lb[7], a potential TN increase that is similar to the calculated change in TN load of 2,500 lb.





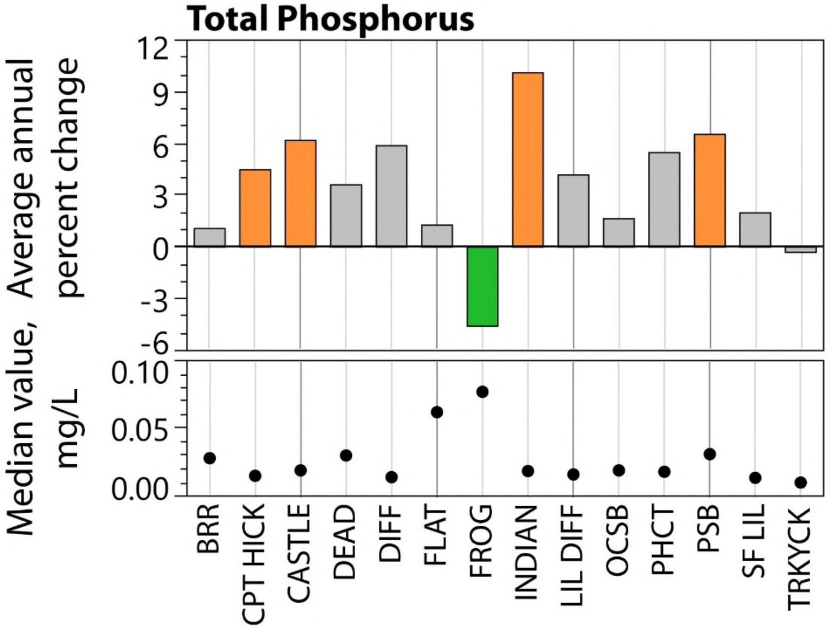
[5]Hyer and others, 2016

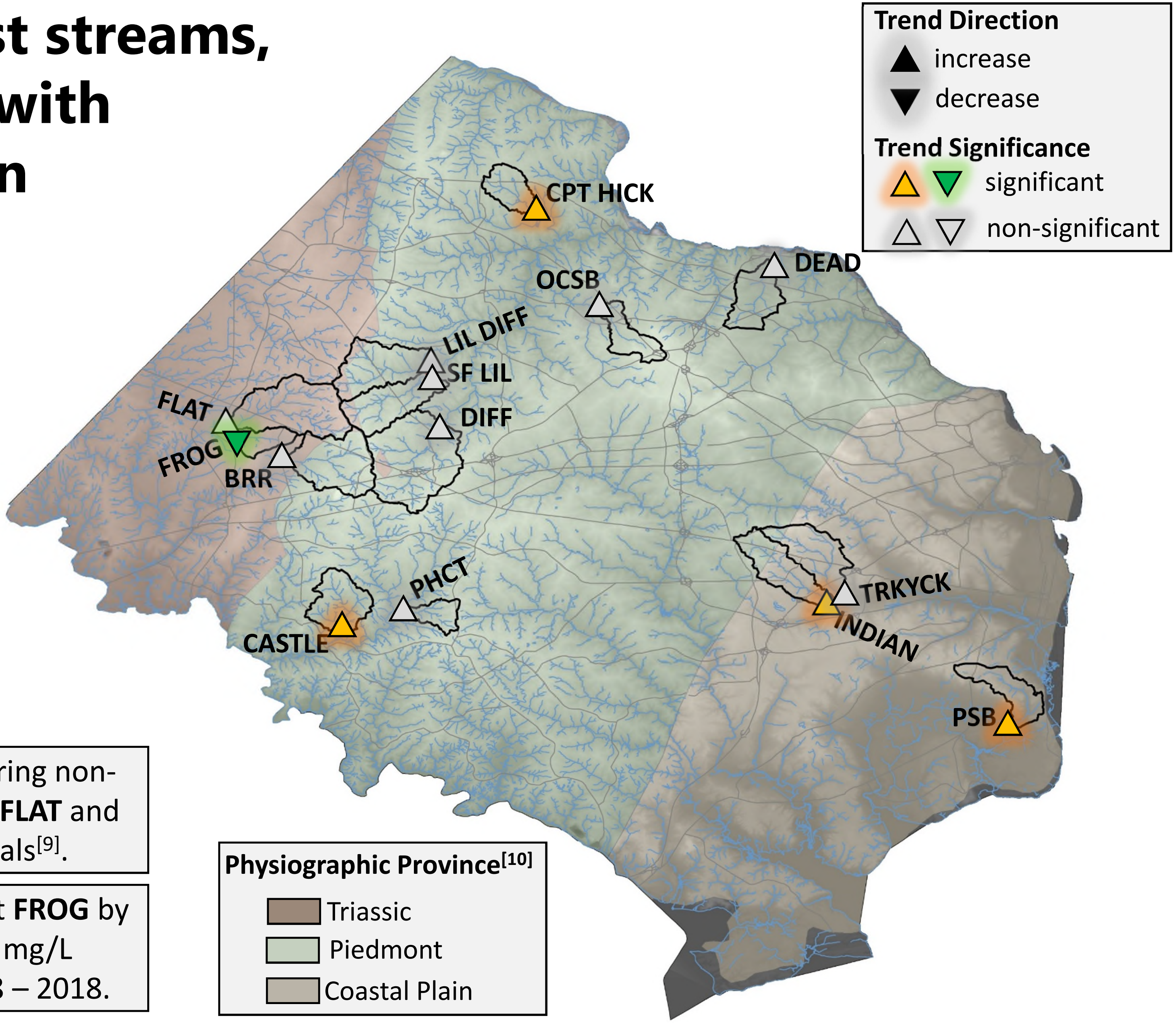
[6]Chesapeake Bay watershed model

[7]using rates from Maizel and others, 1997

[8]Paul Shannon, written commun.

Phosphorus increased in most streams, but decreased at the station with highest median concentration





TP concentrations of 0.02 – 0.03 mg/L are common during non-stormflow conditions at most sites, but are elevated in **FLAT** and **FROG**, watersheds that drain P-rich geologic materials[9].

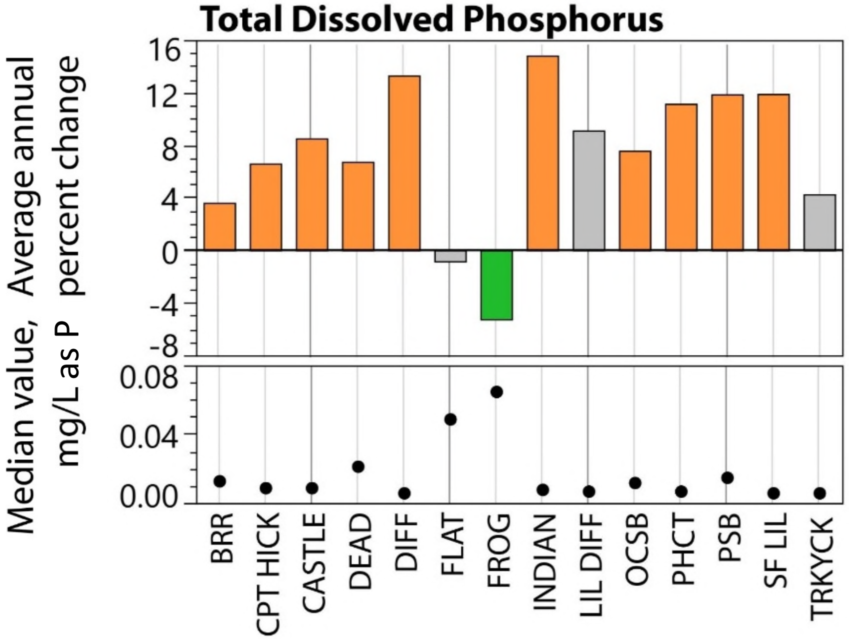
TP increases were observed in most sites; the average increase between 2008 – 2018 was 0.01 mg/L.

TP decreased at **FROG** by about 0.03 mg/L between 2008 – 2018.

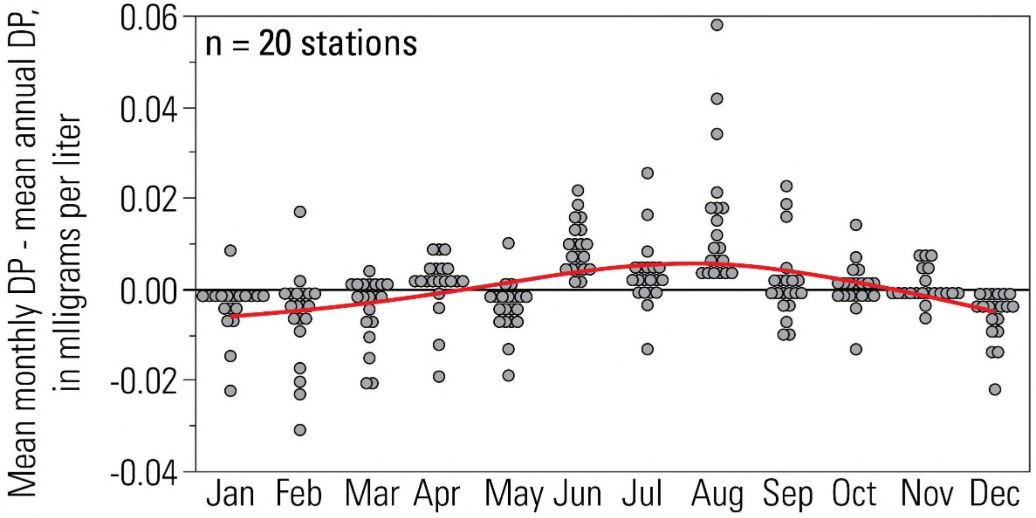
[9]Jastram, 2014

[10]Fenneman and Johnson, 1946

TP trends are primarily driven by changes in dissolved phosphorus (DP)



The highest DP and OP concentrations are typically observed in summer months, periods when warm temperatures promote the desorption of OP from stream sediments[14].



Most TP is as DP during non-stormflow conditions (60-80%). DP is primarily composed of orthophosphate (OP), the most bioavailable P form[11].

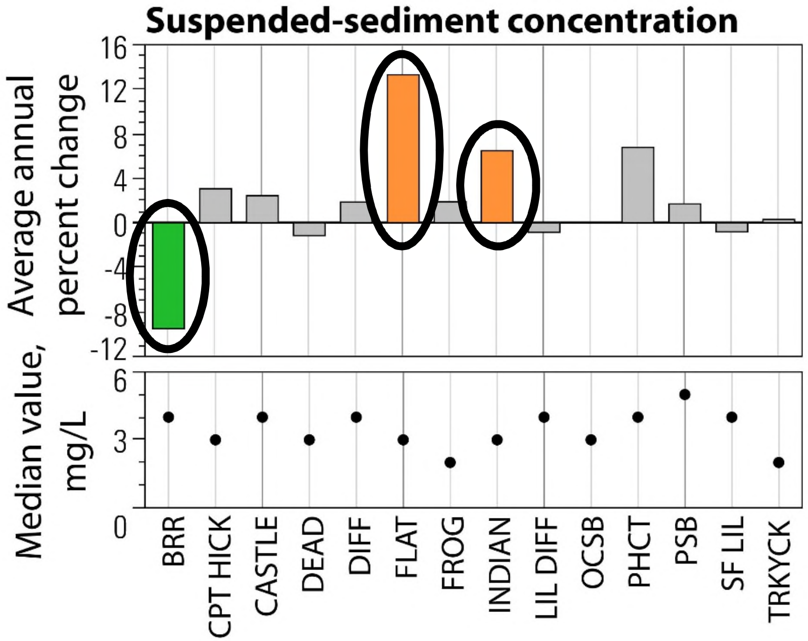
These increases are a concern as OP can cause eutrophication in freshwaters[12] and has been associated with harmful algal bloom (HAB) outbreaks[13].

DP concentration trends can result from changes in P sorption or desorption from stream sediments driven by differences in soil temperature[14], anoxia[15], alkalinity[16], and/or P saturation[17]; with increases in all conditions favorable to desorption.

Drivers of DP and OP are rarely assessed despite their importance on water quality and biological health[18].

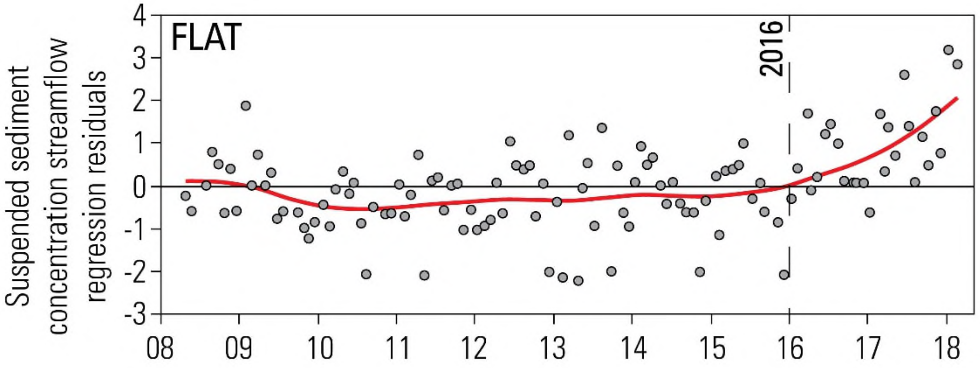
[11]Harrison and others, 2010
[12]Correll, 1998
[13]Davis and others, 2015
[14]Duan and others, 2012
[15]House and Denison, 2002
[16]James and Barko, 2004
[17]Sharpley, 1995
[18]Fanelli and others, 2019

Significant sediment trends occurred in watersheds disturbed by construction and/or restoration activities



FLAT: 6,500 feet of stream reach underwent restoration between 2016 – 2018 immediately upstream of the monitoring location [19].

FROG, a watershed directly adjacent to **FLAT** was not targeted for restoration and experienced no trend in SSC.



Suspended sediment concentrations (SSC) are typically low during non-storm events. Only 3 streams had a significant trend.

Stream restoration and or construction activities occurred in these 3 watersheds[19], which likely affected the sediment trend.

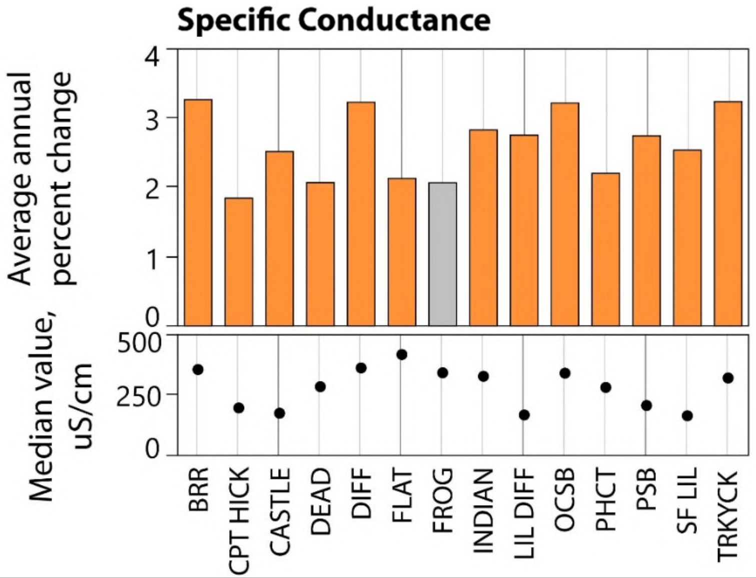
INDIAN: a stream restoration project targeted 3,000 feet of stream about ½ mile upstream of the monitoring location and was completed in 2014[19].

BRR: a road construction and trail restoration project occurred next to the monitoring location in 2008[19].

Stream restoration activities are designed to improve water-quality; however, these patterns highlight a short-term consequence of their installation.

[19]Fairfax County Stormwater Improvement Projects

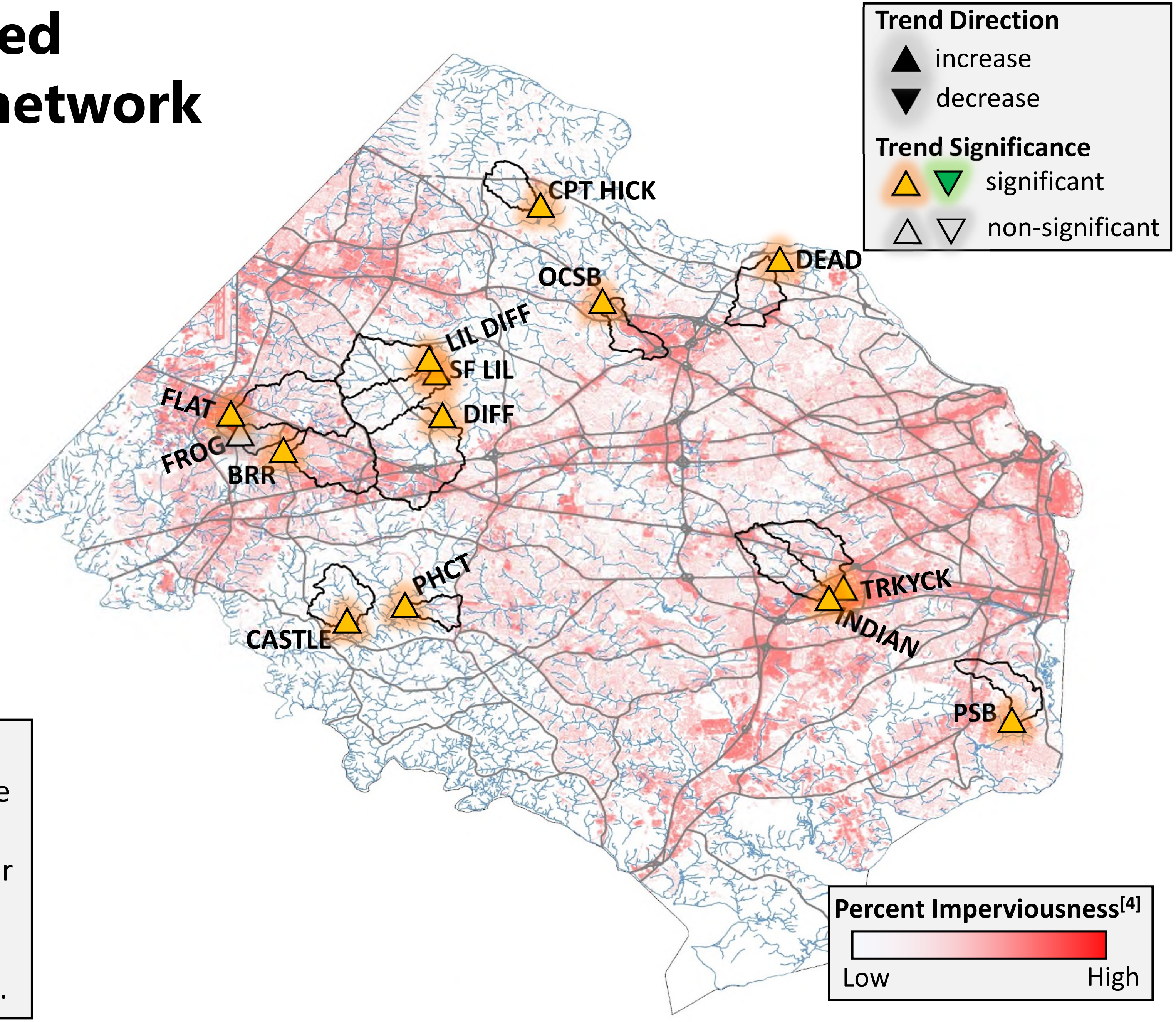
Specific conductance increased throughout the monitoring network



Specific conductance increases of about 2.5%, or 7.5 uS/cm/yr were observed throughout the network.

Previous work by Fairfax County identified: (1) County-wide increases in specific conductance between 2004 – 2017 [20]. (2) The largest increases occurred in the most impervious watersheds[20].

These trends are likely related to the increased use of road salts[21] and/or the increased delivery of road salts to streams[22].



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[20]Jonathan Witt, written commun.

[21]Bock and others, 2018

[22]Kaushal and others, 2018

[4]Falcone, 2015

Increasing specific conductance trends were quantified at DIFF using a novel method to estimate trends in continuous water-quality data

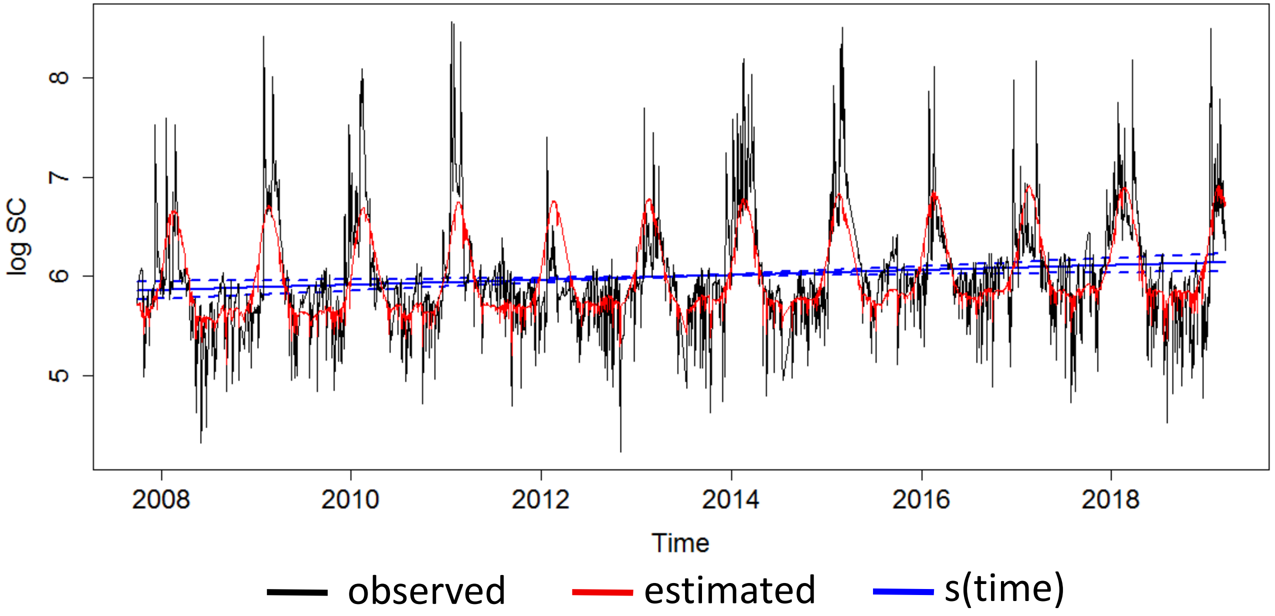
The use of water-quality data sondes to record water-chemistry data at subdaily timesteps (*"continuous data"*) has increased throughout the nation.

Continuous water-quality data have numerous scientific applications, but using the data for trend computation has been an unresolved need.

Gavin Yang (Virginia and West Virginia USGS Water Science Center) is developing such a method using a General Additive Model (GAM) framework, which will be published in a forthcoming journal article.

The approach was applied at **DIFF** and identified a significant increase in specific conductance between 2008 – 2018.

DIFF, specific conductance



Gavin Yang
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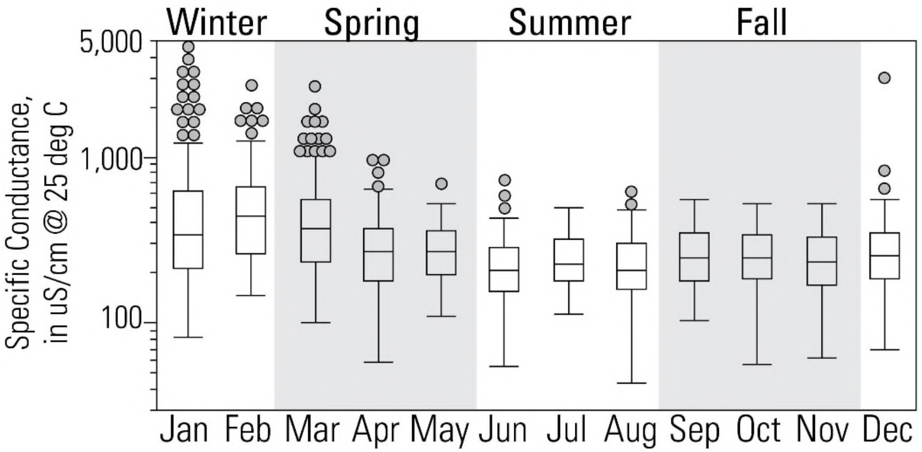
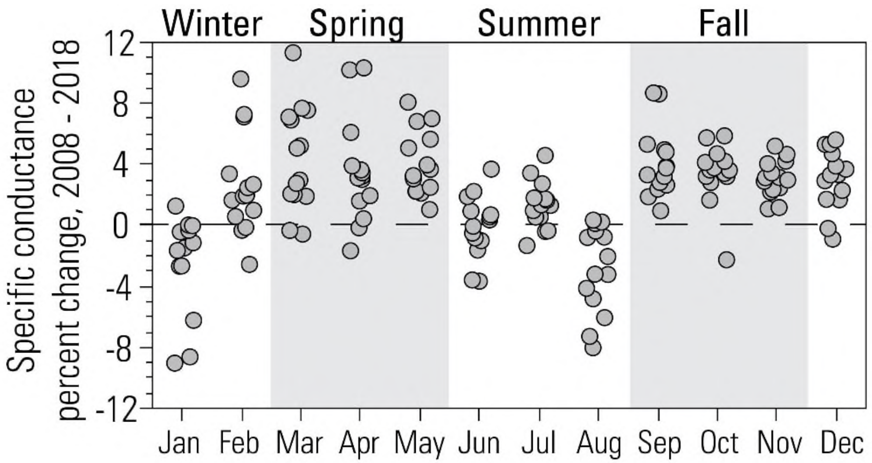
Specific conductance increases occurred in both winter and non-winter months

Specific conductance values are typically largest in winter months, a time of year that receives the greatest road salt applications, some of which runoff into streams.

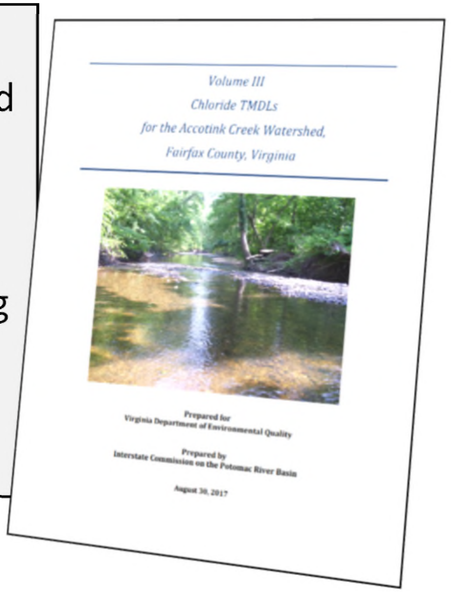


Freshwater salinization is not mitigated through traditional stormwater management practices such as detention ponds and riparian buffers[24]. Effective management will rely on changing application practices.

Specific conductance increased in winter, spring, and fall months in most sites. Such non-winter trends can occur when chloride, which is highly soluble, reaches the groundwater and is discharged to streams year-round[23]



The Virginia Department of Environmental Quality issued the state's first chloride TMDL 2017 for Accotink Creek, a Fairfax County watershed, after recognizing the effects of road salt applications on stream and drinking water quality[25]



[23]Corsi and others, 2015

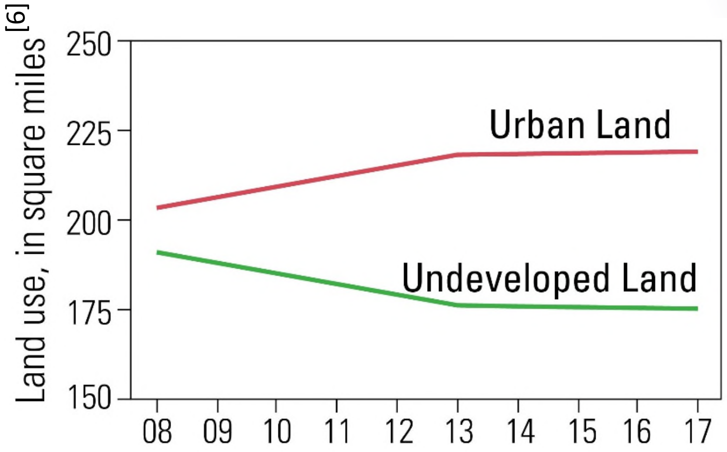
[24]Snodgrass and others, 2017

[25]Interstate Commission on the Potomac Basin, 2017

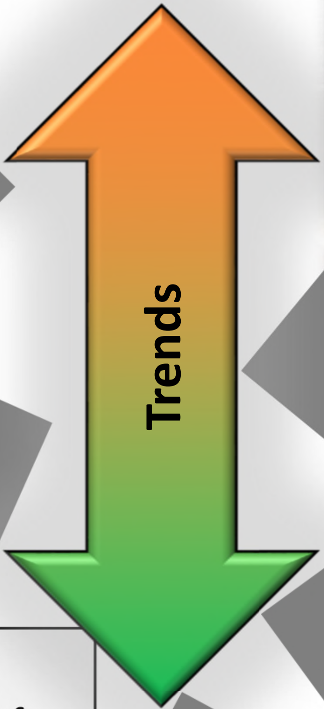
Future analyses will explore linkages between water chemistry trends and watershed changes

N and P trends can result from **increasing or decreasing watershed nutrient inputs**, which include (1) human and animal waste, (2) fertilizer, and (3) atmospheric deposition.

Expansion of urban land has been associated with increased N loads in Chesapeake Bay streams[26] and increased P inputs to watersheds[27]

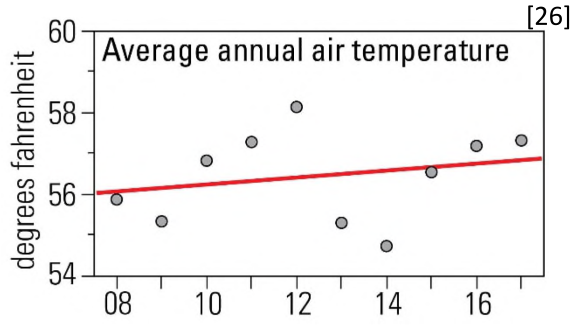


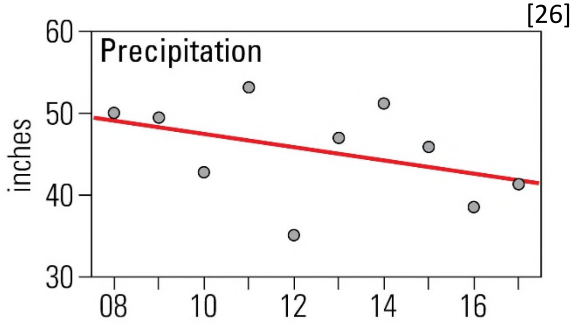
Urban land increased in Fairfax County by about 8% ($16\ mi^2$) between 2008 – 2017, almost entirely at the expense of undeveloped land[6].



Fairfax County has invested heavily in the **implementation of management practices** over the study period, and has been credited with the removal of 38,700 lb of N; 8,000 lb of P and 3,000,000 lb of S[3].

N reductions and DP increases can result from warmer and wetter **climatic conditions** [14,15, 26]





Other unidentified drivers

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[3]Shannon Curtis, written commun.

[6]Chesapeake Bay Watershed Model

[14]Duan and others, 2012

[15]House and Denison, 2002

[26]Chanat and Yang, 2018

[27]Alvarez-Cobelas and others, 2009

[28]PRISM Climate Group

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Castle Creek, April 2018

Castle Creek, April 2008

Concluding Presentation:

Detecting and assessing ecological responses in urban waters.

Shannon Curtis

Fairfax County Stormwater Planning Division

In cooperation with Fairfax County, VA

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