Don’t be salty! Best practices to keep waterways

Sujay Kaushal[1] & Friends…

[1]University of Maryland, Department of Geology & Earth System Science Interdisciplinary Center

Acknowledgements:

Washington Metropolitan Council of Governments

National Science Foundation

Maryland Sea Grant

Chesapeake Bay Trust

Establishing A Science Partnership to Understand Salinization







Vision: A collaborative scientific partnership is needed to address a complex, regional issue…

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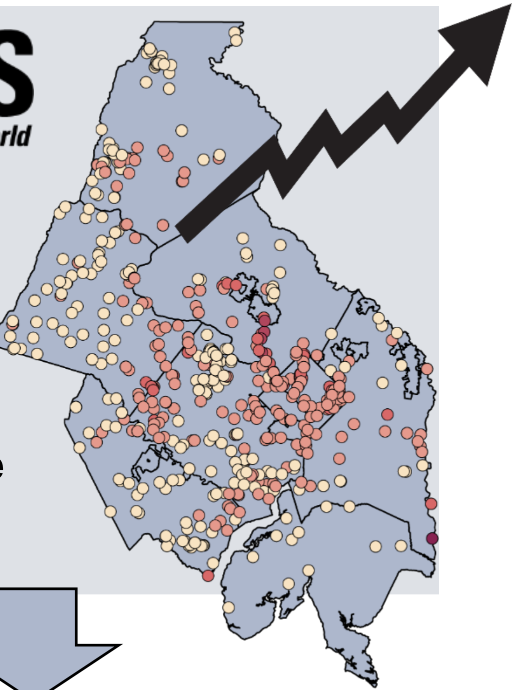
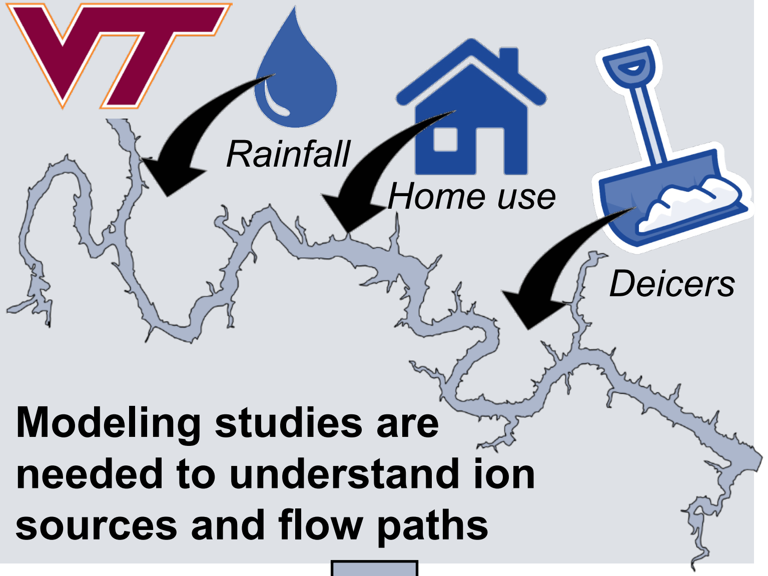
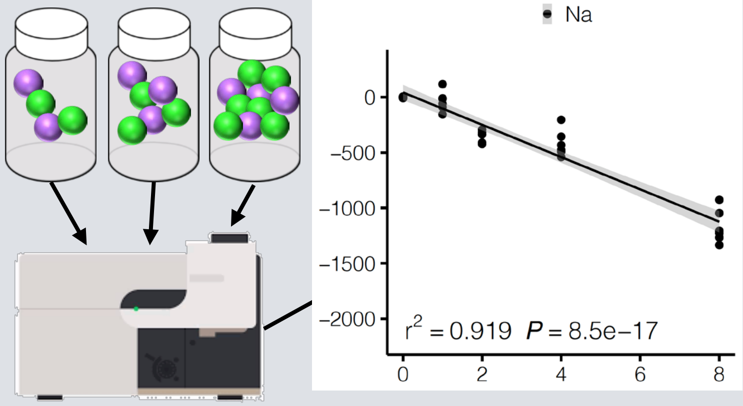
Monitoring networks can characterize patterns over time and space





Modeling studies are needed to understand ion sources and flow paths

Field and lab experiments are needed to evaluate impacts and mechanisms



Synthesizing this knowledge is needed to understand and manage FSS in the MWCOG region

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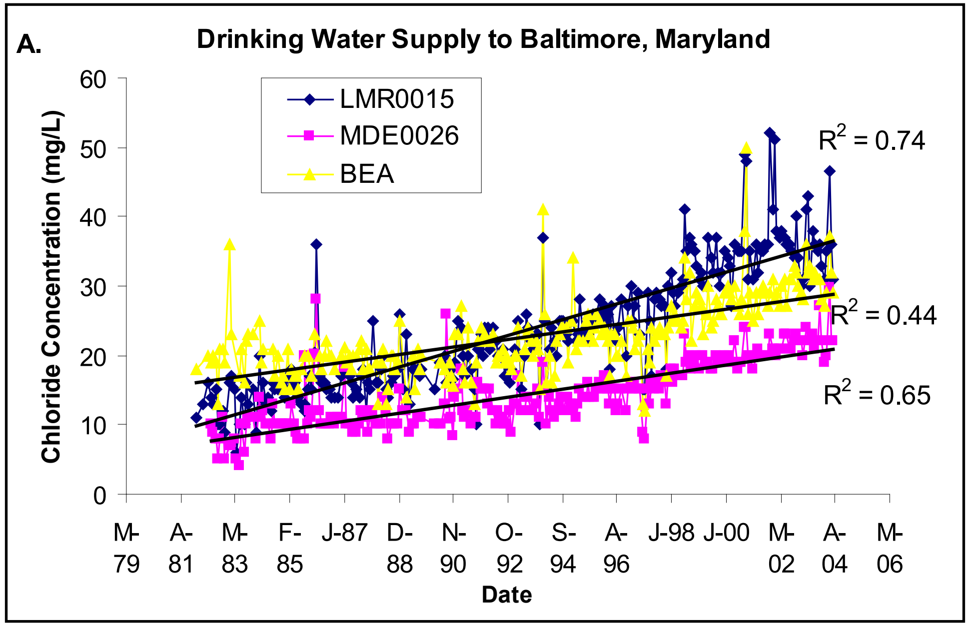
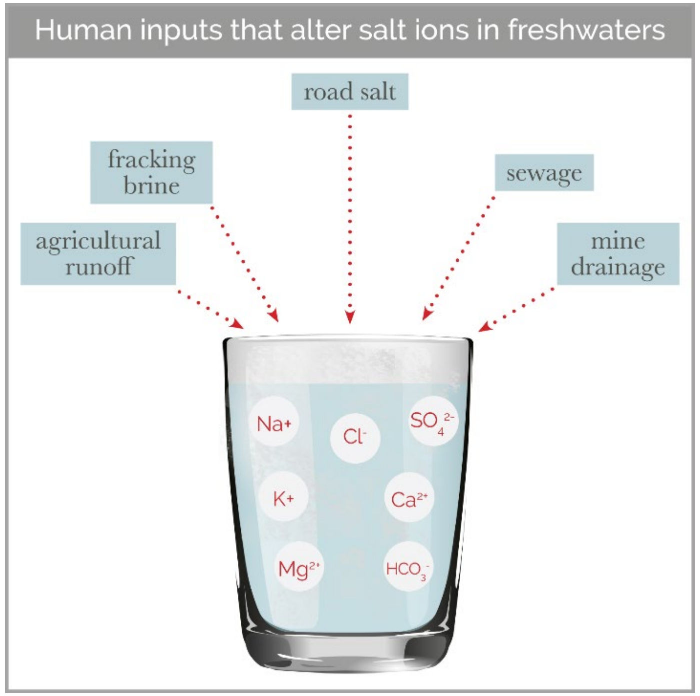
Outline

- The Spread of Freshwater Salinization Syndrome
- Salinization Mobilizes Chemical Cocktails
- Managing Freshwater Salinization Syndrome

Freshwater Salinization Syndrome Impacts Drinking Water

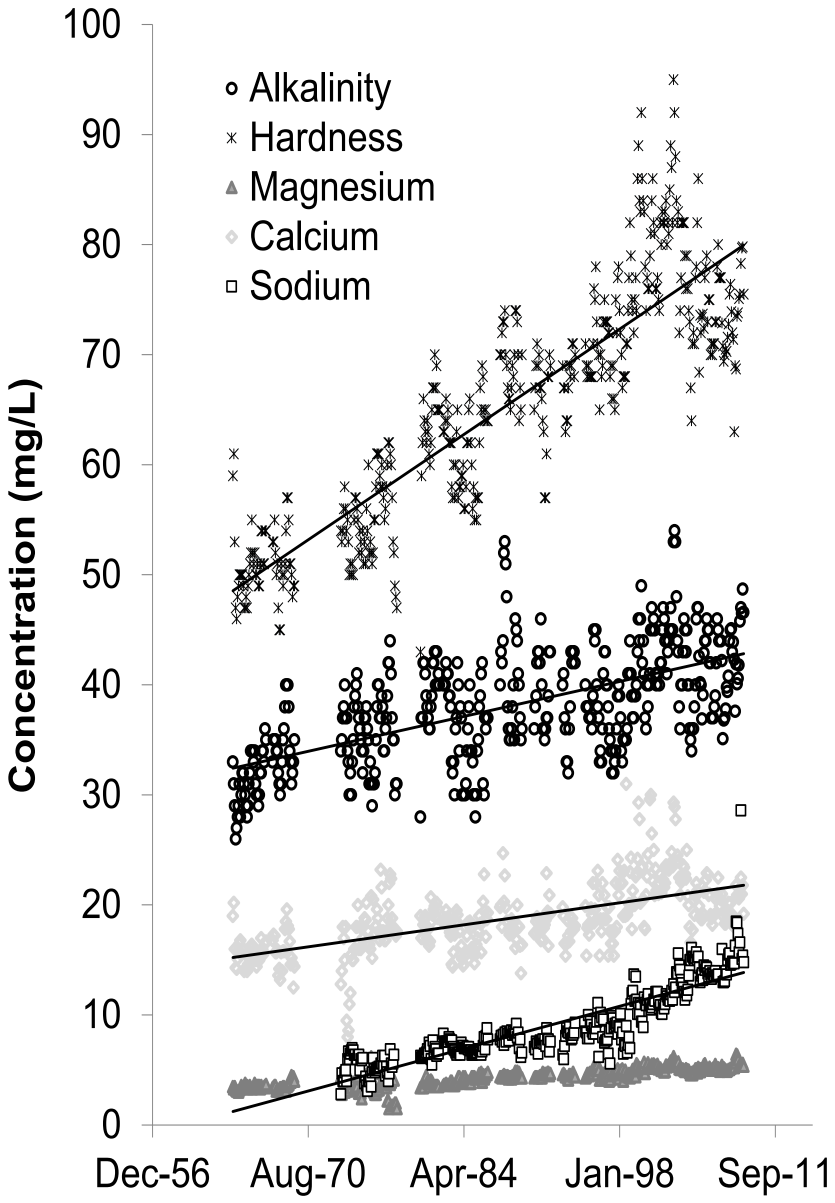


Kaushal et al. (2005) *PNAS*



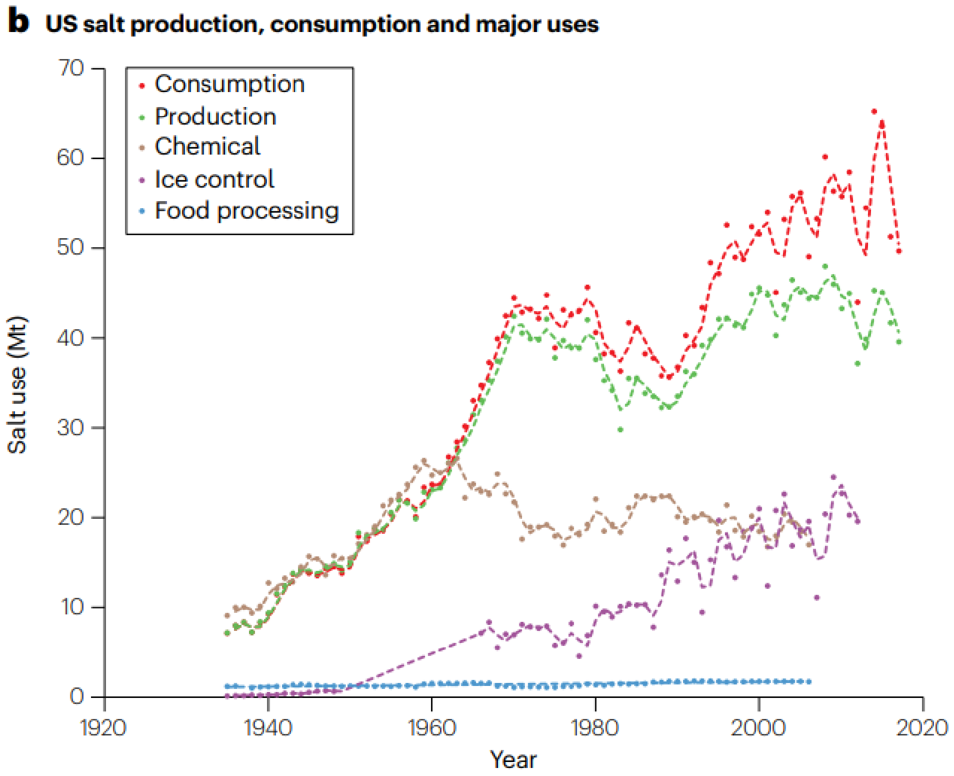
L. Quillen (2018) FSS Press Release

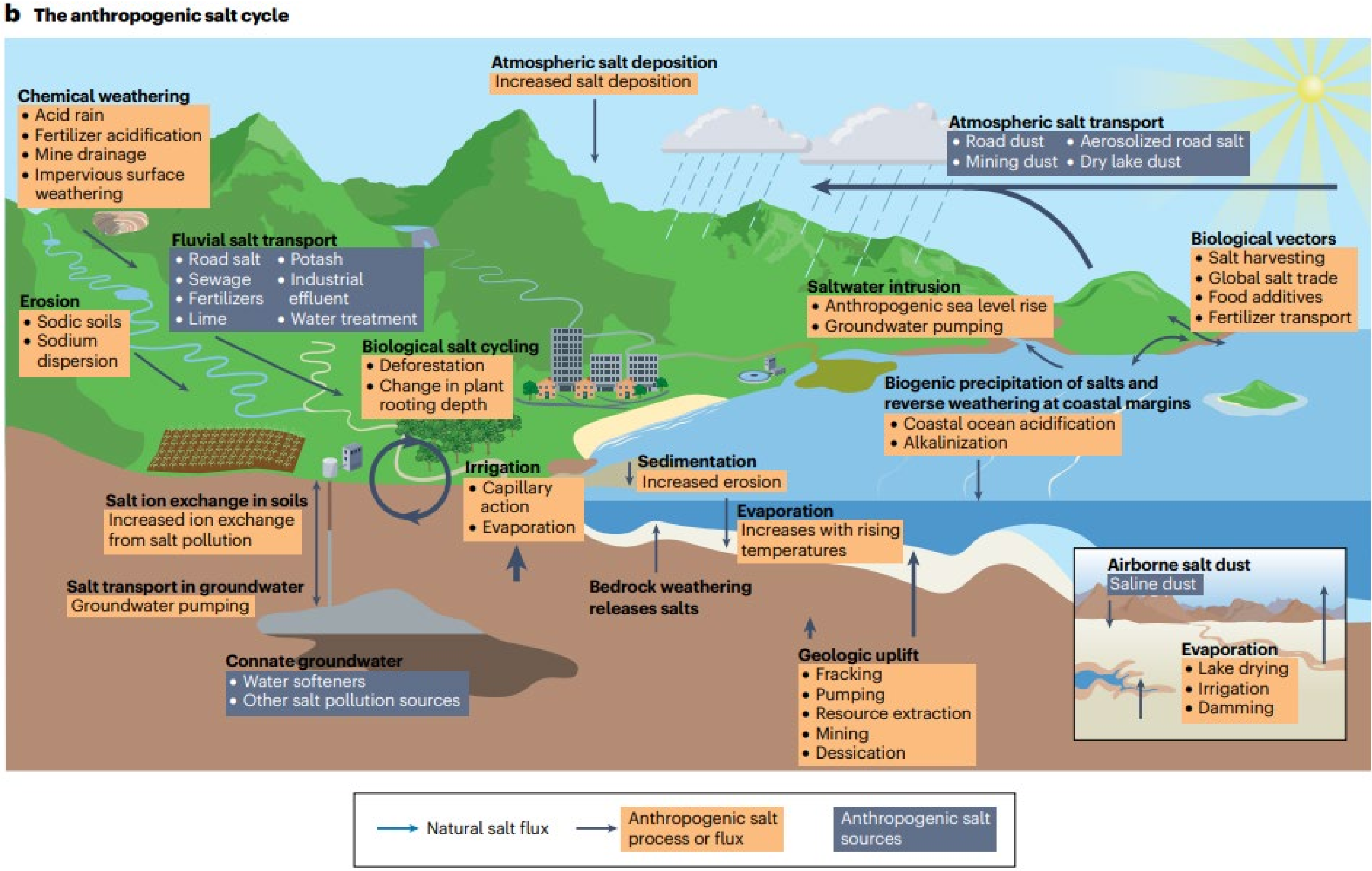
Thank You to Early Mentor: Bill Stack



Kaushal et al. (2017) *Appl. Geochem*

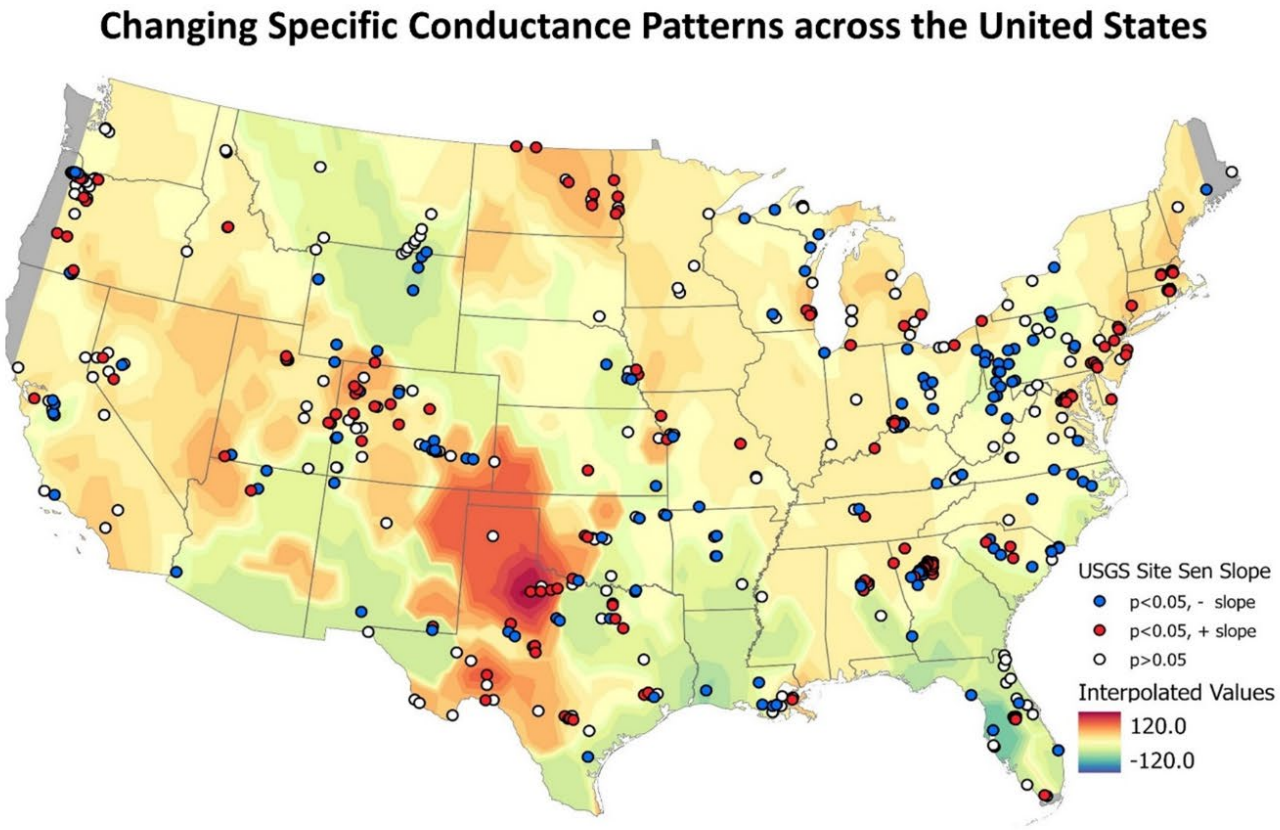
Salt Consumption Is Accelerating Global Salt Cycle



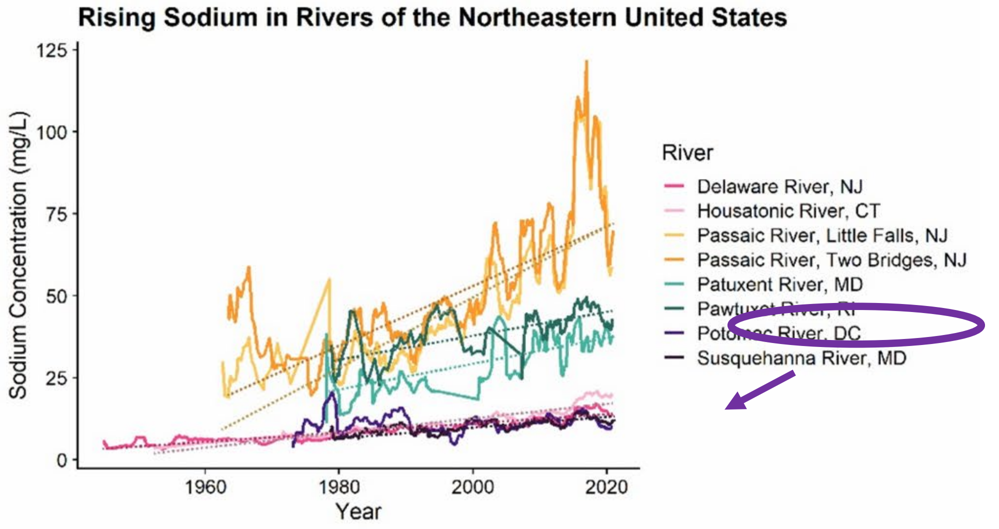


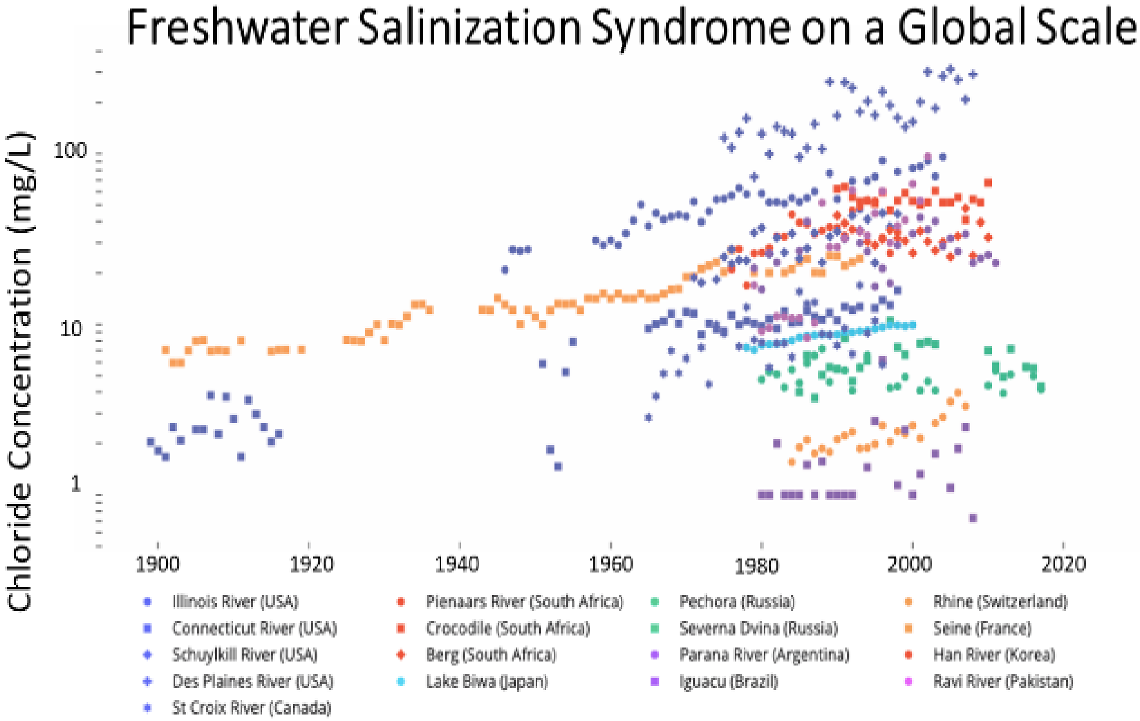
Kaushal...Grant et al. *Nature Reviews Earth & Environment* (2023)

Freshwater Salinization Impacts Potomac…and the U.S.



Kaushal et al. (2021, 2022a)





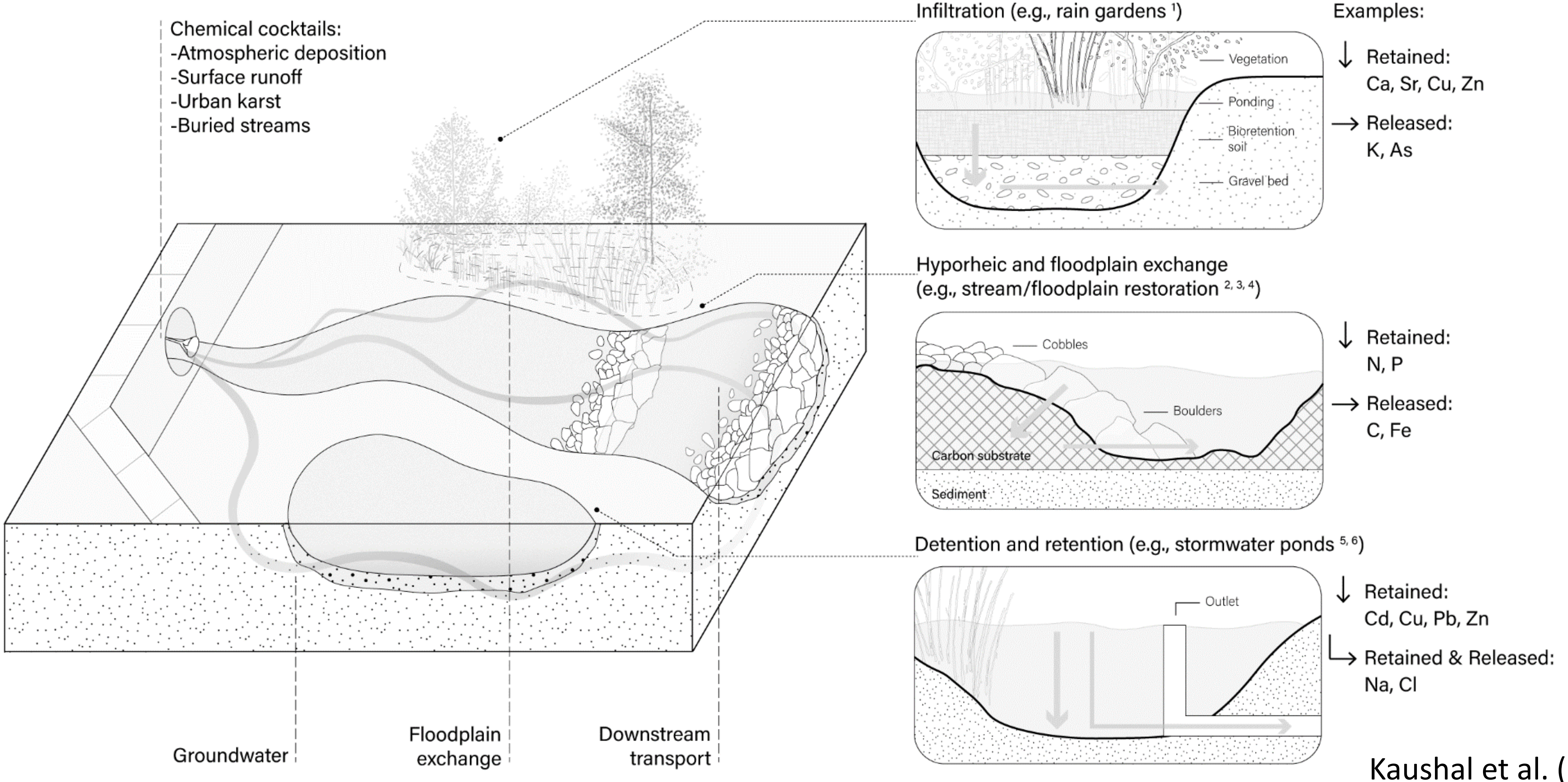
Prior Studies: Kaushal et al. (2005, 2009, 2013, 2015, 2016, 2018, 2019)

2. Salinization Mobilizes Chemical Cocktails

Salt Pollution Mobilizes Other Salts, Nutrients, Organic Matter, and Metals

Photo Courtesy: Kelsey Wood

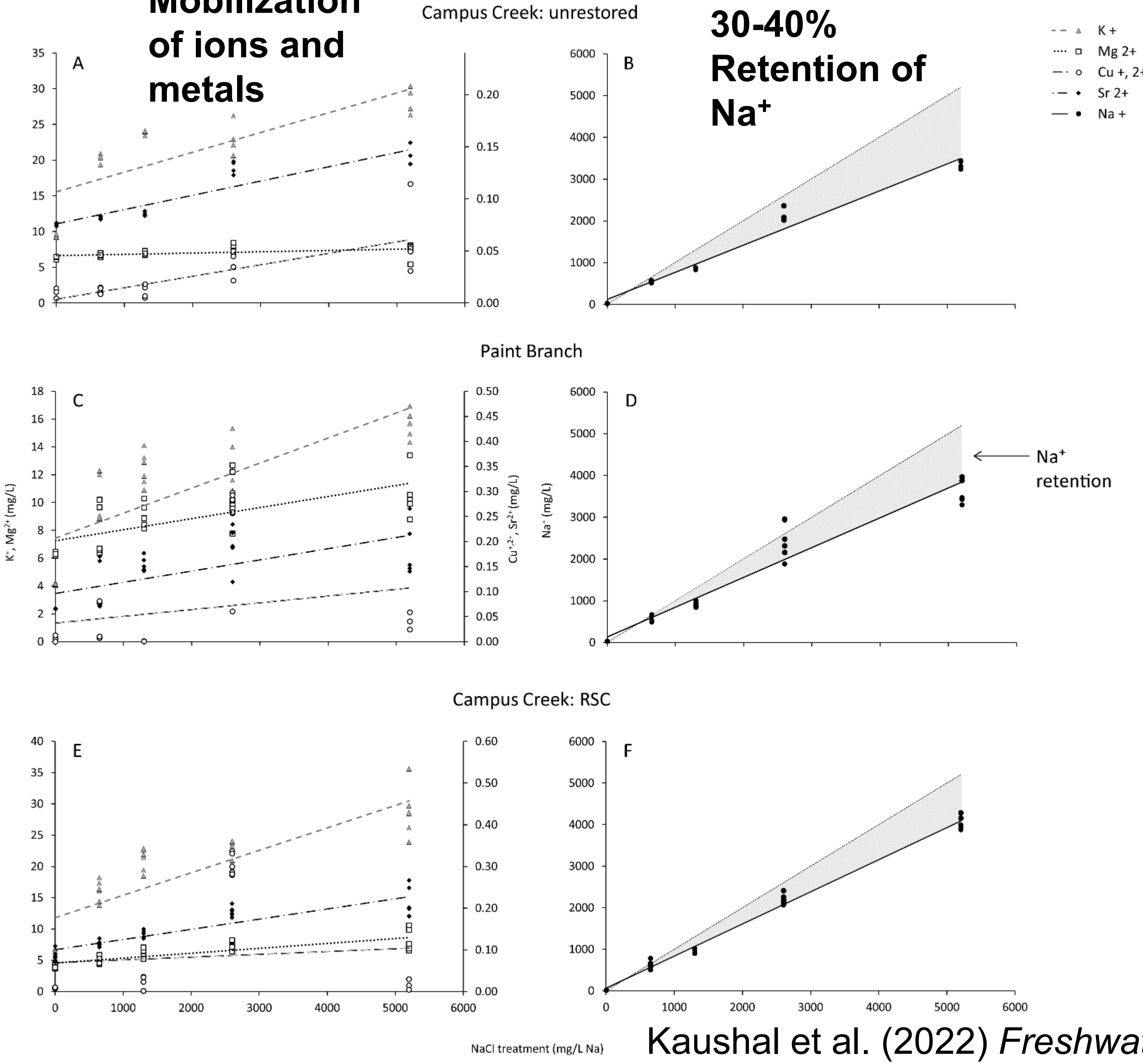
Retention and release of chemical cocktails along stream and stormwater flowpaths



Kaushal et al. (2022)
Freshwater Science

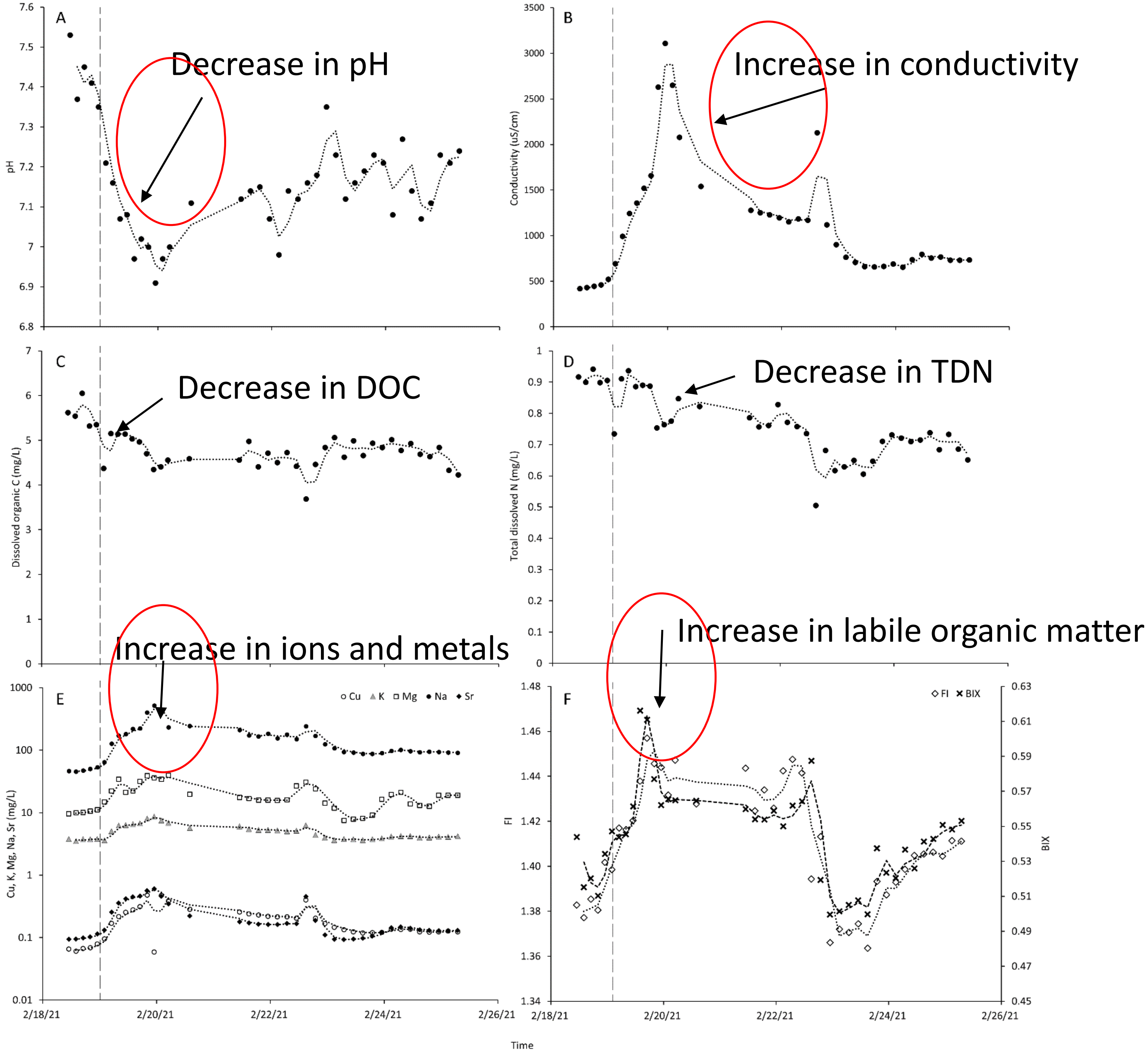
Mobilization of ions and metals

30-40% Retention of Na^+



Stormwater Best Management Practices (BMPs) can retain 30-40% of added salt!

Kaushal et al. (2022) *Freshwater Science*



Changes in water quality following road salting

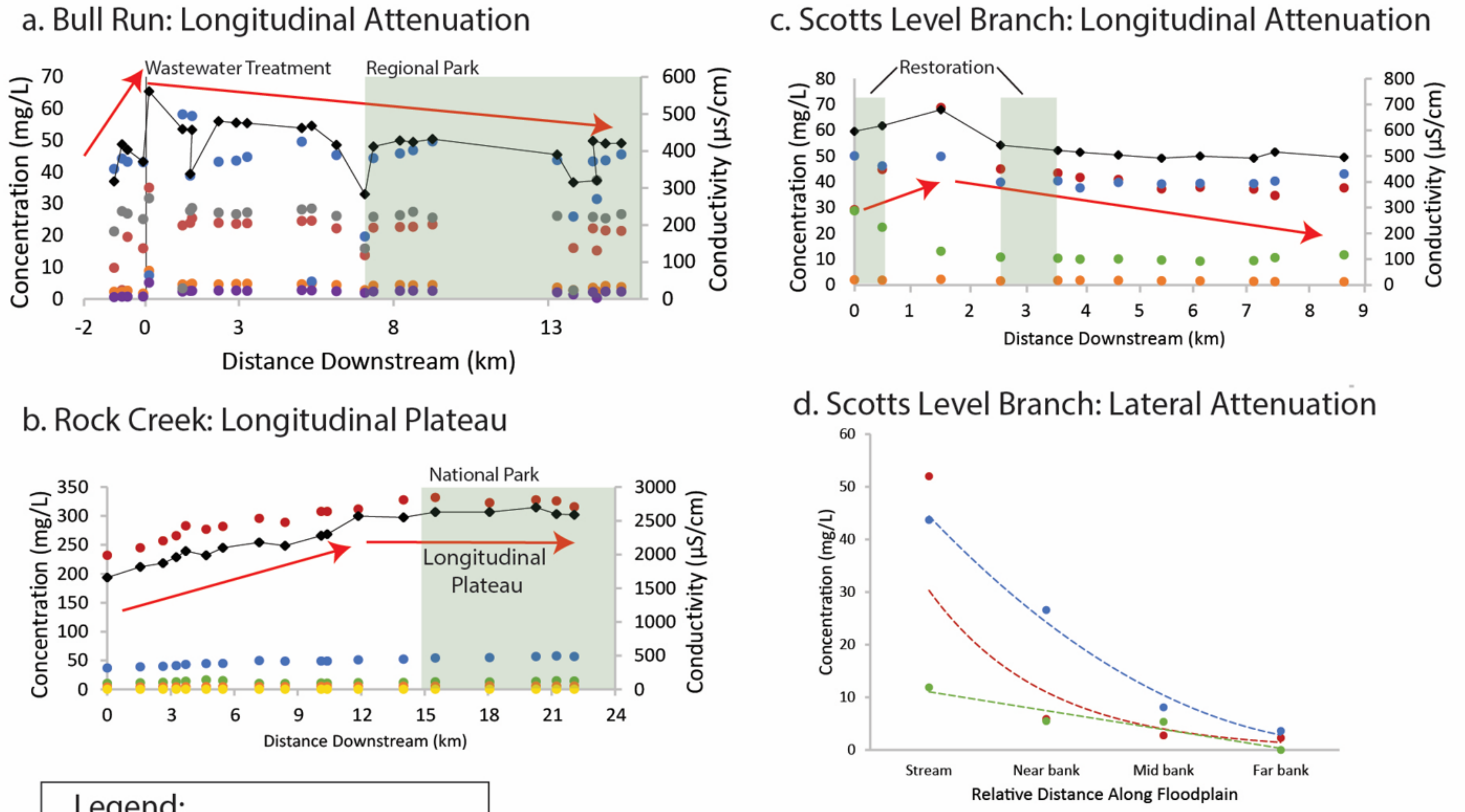
- *Acidification*
- *Metals Mobilization*
- *Nutrient Mobilization*
- *Reactive Organics*

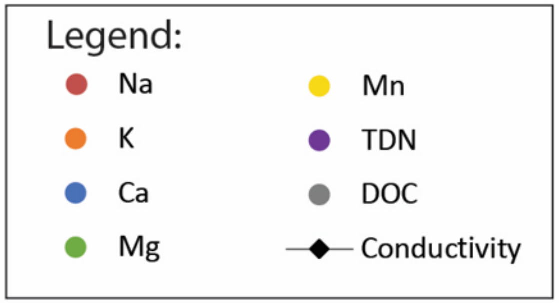
Kaushal et al. (2022)
Freshwater Science

3. Managing Freshwater Salinization Syndrome

Additional collaborations with Steve Hohman (EPA Region 3), Virginia Hogsten (EPA Region 3), Patrick McGettigan (EPA Region 3), Paul Mayer (EPA ORD), Tammy Newcomer Johnson (EPA ORD), and Sydney Shelton (EPA ORISE Fellow)…THANK YOU, EPA ROAR!

Conservation and Restoration Attenuate Salt Pollution

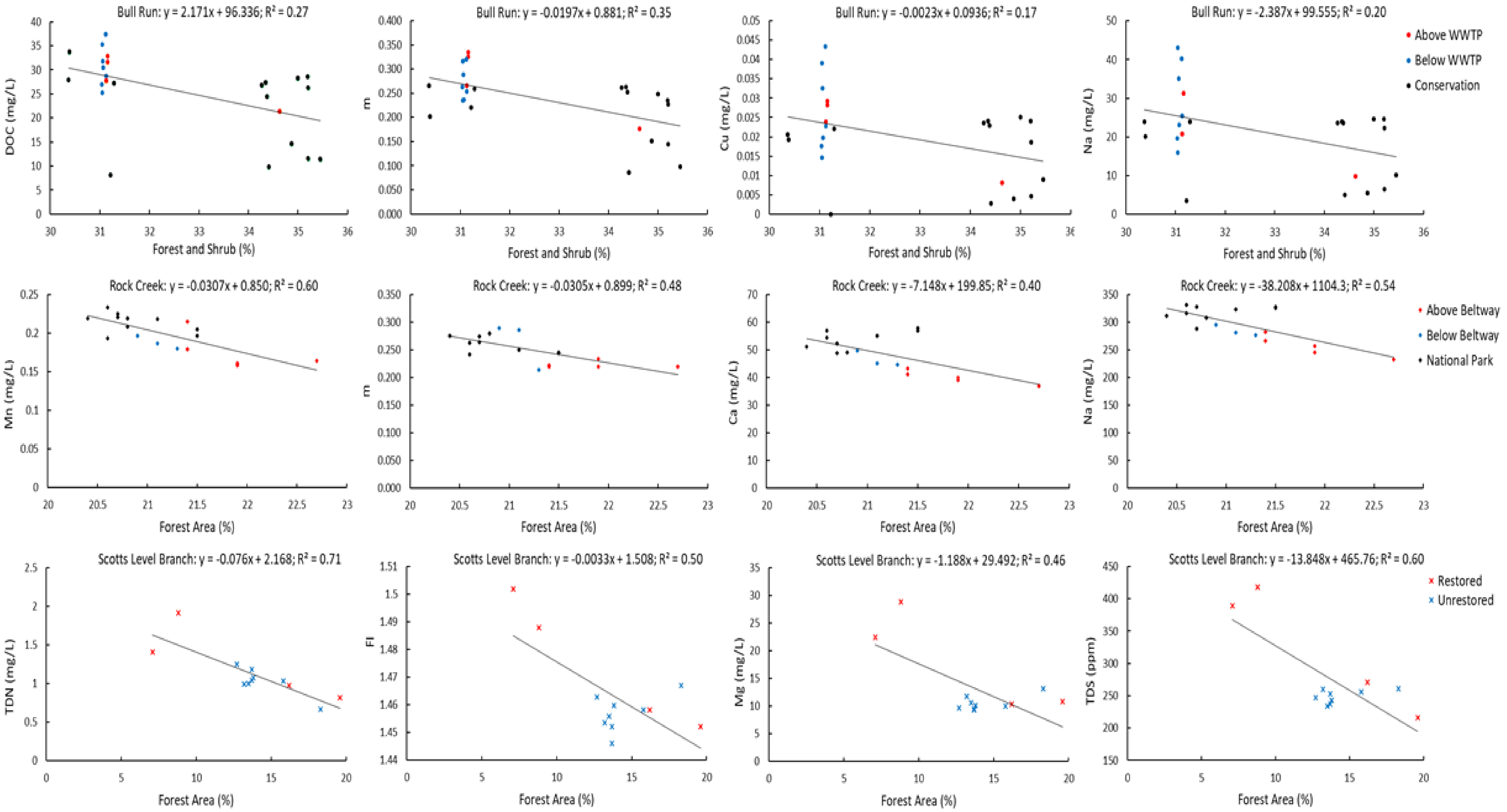




Salt Attenuation and Plateaus along Stream and Riparian Flowpaths

Kaushal, Maas,…Grant… et al. (2023), *Front. Env. Science*

Reductions in Contaminants Related to % Forest Cover along Flowpaths



Kaushal Maas Grant et al (2023) *Front Env Science*

How Will Salt Impact Drinking Water?

- Salinization Syndrome Is Spreading
- Salt Mobilizes Chemical Cocktails
- Salinization Syndrome Can Be Managed

EPA MID-ATLANTIC REGION
2024 VIRTUAL SUMMIT

NSF

VIRGINIA TECH

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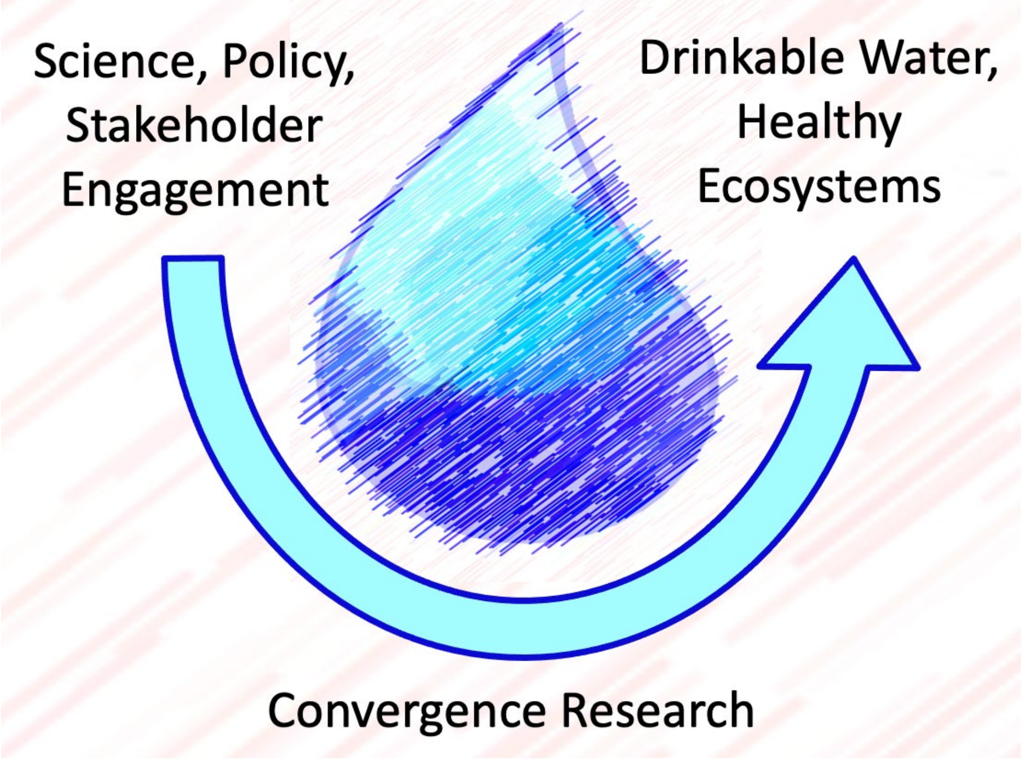
UNIVERSITY OF MARYLAND

OAK RIDGE National Laboratory

Fairfax Water

UPPER OCCOQUAN SERVICE AUTHORITY

Reversing Freshwater Salinization

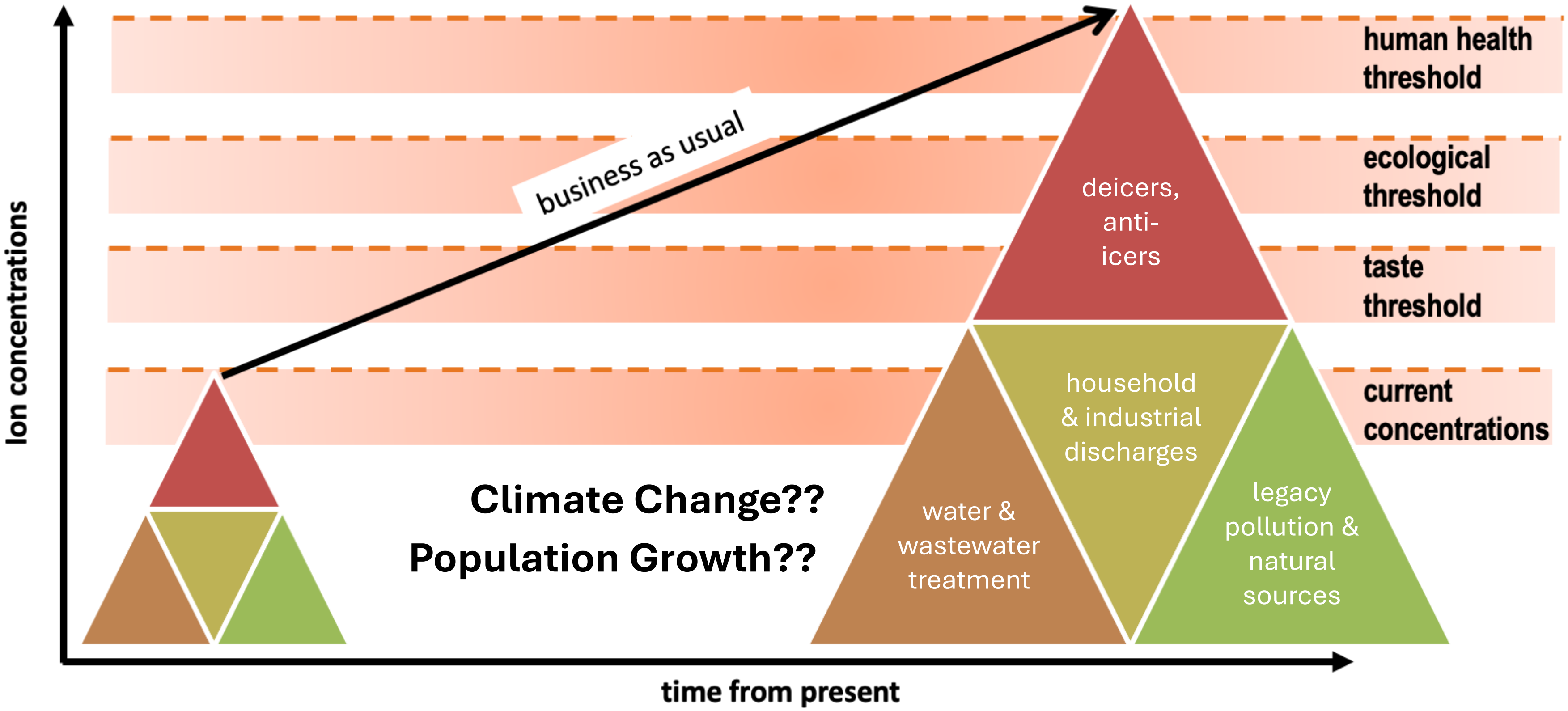


Don’t be salty! Best practices to keep waterways fresh—lessons from the Occoquan Reservoir

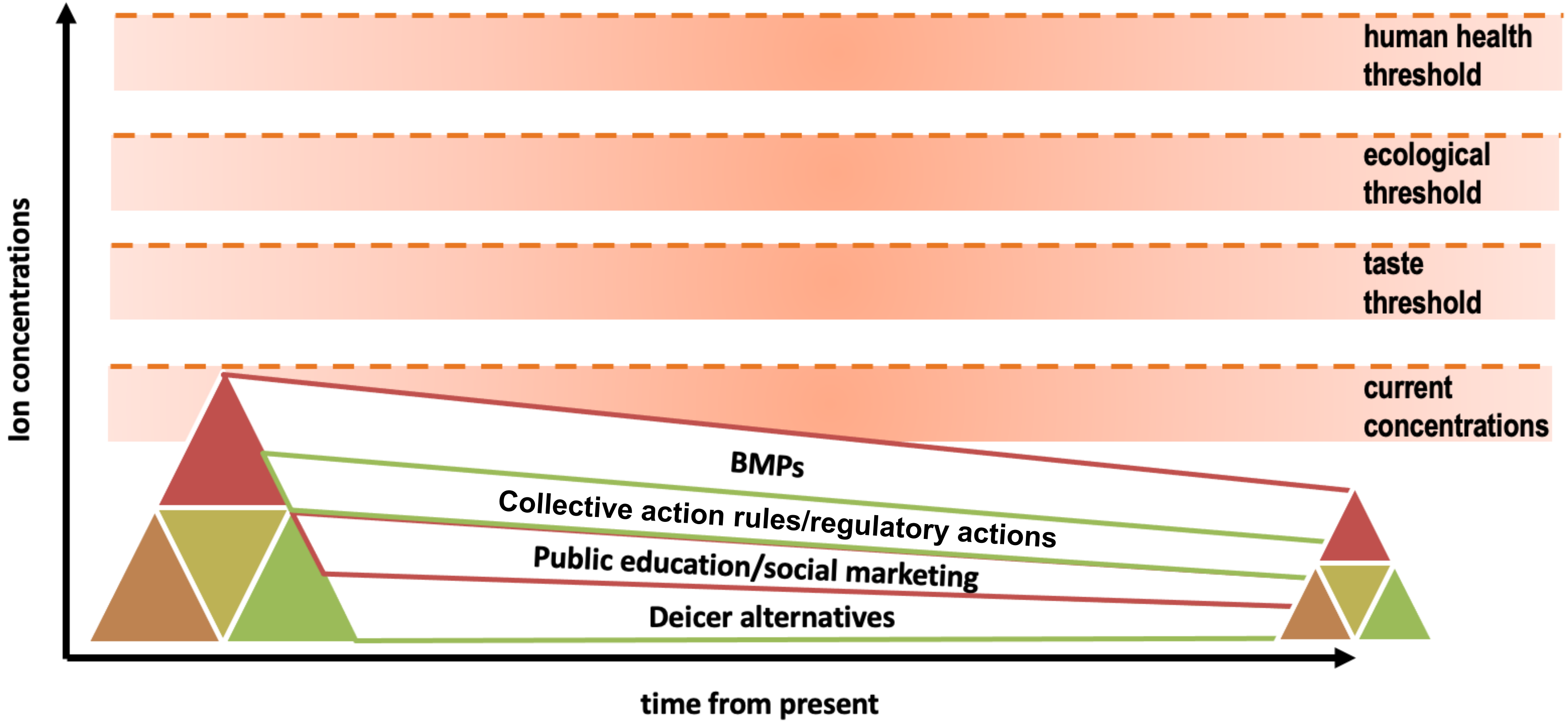
Stanley B. Grant
CEE Department
Virginia Tech

5/3/24

How will salt concentrations increase and what's driving the increase?



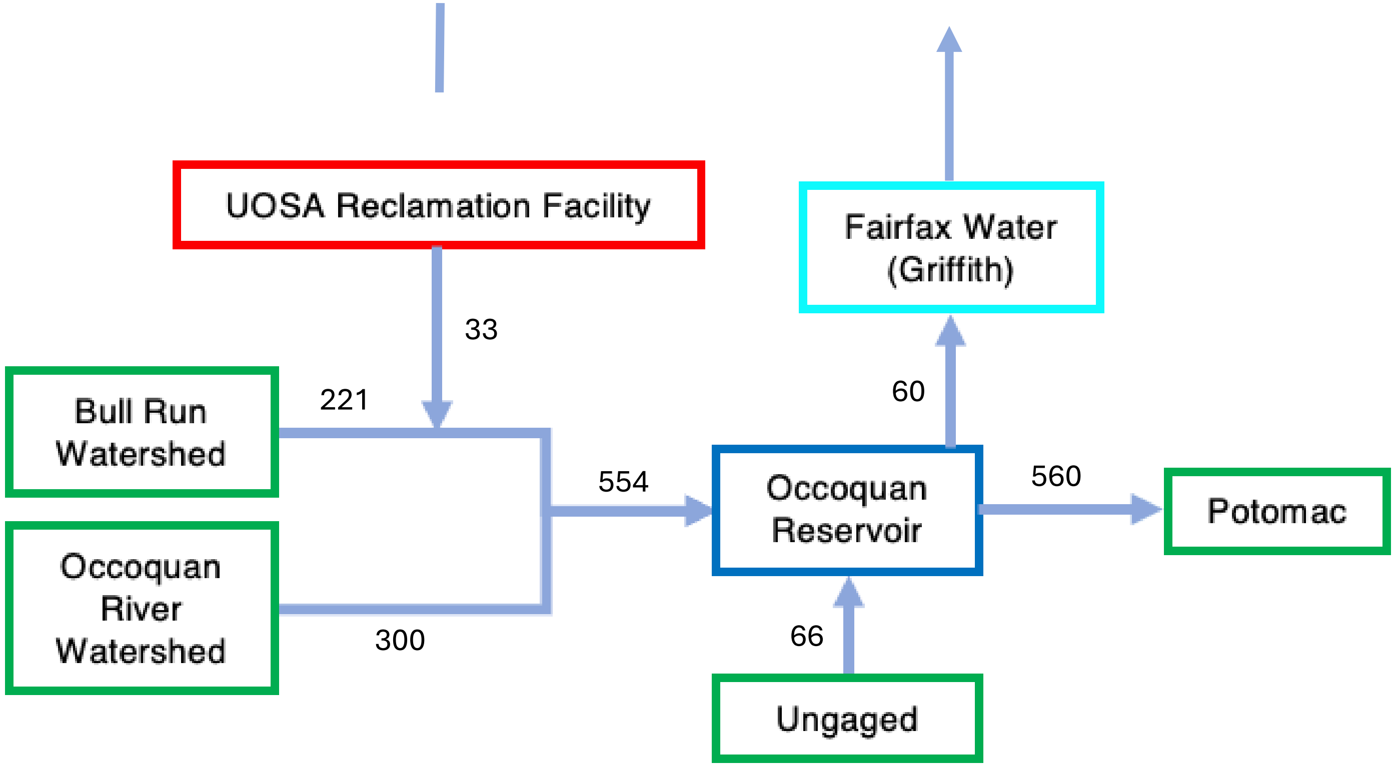
What can we do to slow or reverse the trends?



The Occoquan Reservoir in Northern Virginia

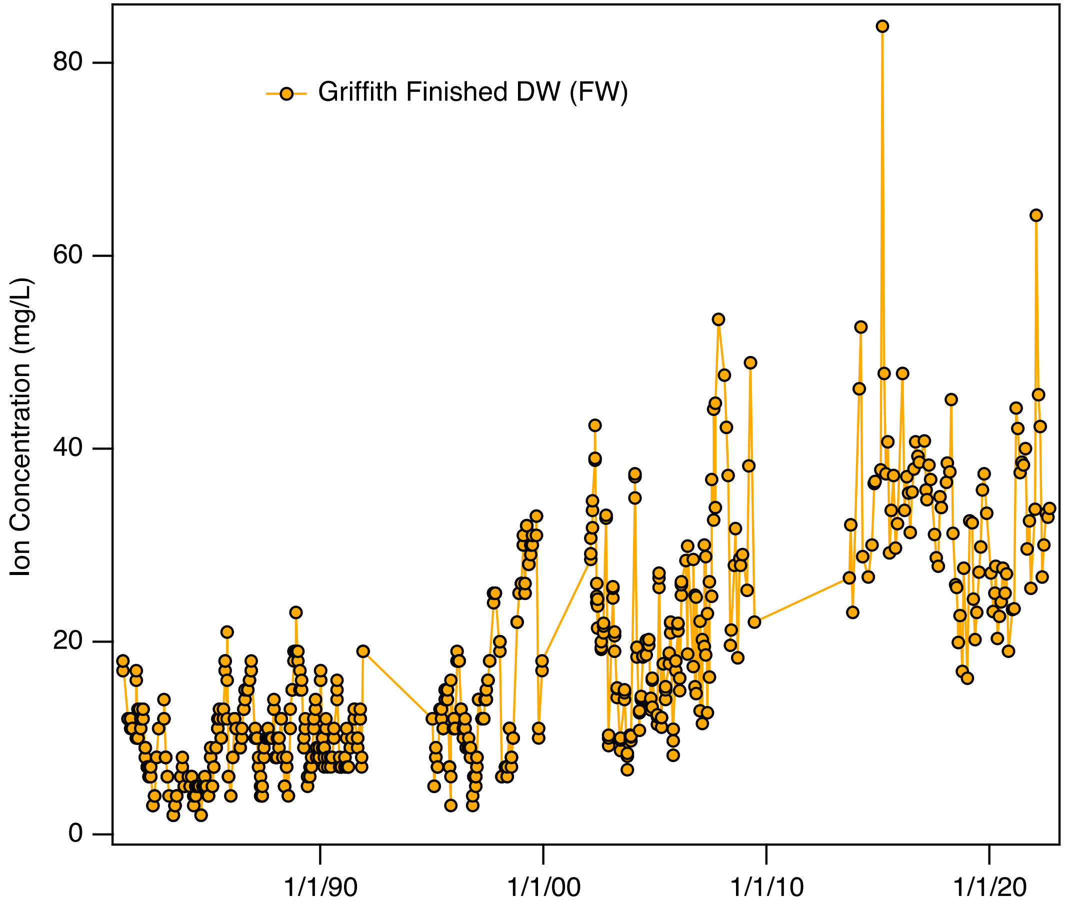
- Drinking Water Source for up to 1 million people in Fairfax County and surrounding communities
- One of the first and largest deliberate indirect potable reuse projects for surface water augmentation in the country
- Reservoir receives gauged inflow from two watersheds (Bull Run and the Occoquan River), ungauged inflow, and treated wastewater from the Upper Occoquan Service Authority

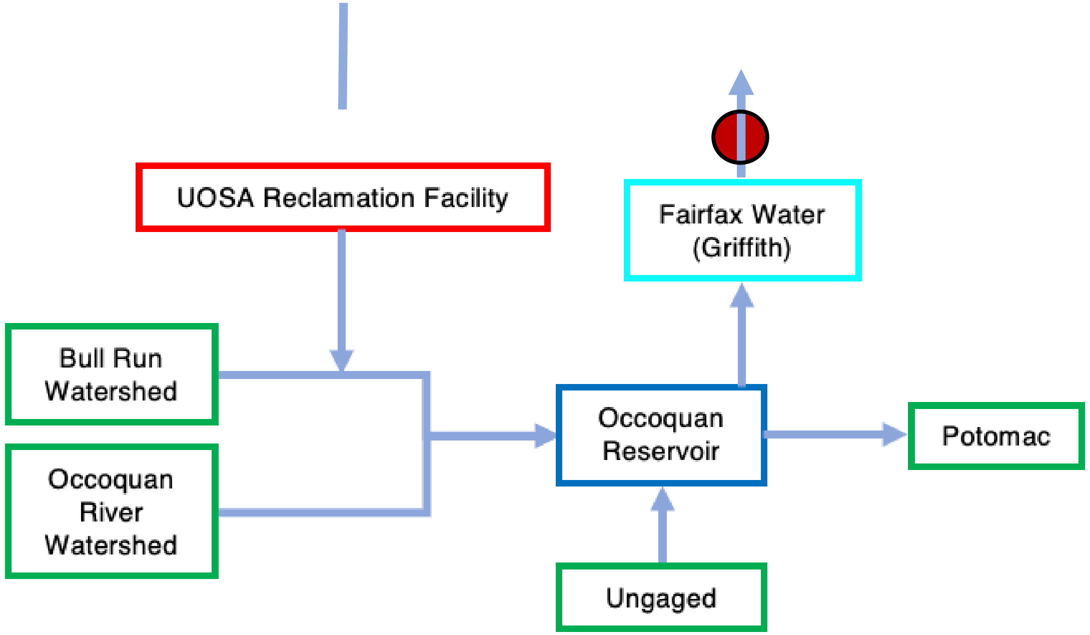
The Occoquan "One Water" System



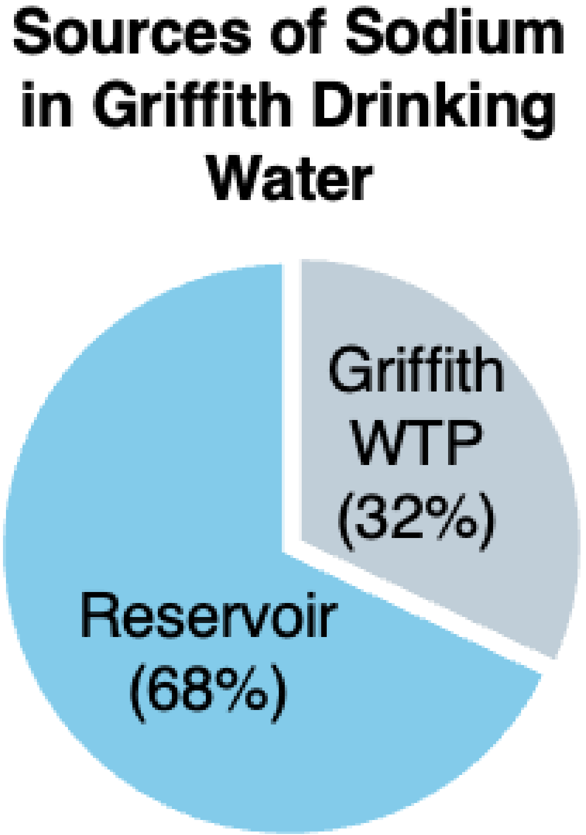
*flows in million gallons per day (MGD)

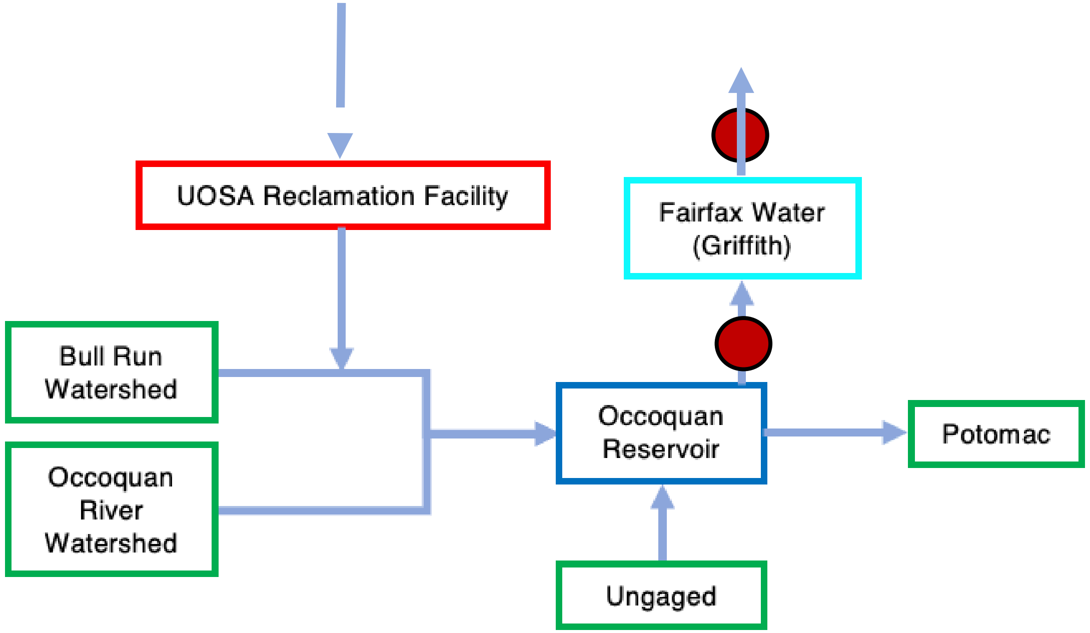
Sodium ion concentration in Griffith Finished Drinking Water is rising over time



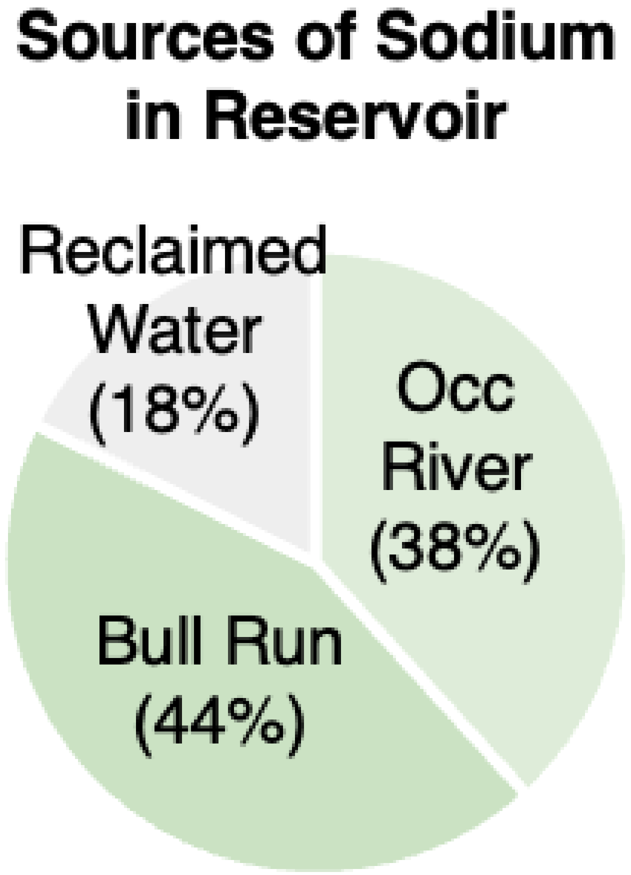


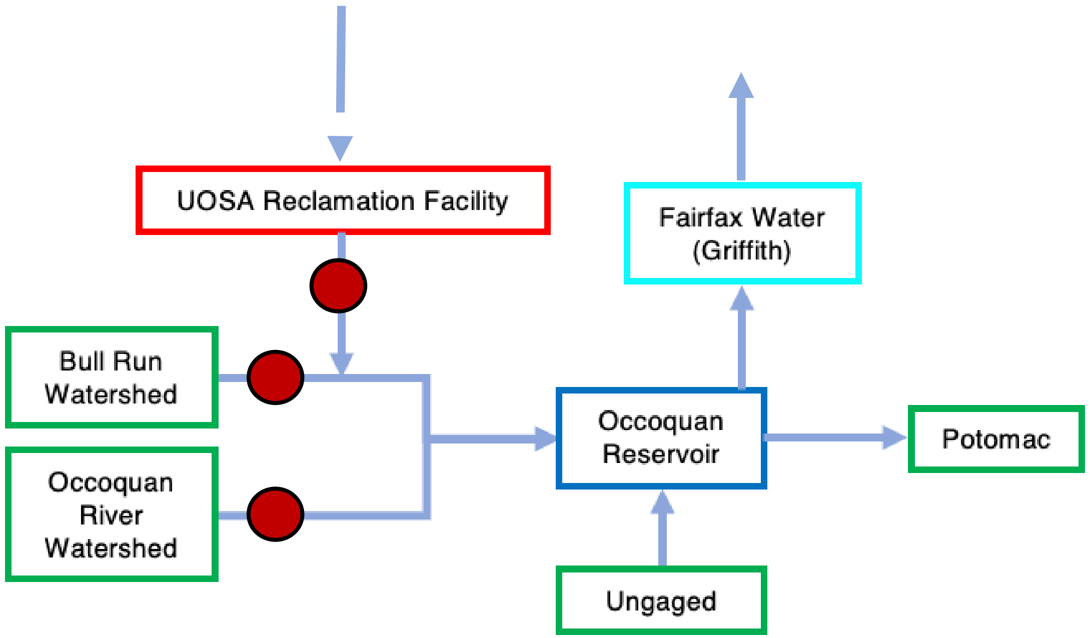
On an annual average basis (2010-2022), the sources of the sodium in Griffith's finished drinking water breakdown as follows





Where is the sodium in the reservoir coming from?





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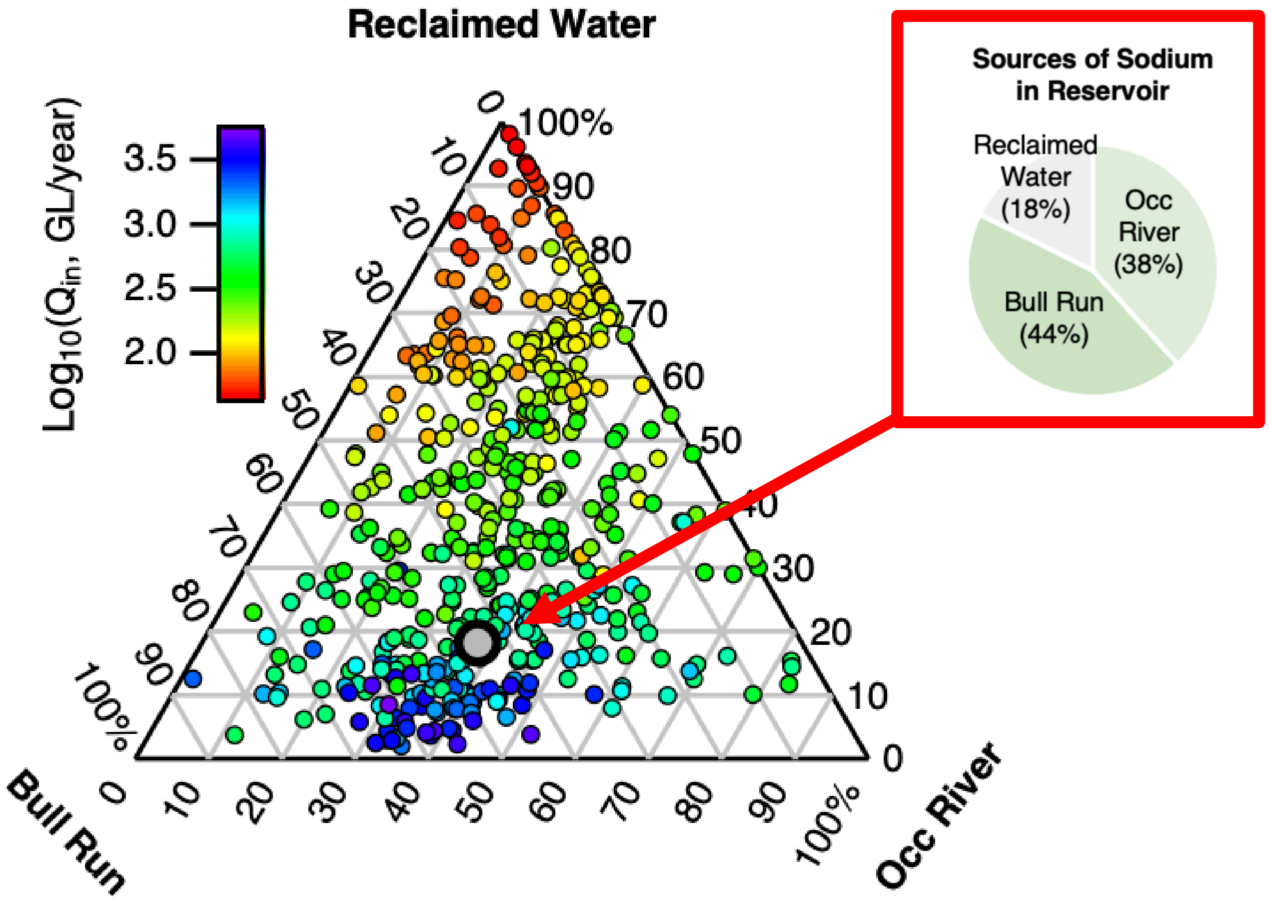
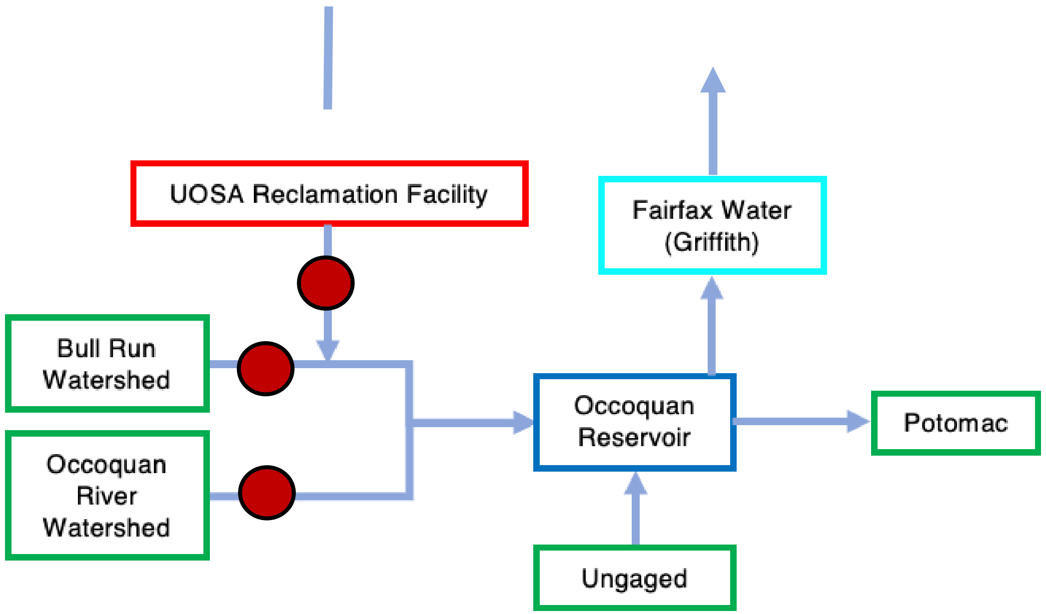
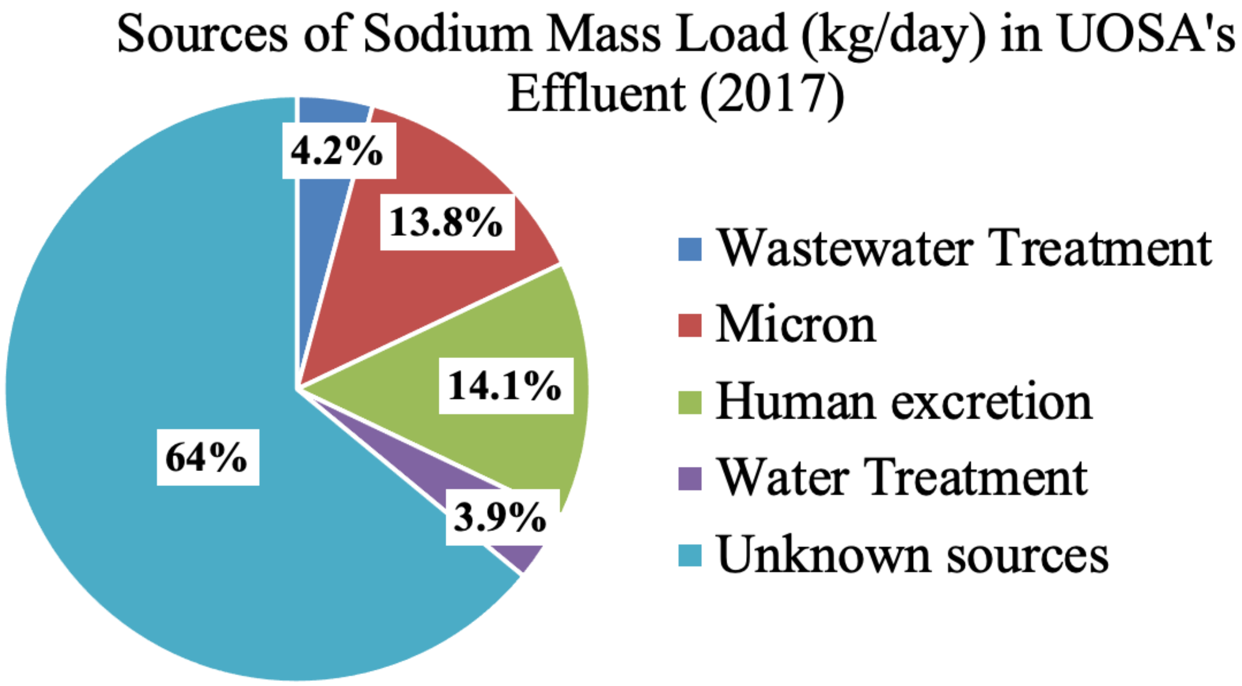
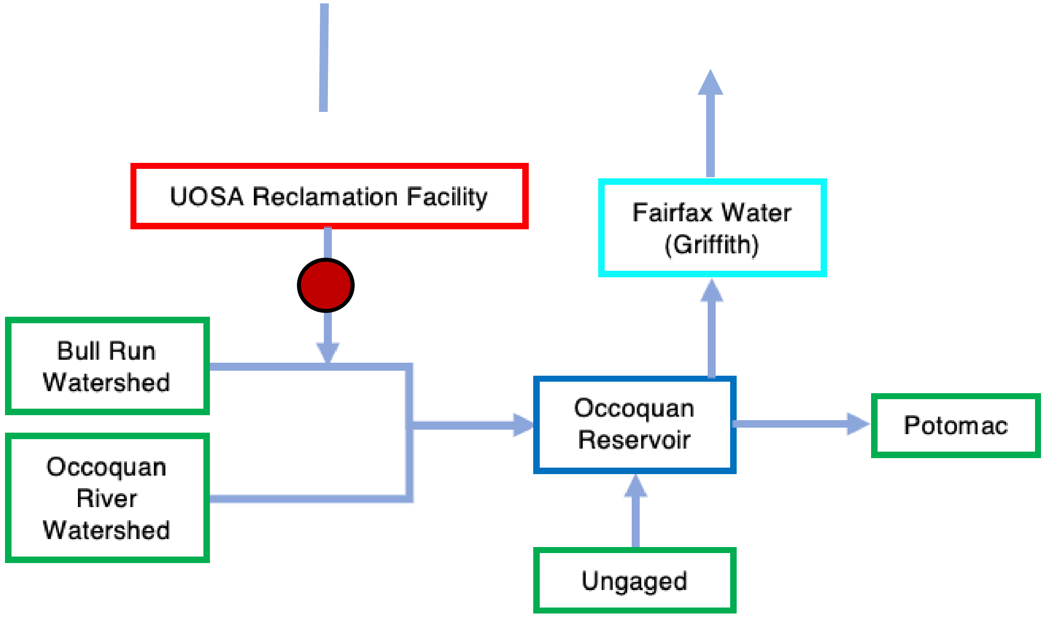




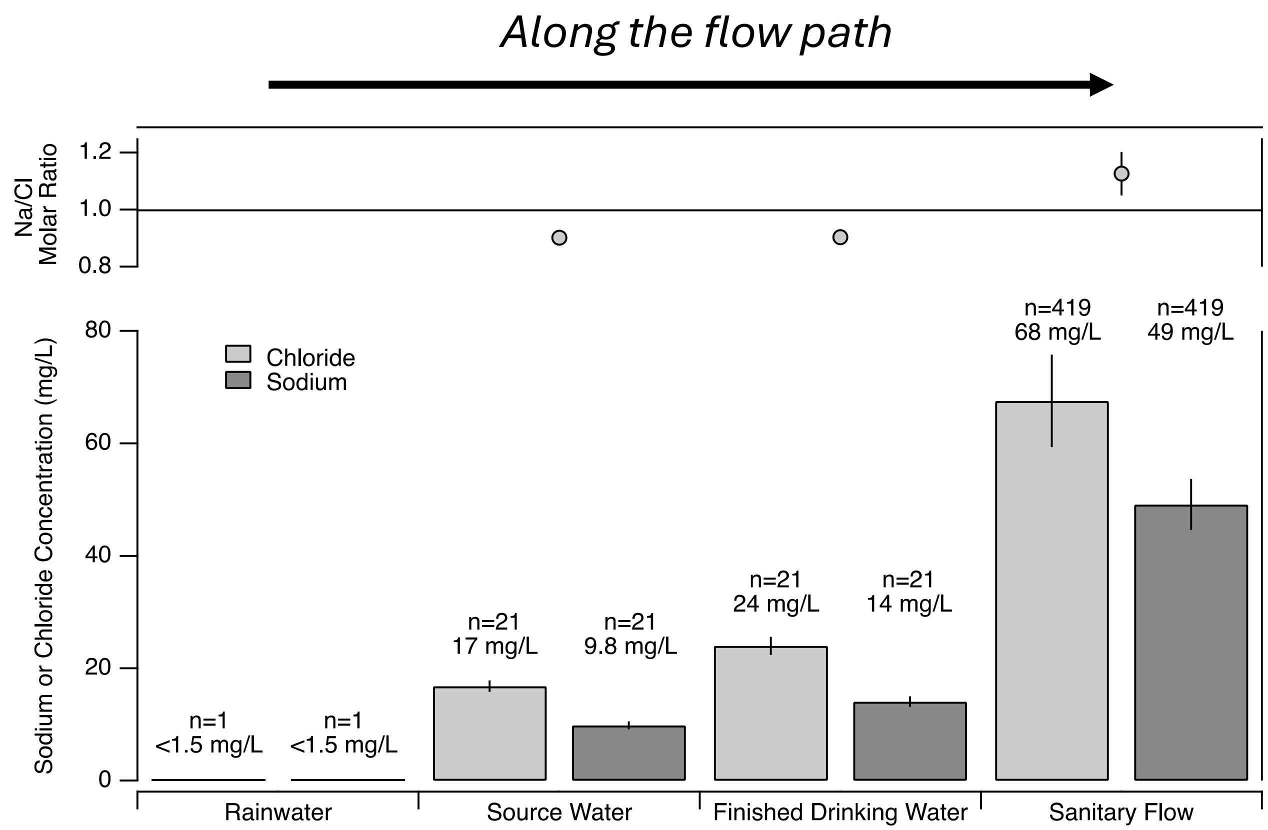
Where is sodium in the reclaimed water coming from?

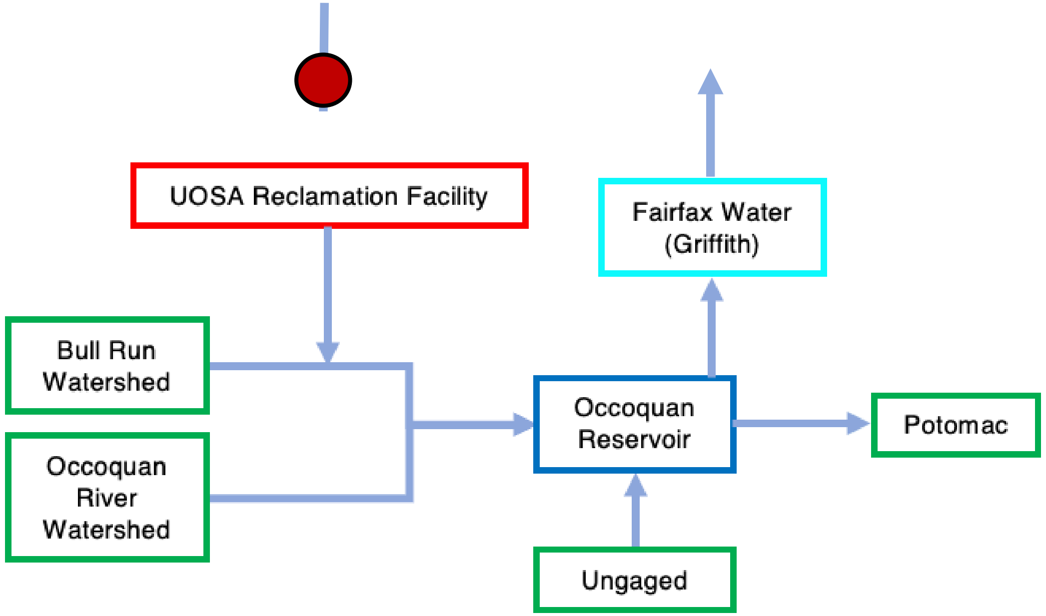




Bhide, S.V.; Grant, S.B; et al. (2021) Addressing the contribution of indirect potable reuse to inland freshwater salinization. *Nature Sustainability*. https://doi.org/10.1038/s41893-021-00713-7

Where is sodium in the reclaimed water coming from?



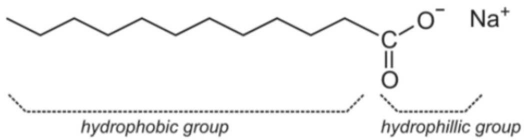


Where is sodium in the reclaimed water coming from?

Table 1. Molar ratios in water discharged from the CSIRO model house

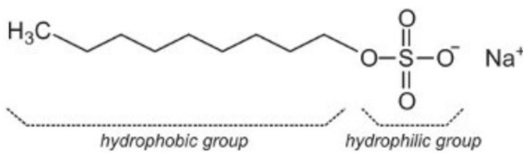
	Washing Machine	Dish Washer	Shower	Kitchen sink	Vanity Unit	Toilet+ Vanity	Total
Cl (g/wk)	6.296	7.580	2.269	5.021	0.5258	15.902	37.595
Cl (mol/wk)	0.178	0.214	0.064	0.142	0.0148	0.449	1.060
Na (g/wk)	55.609	7.456	2.466	3.213	0.766	15.362	84.872
Na (mol/wk)	2.418	0.324	0.107	0.140	0.033	0.668	3.69
Molar Na/Cl	**13.58**	**1.51**	**1.67**	**1.00**	**2.23**	**1.5**	**3.48**

Soaps

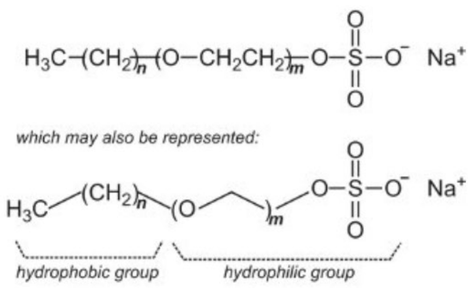


a soap

Detergents

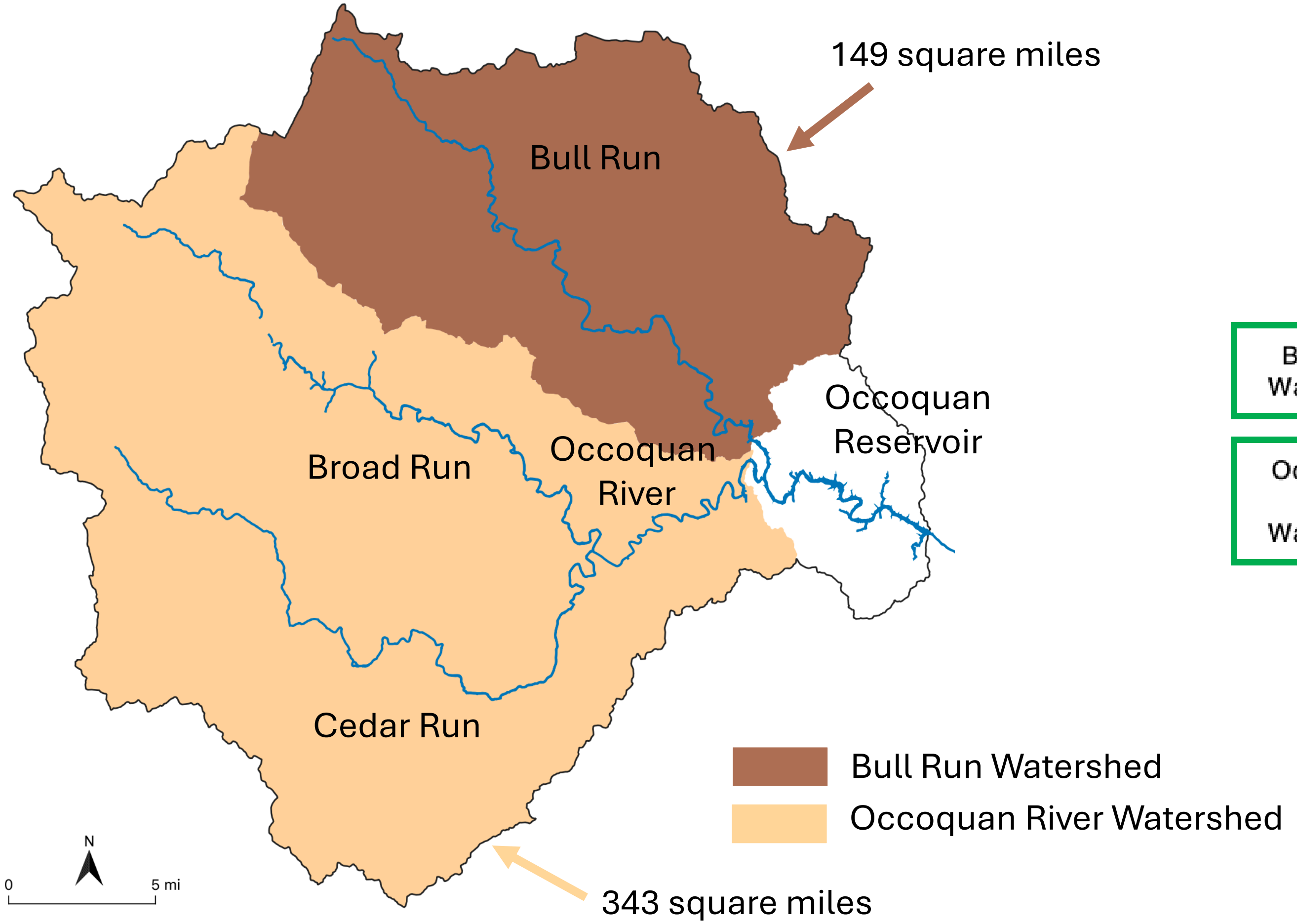


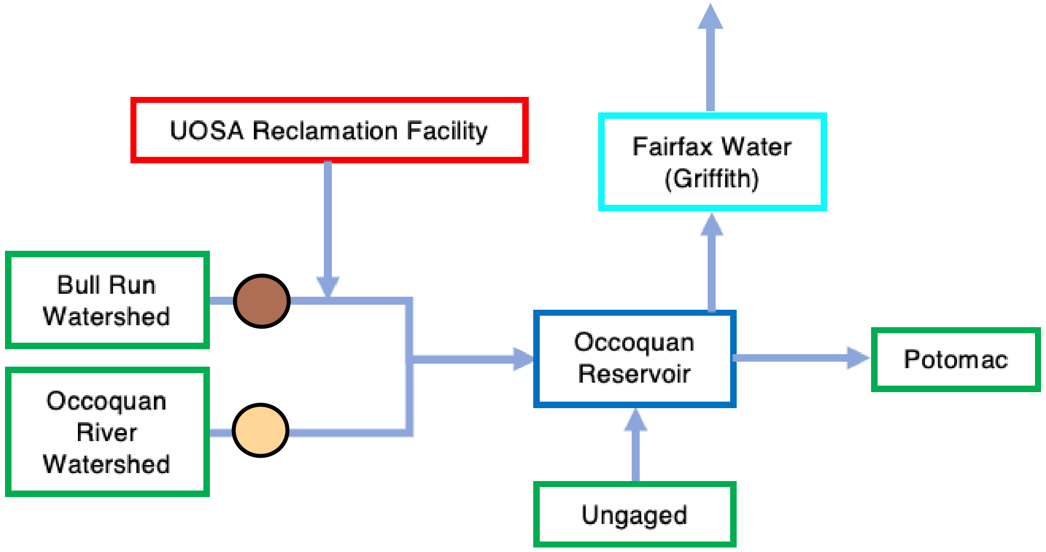
an alkyl sulfate



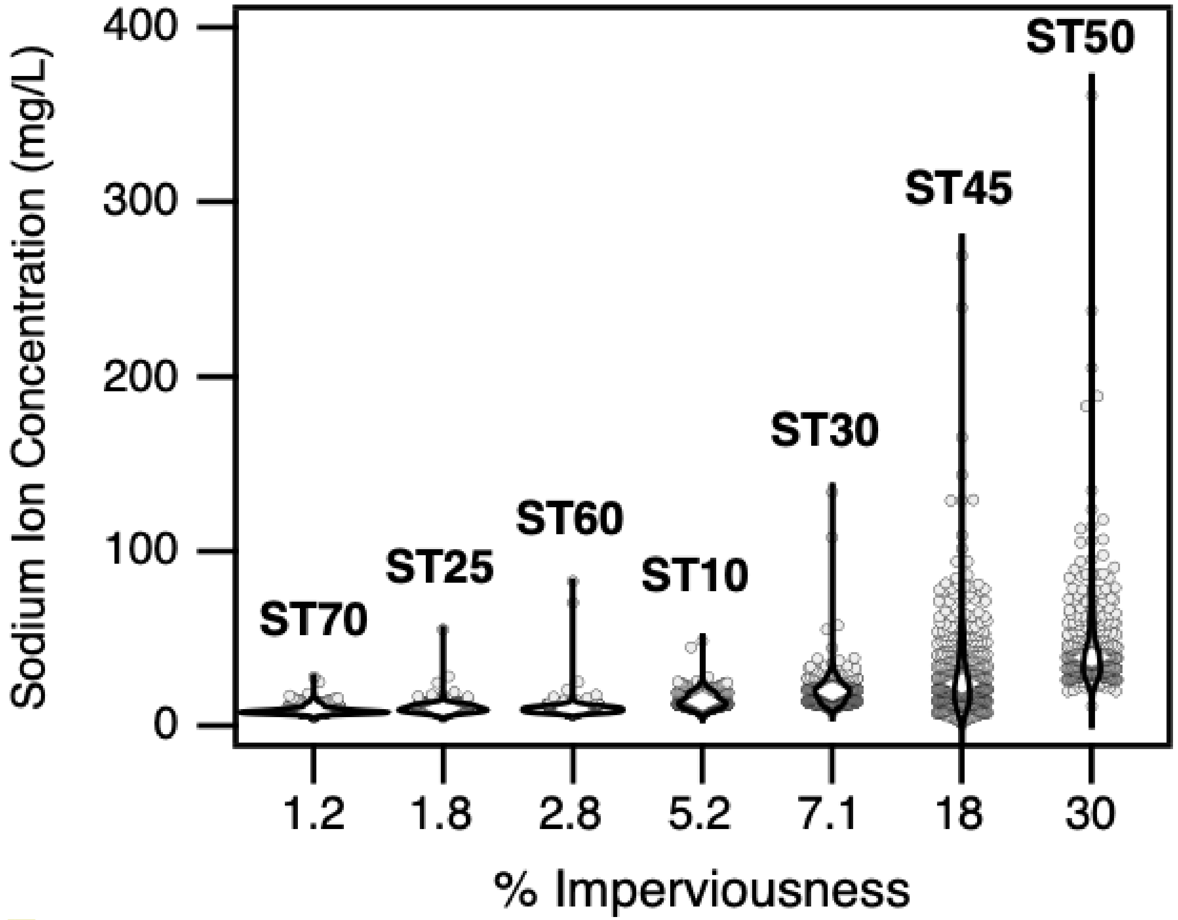
an alkyl ether sulfate

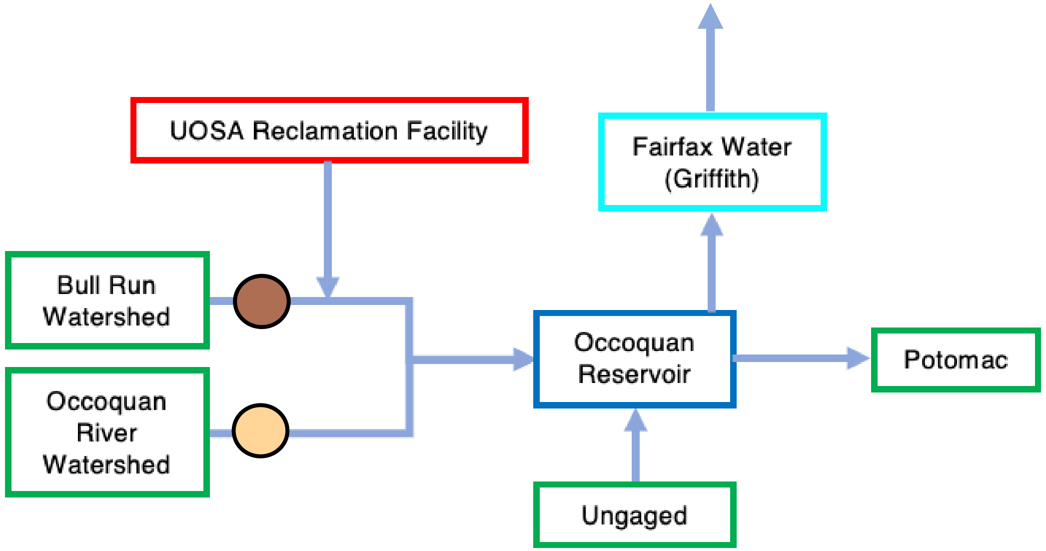
Where is sodium in watershed outflow coming from?





Deicers/anti-icers are a major source of sodium in the reservoir and drinking water





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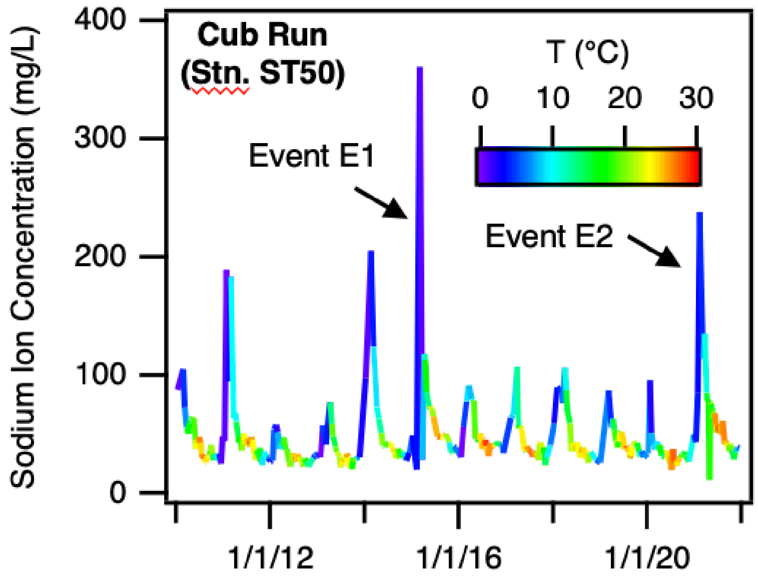
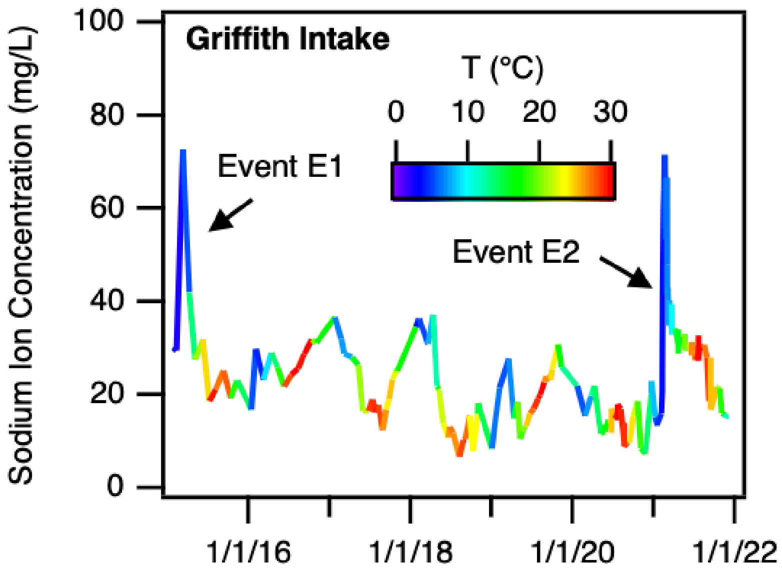
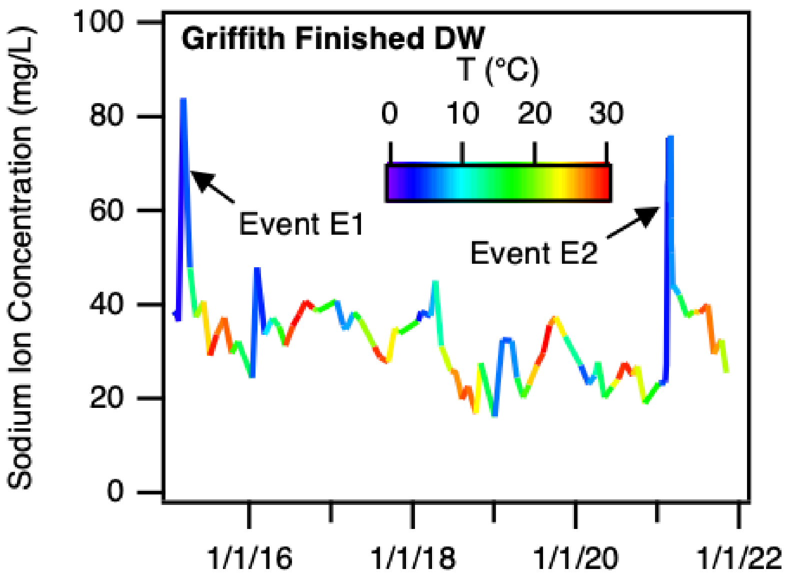
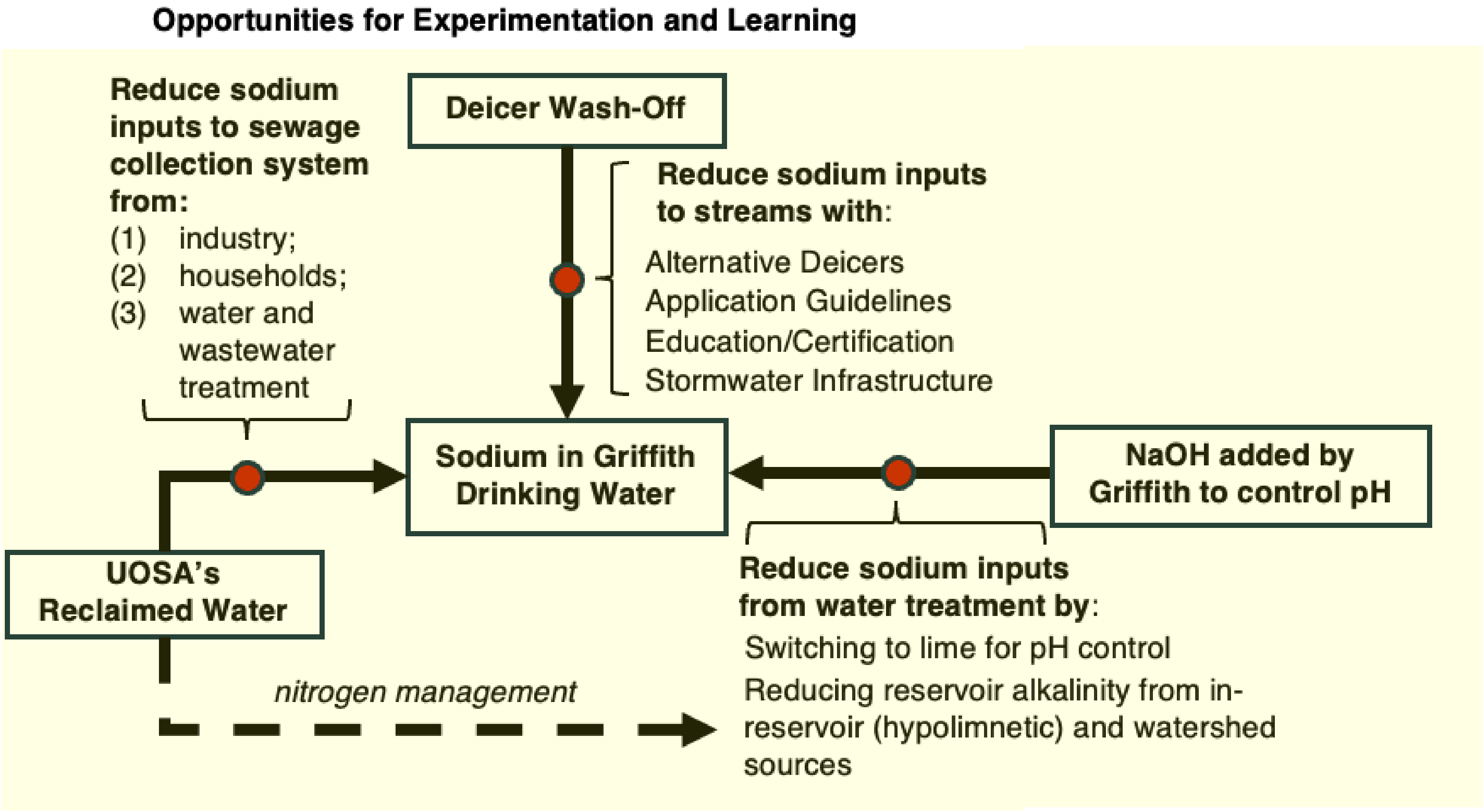






What are some possible solutions...



Fairfax County Water-Resources Monitoring:

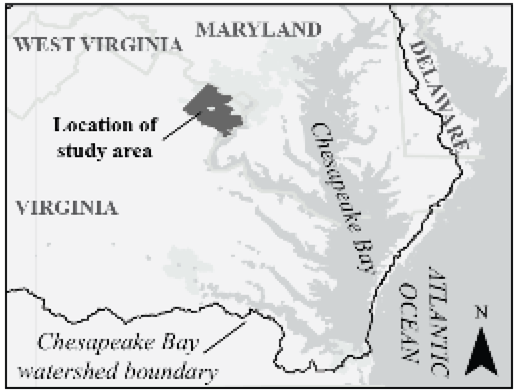
Assessing Watershed Scale Responses to BMP Implementation in Urban Watersheds

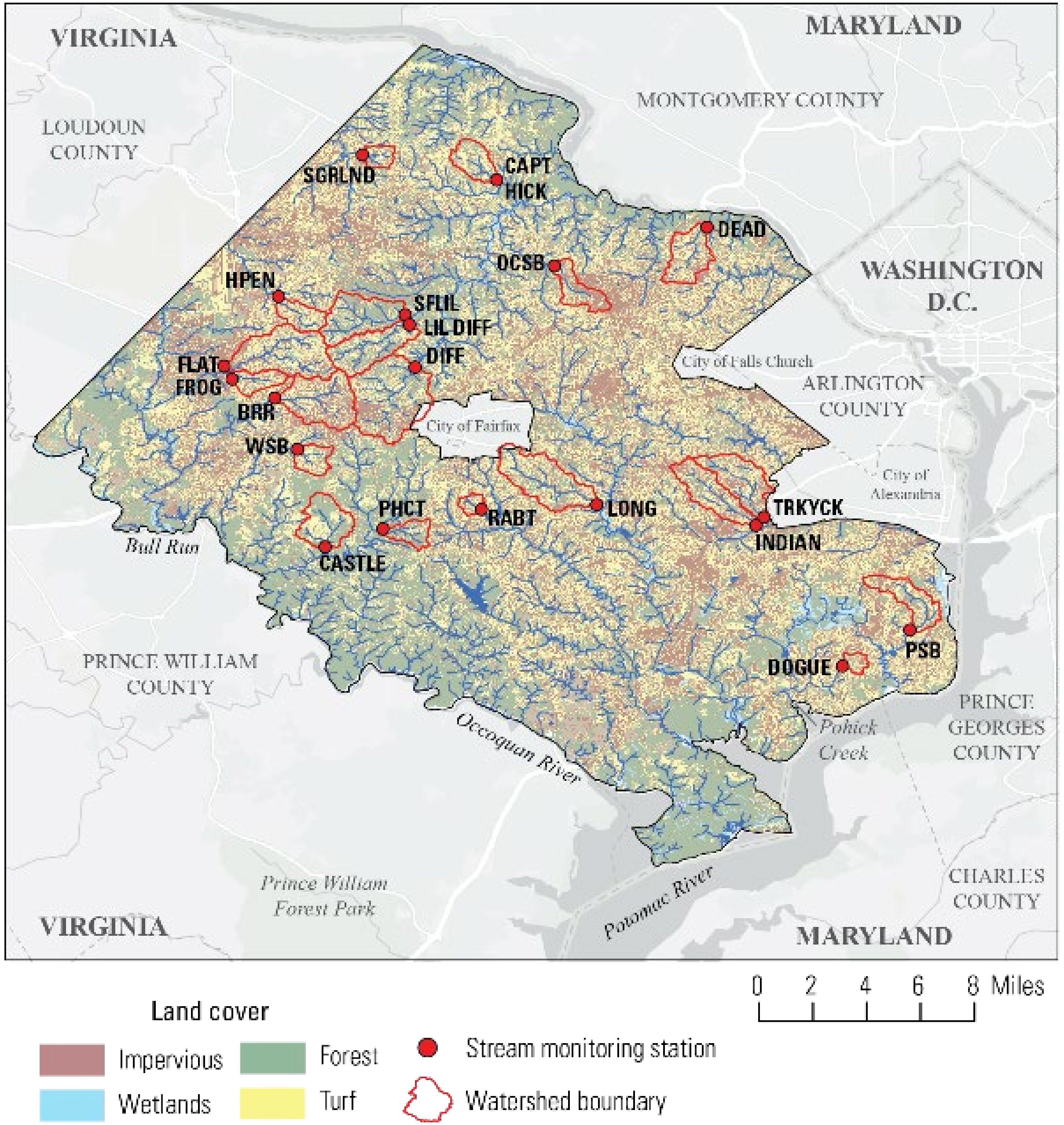
John Jastram, Aaron Porter, and Jeff Chanat

USGS – Virginia and West Virginia Water Science Center

The monitoring network is designed to assess Fairfax County stream conditions

- 21 stream monitoring stations, 0.5 to 5.5 mi^2
- Measurements of hydrology, water quality, and ecology
  - Nitrogen, phosphorus, and suspended-sediment concentrations analyzed from water-quality samples
  - Specific conductance measured at all stations each month, measured continuously at 6 stations
  - Major-ion (including chloride) concentrations have been collected at 6 stations since 2020





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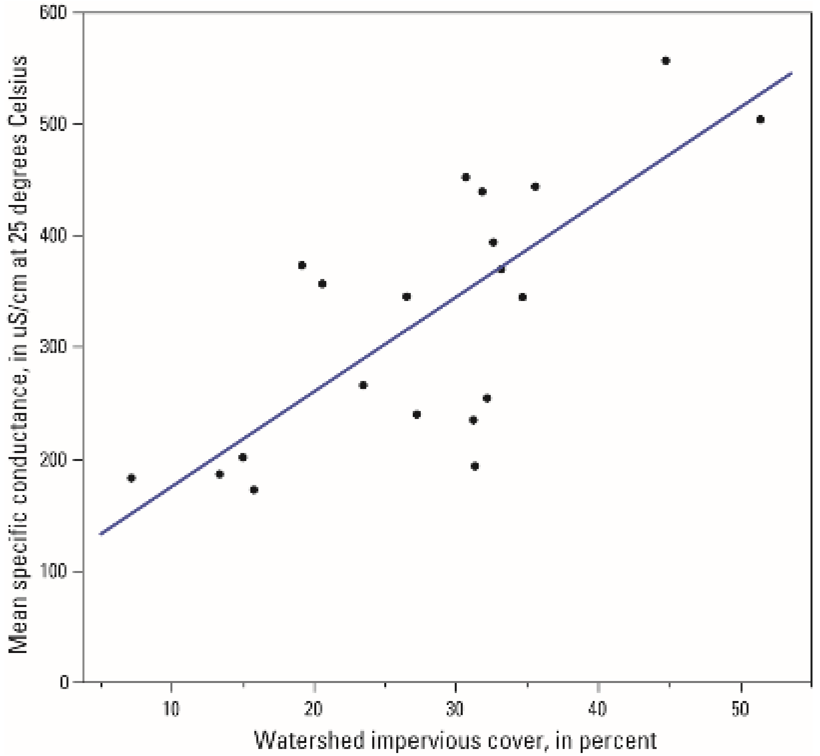
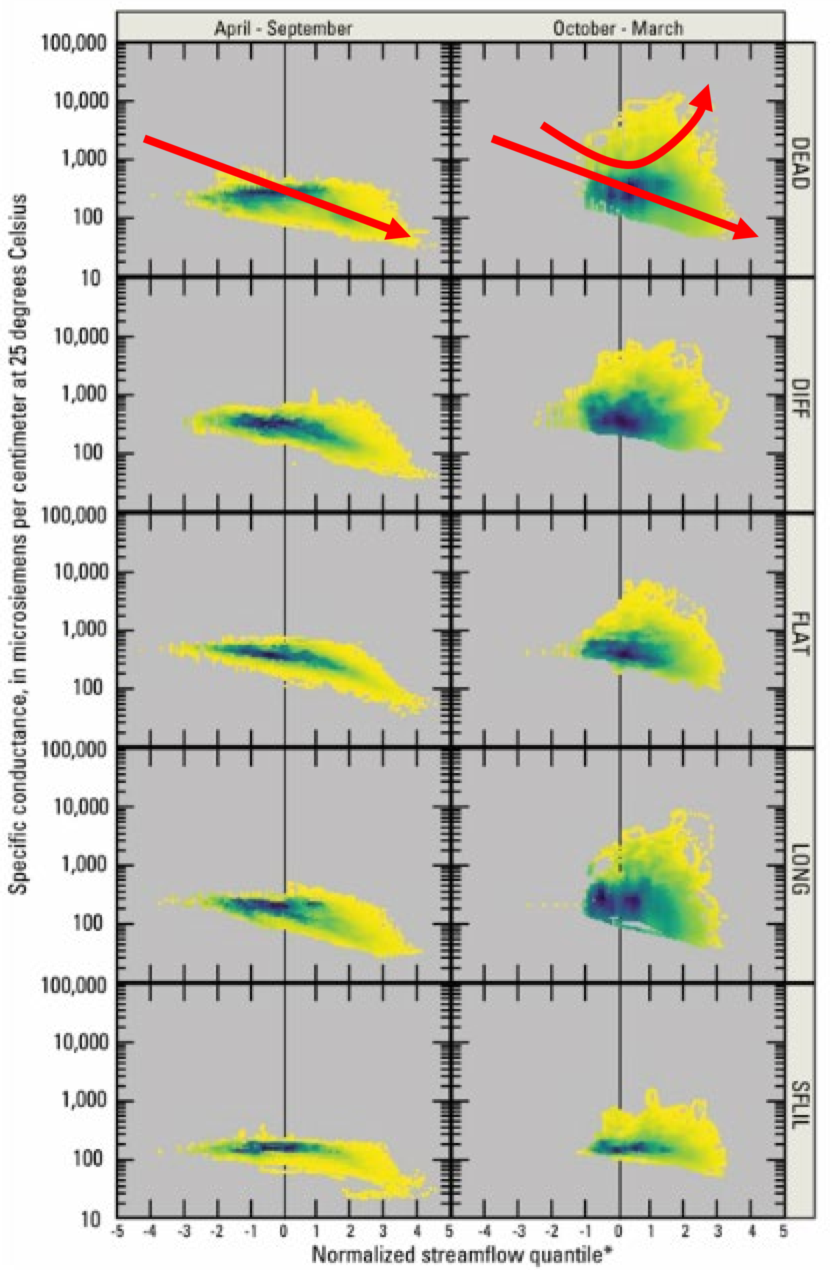
Specific conductance is positively correlated to watershed imperviousness and is a strong surrogate for chloride concentration.

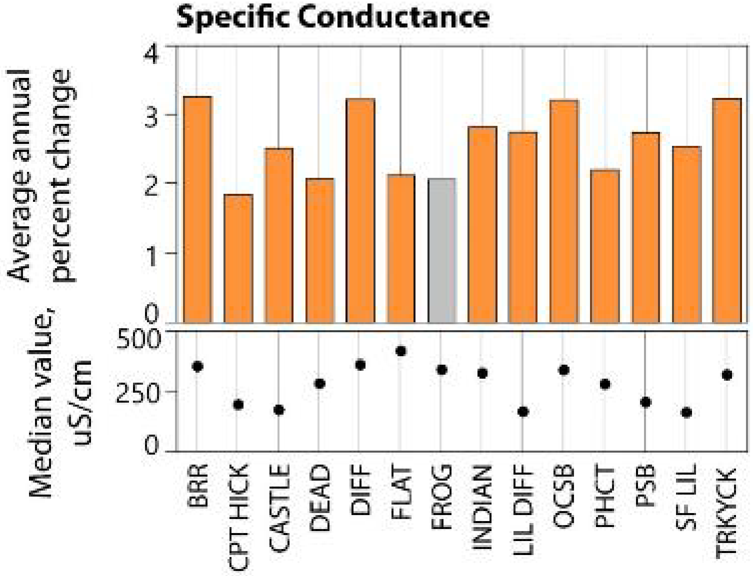
Stream conductance is diluted by runoff in the "warm" season, but can become enriched during the "cool" season when deicing salts are applied to impervious surfaces.



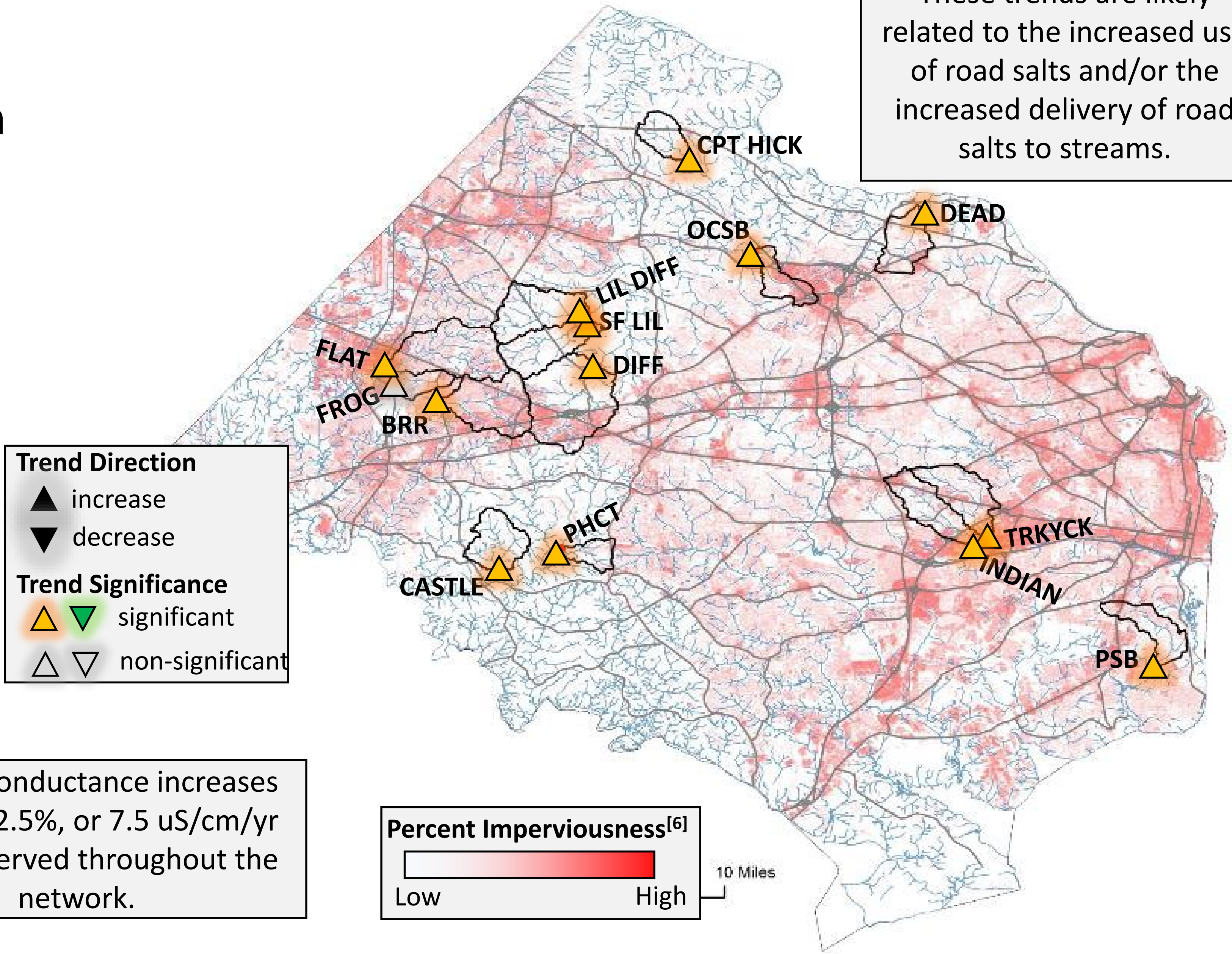


Porter et al., 2020 Spatial and Temporal Patterns in Streamflow, Water Chemistry, and Aquatic Macroinvertebrates of Selected Streams in Fairfax County, Virginia, 2007–18

Specific conductance increased throughout the monitoring network from 2008 – 2018.



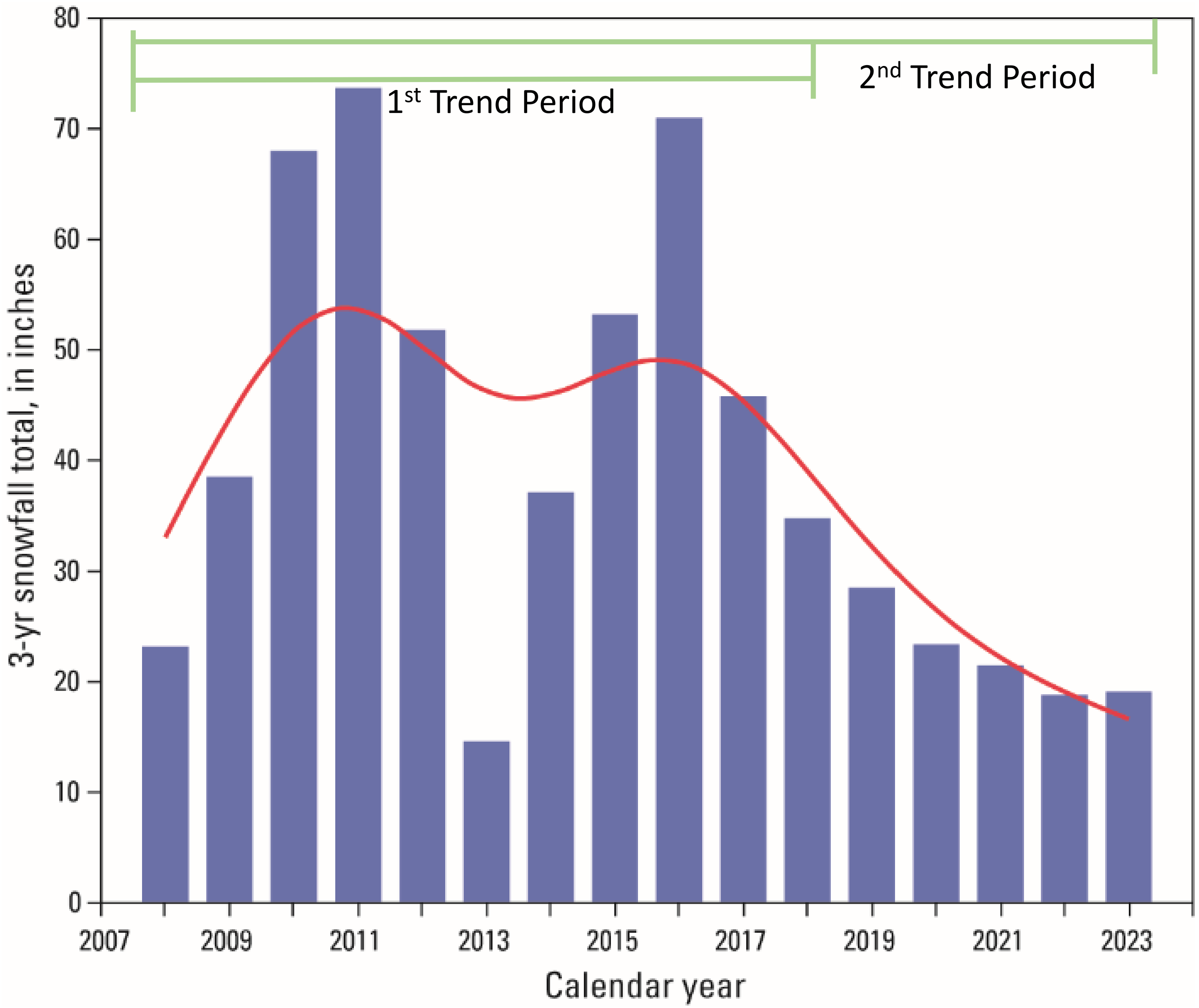
These trends are likely related to the increased use of road salts and/or the increased delivery of road salts to streams.



The largest increases occurred in the most impervious watersheds.

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

In recent years, Fairfax County has received little snowfall.

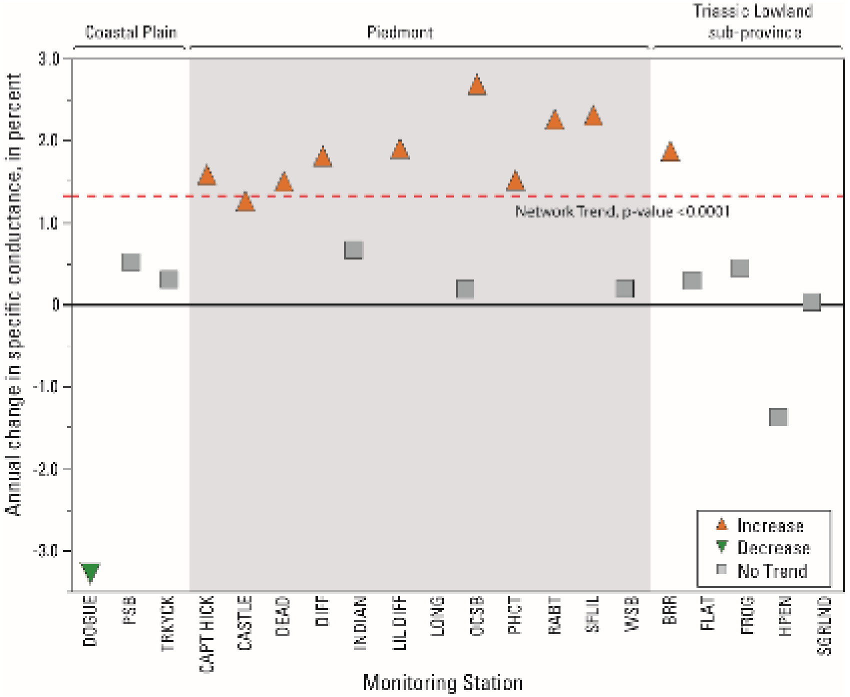


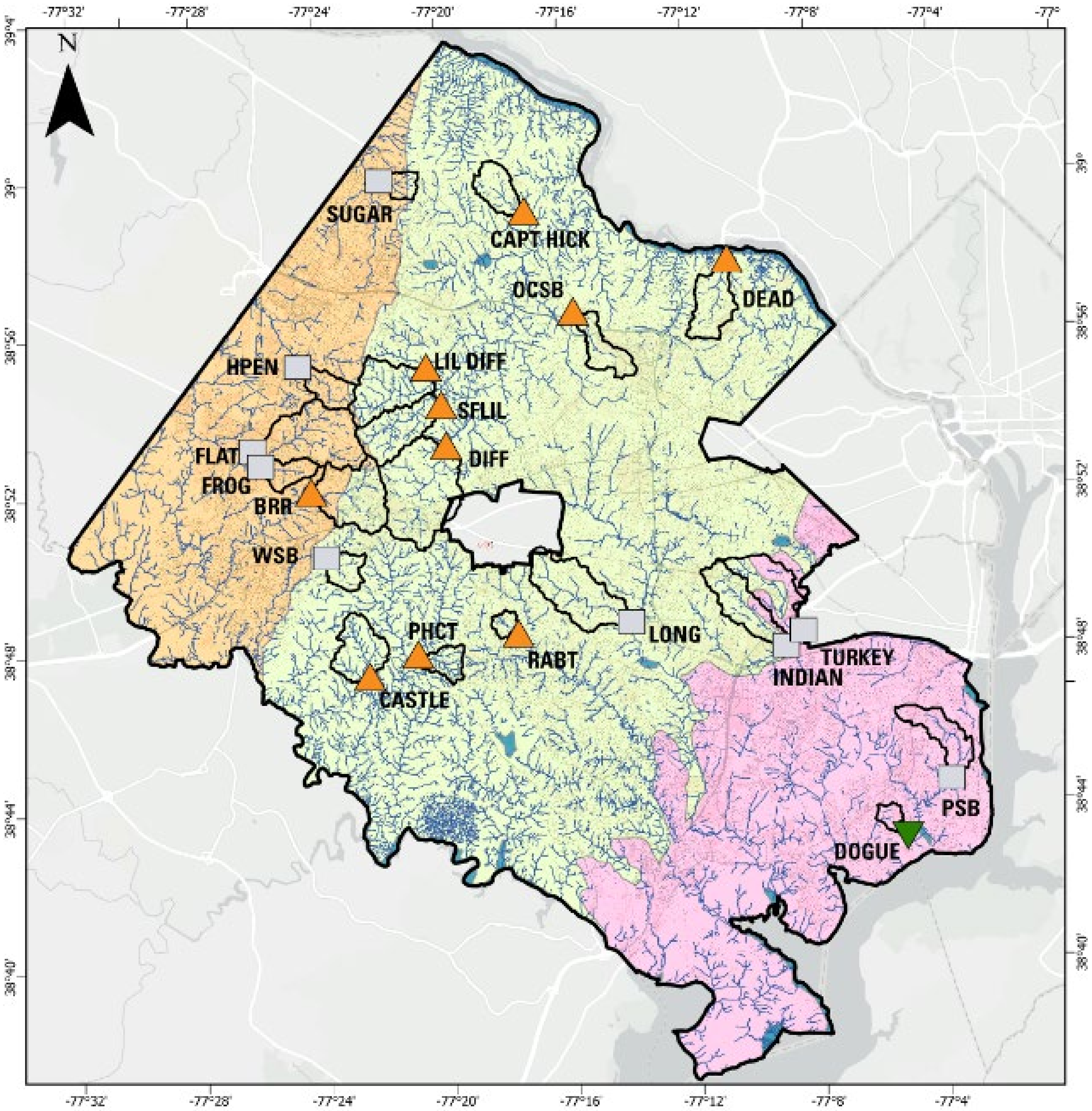
3-year snowfall is the total snowfall in each year plus the previous two years

Preliminary Information-Subject to Revision. Not for Citation or Distribution

Specific conductance increased in about half the monitored watersheds from 2008 – 2023.

- Increasing trends are most commonly occurring at stations located in the Piedmont physiographic province.
- The exception is BRR (Big Rocky Run) where impervious cover is one of the highest in the network.

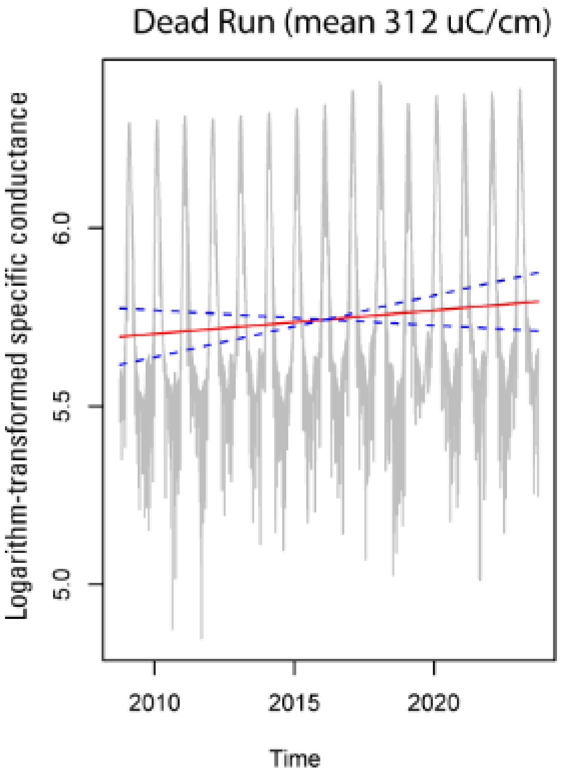




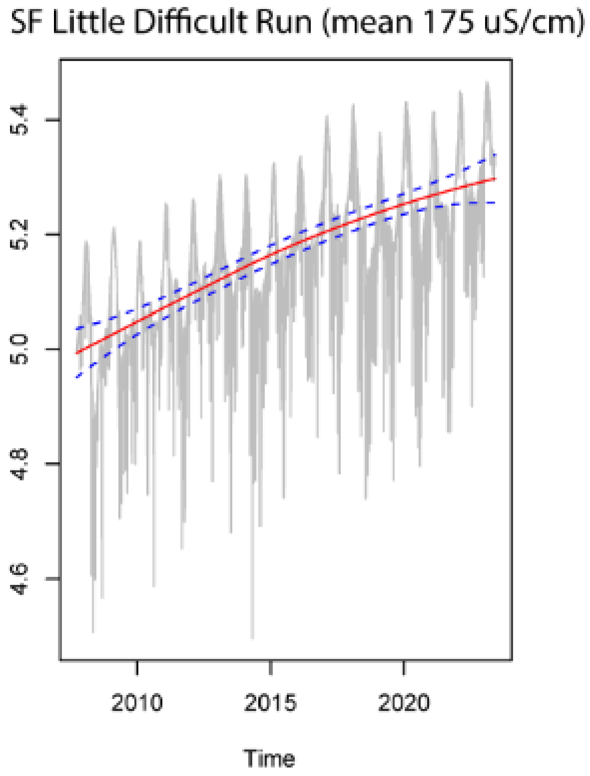
Preliminary Information-Subject to Revision. Not for Citation or Distribution

USGS has multiple tools to evaluate changing conditions

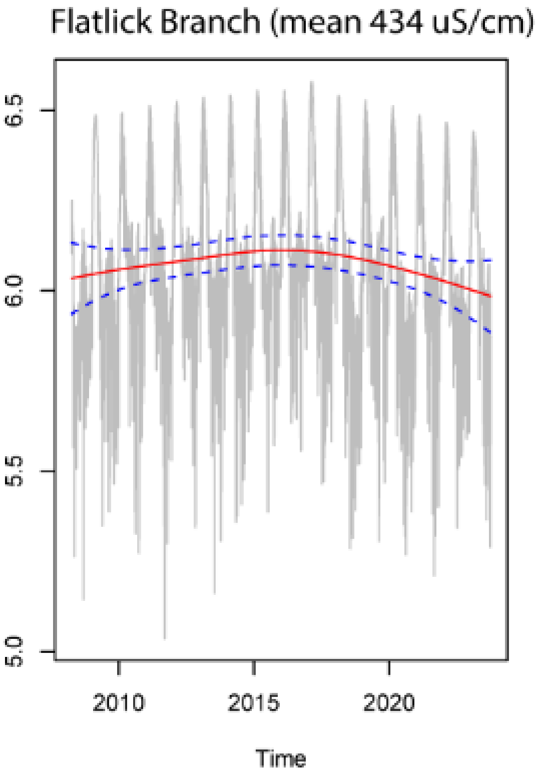
Trends in high-frequency specific conductance data



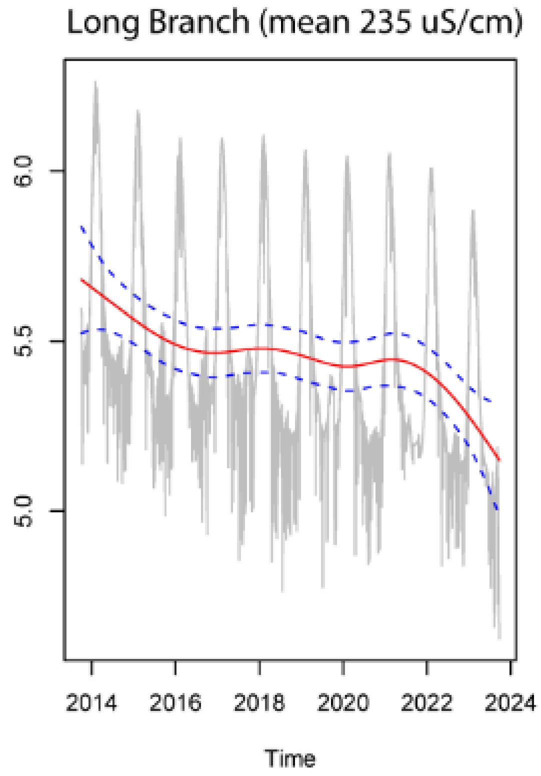
Likely increase of 34 uS/cm



Extremely likely increase of 54 uS/cm



Likely increase of 30 uS/cm



Extremely likely decrease of 135 uS/cm

Trend determined by likelihood calculation[1]

[1]Graham B. McBride (2019), J. Environ. Qual. 48:412–420 (2019)

Preliminary Information-Subject to Revision. Not for Citation or Distribution

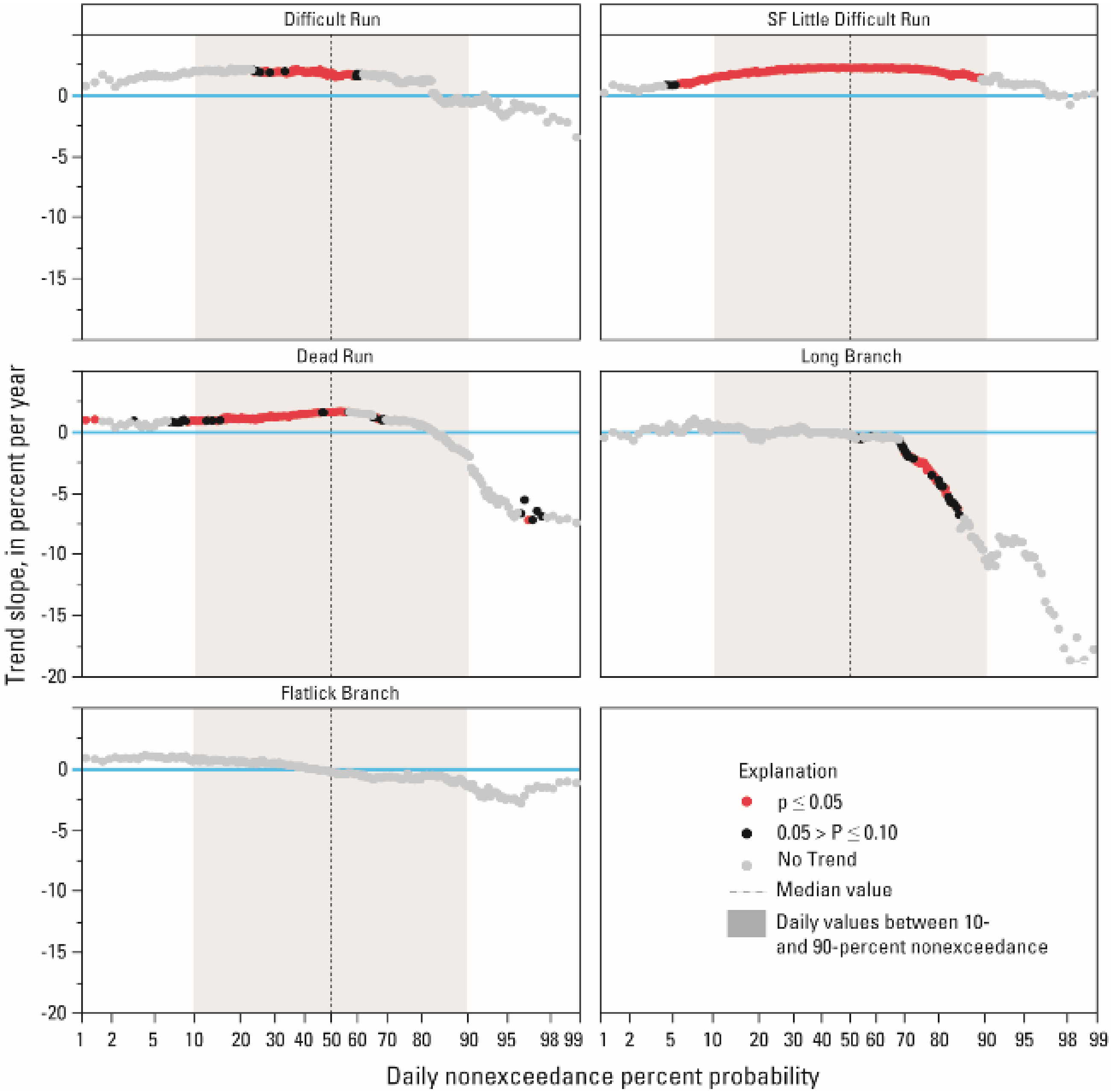
Changes in specific conductance may not be uniform across all conditions.

We have additional tools for investigating trends that can help identify mechanisms of change.

Are high values of SC increasing? What about average levels? What about the lowest levels? The distribution of observed SC may not be changing in the same way.

At Long Branch, SC is decreasing, and this is occurring in the higher values. This means there may have been a reduction in salt-loading events.

At other sites, the average values are increasing, which may be related to a slow release of salts stored in soils from past loading events.



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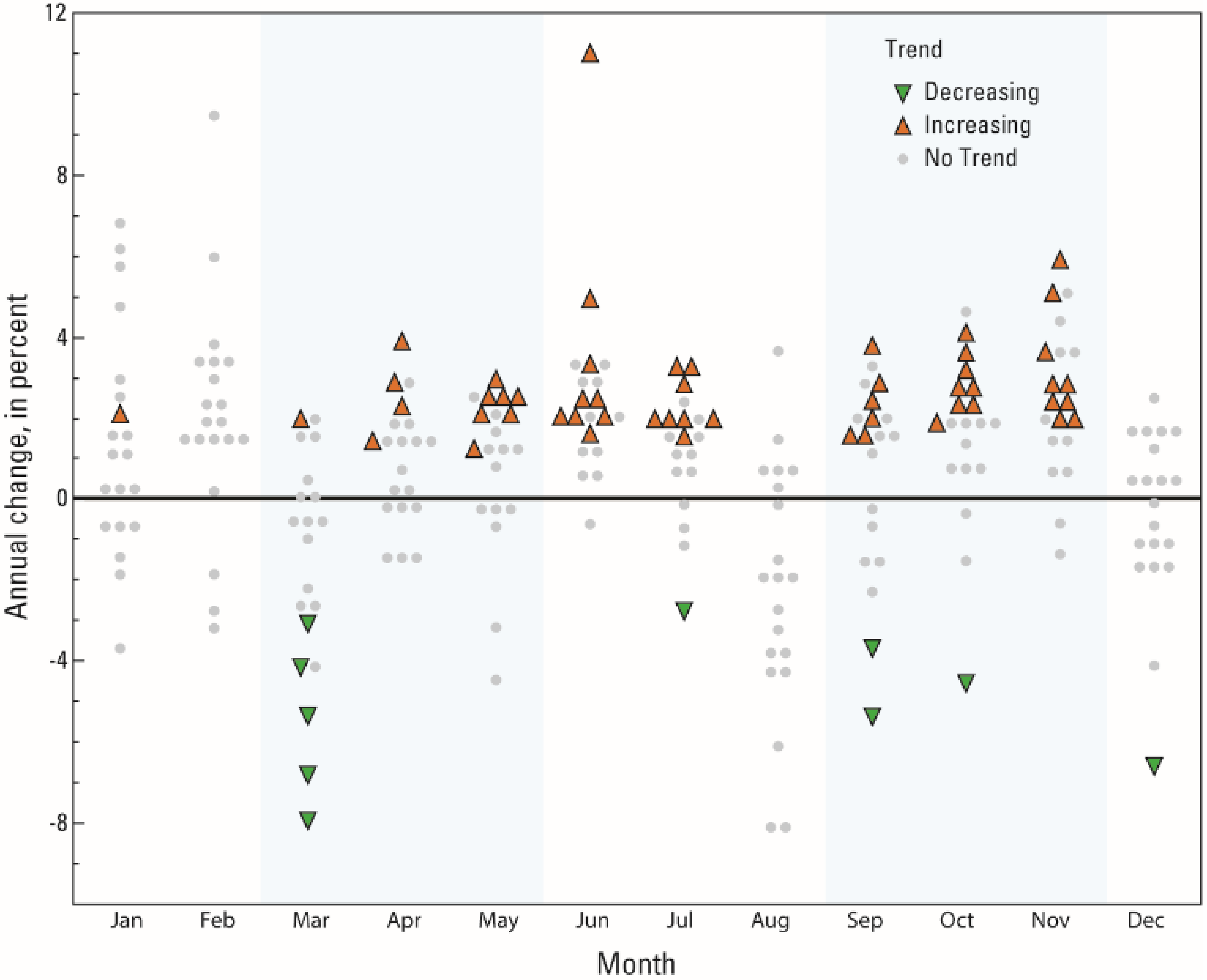
We also can assess how conditions are changing throughout the year



Most notably, trends are rarely identified during Winter when deicing salts are applied.

Increasing trends in Spring and early Summer may be indicative of transport of salts applied the previous winter.

Increasing trends in Fall may suggest salts stored in soils and shallow groundwater are released to streams during periods of drought.

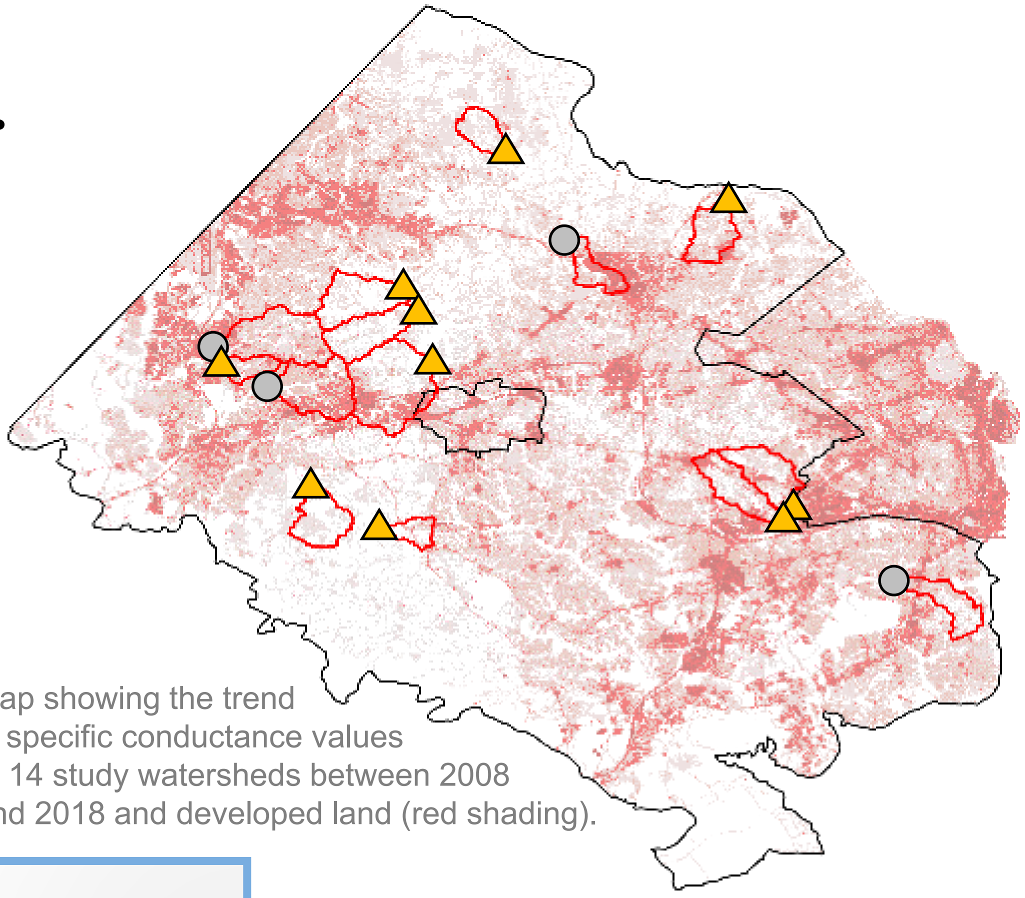
What is driving differences between watersheds and changes over time?

Specific conductance (SC) was likely related to the applied amount and storage of salt on the landscape.

Observed Responses

SC values (on average, 150 – 500 uS/cm) declined in 0 (▼) and increased in 10 (▲) study watersheds between 2008 and 2018.

Other stations had no trend (●).



Map showing the trend in specific conductance values at 14 study watersheds between 2008 and 2018 and developed land (red shading).

Explanation of Variability

Developed Land

SC values were higher in watersheds with more developed land uses.

Soil Depth

SC values were higher in watersheds with more shallow soils.

Air Temperature

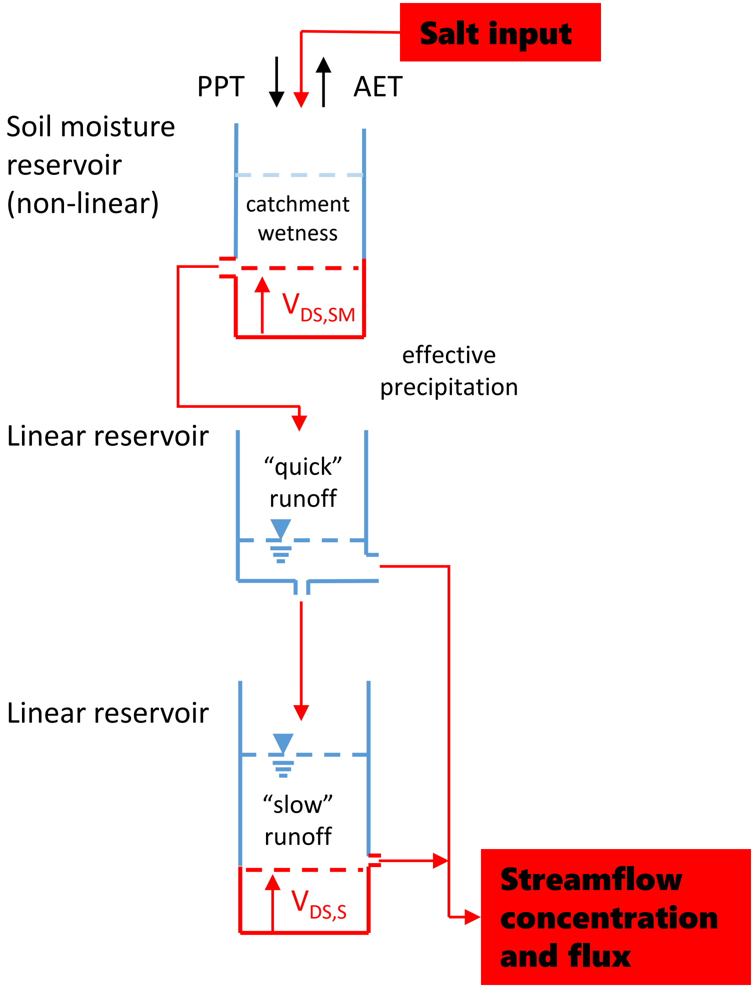
SC values were higher in years with colder minimum air temperatures.

Long Branch (Fairfax County) Chloride Study

Research questions

1. ***How much Cl^- is being exported in streamflow? What are the trends?***
2. ***How much are we applying? What are the trends?***
3. ***How much Cl^- is currently stored in the watershed?***
4. ***What input reductions would be necessary to reach a specified reduction in export?***
5. ***How long would it take for us to observe such a reduction?***

Conceptual model



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Why is this information useful to stakeholders?

Metropolitan Washington
Council of Governments

These data can be used to answer many practical questions.

- Stream salinization is a growing concern, in particular, in urban watersheds.
  1. Where are these issues occurring?
  2. Are conditions getting better or worse, and by how much?
  3. Why are streams becoming more saline?
  4. Are some watersheds at greater risk than others?

- Tracking progress towards meeting regulatory requirements (e.g., chloride TMDL in the Accotink Creek/Long Branch watershed)

- Scenario building and forecasting – if a management action is taken to improve stream condition, how long might it take to achieve the project's stated goals?

- Determining causes of stream impairment – what is the most probable stressor (303d list)? Salinization should be considered alongside many other factors in multi-stressor studies.

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