Freshwater salinization – *causes, consequences, and trends*

Meg Rippy – Assistant Professor of Civil and Environmental Engineering
Occoquan Watershed Monitoring Lab - NOVA

Outline

- Introduction to Urban Freshwater Salinization (the FSS)
  - Scope
  - Scale
  - Why we should care

- Introduction to “Wicked” problems (why the FSS qualifies?)

- Why wickedness matters as we push towards solutions

This talk will stay intentionally broad. The next speaker (Stanley Grant) will provide a more detailed local example of freshwater salinization which has global implications

What do I mean by Freshwater Salinization?

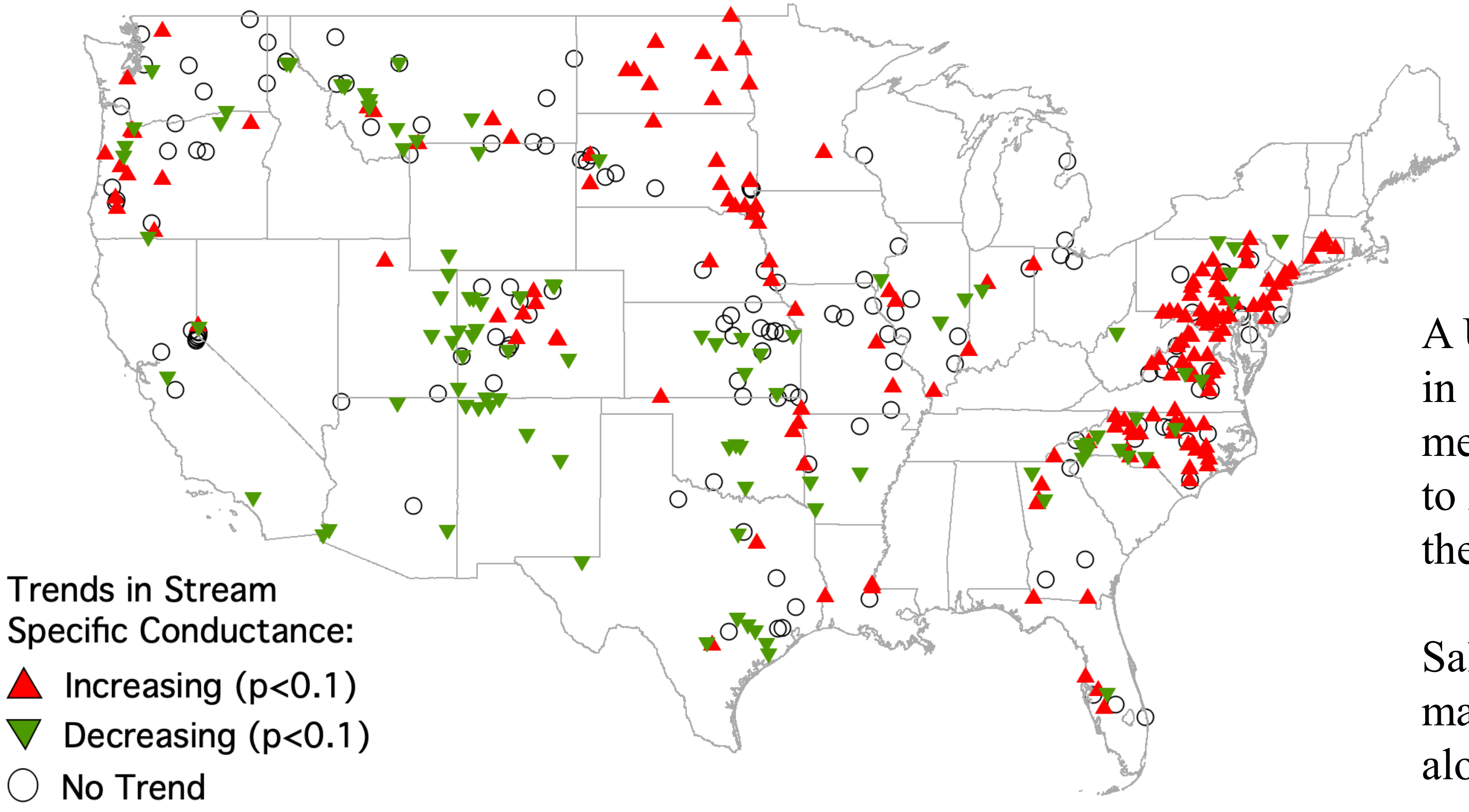
Freshwater salinization refers to the process of increasing ion concentrations, pH, alkalinity, and hardness in our nation's freshwaters over time *(major ions: sodium, chloride, calcium, magnesium, potassium, sulfate)*

Causes are diverse, regionally specific, and complex *(not always agreed upon)*

- Road salts (Na^+, Cl^-, Ca^{2+}, Mg^{2+}): 20 billion tons are applied each year in the US
- Weathering of concrete (Ca^{2+}, Mg^{2+}, alkalinity, pH)
- Inputs of sewage and animal wastes (Na^+, Cl^-, alkalinity)
- Lawn irrigation with recycled water (Na^+, Cl^-)
- Application of lawn fertilizers (N, P, K)
- Use of water softeners (Na^+, Cl^-, K^+)

And many more…..

The scale of the problem is broad *(Continental U.S. View)*



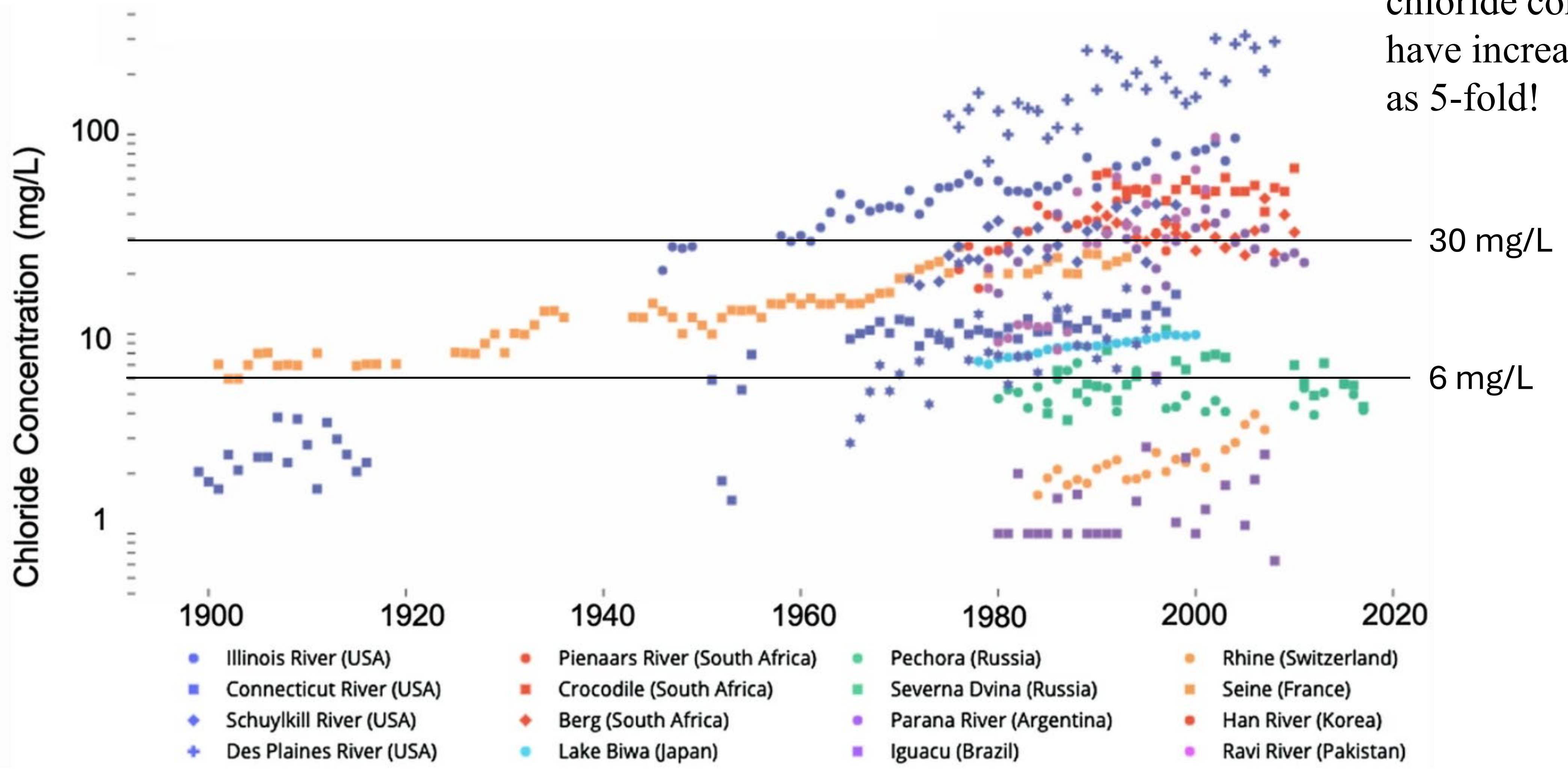
A USGS assessment of trends in specific conductance, a measure of salinity, from 1992 to 2012, in 422 streams across the United States

Salinization is increasing in many regions, particularly along the east coast

Stets, E.G.; Sprague, L.A.; Oelsner, G.P.; Johnson, H.M.; Murphy, J.C.; Rybert, K.; Vecchia, A.V.; Zuellig, R.E.; Falcone, J.A.; Riskin, M.L. Landscape drivers of dynamic change in water quality of US rivers. *Environ. Sci. Technol*. **2020** *54*(7), 4336-4343.

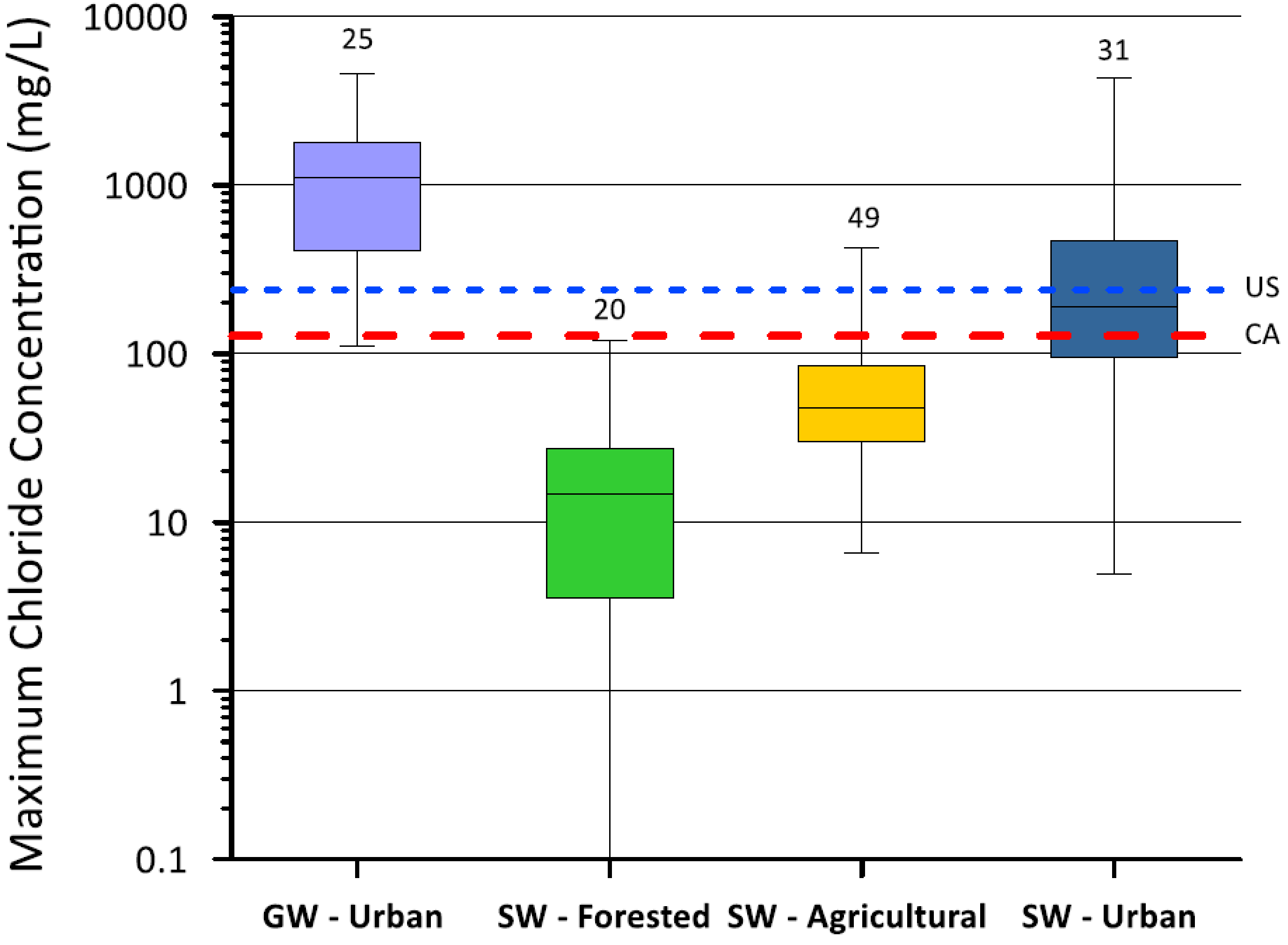
The scale of the problem is broad *(Global View)*

In the past 100 years, chloride concentrations have increased as much as 5-fold!



Kaushal et al., 2021 Freshwater Salinization Syndrome: From emerging challenges to managing risks

Why should we care about freshwater salinization?



We care about the environment

Surface and groundwaters in urban areas often exceed the EPA's chronic aquatic life guidelines, indicating they can be harmful to aquatic life

US: 230 mg/L, CAN: 160 mg/L

Roy, 2019: Endobenthic organisms exposed to chronically high chloride from groundwater discharging along freshwater urban streams and lakeshores

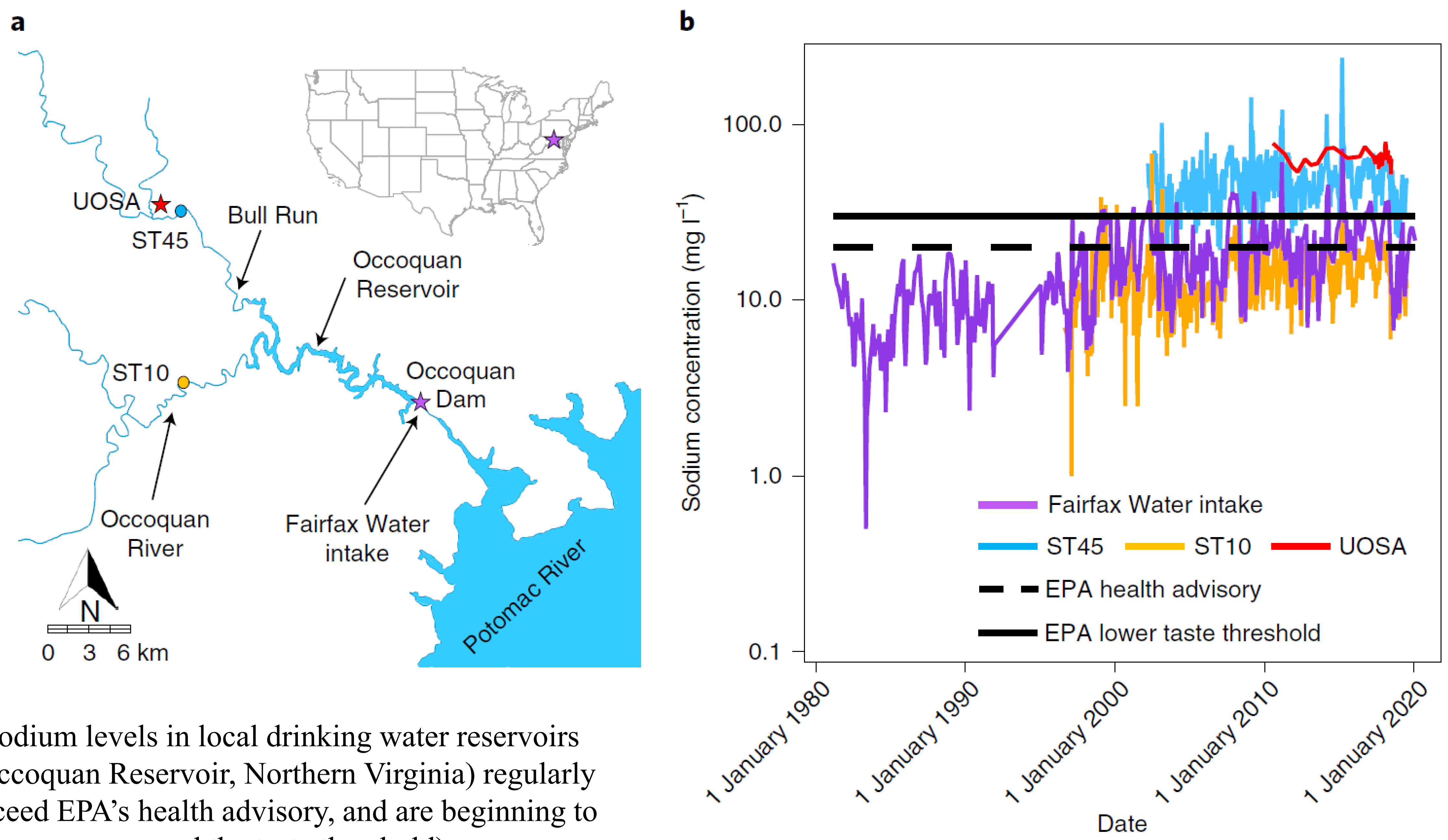
Why should we care about freshwater salinization?

We care about public health

In the state of Virginia, we do not have drinking water thresholds for key ions like sodium that have public health implications, but the US EPA and the WHO do make recommendations that are intended to

1) *Be protective of people on low sodium diets (20 mg/L Na^+)*

2) *Be protective of drinking water taste (30-60 mg/L Na^+)*



Sodium levels in local drinking water reservoirs (Occoquan Reservoir, Northern Virginia) regularly exceed EPA's health advisory, and are beginning to exceed the taste threshold)

Why should we care about freshwater salinization?

We care about our infrastructure

Salt is hygroscopic (it absorbs water from the air) which allows corrosion to occur at lower humidity levels and for longer periods of time than it otherwise would

Salt also increases the capacity of water to carry a current, which speeds up the corrosion process

Chloride can break down protective oxide layers that form on the surface of some metals

Source: Lesik Aleksandr / Dreamstime.com

Corrode metal pipes used to convey water and waste

Corrode metal components of bridges and roads

Replacing corroded infrastructure is a multi-billion dollar proposition

Why should we care about freshwater salinization?

We don't want to have to desalinate our "fresh" water in order to drink it

Not as farfetched as you might believe

Fairfax Water

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January 30, 2020

Stanley B. Grant, PhD
Department of Civil and Environmental Engineering, Virginia Tech
Occoquan Watershed Monitoring Laboratory
9408 Prince William Street
Manassas, Virginia 20110

Over the past twenty years, the continued increase of sodium concentrations in both our source waters, especially in the Occoquan Reservoir, is a source of concern for us. Fairfax Water is collaborating with regional partners in efforts to reduce both point and nonpoint salt discharges with the goal of reversing the observed upward long-term trend of sodium concentrations. As you may be aware, sodium and other inorganic constituents like bromide and chloride are not removed by the water or wastewater treatment technologies currently employed in our region. Therefore, curtailing it at the source is the most viable option, given that the treatment capability to remove sodium can be very expensive, putting it conservatively at over $1 billion. With this objective in mind, Fairfax Water helped support the faculty-stakeholder workshop put together by Virginia Tech on January 14, 2020 to identify research needs and foster collaborations to better address the issue of salinization.

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  - Scope
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- Introduction to “Wicked” problems (why the FSS qualifies)
- Why wickedness matters as we push towards solutions

What is a wicked problem anyways?

1) All wicked problems are unique and novel
2) The solution depends on how the problem is framed and vice versa
3) Stakeholders have radically different worldviews and different frames for understanding wicked problems (this makes them difficult to frame and solve – see 2)
4) The constraints that the problem is subject to, and the resources needed to solve it change over time
5) The problem is never solved definitively
6) Solutions are not strictly right or wrong (may be viewed positively or negatively)
7) They cannot be studied through trial and error. Every trial counts

Common examples: Climate change, homelessness, freshwater salinization

Freshwater salinization has many wicked elements

1) All wicked problems are unique and novel
2) The solution depends on how the problem is framed and vice versa
3) Stakeholders have radically different worldviews and different frames for understanding the wicked problems (this makes them difficult to frame and solve)
4) The constraints that the problem is subject to, and the resources needed to solve it change over time
5) The problem is never solved definitively
6) Solutions are not strictly right or wrong (may be viewed positively or negatively)
7) They cannot be studied through trial and error. Every trial counts

Stakeholders have radically different worldviews and different frames for understanding wicked problems

(this makes them difficult to define and solve)

Contested consequences

"I don't know that there are any impacts [on aquatic life] right now. I haven't seen them"

"I think [the impact of salinization on aquatic life] is going to be really high, because if you exceed the threshold of whatever the species is then it can't make it"

"I don't believe that the change of salt level we are experiencing will have a meaningful impact on corrosion of the distribution system or any concrete structures"

"If you want infrastructure to last long, you want to have less salinization. Obviously, the infrastructure is not going to last long if it gets corroded faster?"

Contested causes

"Everything in the detergent aisle is salty. It is going to be heading to the sewage treatment plant and those salts will wind up in our drinking water"

"Most of the problem is private sector deicer use. Its just not regulated"

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Recognizing freshwater salinization as a wicked problem has important implications for how it is approached

Wicked problems are not "solved" in the conventional sense but rather managed through iterative, adaptive, and participatory processes that acknowledge contested values

This requires innovative approaches that facilitate shared learning *(approaches that clarify how different actors view freshwater salinization, how those views shape perceived risks and solutions, and where opportunities exist for aligning priorities)*

If we accept that freshwater salinization is a wicked problem, then we must also accept that our ability to address it depends not only on biophysical understanding, but on our collective understanding of divergent values and why perspectives about freshwater salinization differ

Wicked problems require new, bottom-up "convergent" approaches for problem solving and salt management that we need to work towards together

Summarize and Conclude

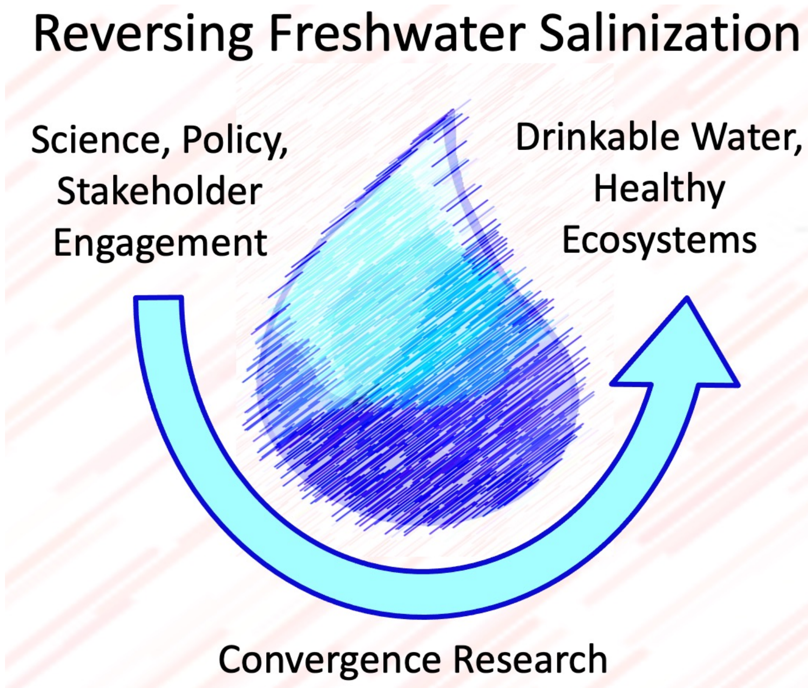
Freshwater salinization is a global challenge with diverse causes and consequences that are regionally specific and complex *(not always agreed upon)*

Freshwater salinization has many elements of a wicked problem (contested values, complexity, uncertainty)

This has implications for how we work together to address it

- Collaborative, iterative, adaptive, and participatory processes that **acknowledge contested values**

Thank You! – ***Any Questions? -***



Freshwater Salinization: A deep dive into the causes of drinking water salinization

Stanley B. Grant

Presentation to Winter Salt Week 2026

1/26/26

Outline

- Rising salinity in the Occoquan Reservoir
- National Science Foundation Stakeholder-Engaged Salt Project
- What we found: three major sources of salt
- Drinking water salinity and road salt
- Next steps: interactive modeling tools for planning, communication, education

Outline

- **Rising salinity in the Occoquan Reservoir**
- National Science Foundation Stakeholder-Engaged Salt Project
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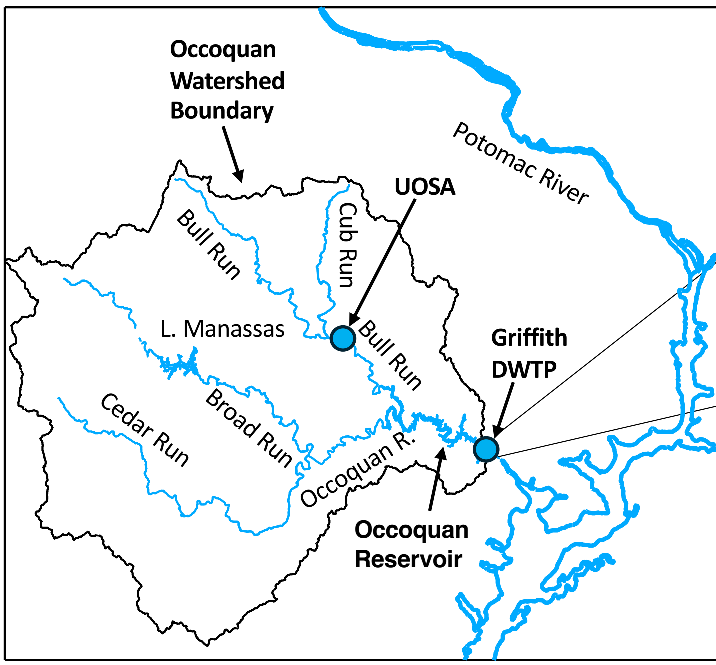
- Next steps: interactive modeling tools for planning, communication, education

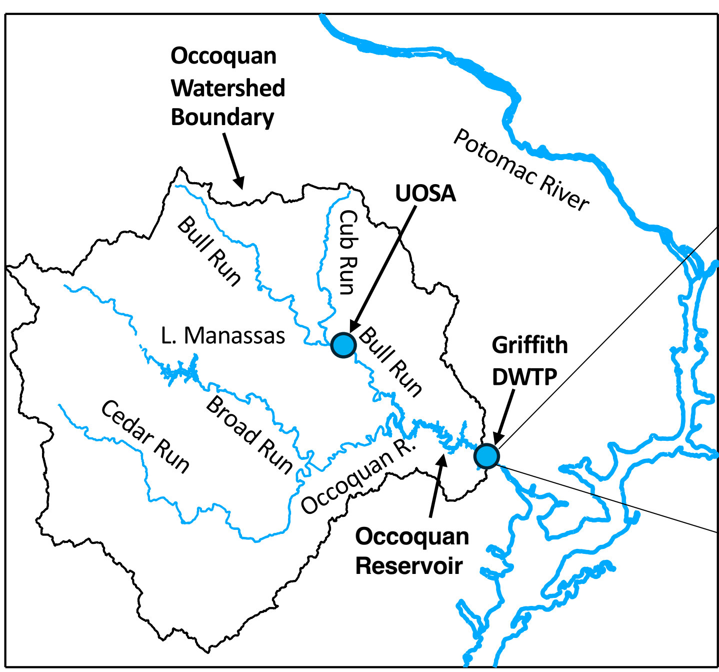
Occoquan Reservoir: Source of drinking water for up to 1 million people

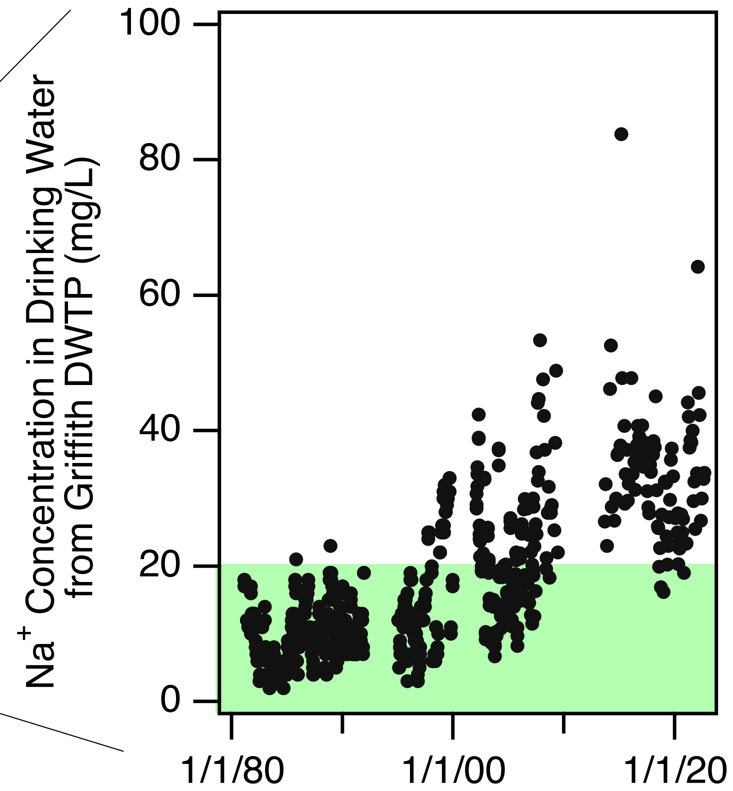


Occoquan Watershed includes ~315,000 acres of mixed urban, agriculture, and forested land-use

- Provides raw water for Fairfax Water's **Griffith Drinking Water Treatment Plant** (DWTP)
- One of the first and largest "One Water" systems in the United States
- Water in the reservoir is from the surrounding watersheds and a water reclamation plant (**Upper Occoquan Service Authority**, UOSA)

Rising Sodium in Griffith Drinking Water





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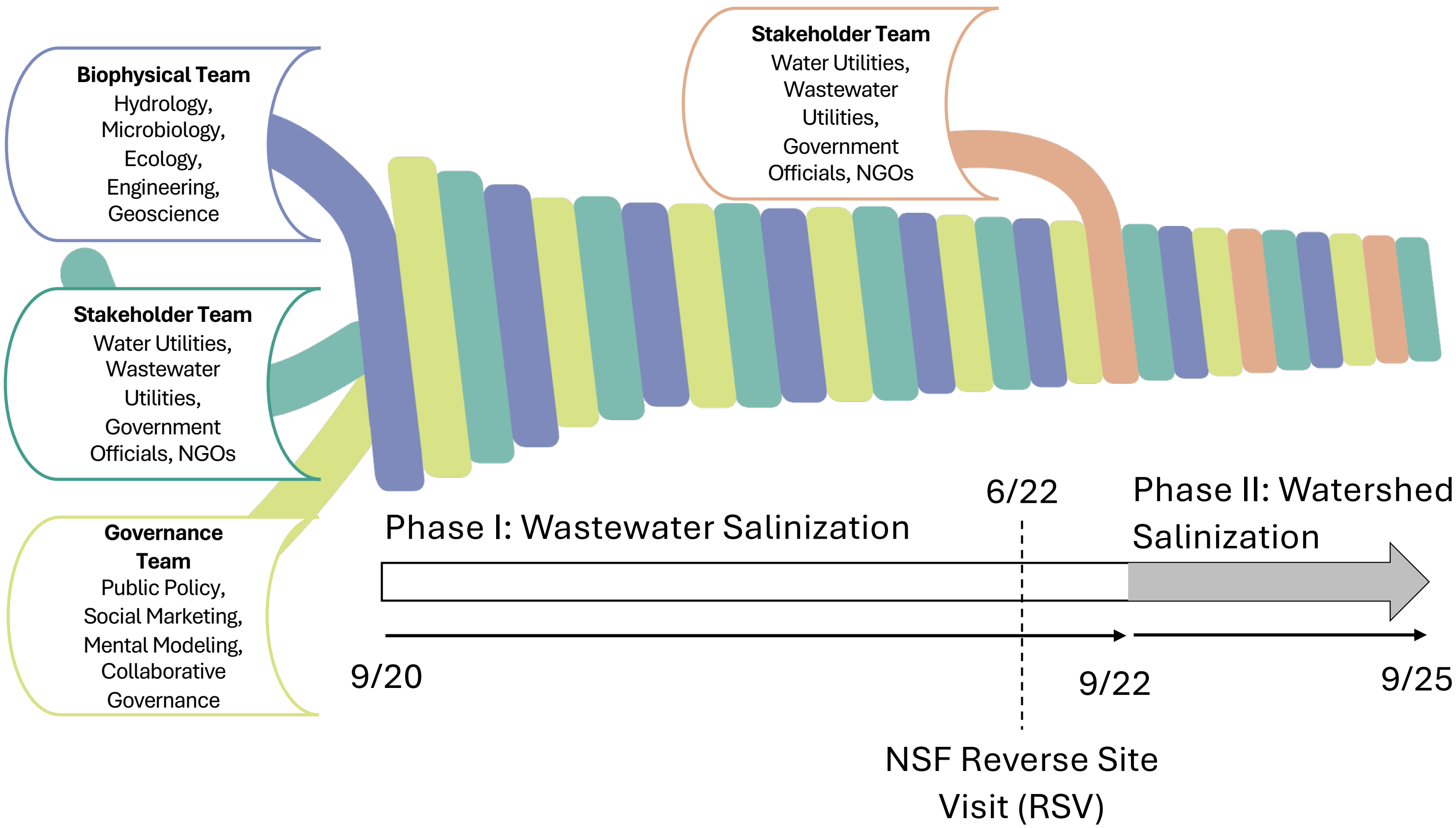
National Science Foundation Growing Convergence Research Salinity Project



VIRGINIA TECH

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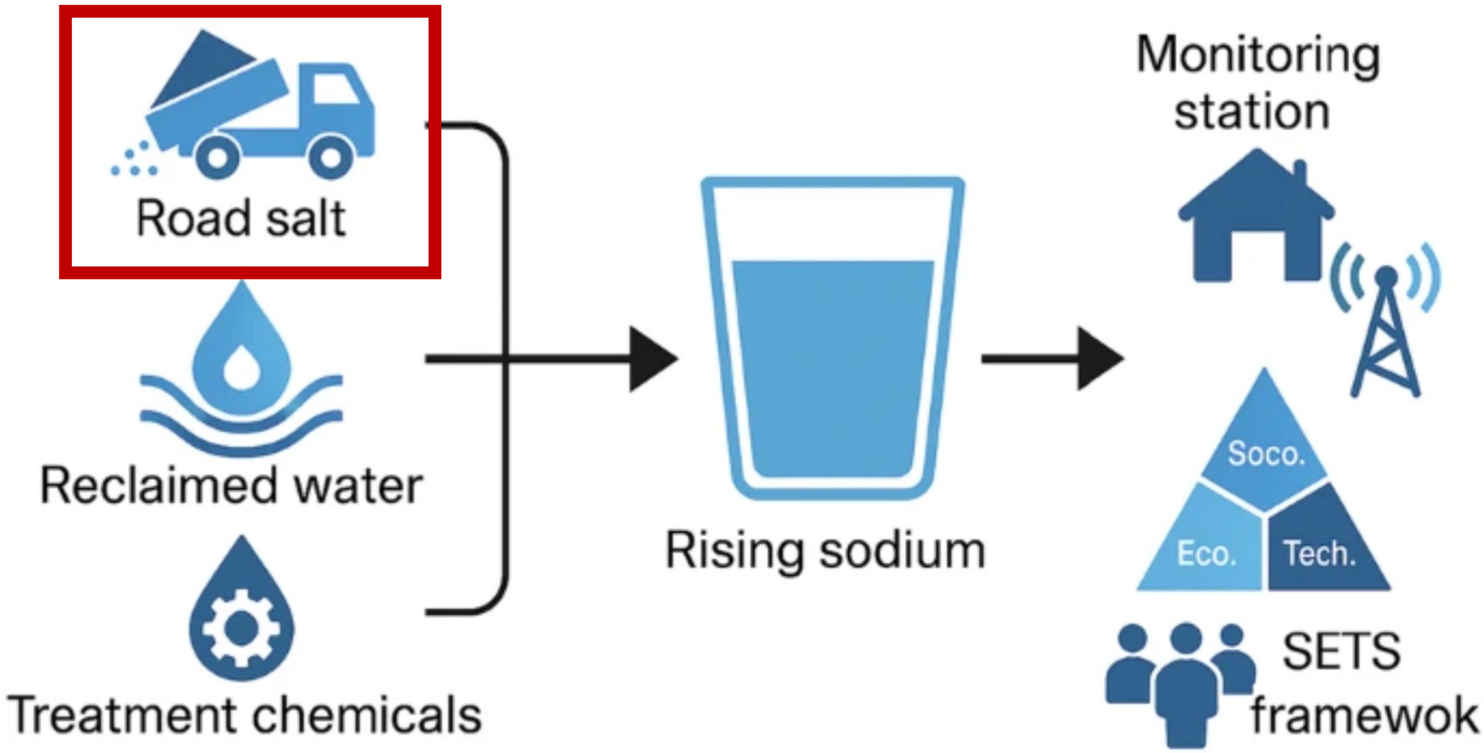
Social-ecological-technological drivers of freshwater salinization in the Occoquan Reservoir, United States

Stanley B. Grant ✉, Shantanu V. Bhide, Anne Spiesman, Shalini Misra, Megan A. Rippy, Christopher S. Galik, Thomas A. Birkland, Todd Schenk, Sujay S. Kaushal, Peter Vikesland, William Knocke, Admin Husic, Harold Post, Chad Coneway, Greg Prelewicz, Brian Steglitz, Bethany Laursen, Kristin Rowles, Shannon Curtis & Ashley Studholme

Communications Earth & Environment , Article number: (2026) | Cite this article



Integrated monitoring and governance to manage rising sodium in One Water systems

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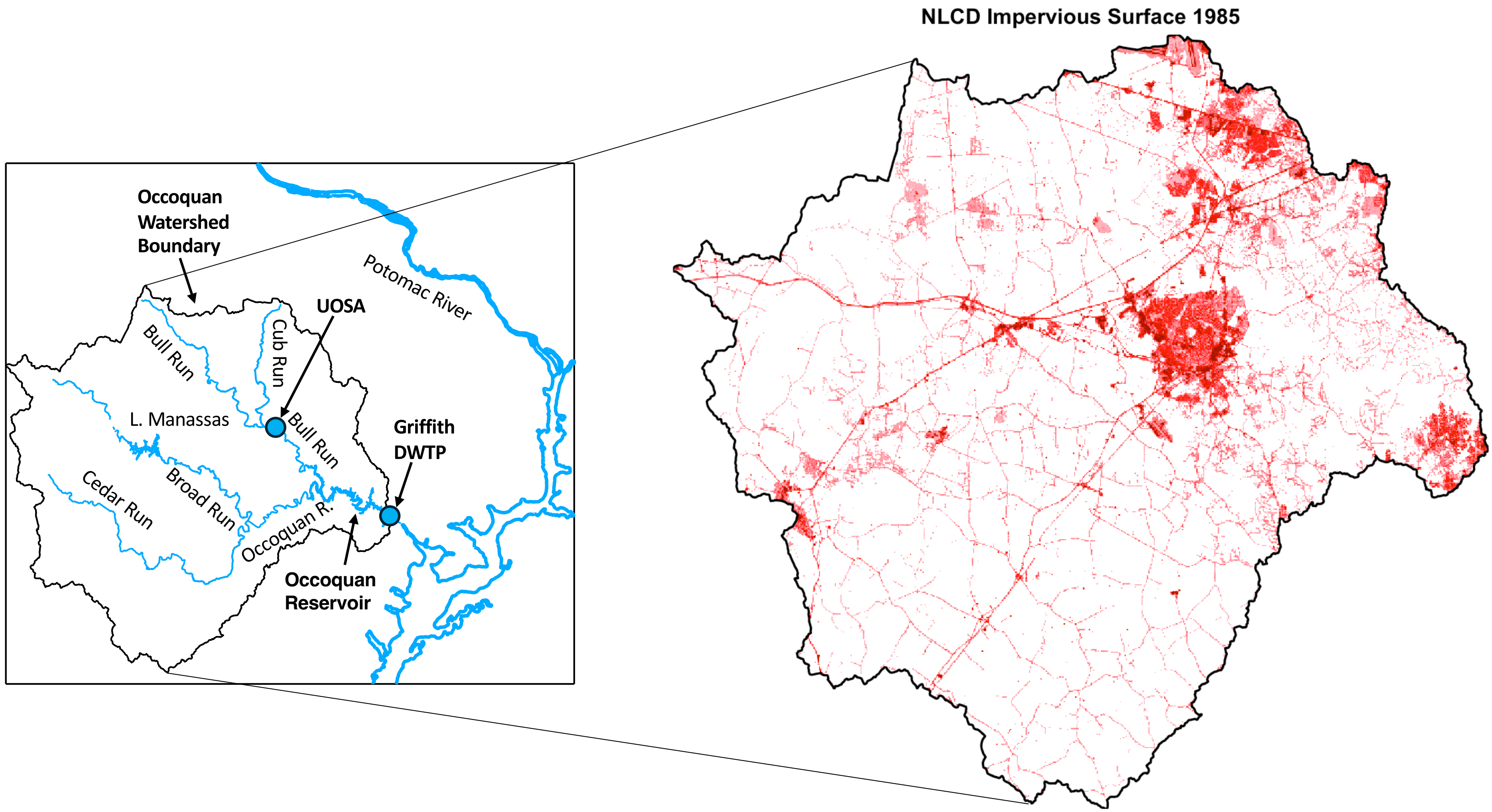
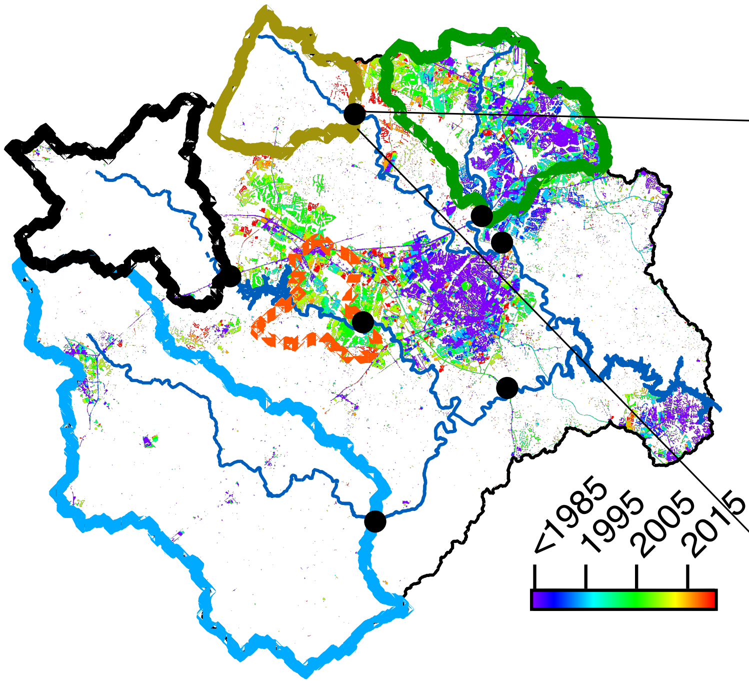
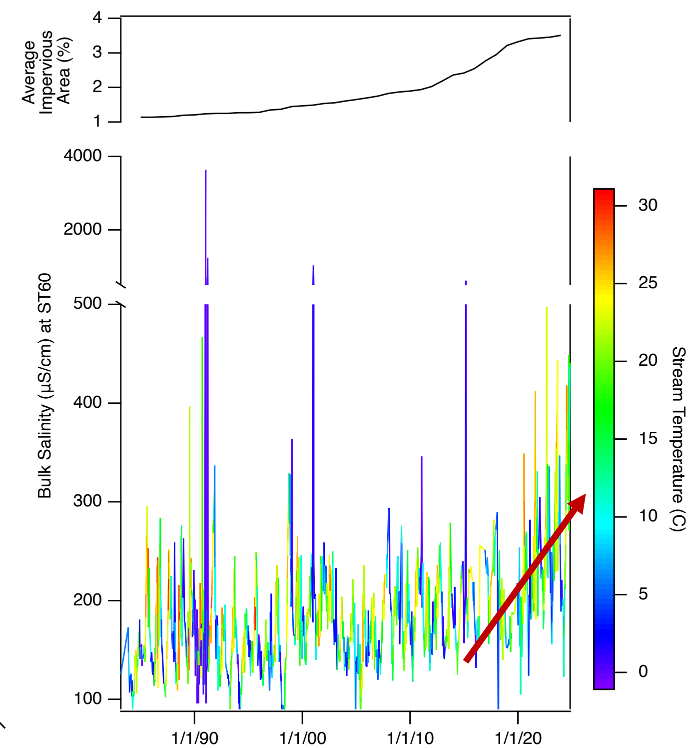

NLCD Impervious Surface 1985
Occoquan
Watershed
Boundary
Potomac River
UOSA
Cub Run
Bull Run
L. Manassas
Bull Run
Griffith
DWTP
Cedar Run
Broad Run
Occoquan R.
Occoquan
Reservoir

Natural experiments: 40-years of monitoring

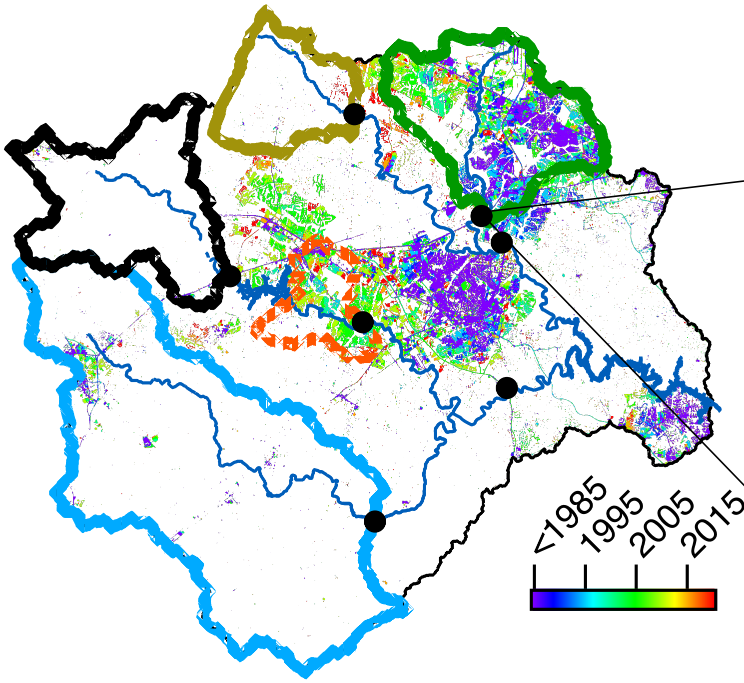
Start seeing salinity impacts downstream at average imperviousness levels as low as 3%!

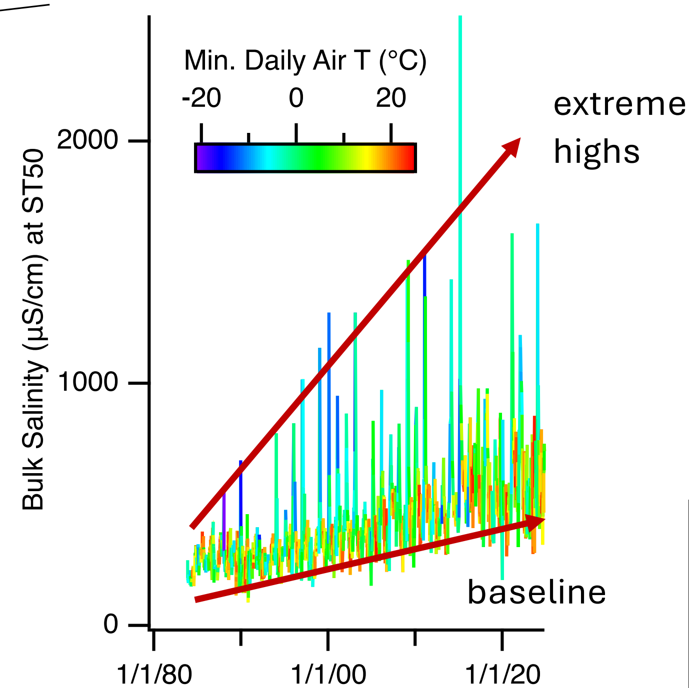




Natural experiments: 40-years of monitoring

As development continues, both the baseline salinity and salinity extremes increase





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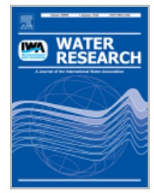

Transit times link pollution sources to drinking water quality in a “One Water” system

Shantanu V. Bhide [a, 1], Stanley B. Grant [a, 1], Paolo Benettin [b], Megan A. Rippy [a], Ahmed Monofy [a], Kirin E. Furst [a], Sydney Shelton [c], Sujay S. Kaushal [c], Shalini Misra [d], Peter J. Vikesland [e], Erin R. Hotchkiss [f], Anne Spiesman [g], Greg Prelewicz [g], Todd Schenk [h], Harold Post [a], Dongemei Alvi [a], Brian Steglitz [i], Admin Husic [a]

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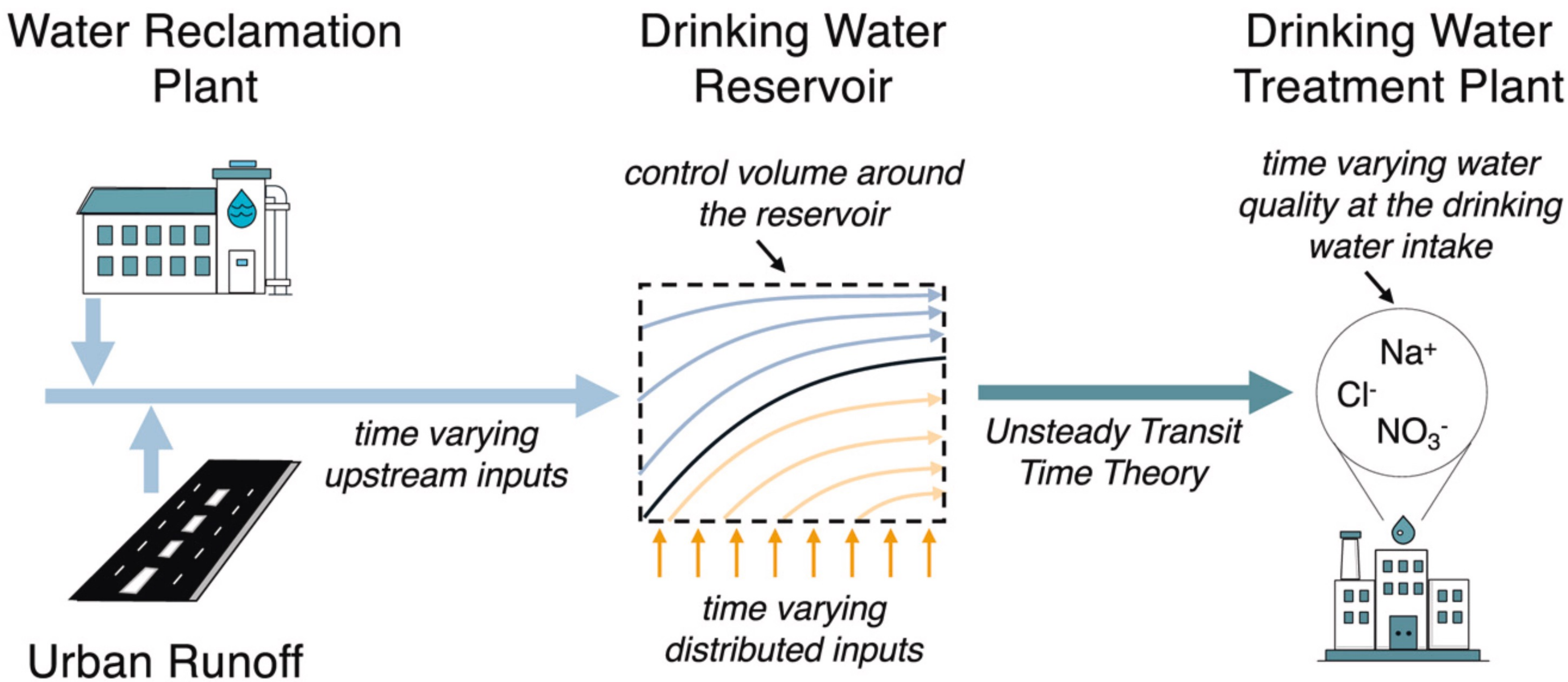
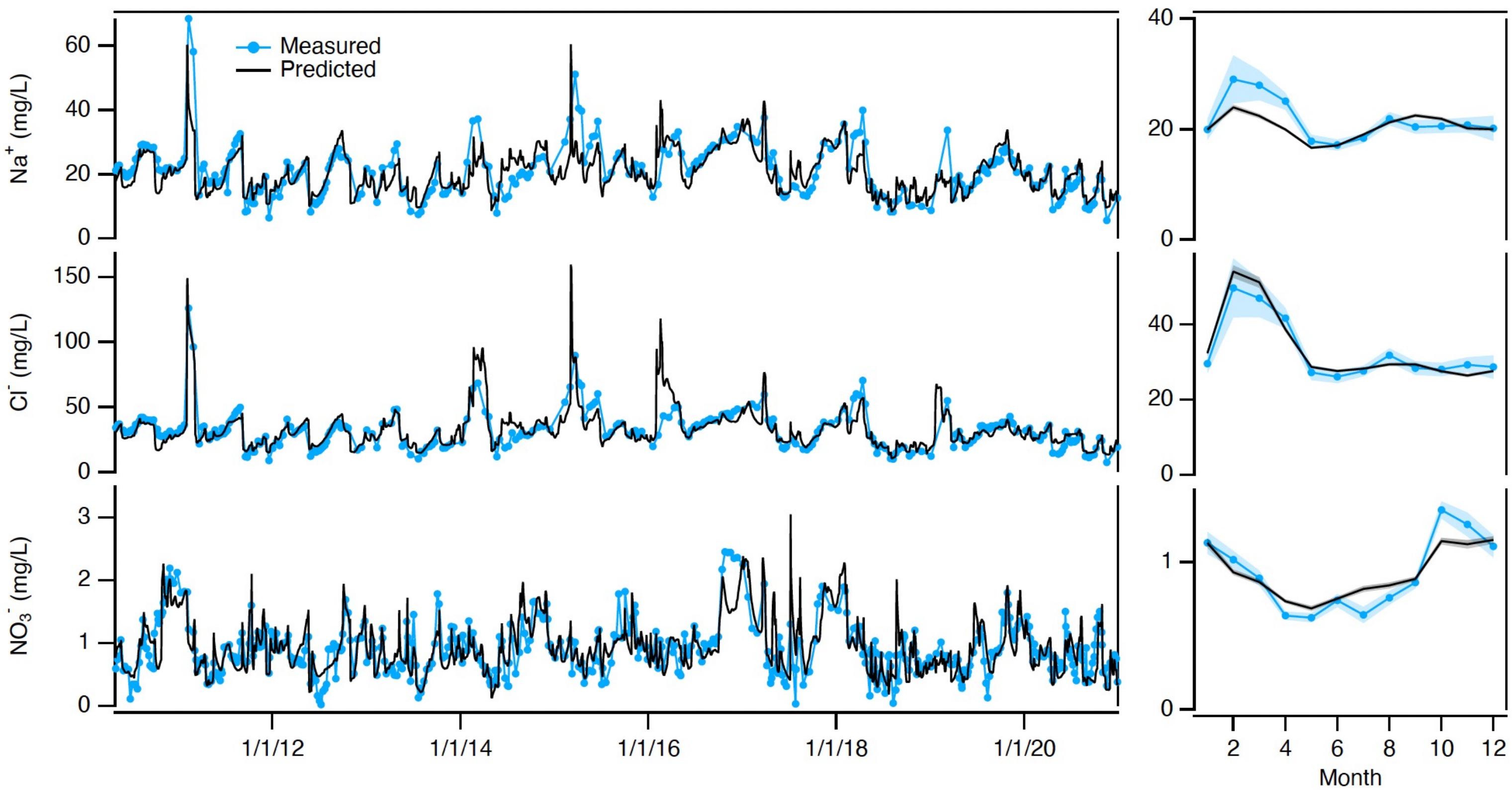
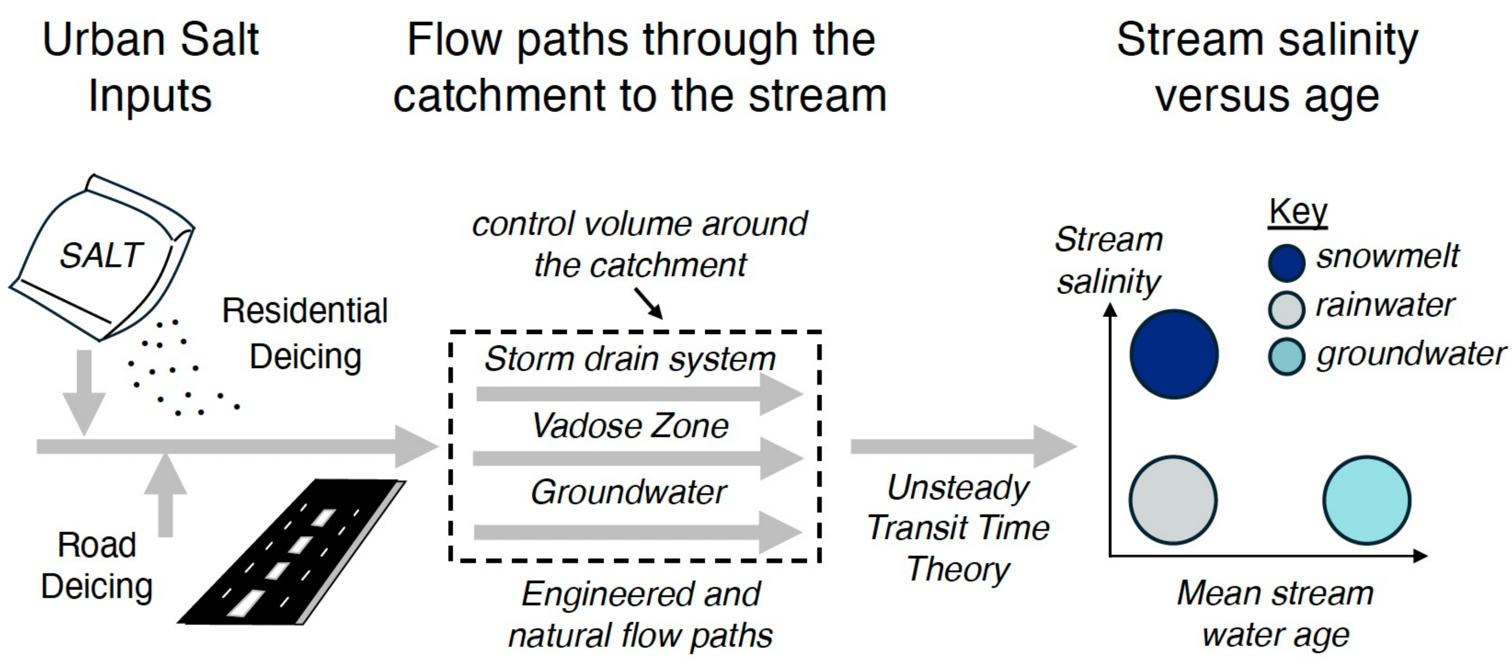

Water Reclamation Plant
Drinking Water Reservoir
Drinking Water Treatment Plant
control volume around the reservoir
time varying water quality at the drinking water intake
Na+
Cl-
NO3-
time varying upstream inputs
Unsteady Transit Time Theory
time varying distributed inputs
Urban Runoff

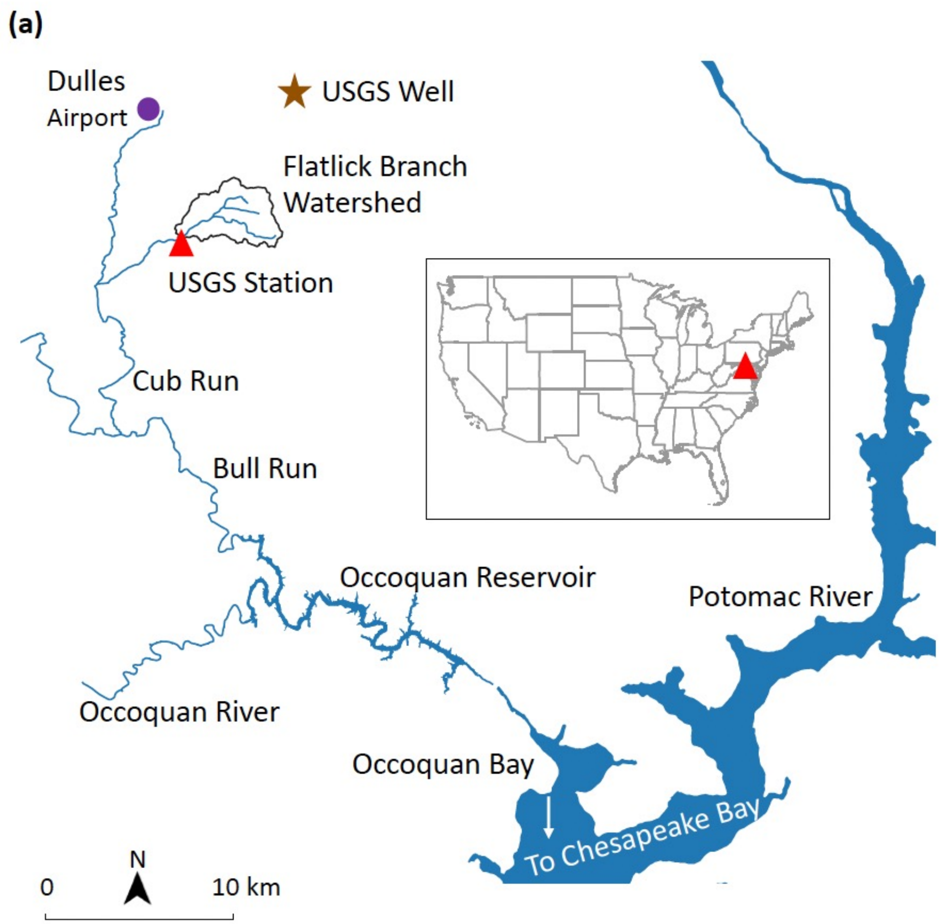
Water quality predictions at the Griffith intake



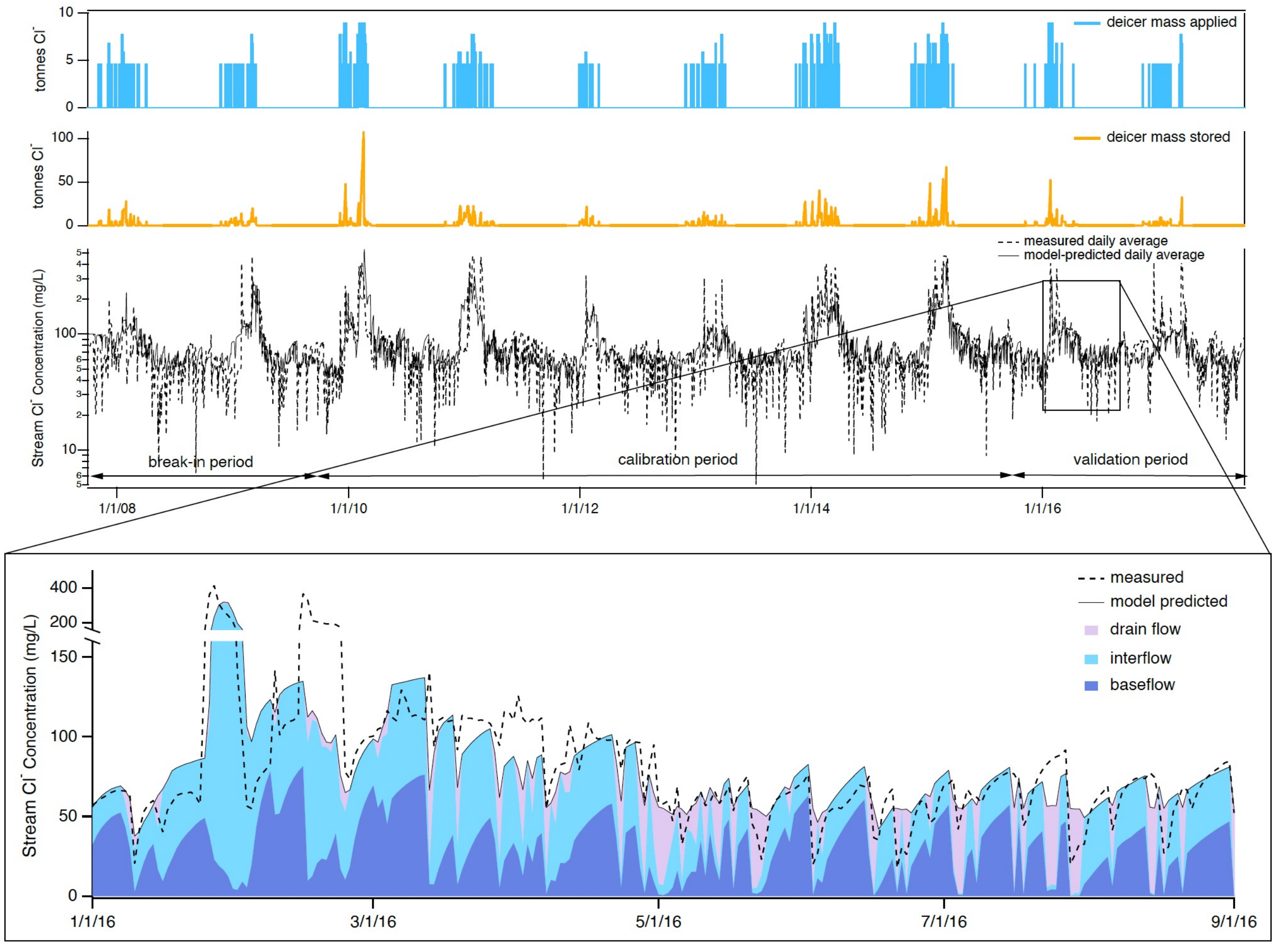
Transit time modeling framework for predicting freshwater salinization in urban catchments

Shantanu V. Bhide, Stanley B. Grant, Kevin McGuire, Karen Prestegaard, Sujay S. Kaushal, Andrew Sekellick, Megan A. Rippy, Todd Schenk, Shannon Curtis, Jesus D. Gomez-Velez, Erin R. Hotchkiss, Peter Vikesland, Siddharth Saksena





- Flatlick Branch
  - Small (10.9 km^2) watershed
  - 20,000 residents (2010 census)
  - **95% classified as developed land cover (NLCD)**
    - 29% Developed Open Space
    - 40% Low-Intensity Development



Model Results

- Reproduces measured chloride concentrations over daily-to-decadal timescales
- **Inferred 206 tonnes of deicer chloride deposited per year**
- This corresponds to around 30 g chloride per person per year

Interactive model play (if we have time)!


Thank you!