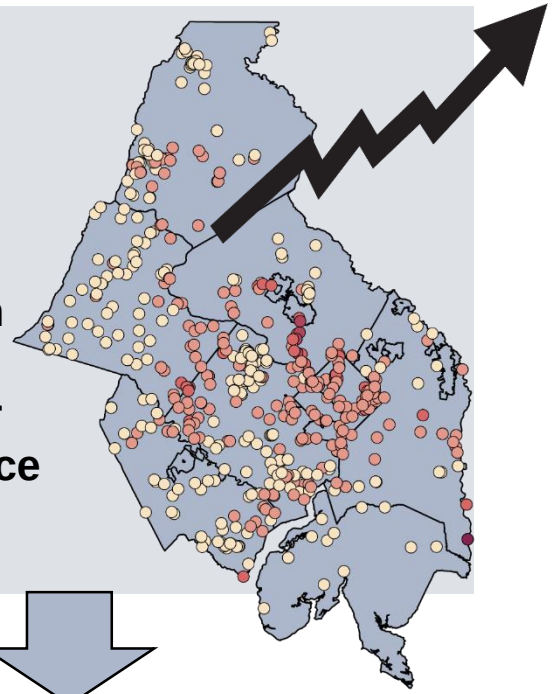
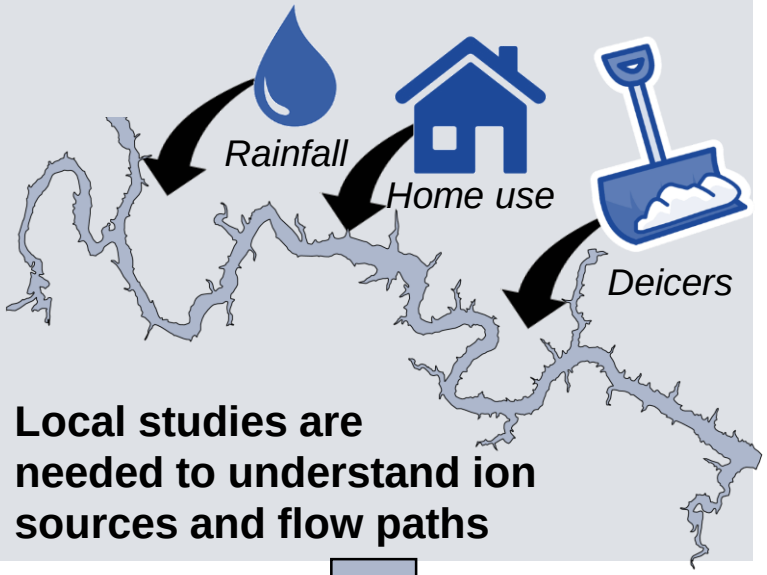
Establishing a Science Partnership to Support Understanding of the Freshwater Salinization Gradient in the Metropolitan Washington, D.C. Region

Contributions from Joe Galella, Carly Maas, Joe Malin, Ruth Shatkay, Alexis Yaculak, and others

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

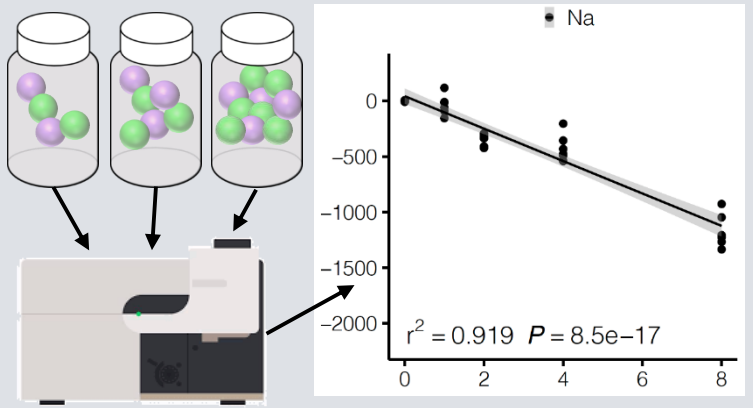
Monitoring networks can characterize patterns over time and space





Local 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

Synoptic Update: Where Does Salt End Up?

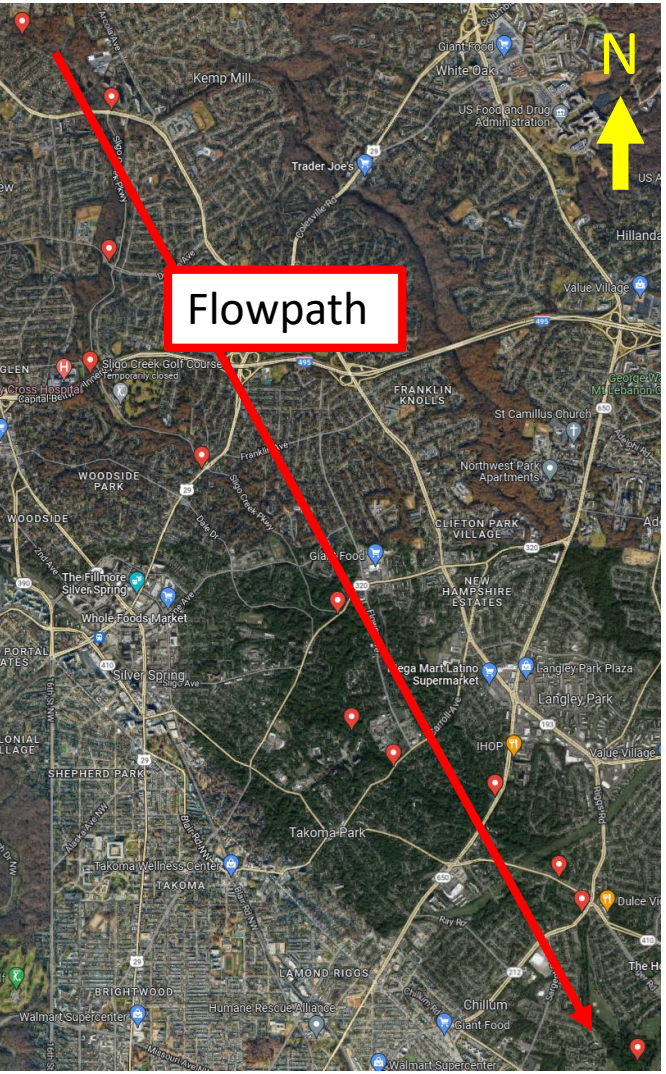
- Can we manage transport of salt along stormwater BMP flowpaths?
- Can we manage fate and transport of salt along watersheds?

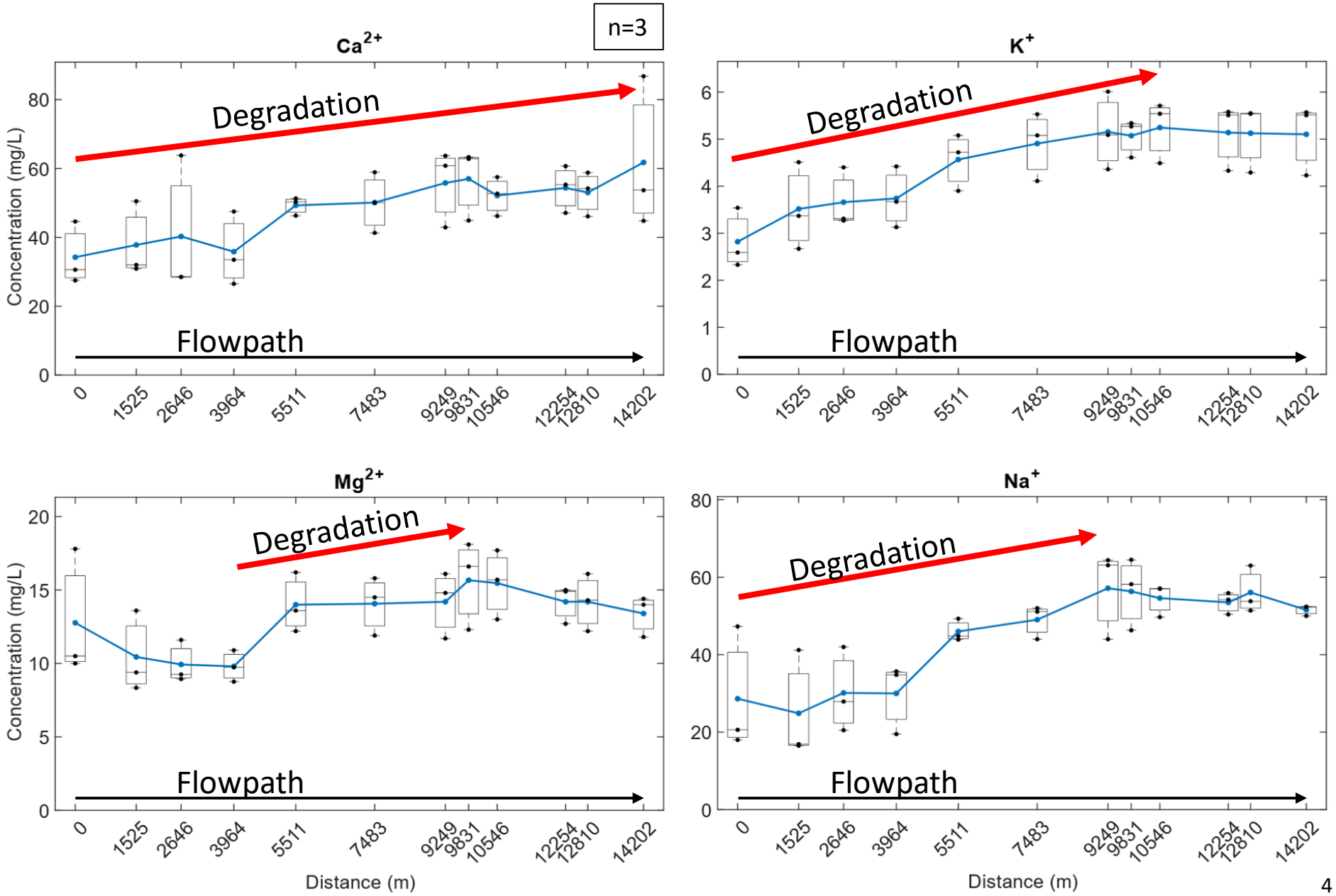
Managing Salt: How Much Can Be Retained in Stormwater Management Best Management Practices?

Retention and Release of Salts, Nutrients, and Metals in Different Stormwater Management Features

Photo Courtesy: Kelsey Wood

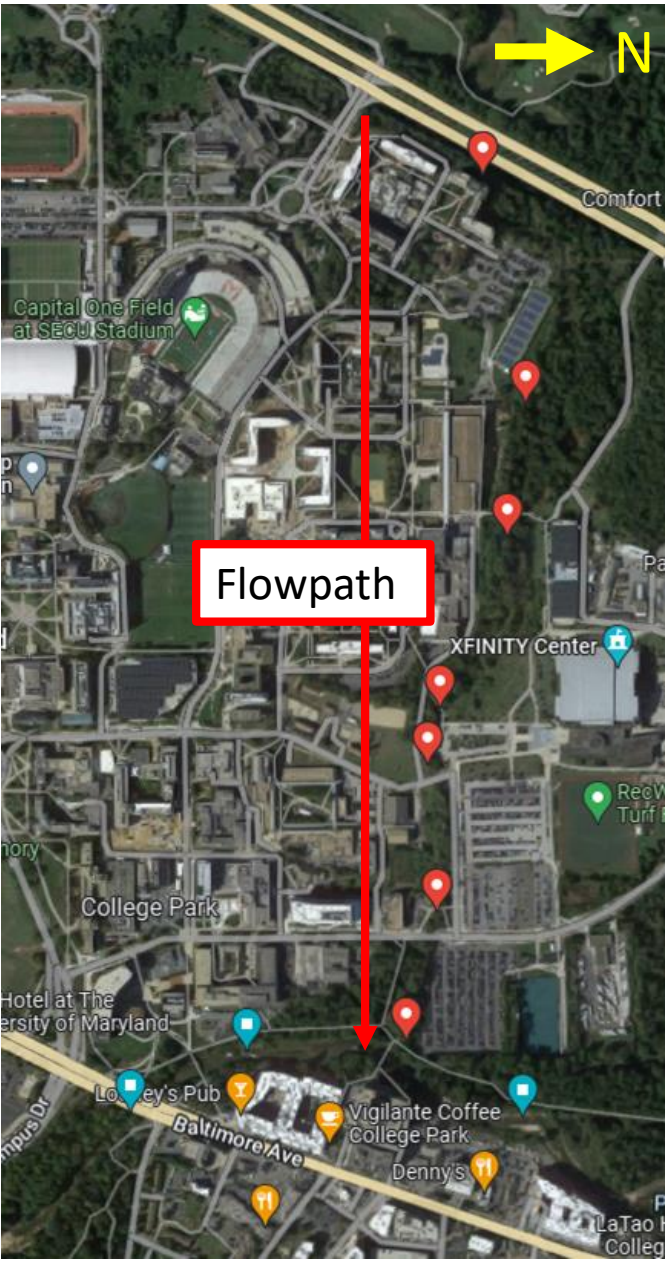
Sligo Creek (Minimal Hydrologic Connection = Degradation)

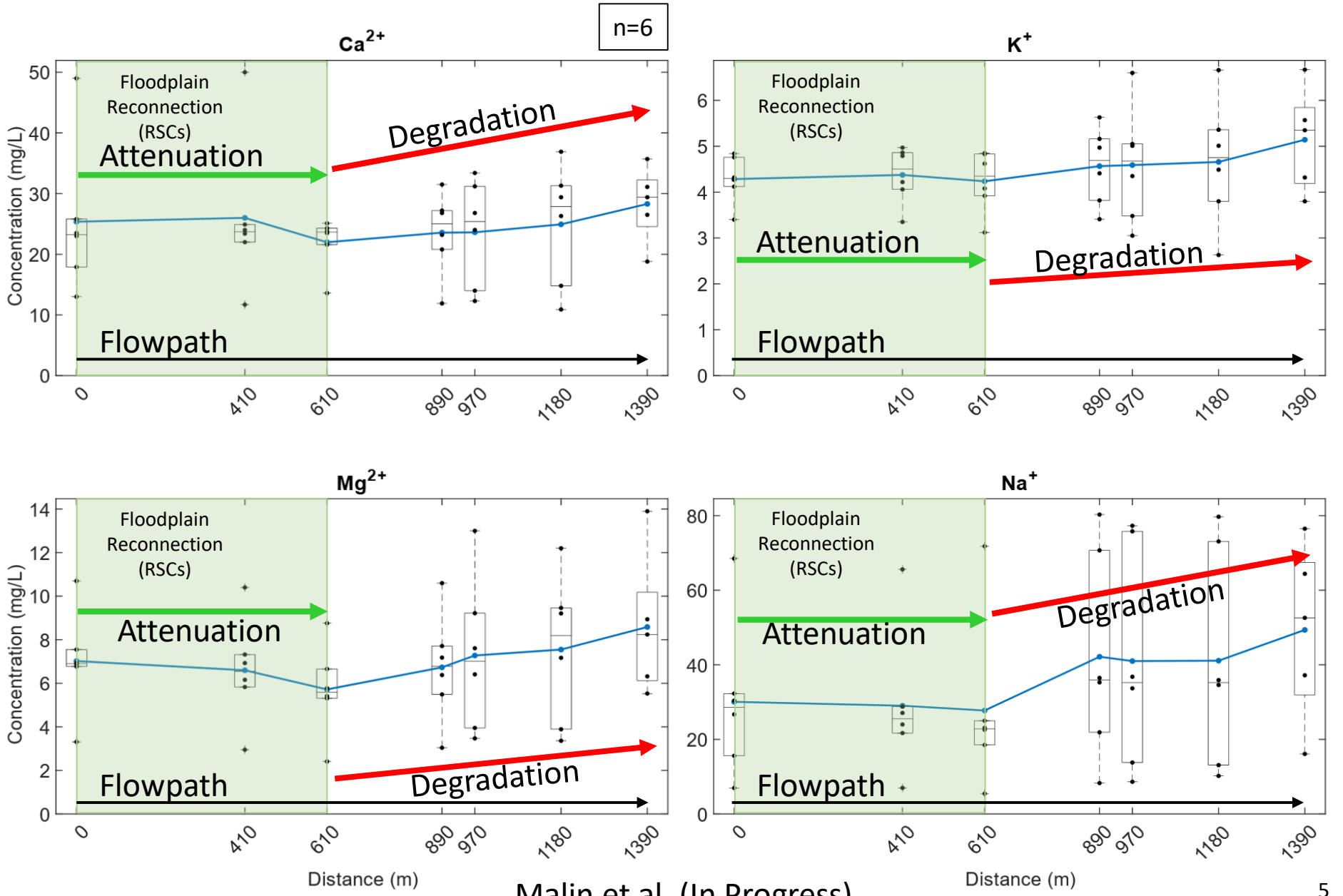




Malin et al. (In Progress)

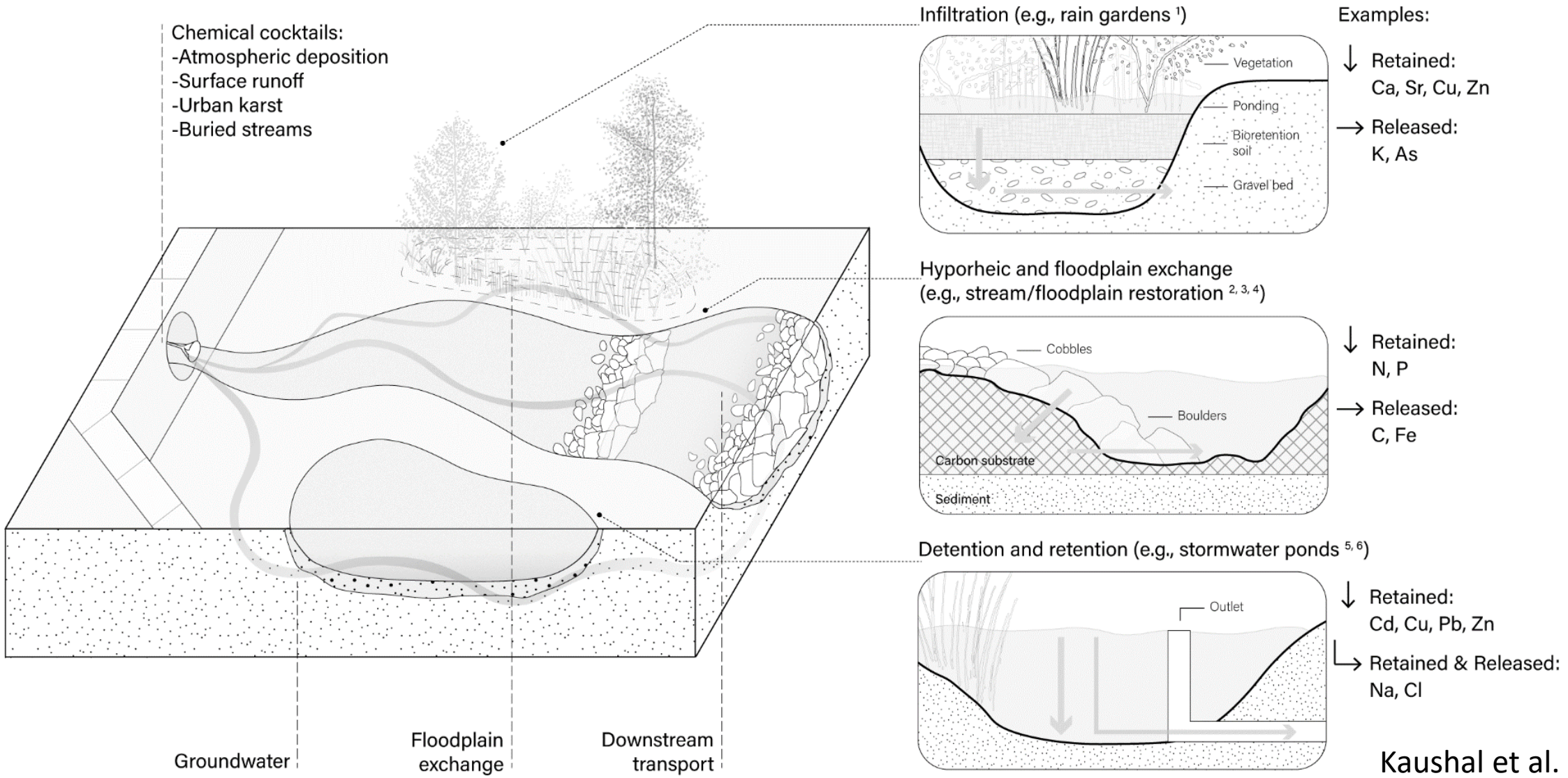
Campus Creek (Highest Connection with Floodplain)



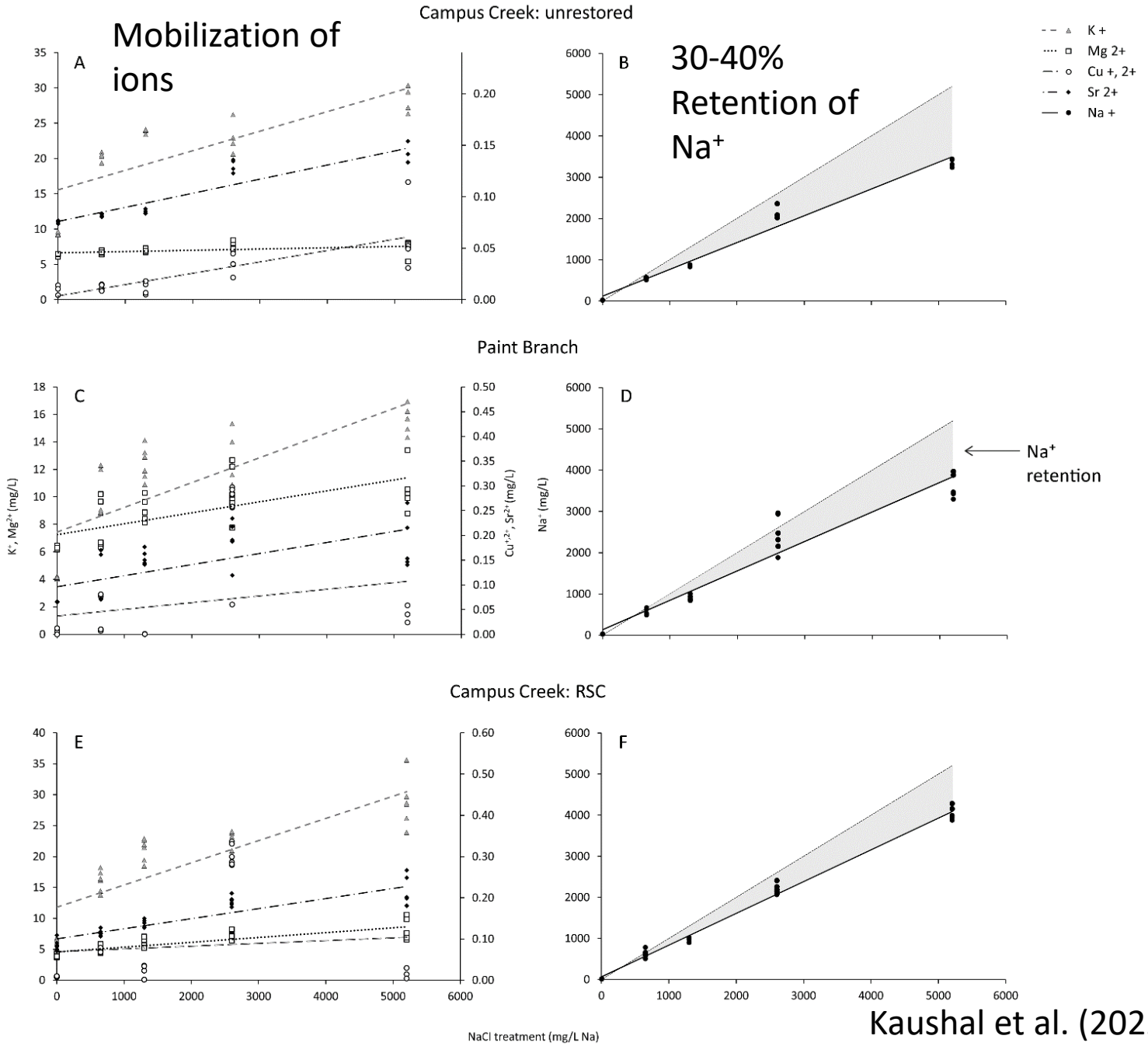


Malin et al. (In Progress)

Retention and release of chemical cocktails along stream and stormwater flowpaths



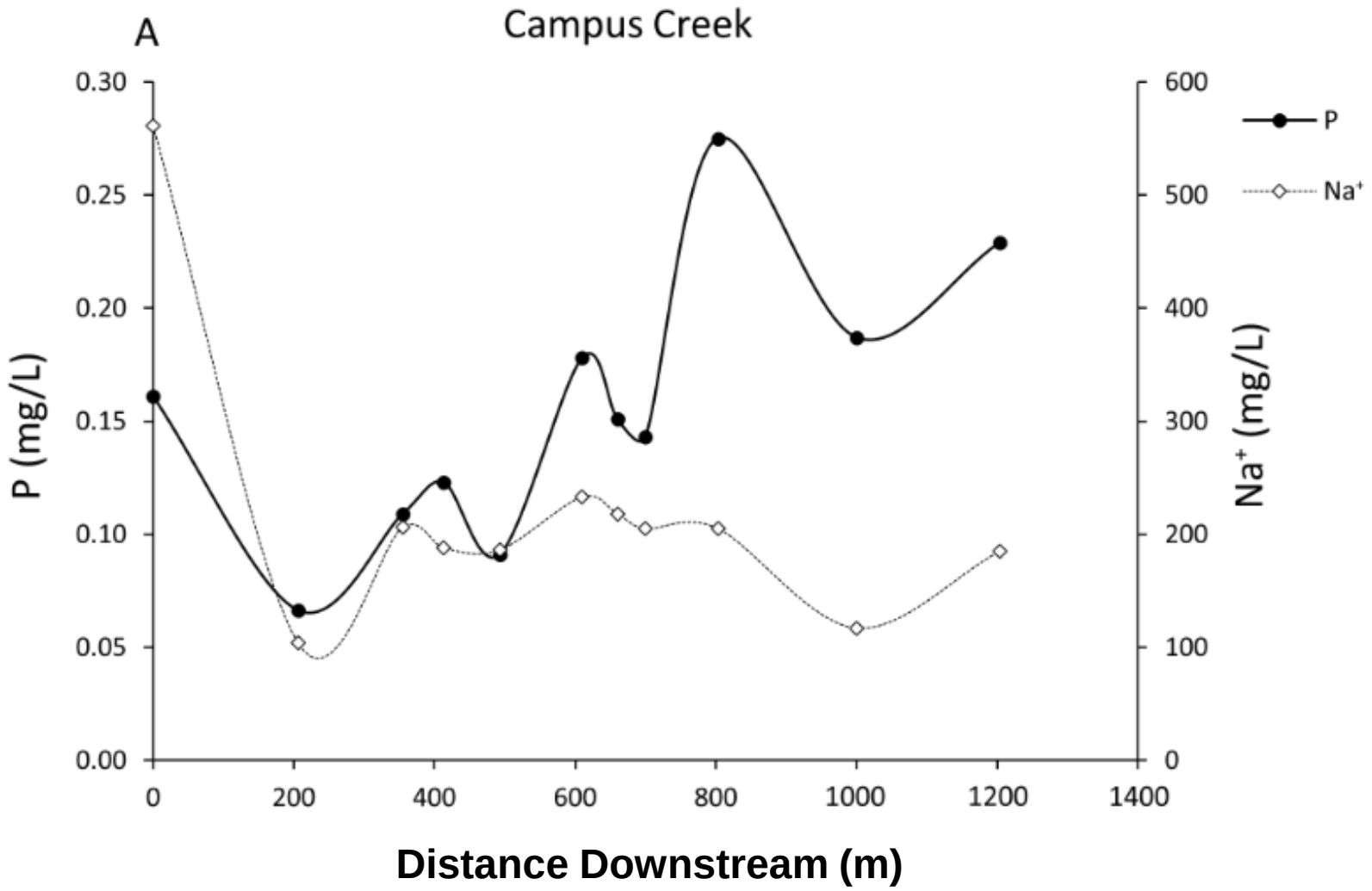
Kaushal et al. (2022b)
Freshwater Science



Stormwater Best Management Practices (BMPs) can retain substantial amounts of salt ions

Kaushal et al. (2022b)
Freshwater Science

Salinization Can Mobilize Phosphorus along Flowpaths

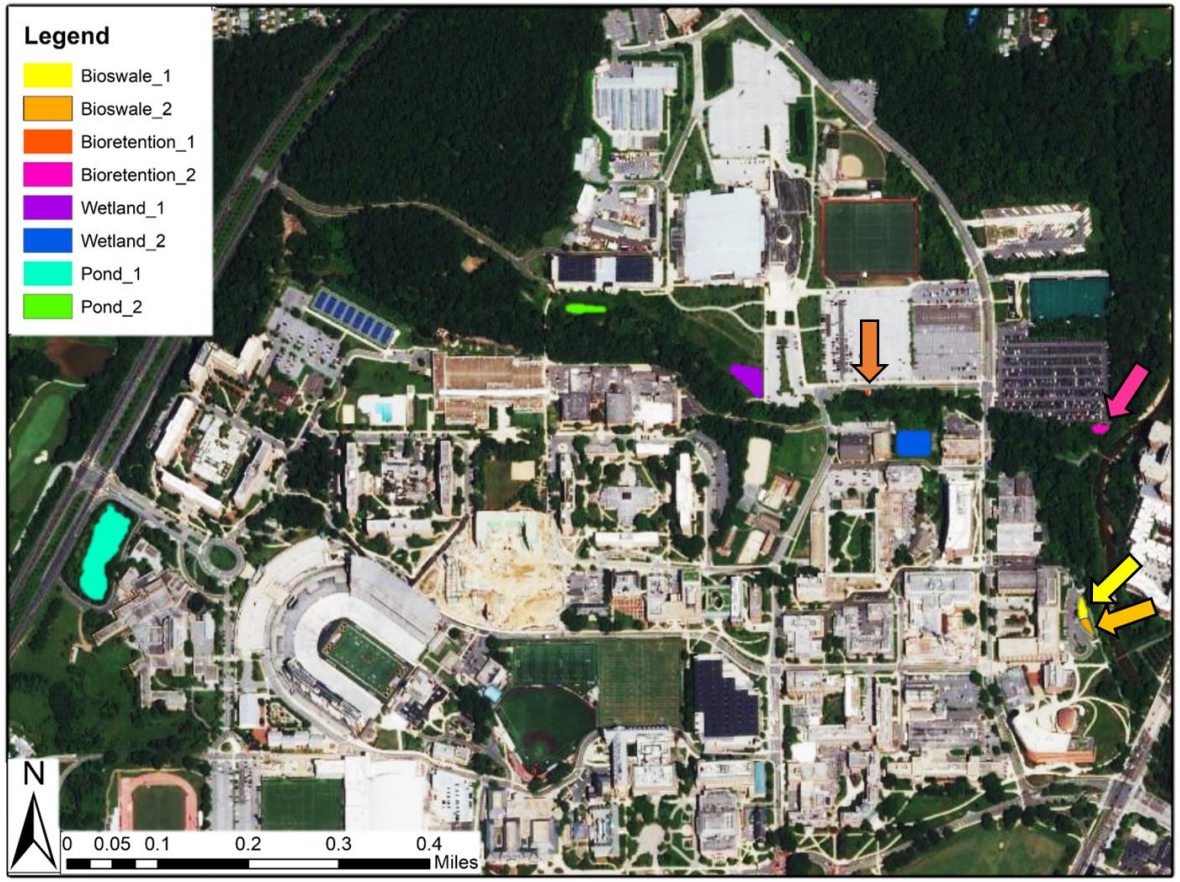


Kaushal et al. (2022b)
Freshwater Science

Study Sites:

- 4 different stormwater management features (with replicates)
- Sites range from 5 to 33 years in age and were almost always constructed concurrently with a building or large area of impervious surface coverage
- Stream restoration sites and regenerative stormwater conveyance (RSC) systems

Galella et al. (In Review)




Bioswale #1


Bioretention #1


Wetland #1

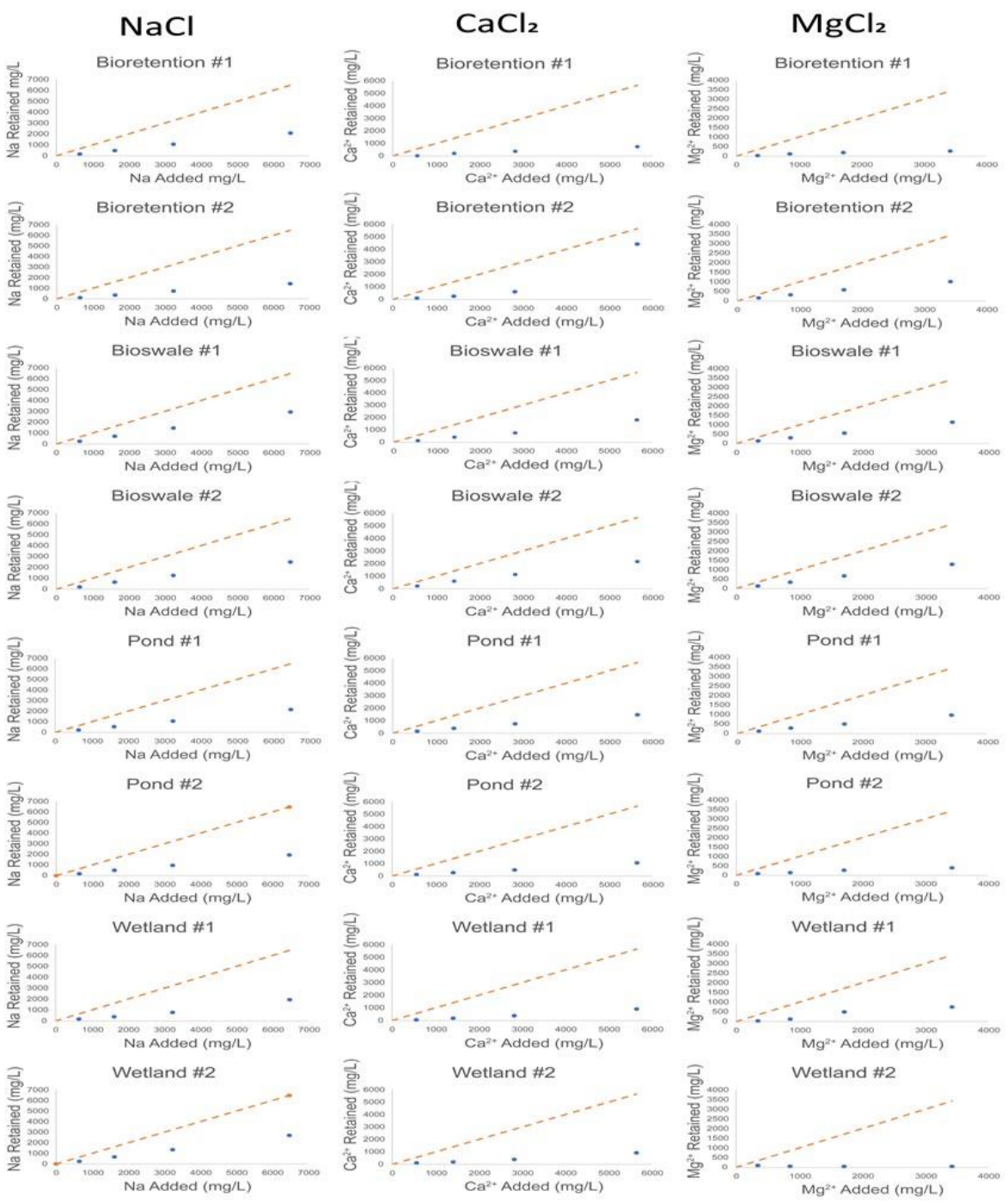

Pond #1


Bioswale #2


Bioretention #2


Wetland #2


Pond #2



Stormwater BMPs retain:

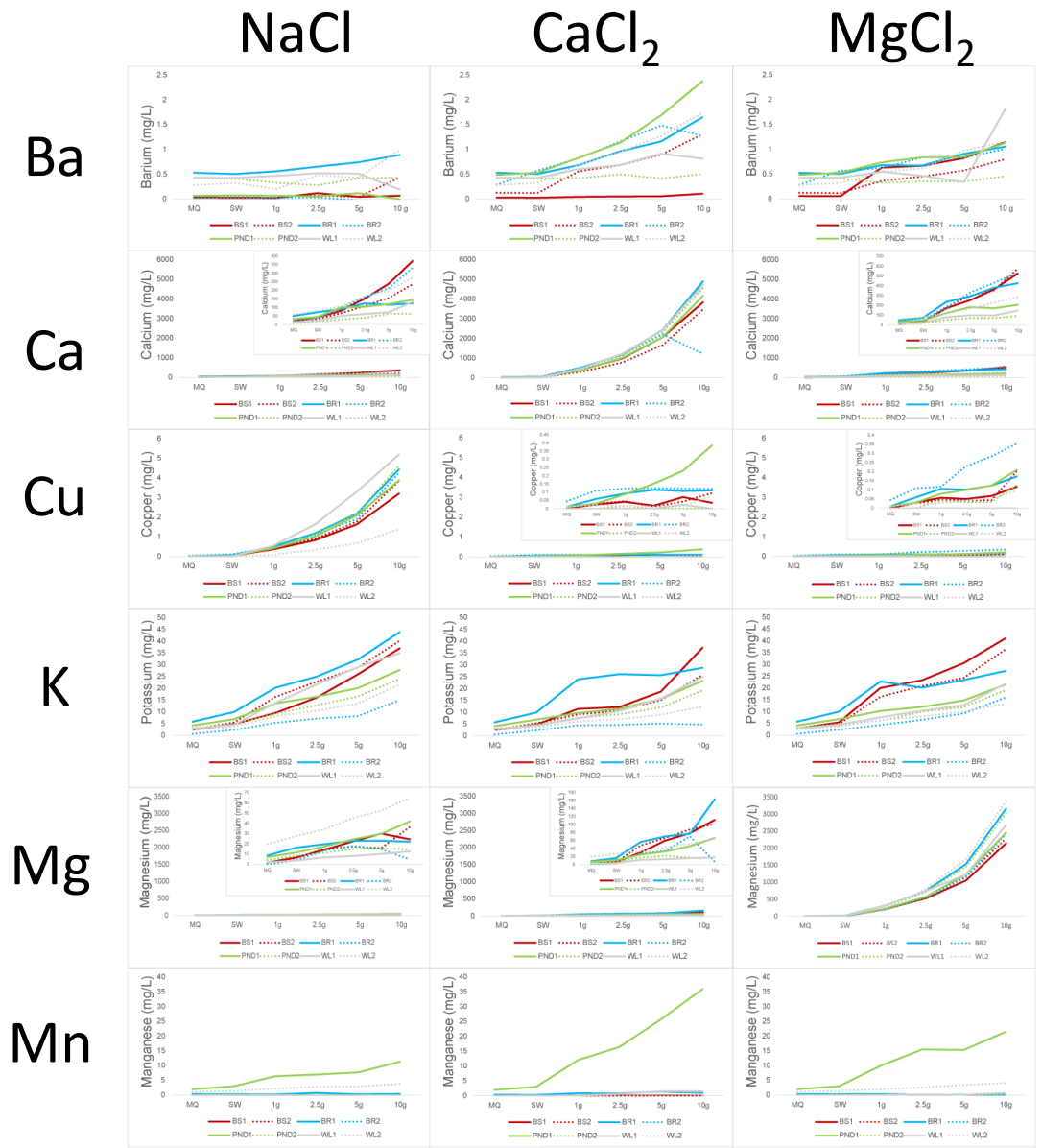
34% Na^+

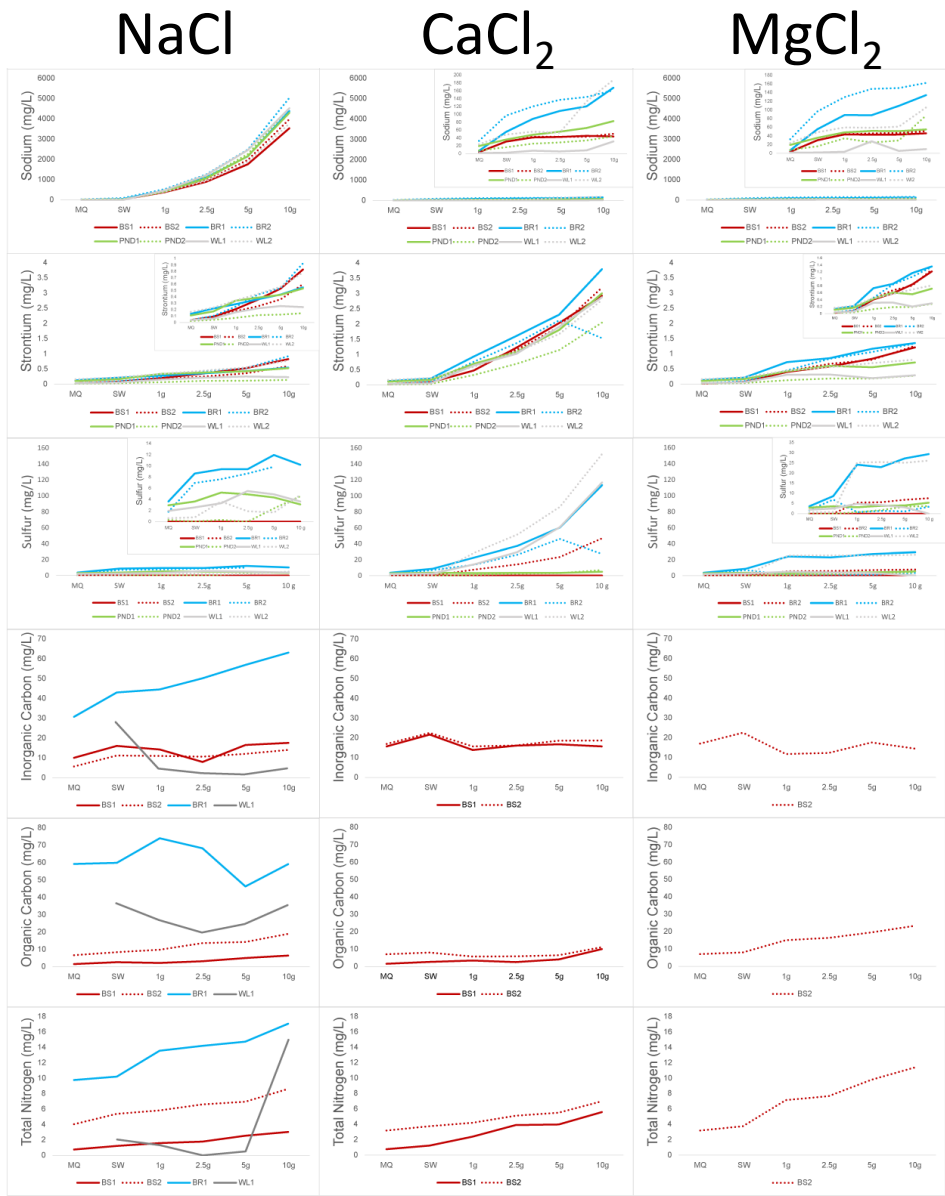
28% Mg^{2+}

26% Ca^{2+}

Significant differences among BMPs Galella et al. (In Review)

Salts Mobilize Multiple Elements





Galella et al. (In Review)

Salts Mobilize Multiple Elements

NaCl

Element	BS1	BS2	BR1	BR2	PND1	PND2	WL1	WL2
B	**0.99**	0.00	0.21	**0.50**	0.07	**0.49**	**0.54**	**0.41**
Ba^{2+}	0.07	**0.43**	**0.67**	**0.69**	**0.94**	0.06	**0.44**	**0.85**
Ca^{2+}	**0.98**	**0.92**	**0.54**	**0.93**	**0.71**	**0.76**	**0.94**	**0.93**
Cu	**0.99**	**0.99**	**1.00**	**1.00**	**1.00**	**1.00**	**0.97**	**1.00**
Fe	**0.47**	**0.37**	0.04		0.18	**0.42**	**0.74**	0.01
K^{+}	**0.96**	**0.88**	**0.88**	**0.90**	**0.89**	**0.93**	**0.85**	**0.95**
Mg^{2+}	**0.55**	**0.83**	0.36	0.04	**0.92**	**0.45**	**0.84**	**0.89**
Mn	0.00	0.12	0.01	0.28	**0.81**	0.12	0.17	**0.81**
Na^{+}	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
S			0.27	**0.53**	0.04	**0.91**	0.06	0.31
Sr^{2+}	**0.97**	**0.96**	**0.87**	**0.94**	**0.73**	**0.75**	**0.55**	**0.94**

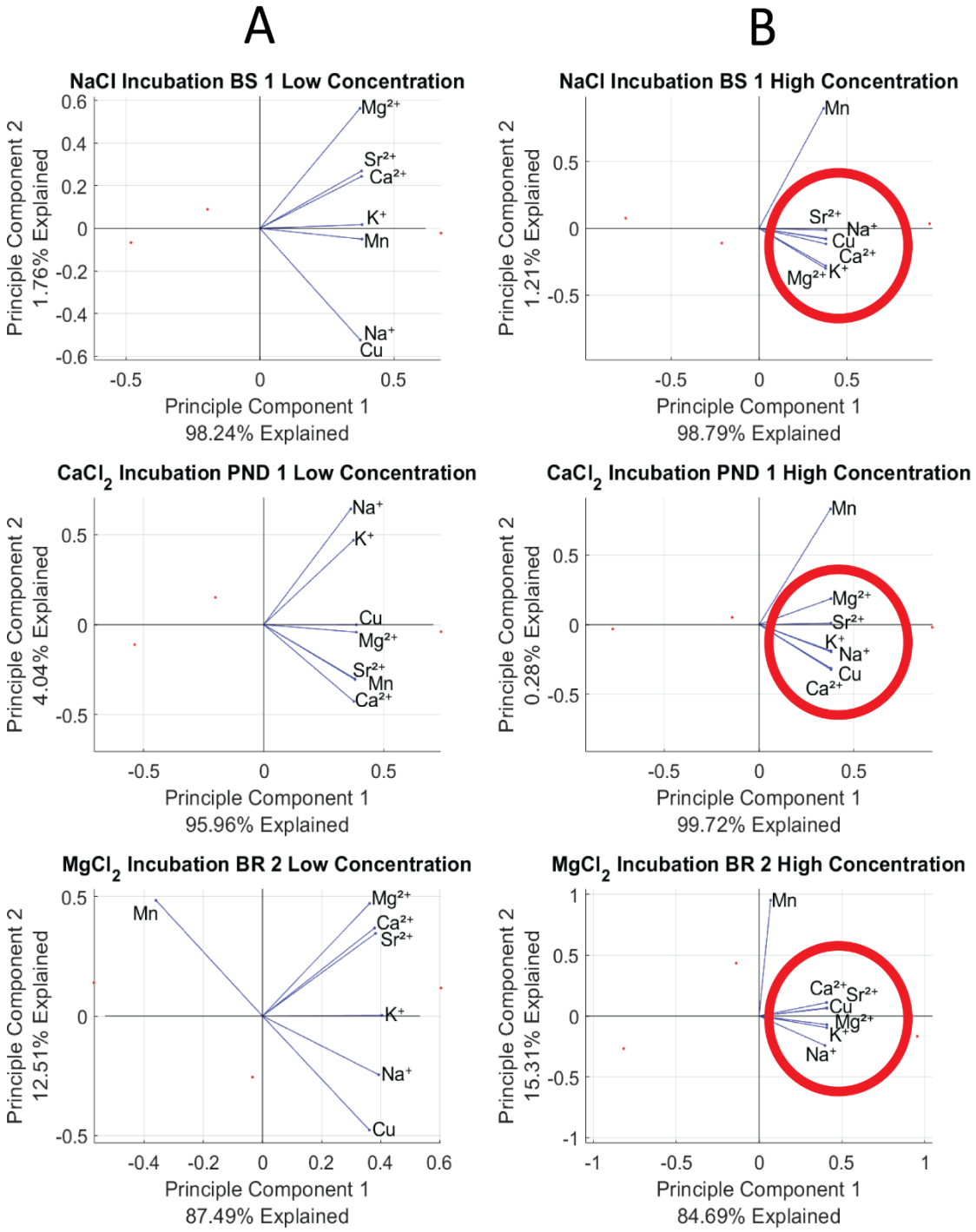
$CaCl_2$

Element	BS1	BS2	BR1	BR2	PND1	PND2	WL1	WL2
B	**0.99**	0.19	**0.81**	**0.32**	**0.64**	**0.41**	**0.54**	0.20
Ba^{2+}	0.30	**0.89**	**0.97**	**0.54**	**0.97**	0.37	**0.51**	**0.93**
Ca^{2+}	**1.00**	**1.00**	**1.00**	**0.43**	**1.00**	**1.00**	**1.00**	**1.00**
Cu	0.02	**0.48**	0.38	0.16	**0.98**	0.07	0.03	0.15
Fe	0.35	0.37	0.36		**0.80**	0.34	0.11	0.28
K^{+}	**0.97**	**0.96**	**0.51**	0.38	**0.96**	**0.96**	**0.98**	**0.92**
Mg^{2+}	**0.91**	**0.76**	**0.93**	0.03	**0.93**	0.22	**0.65**	**0.87**
Mn	**0.60**	0.05	0.15	0.12	**0.92**	0.17	**0.76**	**0.88**
Na^{+}	0.32	**0.41**	**0.78**	**0.55**	**0.83**	**0.82**	**0.54**	**0.94**
S		**0.99**	**0.99**	**0.42**	**0.56**	**0.97**	**1.00**	**0.99**
Sr^{2+}	**0.95**	**0.98**	**0.97**	**0.53**	**0.98**	**0.99**	**0.96**	**0.99**

$MgCl_2$

Element	BS1	BS2	BR1	BR2	PND1	PND2	WL1	WL2
B	0.22	0.23	0.00	0.28	0.26	**0.58**	**0.40**	0.04
Ba^{2+}	**0.78**	**0.87**	**0.84**	**0.62**	**0.81**	0.10	**0.68**	**0.84**
Ca^{2+}	**0.92**	**0.92**	**0.75**	**0.84**	**0.65**	**0.72**	**0.69**	**0.91**
Cu	**0.80**	0.16	**0.63**	**0.82**	**0.92**	**0.65**		**0.60**
Fe	0.17	**0.43**	0.36	0.01	0.24	0.33	0.13	**0.11**
K^{+}	**0.87**	**0.84**	**0.58**	**0.97**	**0.93**	**0.94**	**0.95**	**0.90**
Mg^{2+}	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
Mn	0.10	**0.90**	0.23	0.07	**0.79**	0.01	**0.88**	**0.87**
Na^{+}	**0.40**	0.33	**0.68**	**0.48**	**0.45**	**0.51**	0.04	**0.78**
S	**0.47**	**0.60**	**0.55**	0.01	**0.64**	**0.65**	0.15	0.39
Sr^{2+}	**0.91**	**0.91**	**0.78**	**0.84**	**0.68**	**0.73**	0.23	**0.81**

Galella et al. (In Review)



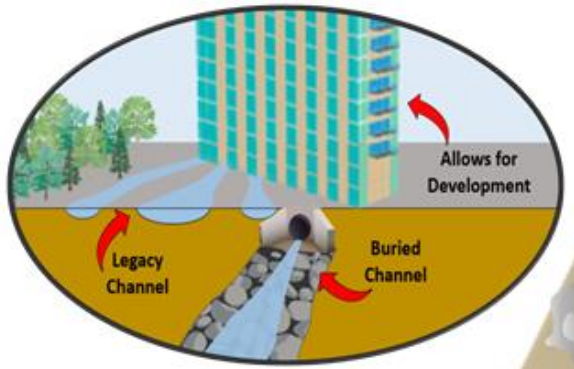
Different types of road salts mobilize different types of chemical cocktails

Galella et al. (In Review)

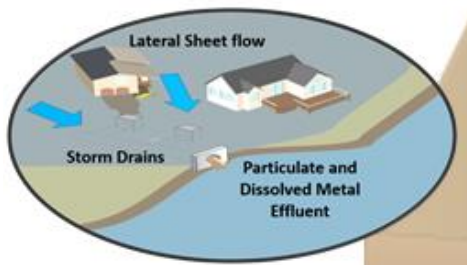
Can we manage fate and transport of salt along watersheds?

The Urban Watershed Continuum's Chemical Cocktails

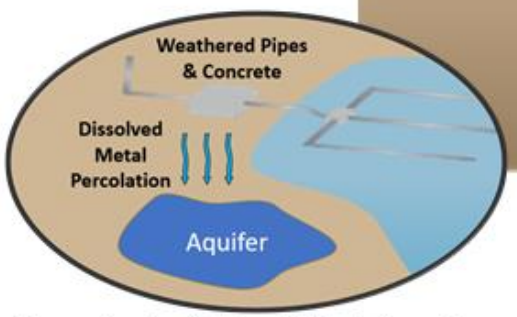
Transport



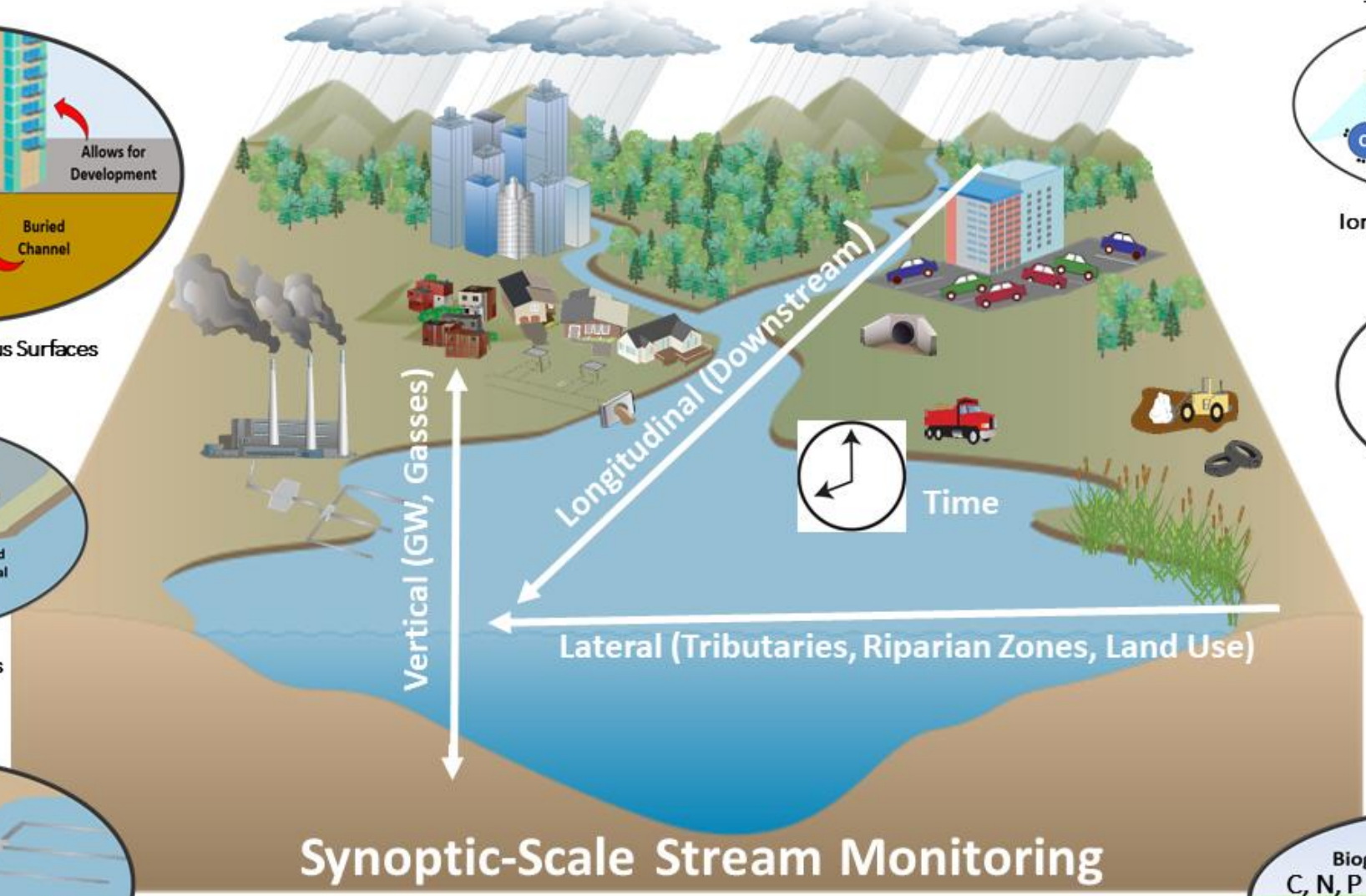
Storm drains and Impervious Surfaces



Point and Nonpoint Sources

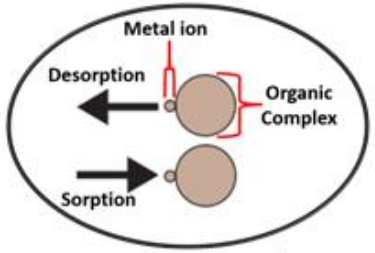


Groundwater-Surface Water Interactions

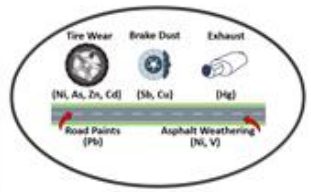


Transformation

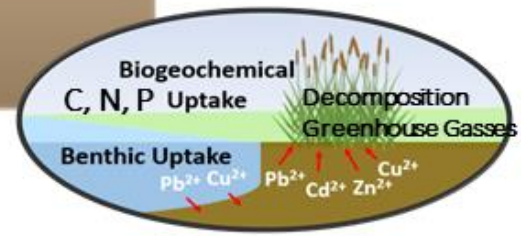
Ion Exchange and Complexation



Sorption of Metals



Weathering of Urban Karst and Tires

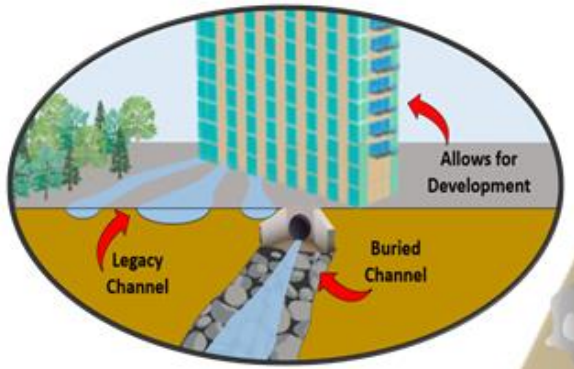


Biogeochemical Transformations

Kaushal et al. (In Review)

The Urban Watershed Continuum's Chemical Cocktails

Transport



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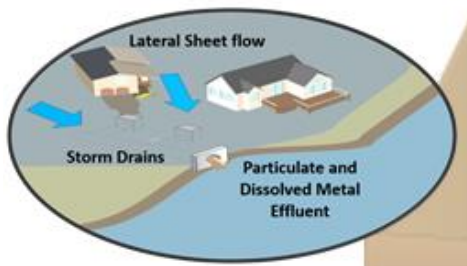
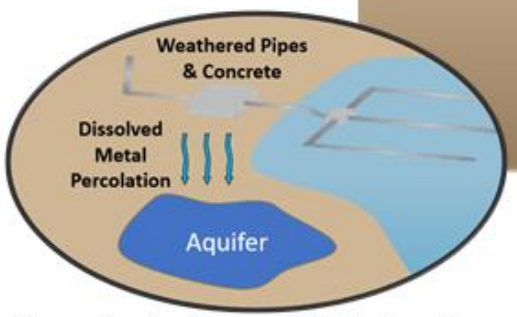


Point and Nonpoint Sources



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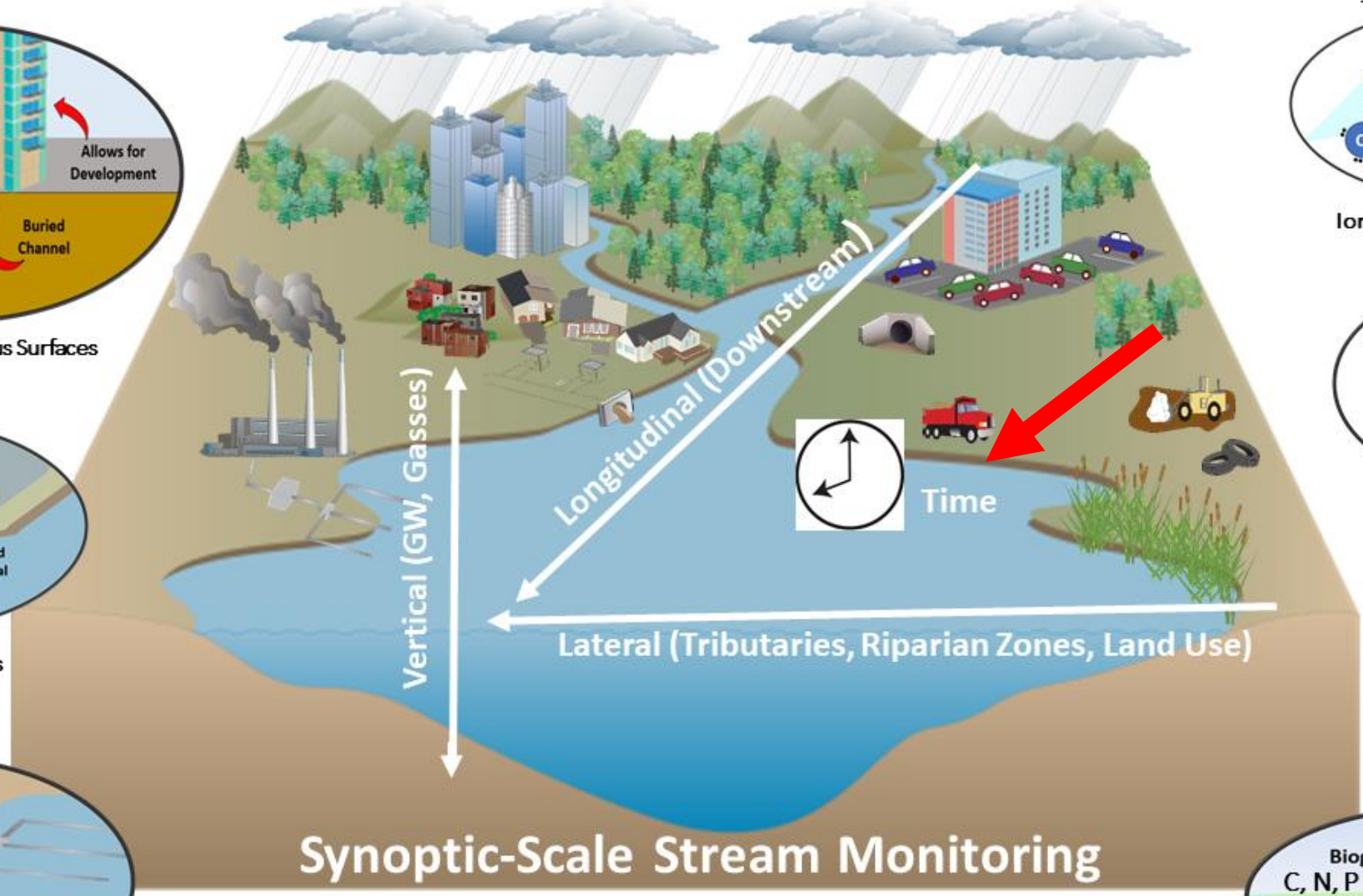

Transformation

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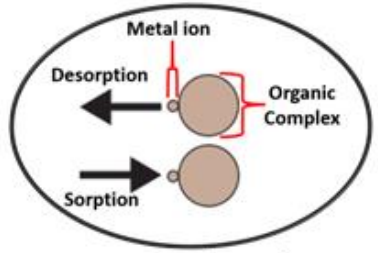

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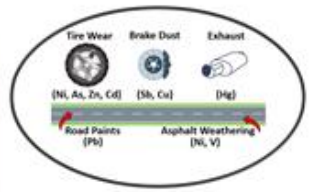

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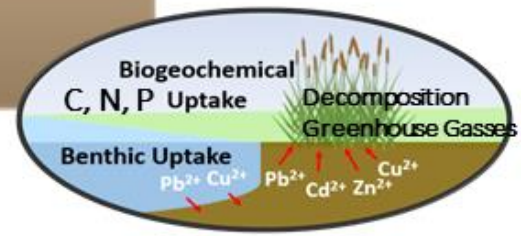
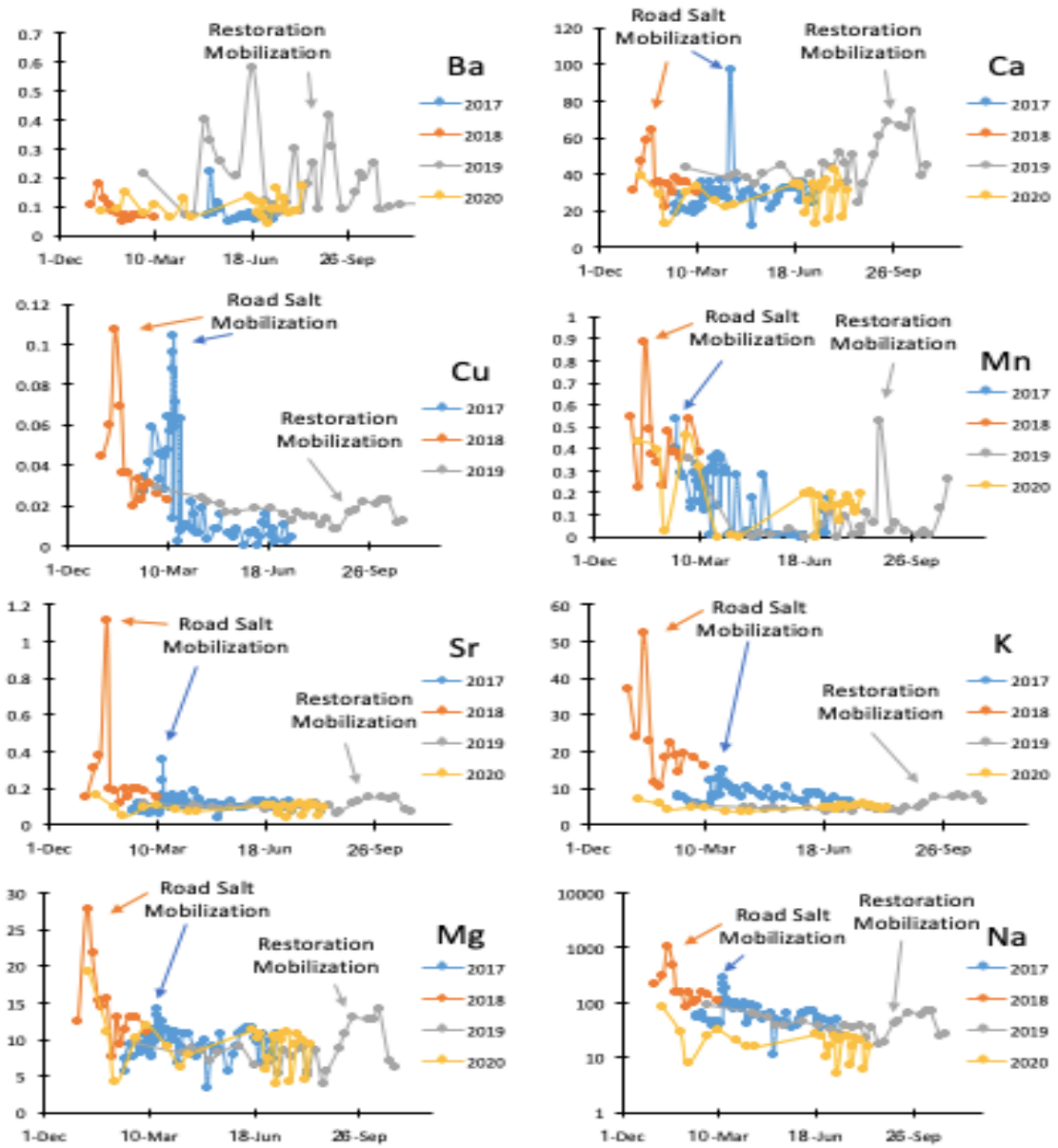


Biogeochemical Transformations

Kaushal et al. (In Review)

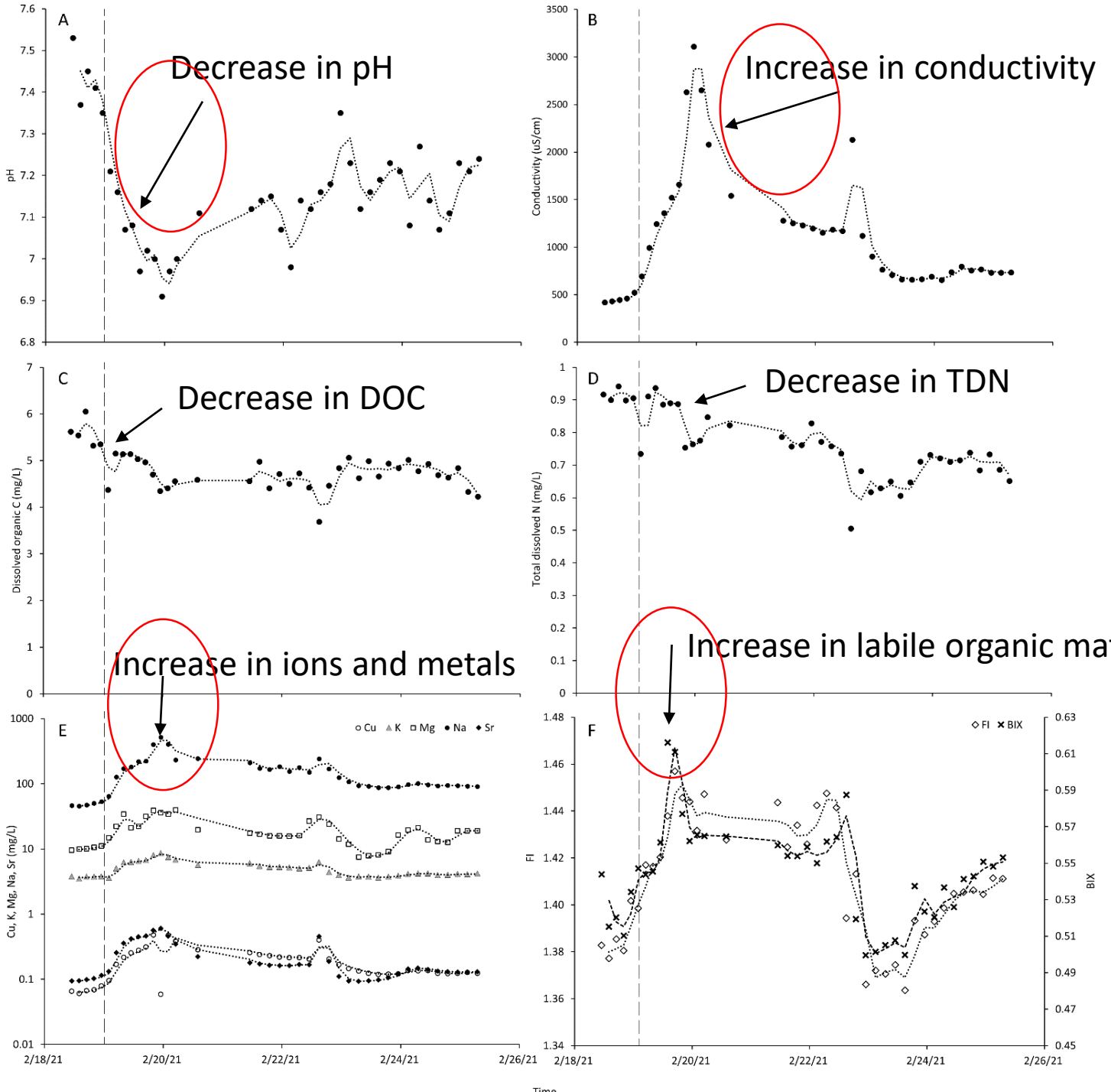
Mobilizing Chemical Cocktails:

Comparison by Year and Season



Decreases in ion concentrations over time (~100 fold) depending on amount of road salt

Kaushal et al. (2022)
Freshwater Science



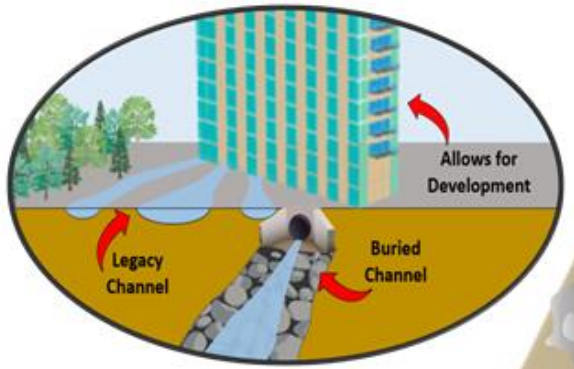
Changes in water quality over time following road salt

-Acidification
-Metals Mobilization
-Nutrient Mobilization
-Reactive Organics

Kaushal et al. (2022)
Freshwater Science

The Urban Watershed Continuum's Chemical Cocktails

Transport



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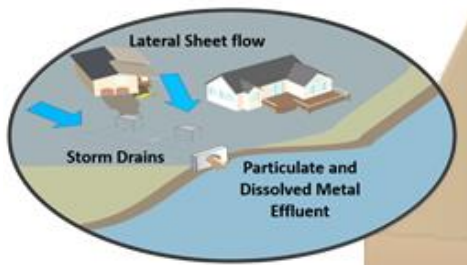

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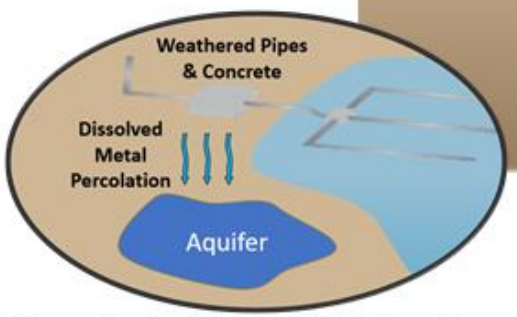

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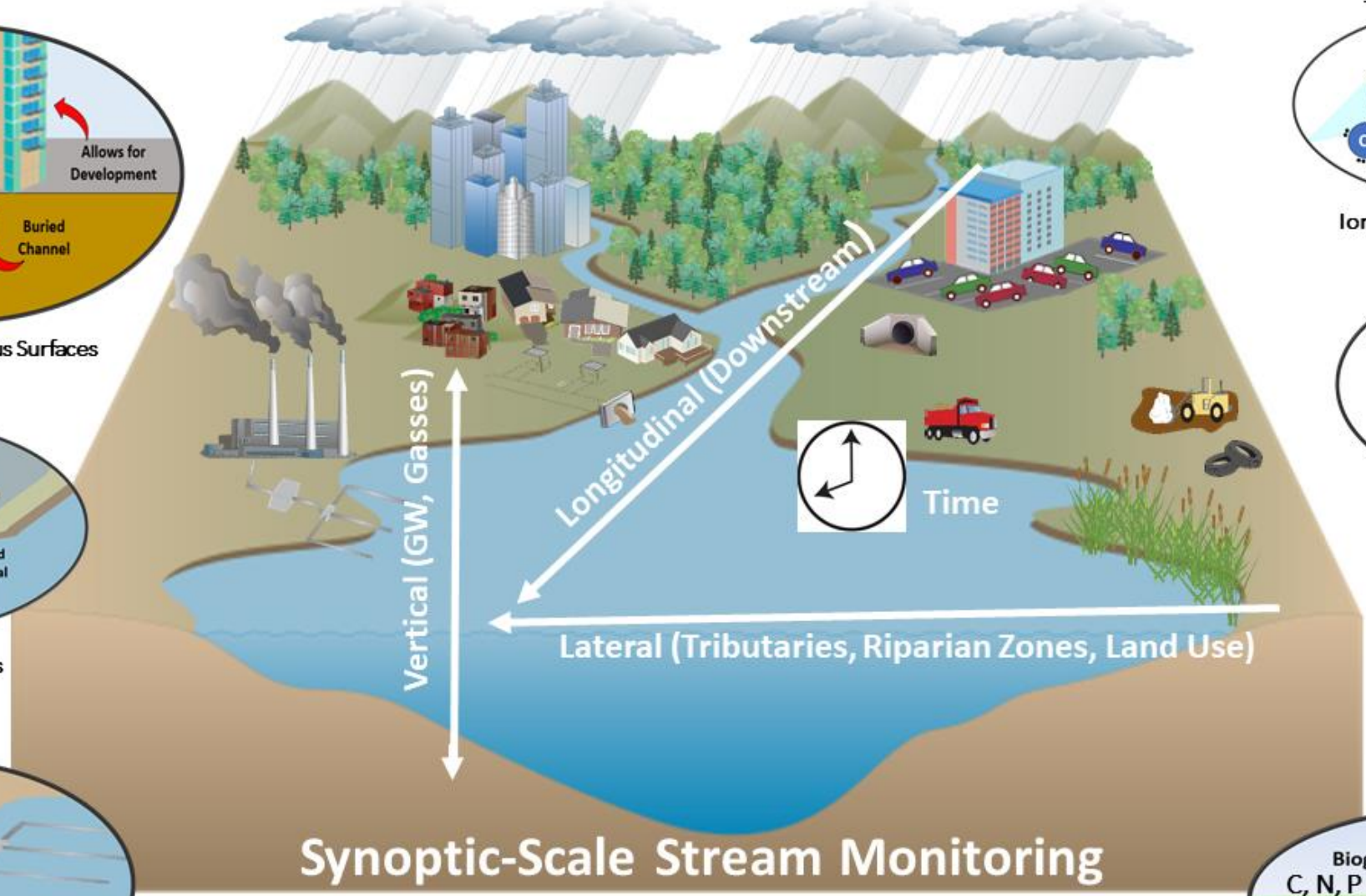

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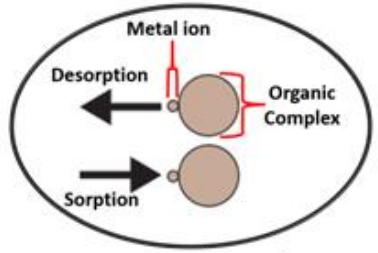

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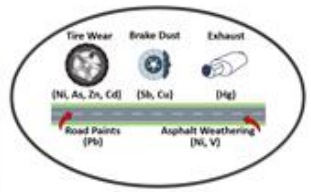

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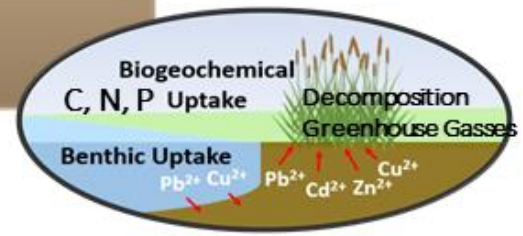

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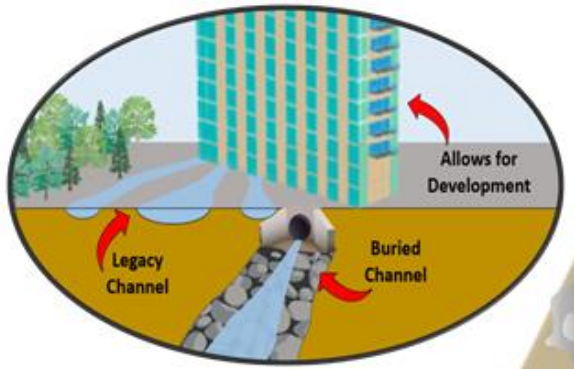

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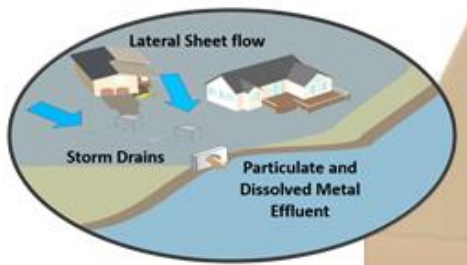

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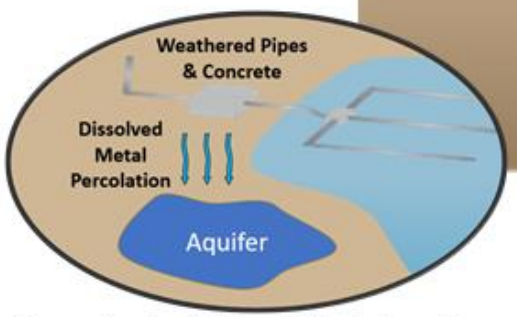
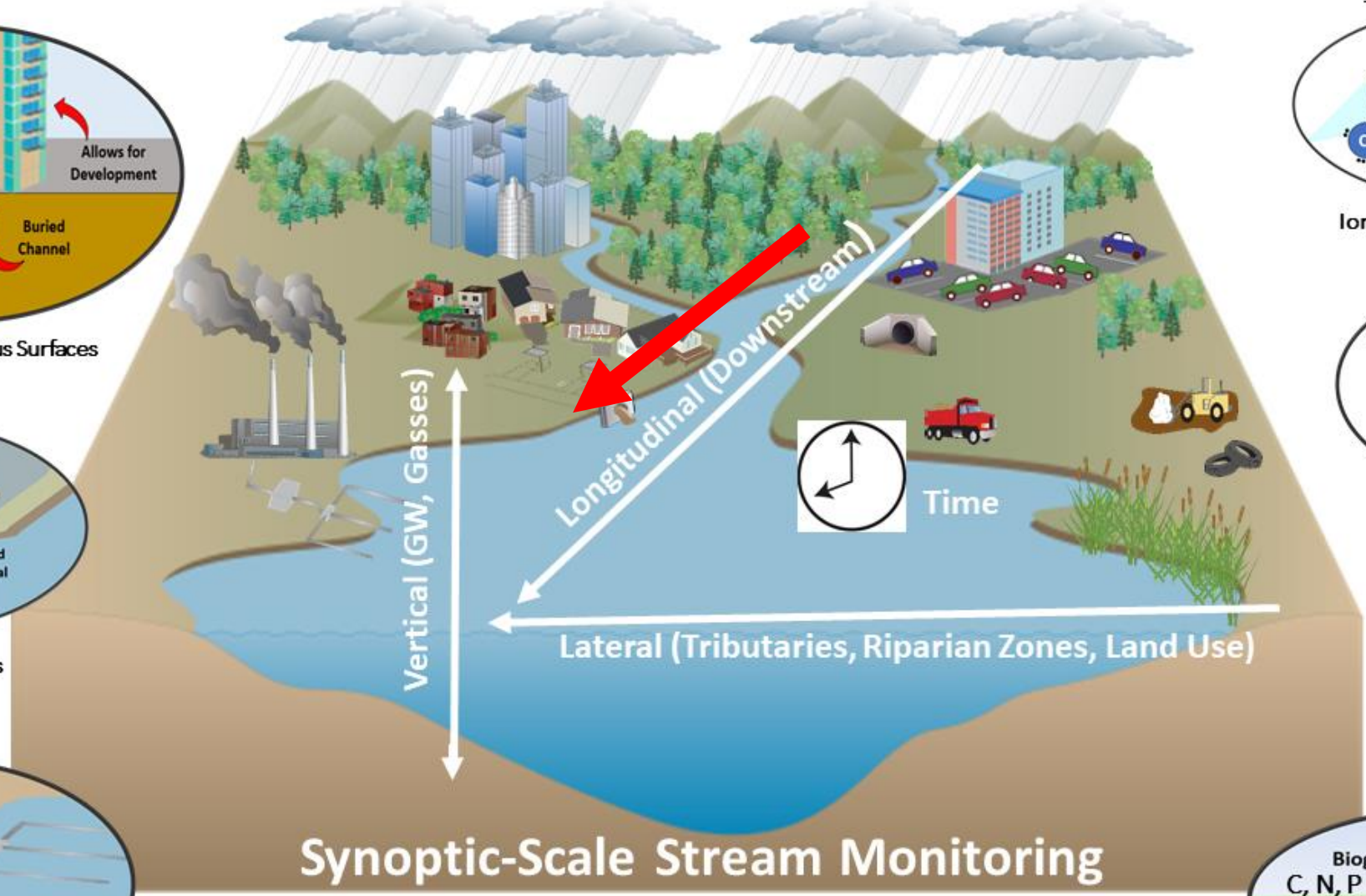
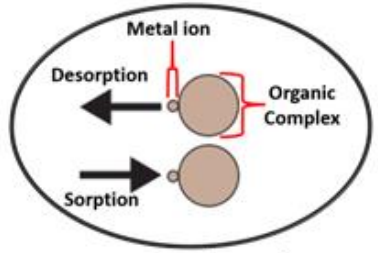


Groundwater-Surface Water Interactions

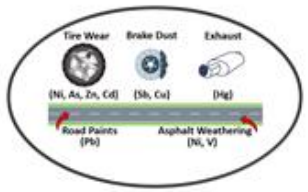


Transformation

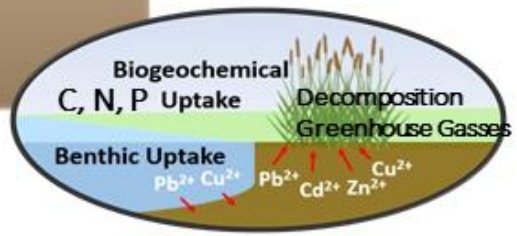
Ion Exchange and Complexation



Sorption of Metals

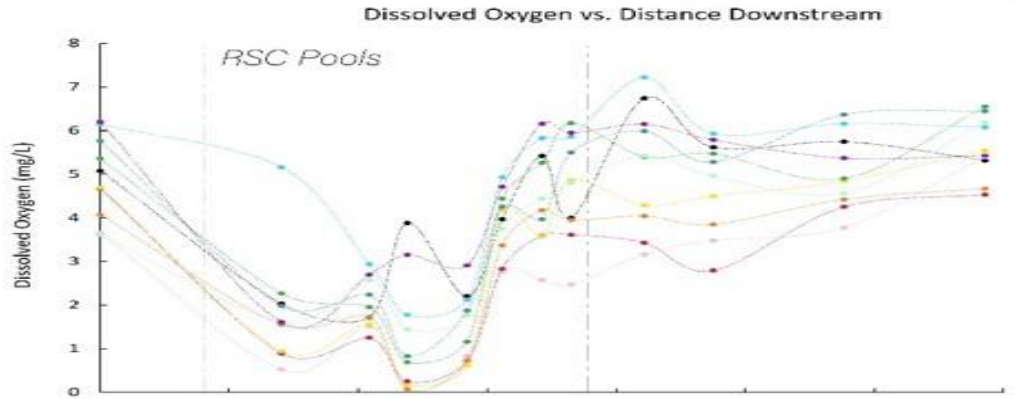


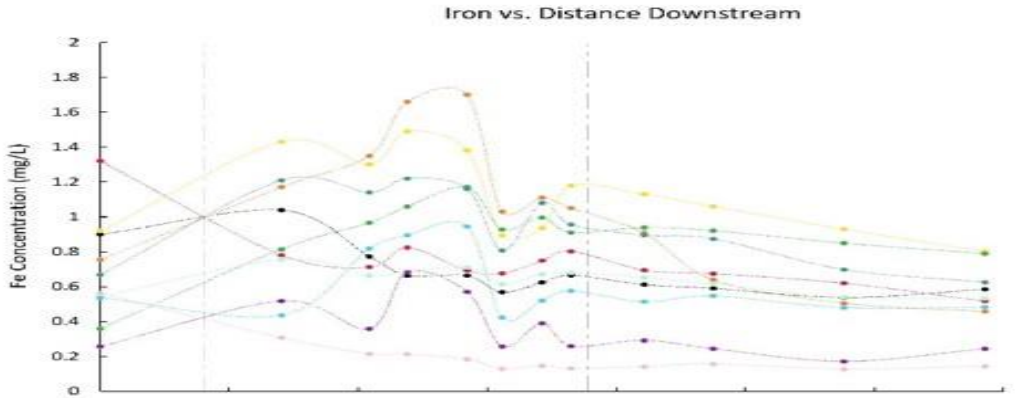
Weathering of Urban Karst and Tires

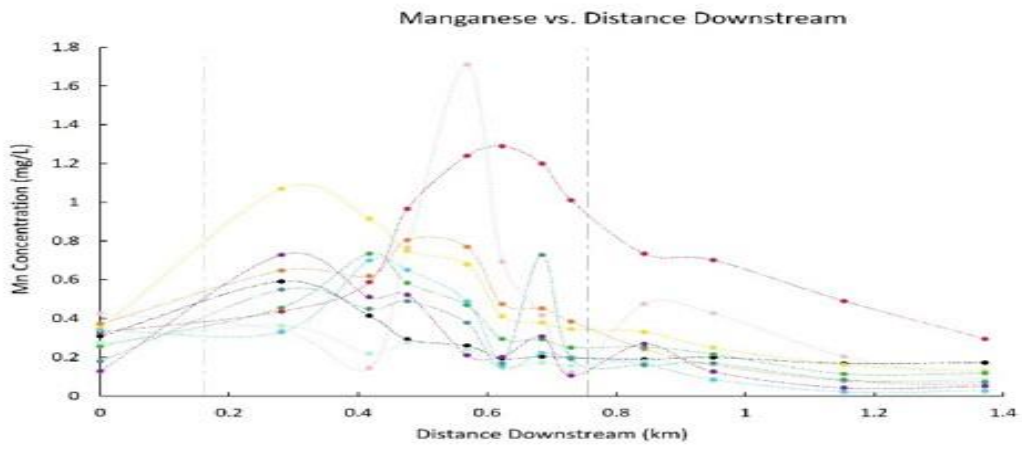


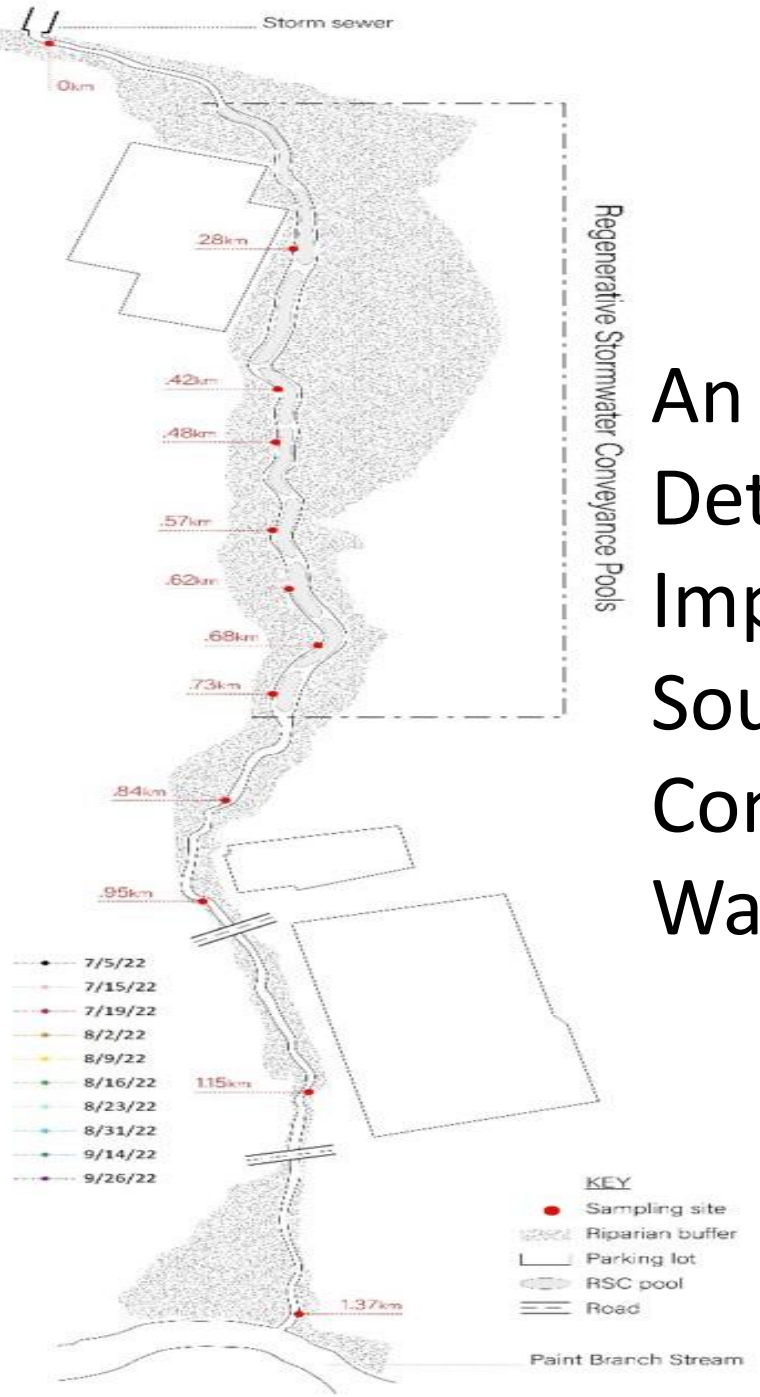
Biogeochemical Transformations

Kaushal et al. (In Review)









An Approach for Detecting Cumulative Impacts of BMPs on Sources and Sinks of Contaminants across Watershed Scales

Kaushal et al. (In Review)

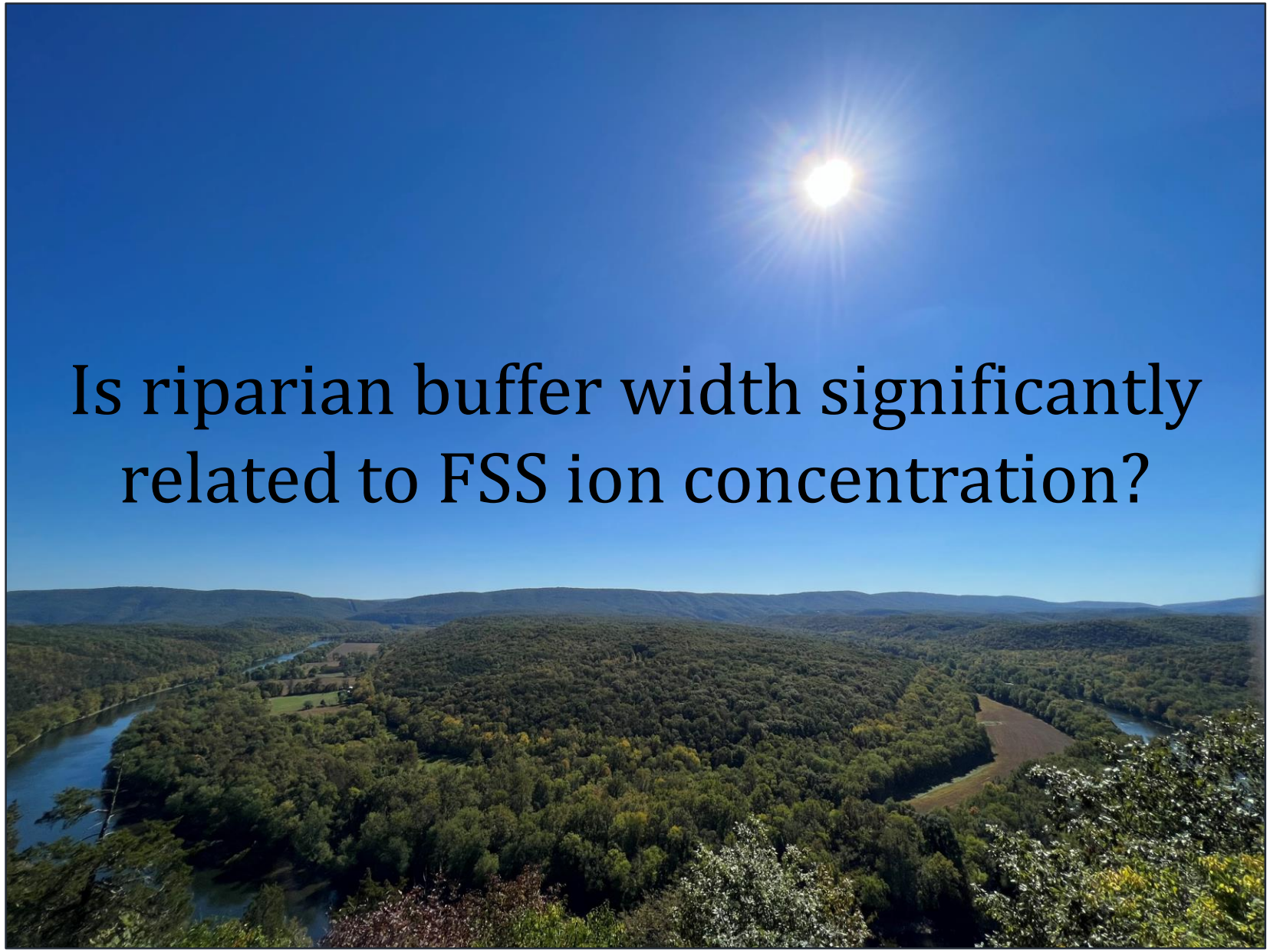


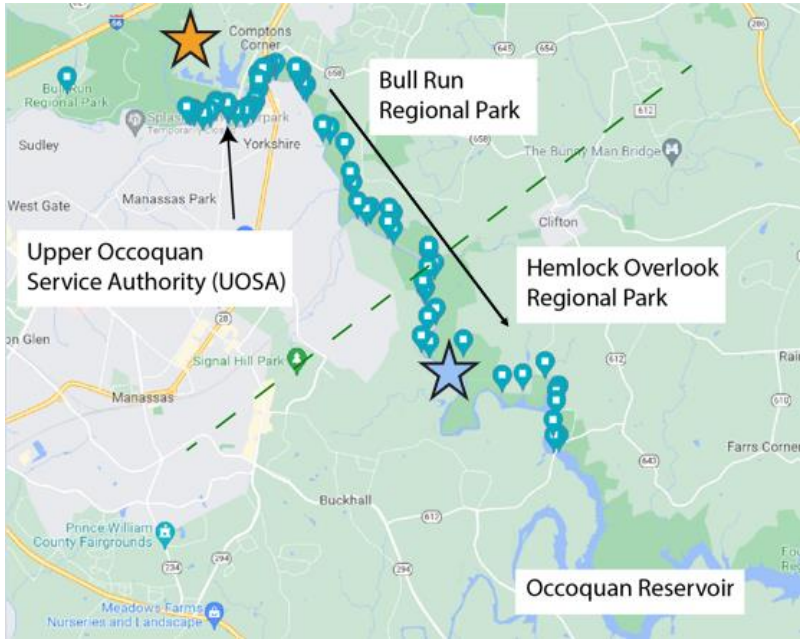
Photo Courtesy:
Carly Maas

Potomac River at Point Lookout Overlook, MD

Do chemical cocktails form over space and time?

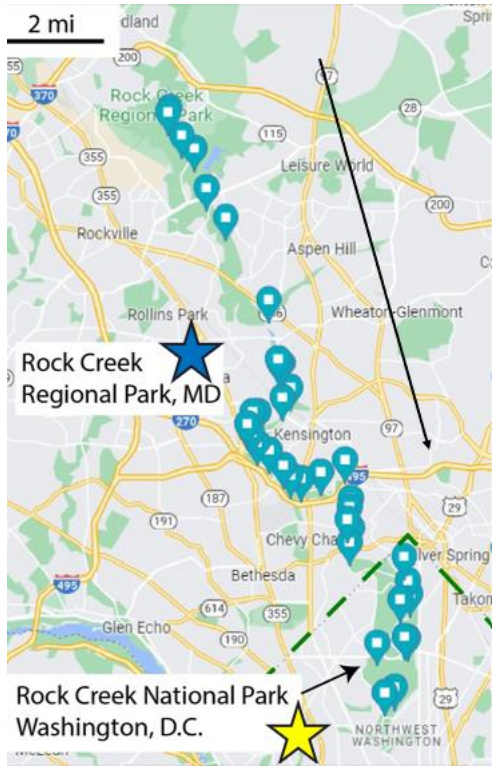
Bull Run, VA

Flowpath from wastewater treatment plant through regional park



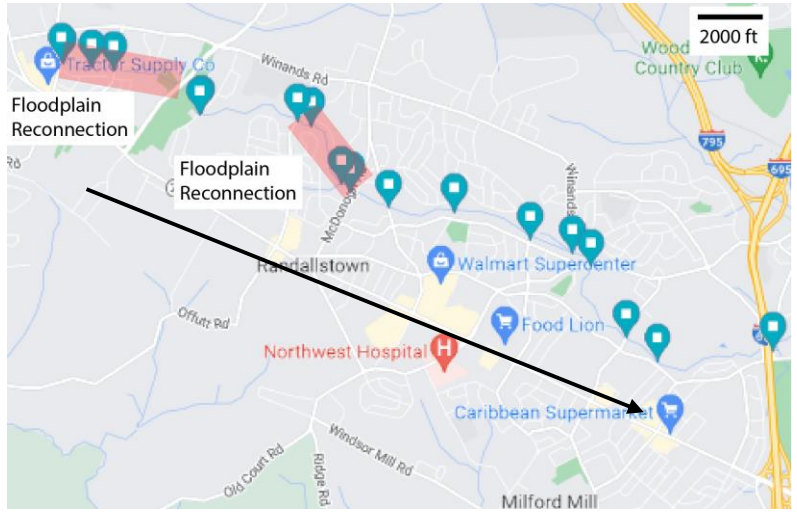
Rock Creek, MD to DC

Flowpath from urban land use through forested national park



Scotts Level Branch, MD

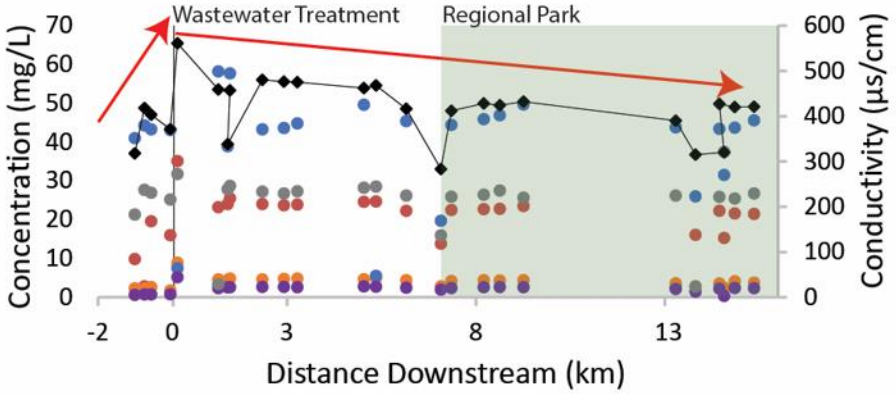
Flowpath through suburban land use with floodplain reconnection



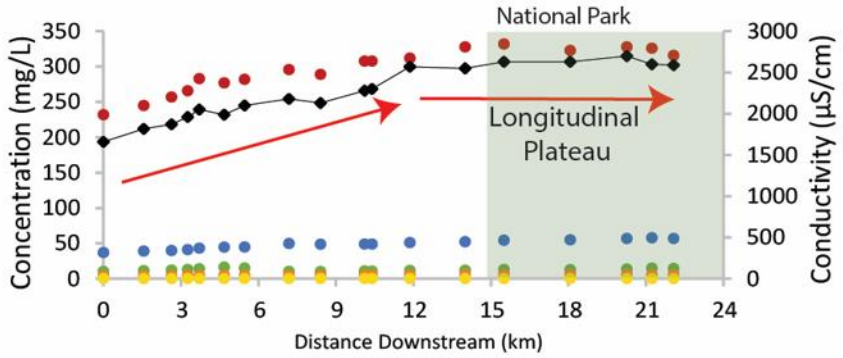
Highest forest cover in watershed → Lowest forest cover in watershed

Maas et al. (In Review)

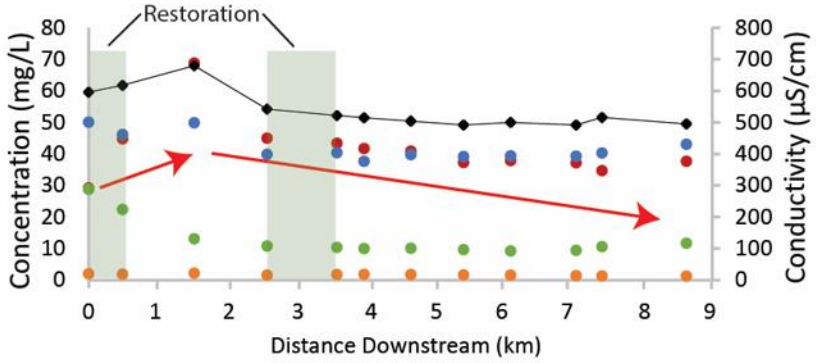
a. Bull Run: Longitudinal Attenuation



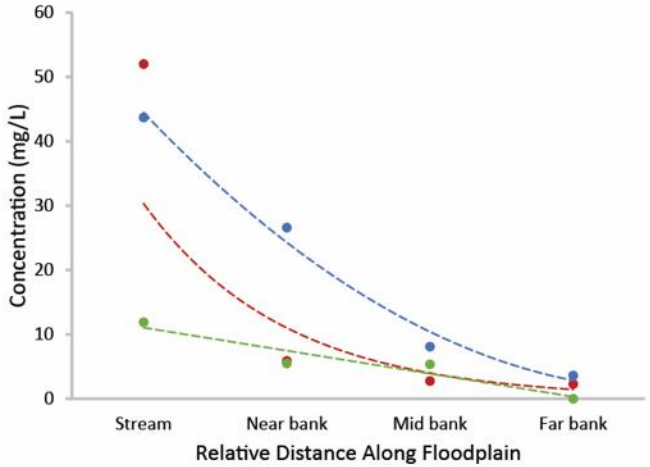
b. Rock Creek: Longitudinal Plateau

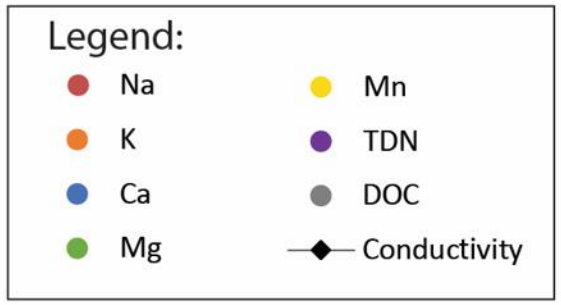


c. Scotts Level Branch: Longitudinal Attenuation



d. Scotts Level Branch: Lateral Attenuation

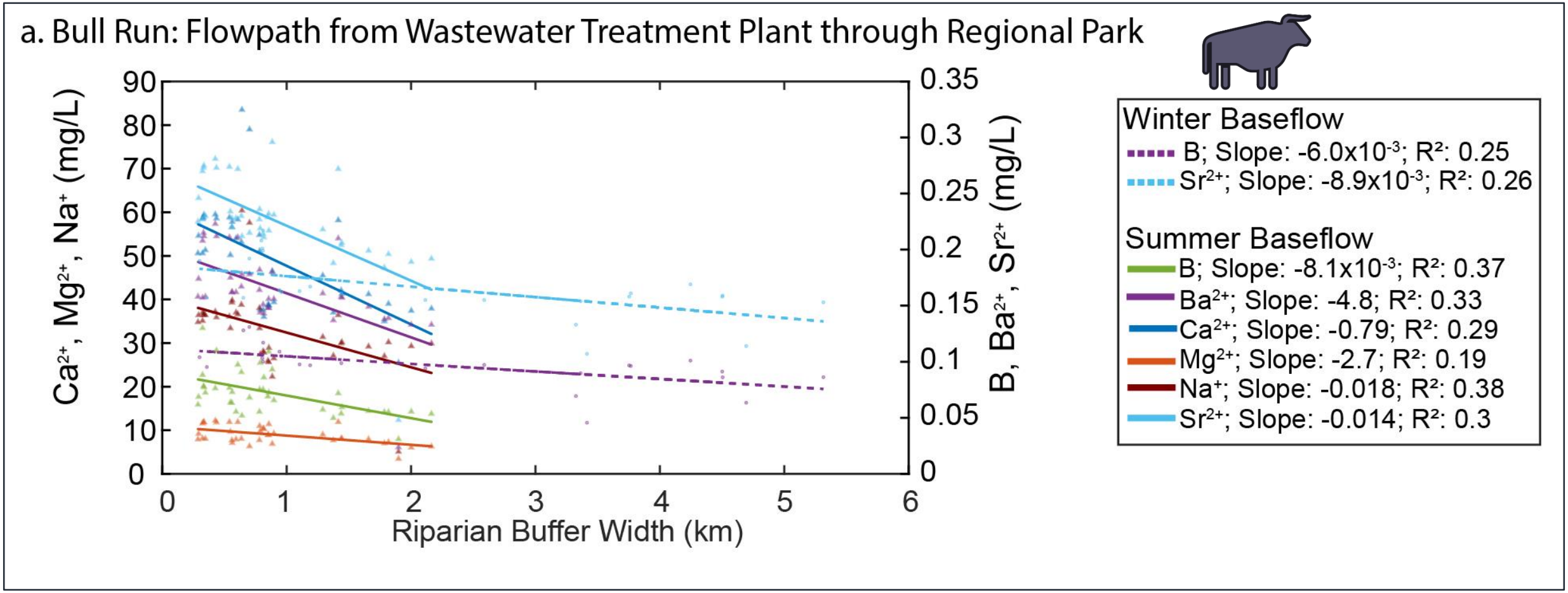




Biogeochemical Attenuation and Plateaus along Stream and Riparian Flowpaths

Kaushal et al. (In Review)

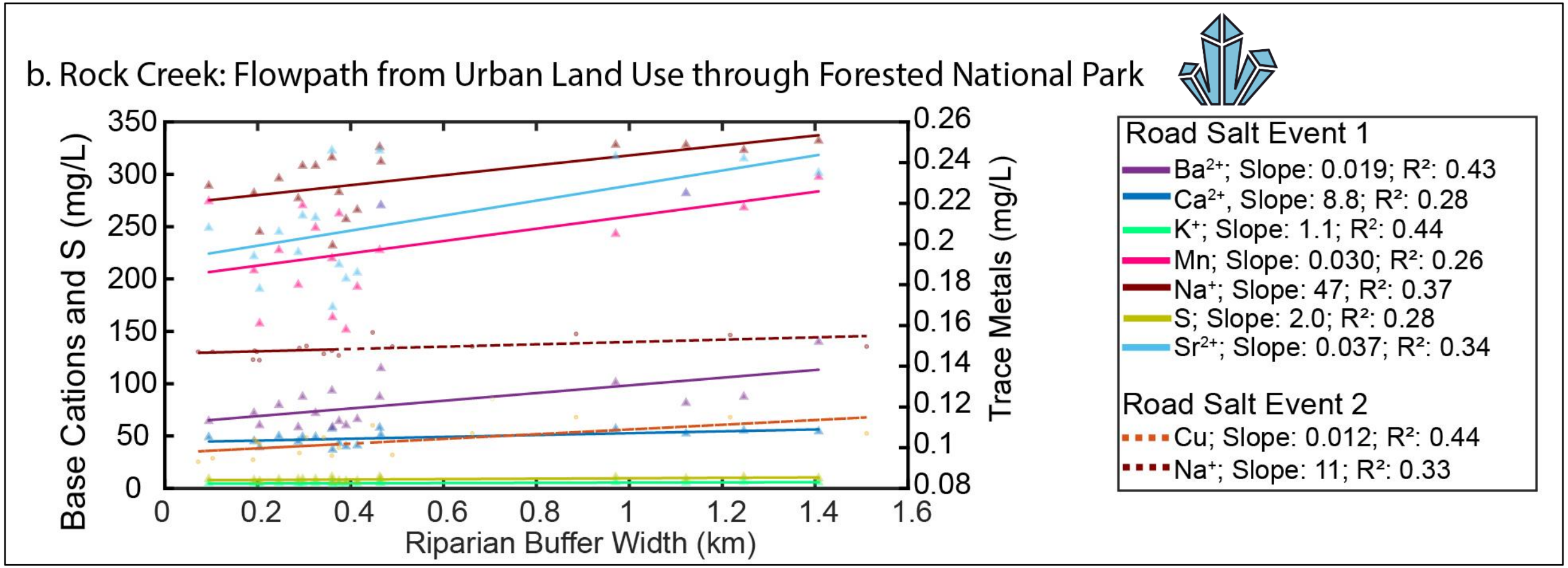
Is riparian buffer width significantly related to FSS ion concentration?



- For $p < 0.05$: Riparian buffer width **was** related to decreasing ion concentrations during baseflow events.
- More ions related in summer than winter – more biologically active!

Maas et al. (In Review)

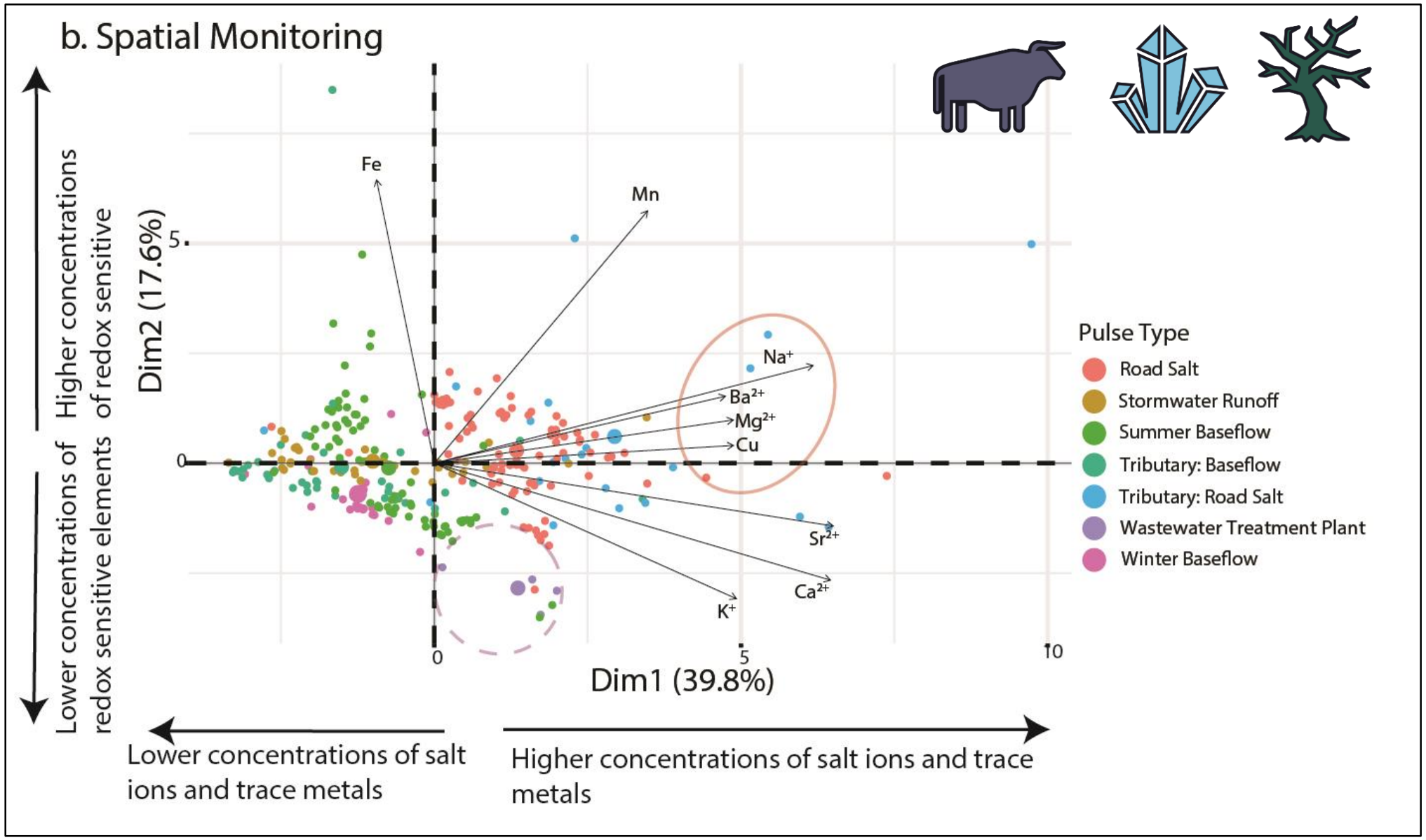
Is riparian buffer width significantly related to FSS ion concentration?



- For $p < 0.05$: Riparian buffer width **was** related to increasing ion concentrations during road salt events
- Many storm drains and sewage lines
- **ROAD SALTING CAN OVERWHELM RIPARIANS ZONES**

Maas et al. (In Review)

We can "fingerprint" chemical cocktails from FSS along flowpaths



Distinct chemical cocktails form over space

Road salt high in salt ions and trace metals

Maas et al. (In Review)

Synoptic Summary….but stay tuned for Jeff!!!

- Stormwater BMPs can retain salt ions along flowpaths
- Release of chemical cocktails depends on amounts and types of salt used and BMP type
- **Synoptic studies can identify fate and transport of salt and multiple contaminants and can be used in watershed assessments and tracking pollution sources**

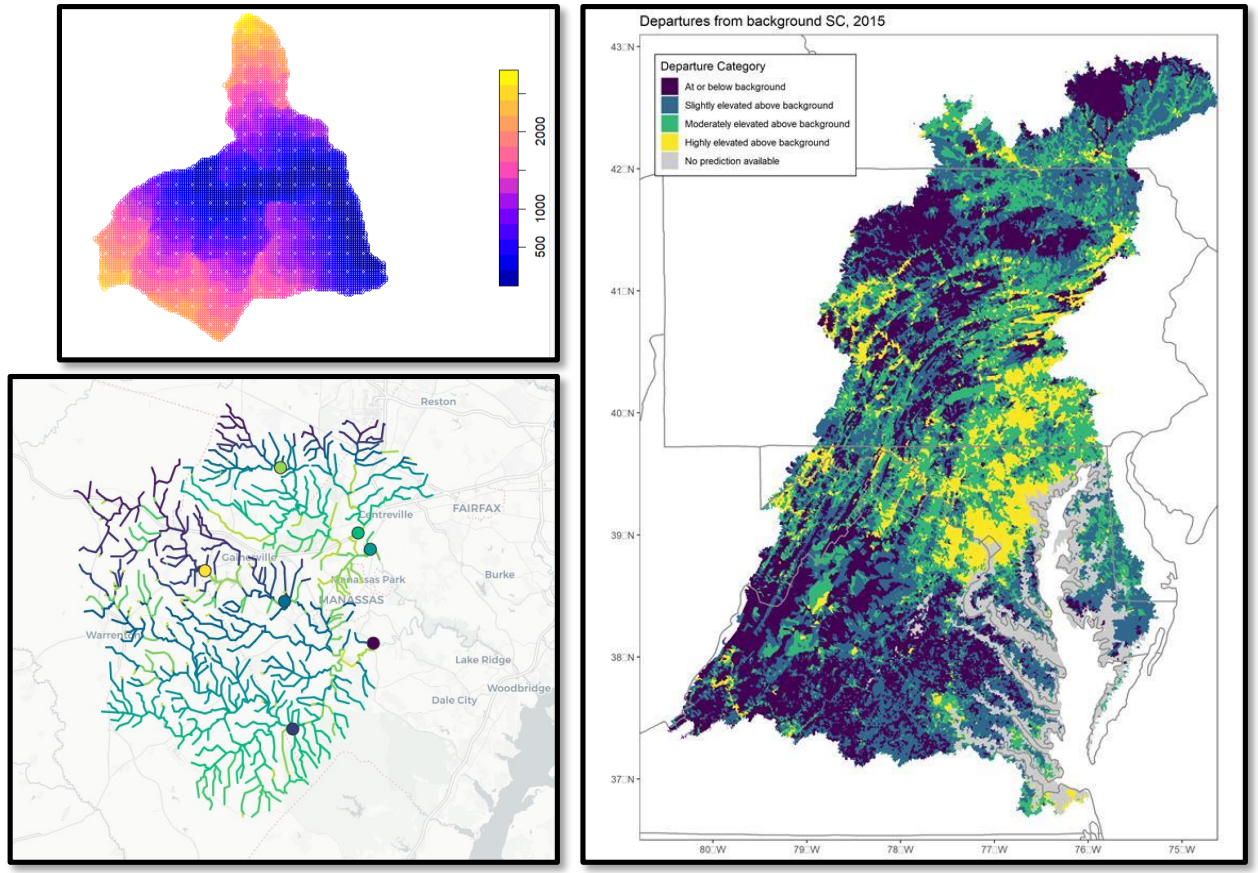
Salty Risks from Regions to Reaches to Reservoirs

Field trip to WSSC….

Developing spatially-referenced regional models

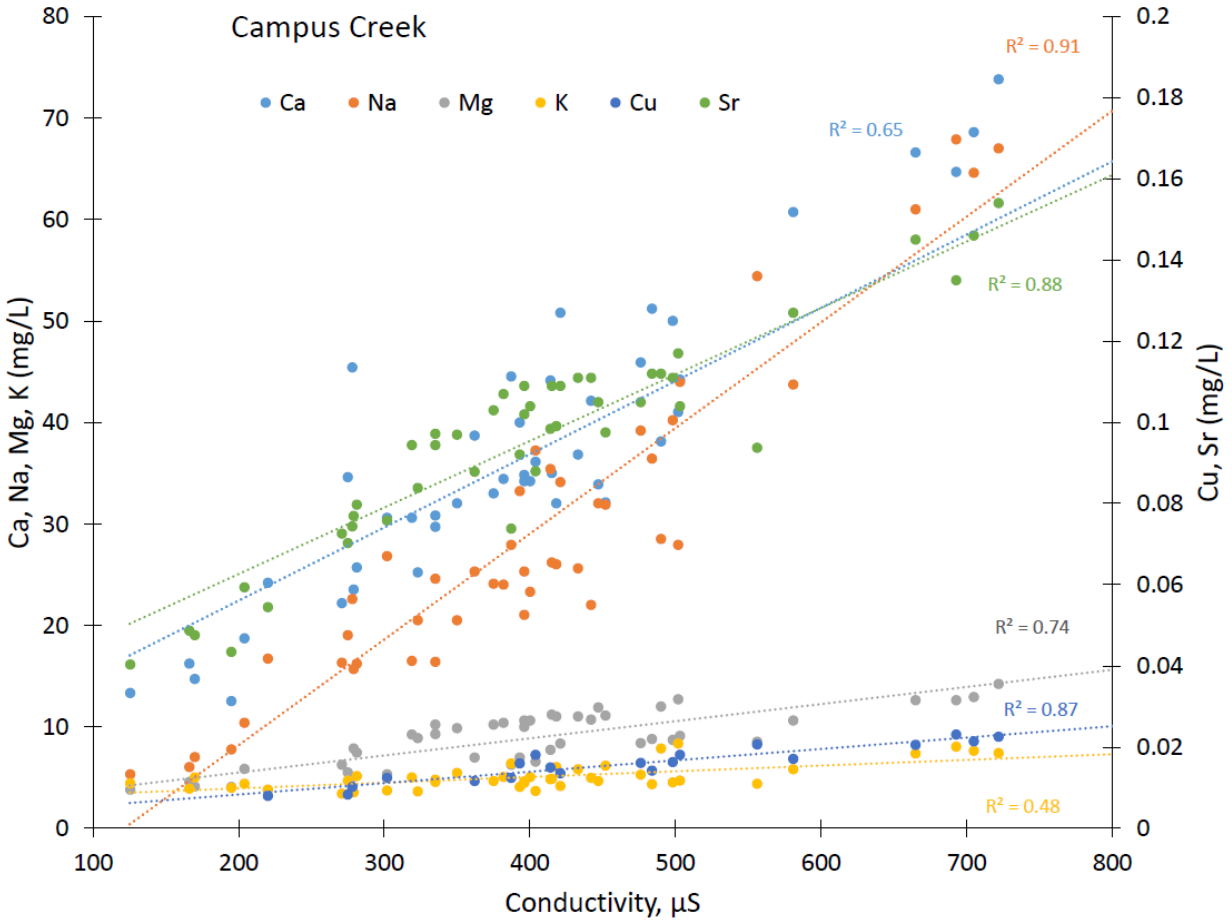
Monitoring and watershed-scale analyses can inform spatially-referenced regional models that:

- Expand our understanding of ***sources*** and ***processes***
- Estimate impacts of ***management practices***
- Predict conditions in ***unmonitored*** areas
- Assess ***risk/vulnerability***

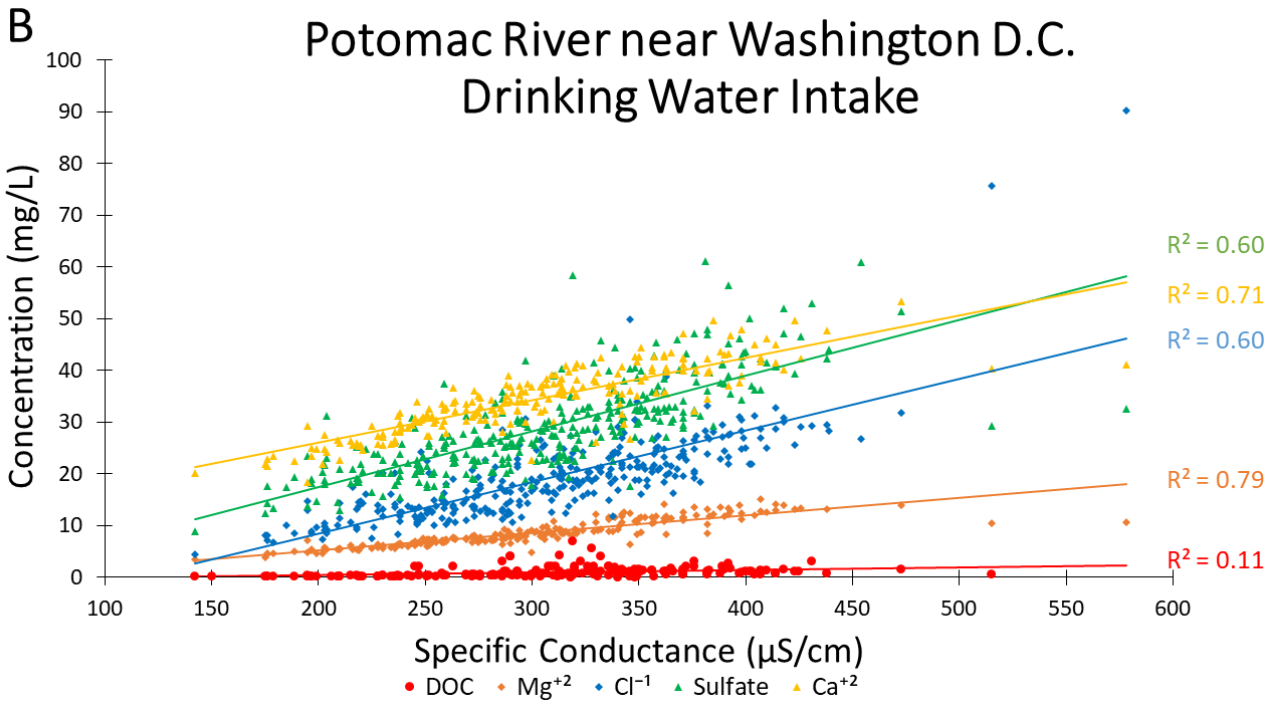


Fanelli and others (in review)

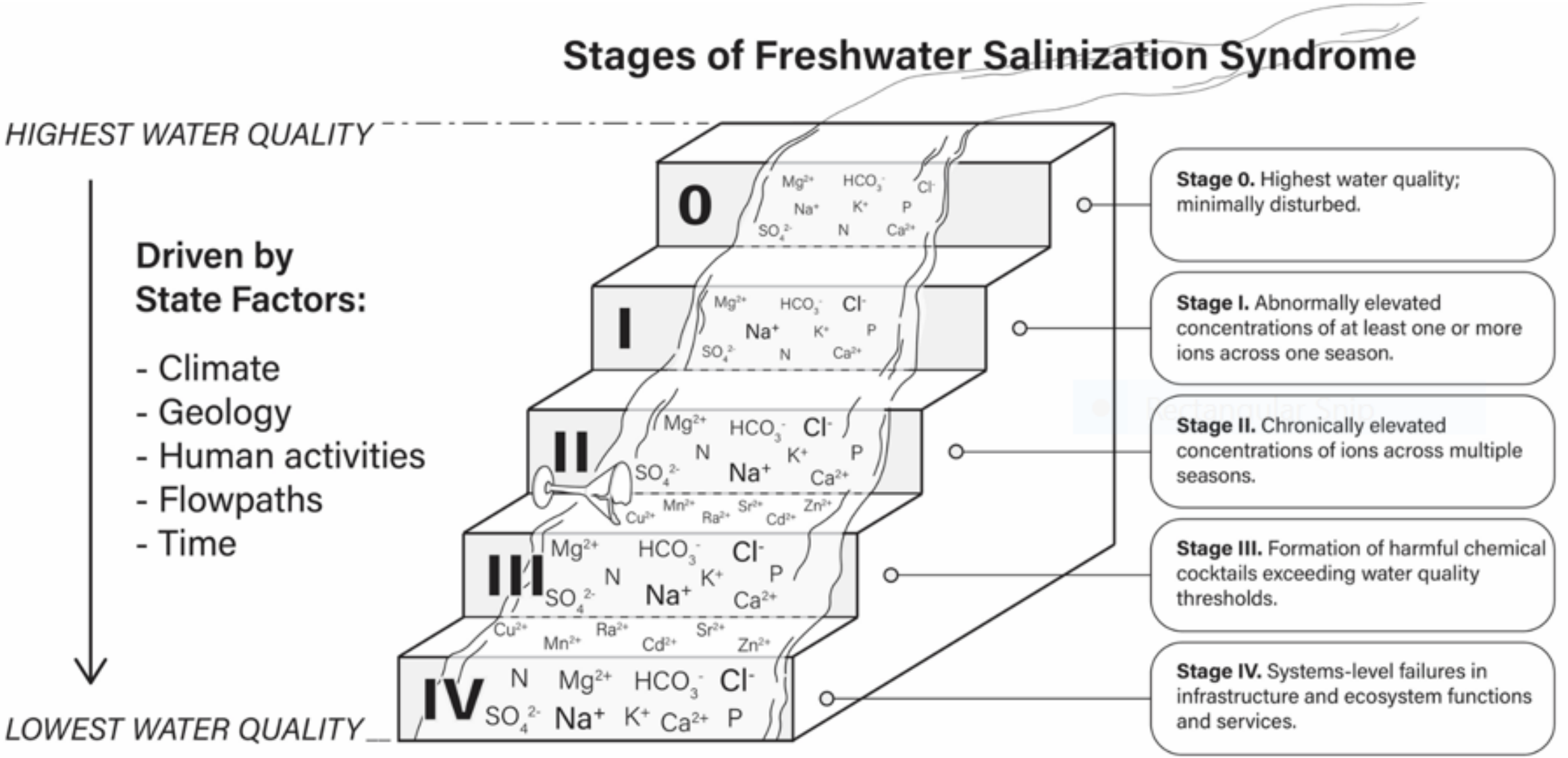
Sensor Monitoring Approaches: Specific Conductance as a Proxy



B

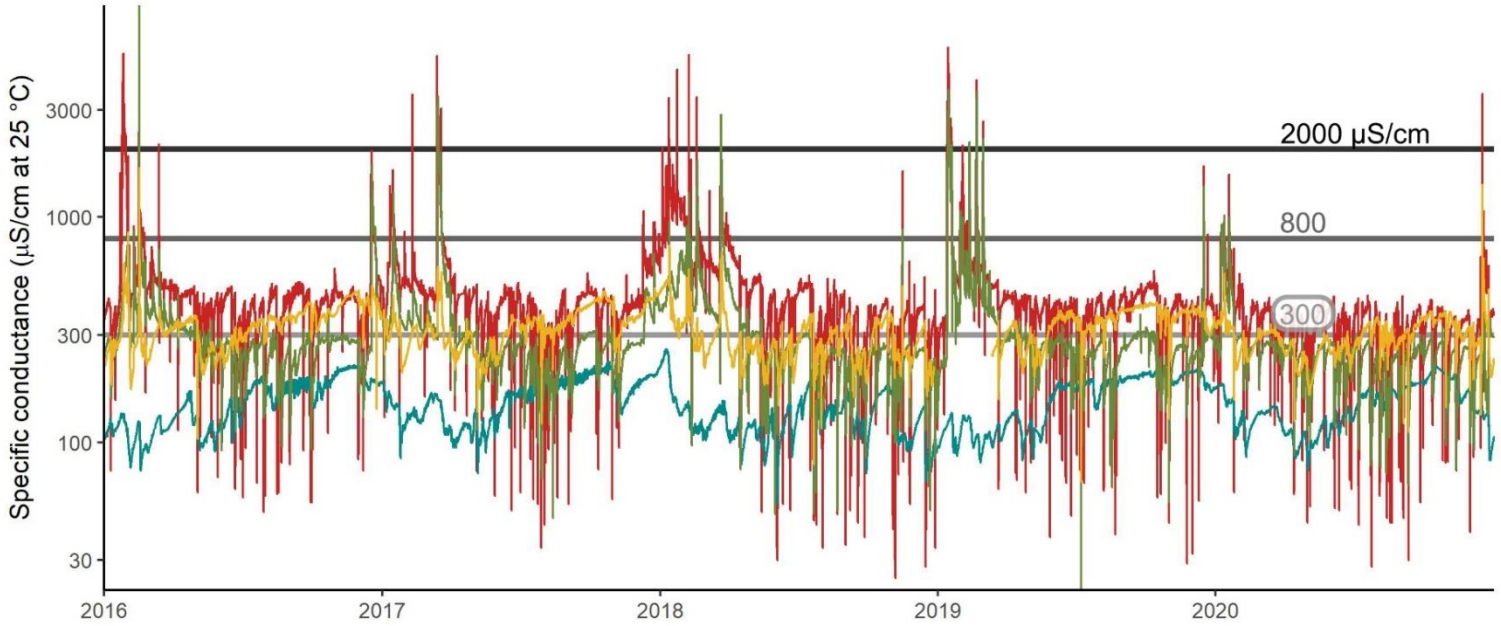


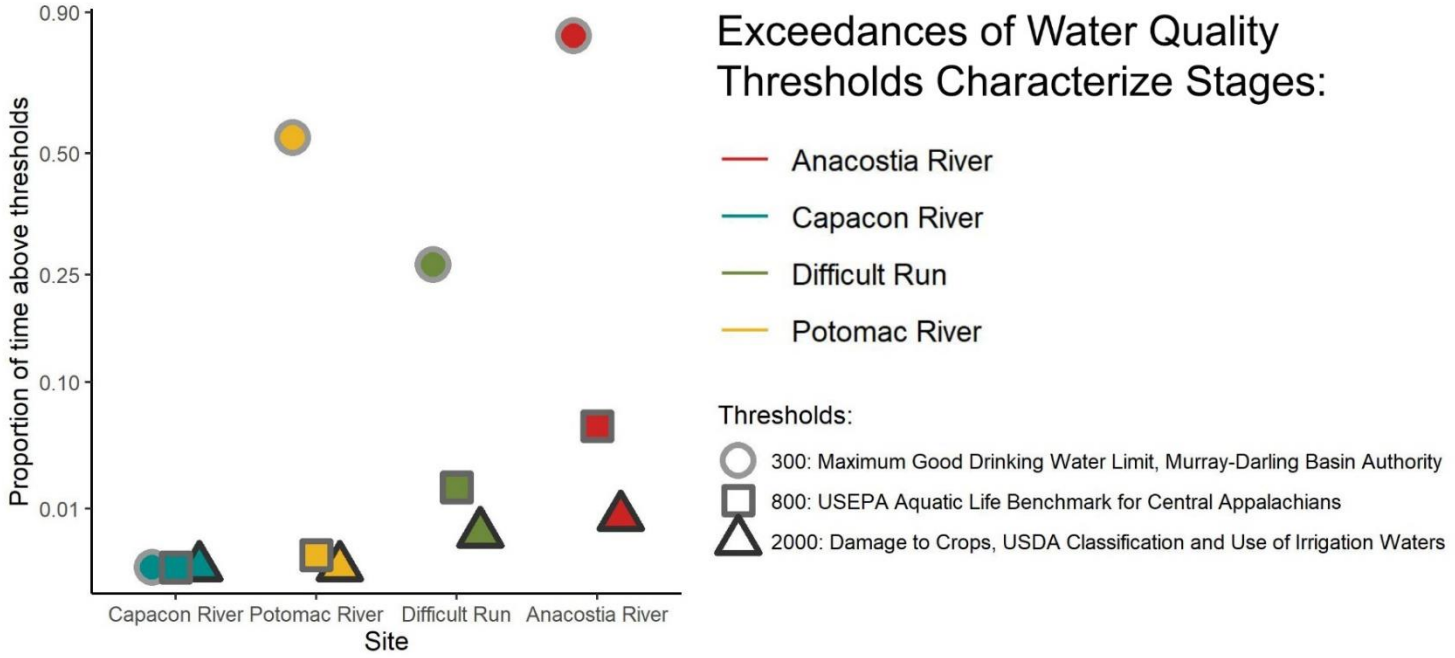
Kaushal et al. (2021) Galella et al. (2021) for Rock Creek



Kaushal et al. 2022, *Limnology & Oceanography Letters*

Modeling Risks Based on State Factors





Diagnosing Stages Using Exceedances of Thresholds

Top 10 Things We Learned This Year

1. Modeling allows predicting future salinization trends and patterns.
2. Modeling allows prediction of the ages of stream water carrying salt to streams.
3. Modeling approaches can have co-benefits for addressing other issues.
4. Roughly 1/3 of salt can be retained along stormwater BMP flowpaths.
5. Chemical cocktails are retained/released based on BMP, salt type, and amount.
6. Synoptic studies “fingerprint” sources, fate, and transport along watersheds.
7. “Hot spots” of salinization exist within watersheds due to flowpaths.
8. Synoptic studies along flowpaths are a useful tool for watershed assessments.
9. Models based on synoptic flowpath data can better assess management.
10. Considerations of risk should account for salt and associated chemical cocktails.

Freshwater Salinization Syndrome: the Search for a Cure

Salinization is increasing and there are many implications and unknowns…

Need for science and management to identify and anticipate risks, mitigation, restoration…

Ounce of prevention is worth a pound of cure – our research on flowpaths through conservation

Steve Nelson hosts meeting at WSSC/field trip.

Thanks to Washingto MCOG, WSSC, COG funders, students..

Sampling along Bull Run before reservoir

Photo Courtesy: Carly Maas