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Uranium Remobilization from a Riparian Wetland: Implications on Long-Term Stewardship and Extreme Rain Events

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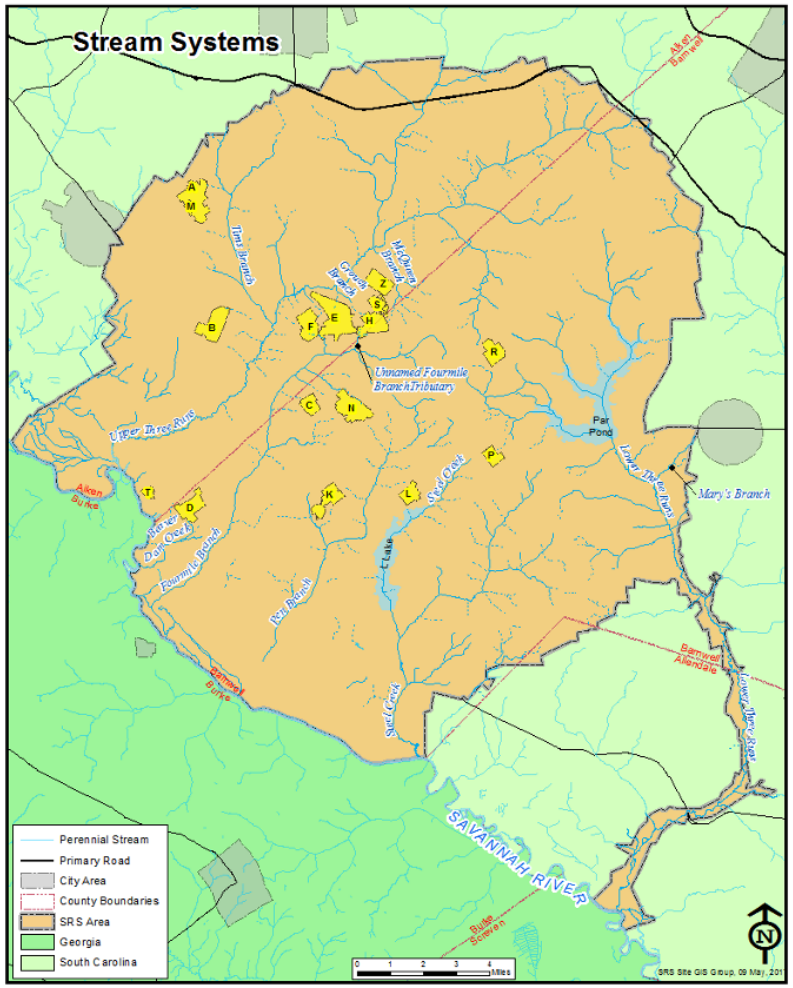
Introduction

➢ Motivation:

Support for the SRS Composite Analysis – estimates human radiological risk posed at watershed scale, combining sources or operable units.

➢ Objective:

- What is the role that streams play in the transport of contaminants off the SRS?
- Use a U-contaminated wetland study site to
  - quantify long-term immobilization
  - measure impact of extreme weather events on U transport down stream.

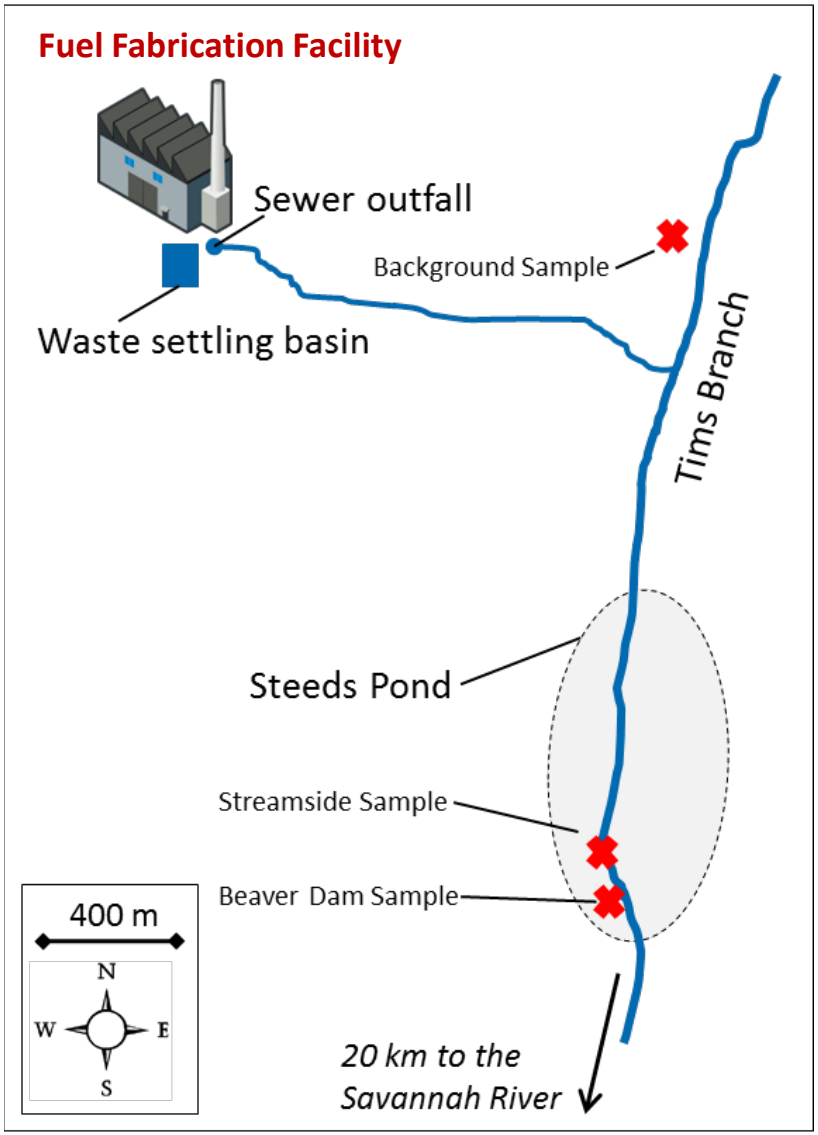


➢ General Approach:

At a study site that has been contaminated for >50 yr:

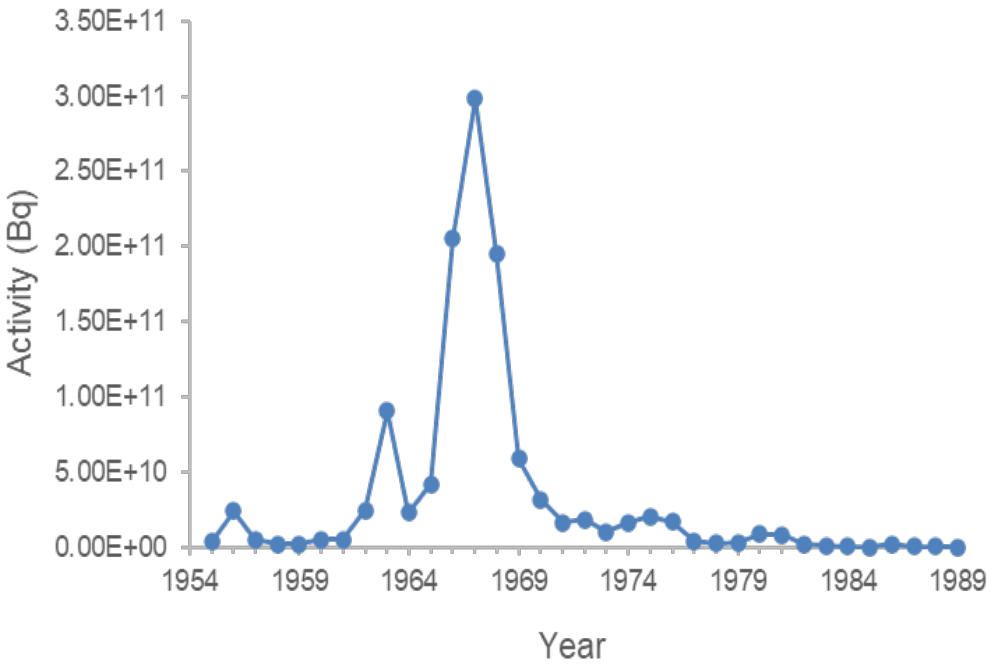
- U mass balance
- Quantified stream U transport in 6 rainstorm events. Attention to role of suspended solids.

Tims Branch Study Site



Fuel Fabrication Facility:

- ❑ Manufactured fuel and target assemblies for nuclear reactors 1954 - 1989
- ❑ Directly disposed of process waste into sewer outfall and settling basin
- ❑ Depleted U, Ni, Al, Cu, Zn, Pb, and Cr.
- ❑ 43,500 kg U released into wetland



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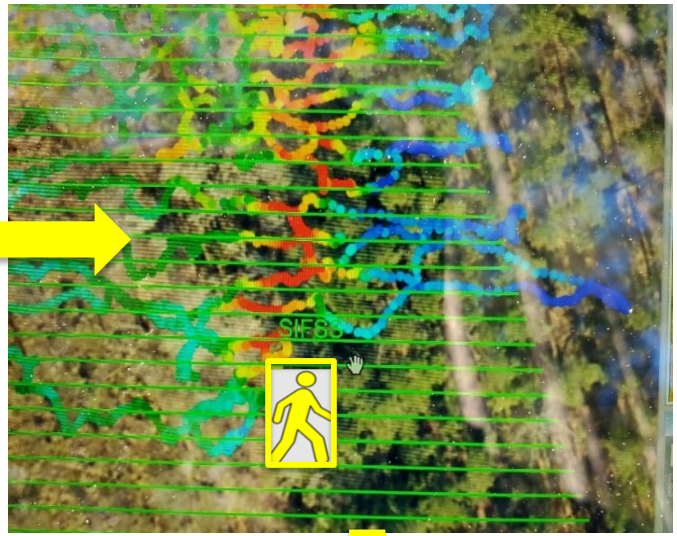
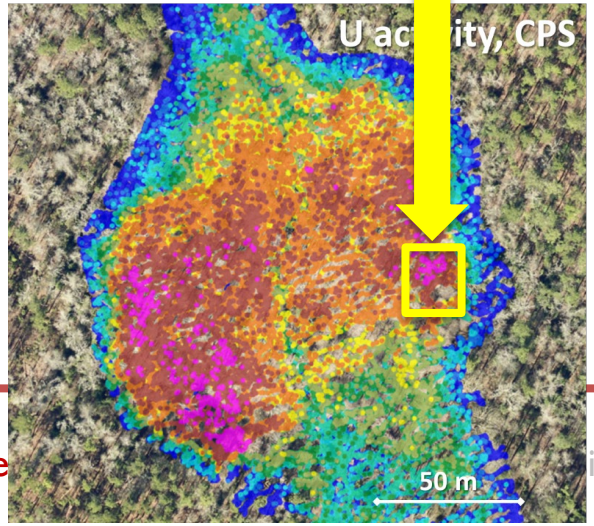
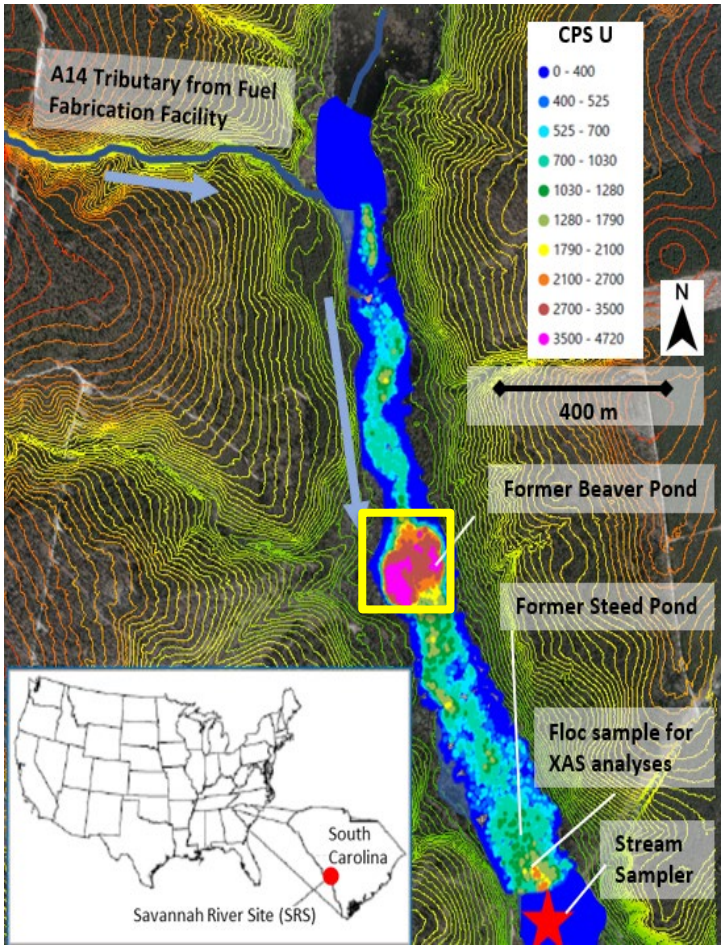
After 50 yr, how much U remains in wetland?





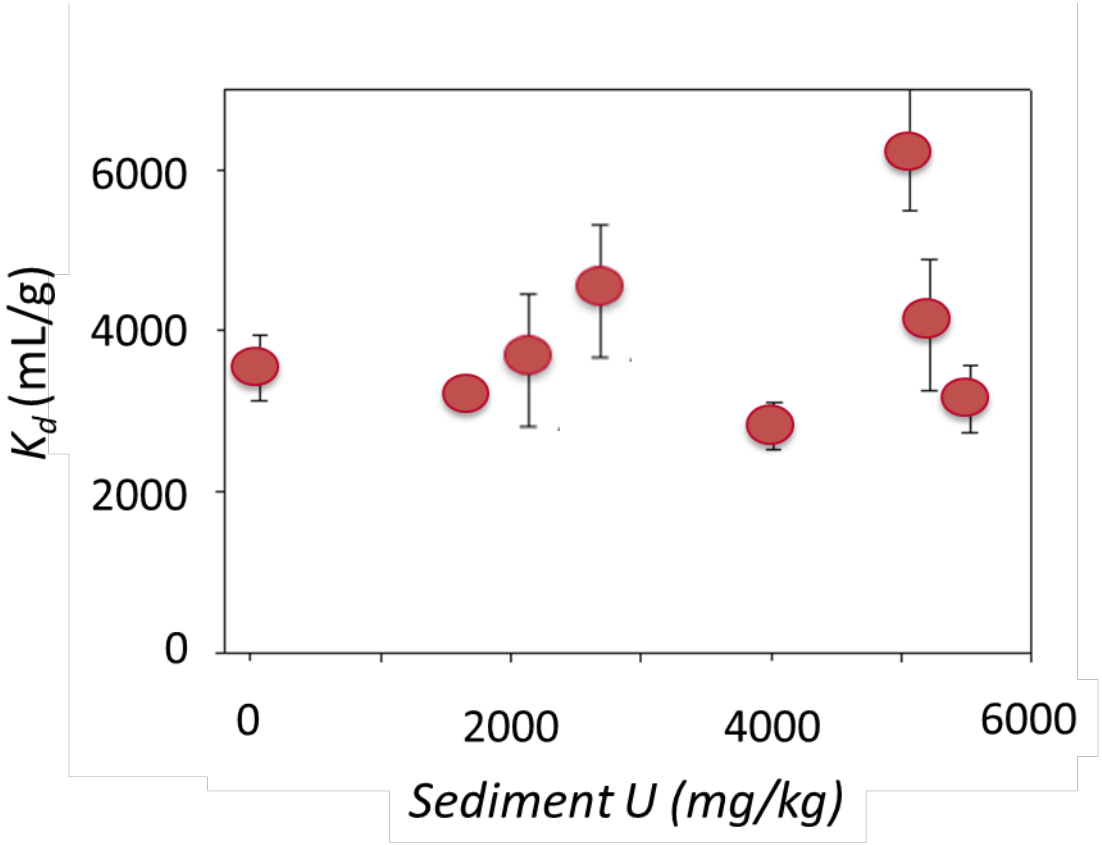


- *Based on 800,000 spectra & a dozen depth profiles: 94% of released U remain in the wetland after 50 years*
- *No U in uplands*

Kaplan et al. 2024
ACS Earth & Space Chem

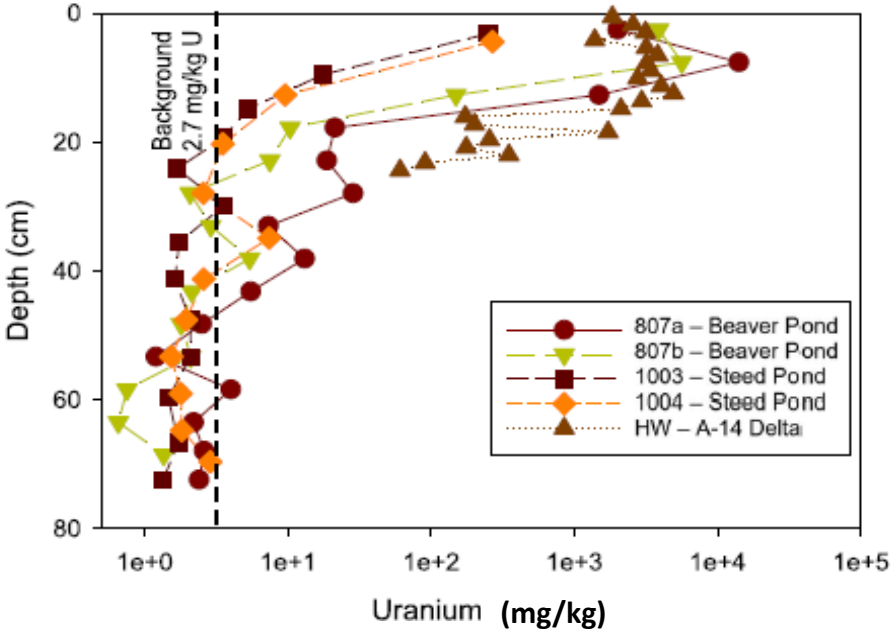
Sediment U: Sorption

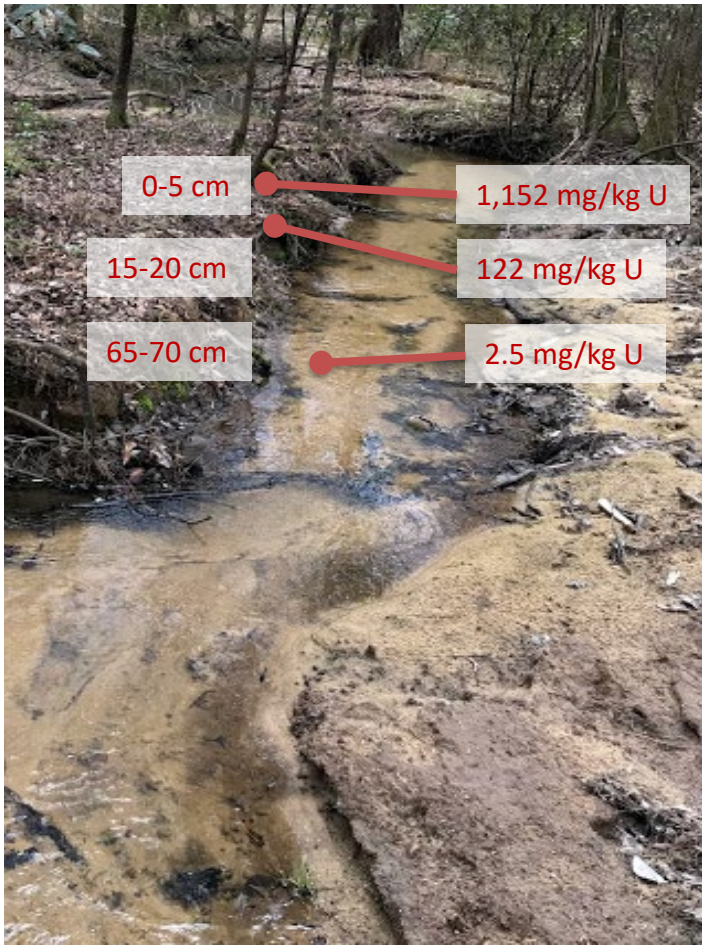
$$K_{d-desorb} = \frac{U_{sediment}}{U_{aq}}$$

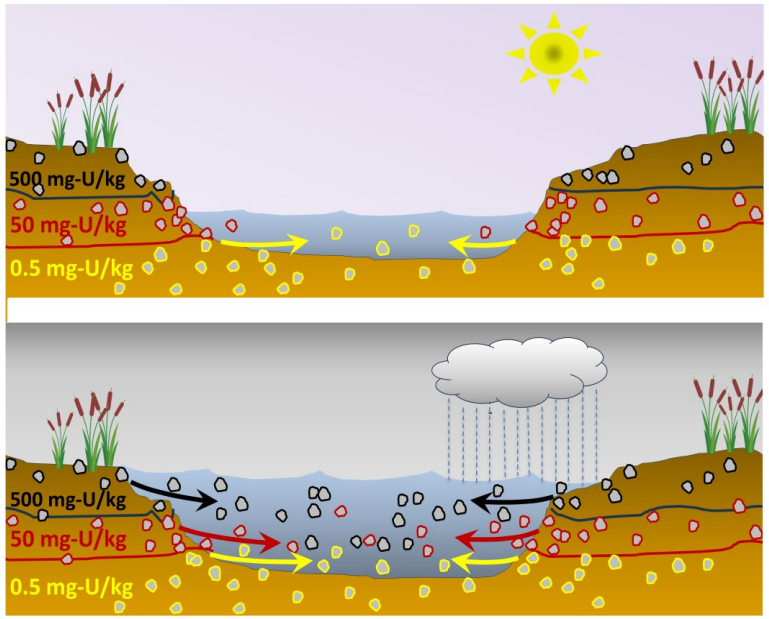


Kaplan et al. 2024 ES&T

Sediment U

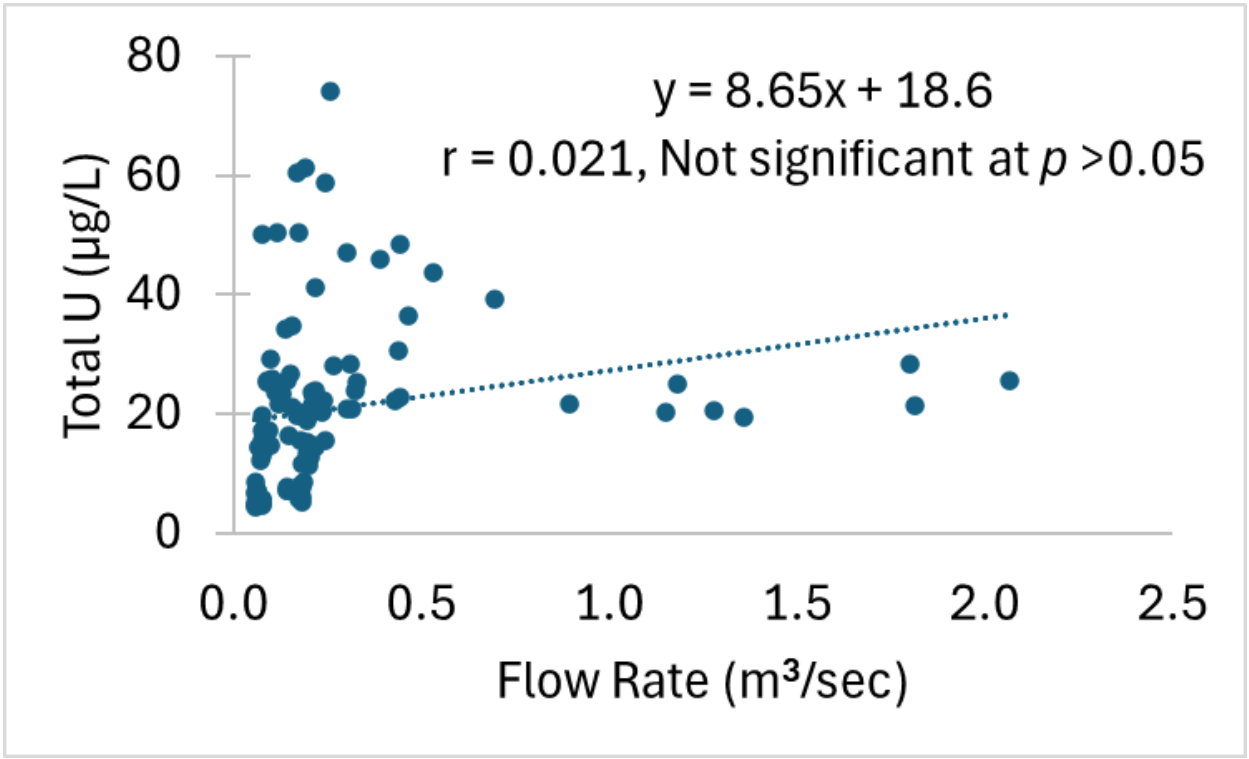






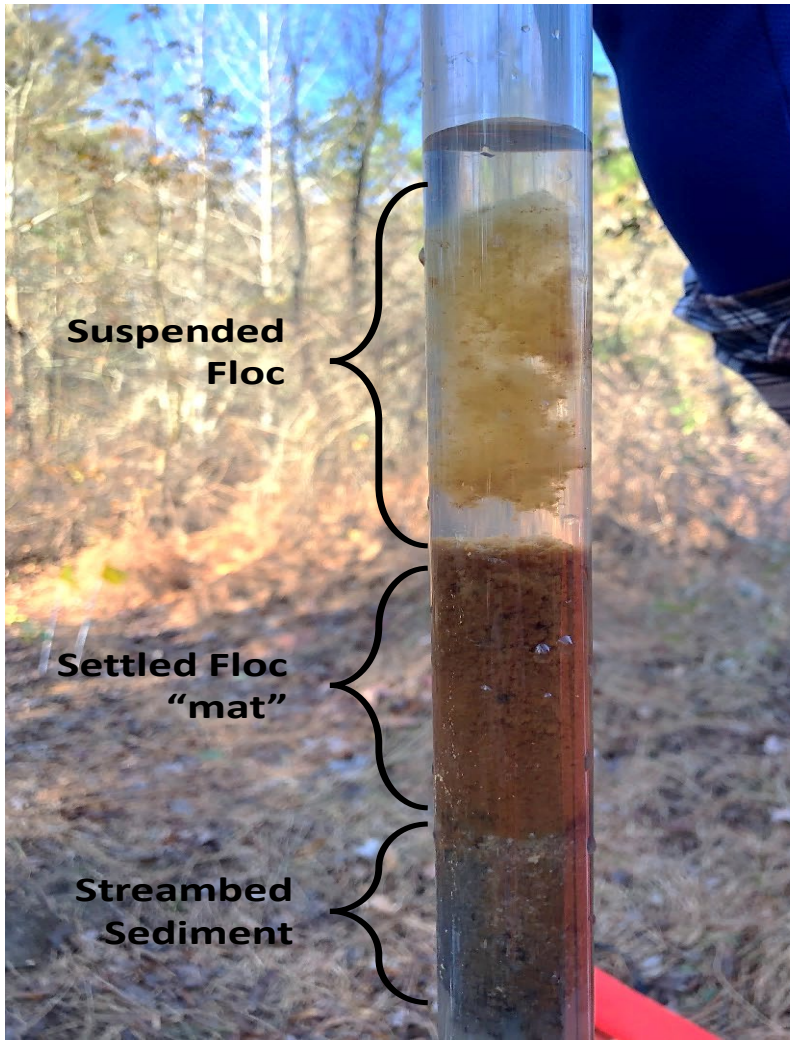
Conceptual model *– vary suspended U concentrations in model based on stream depth*

Stream U: Flow Rate



Problem: Contrary to a core assumption of our USACE stream model

Stream U: Suspended Solids



Suspended Solids Concentration early & late during Storm-A

Samples	Early	Late
# of samples	13	11
U (mg/kg)	**562*** **	181
Fe (wt%)	**26.8*** **	4.7
Mn (mg/kg)	**3909*** **	511
K_d ($U_{Solid}/U_{<0.45\mu m}$)	**56,200*** **	29,500
Diameter (nm)	**267*** **	215
Amorph. phases (wt%)	**59** **	12
Quartz (wt%)	17	**38** **
Kaolinite (wt%)	22	**43** **
Gibbsite (wt%)	2	7
, * = significant difference at $p < 0.01$ and $p < 0.001$		

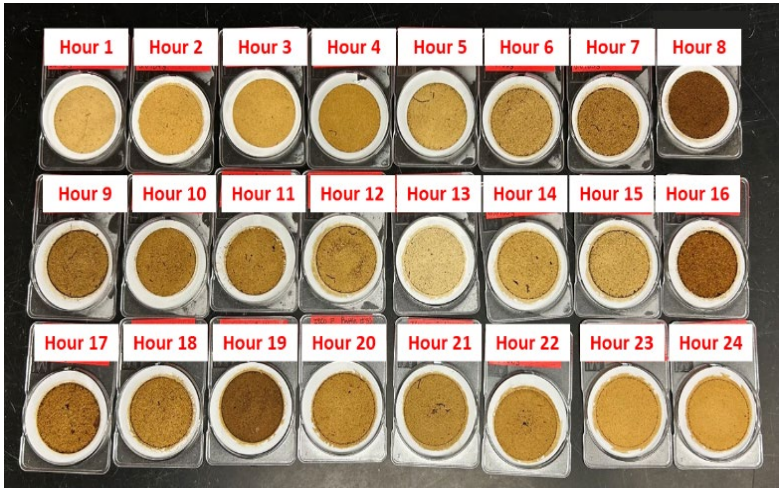
Kaplan et al. 2025 ES&T
Parker et al. 2024 App. Geochem

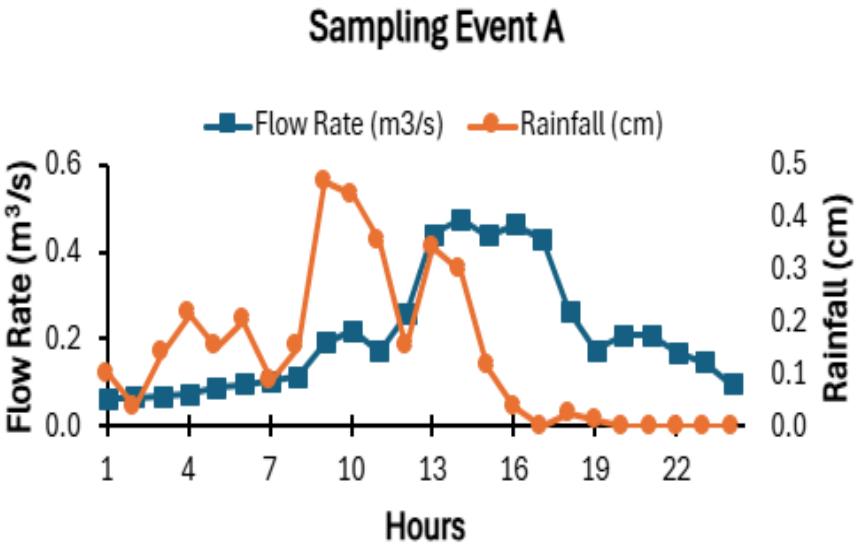
Stream U: Suspended Solids

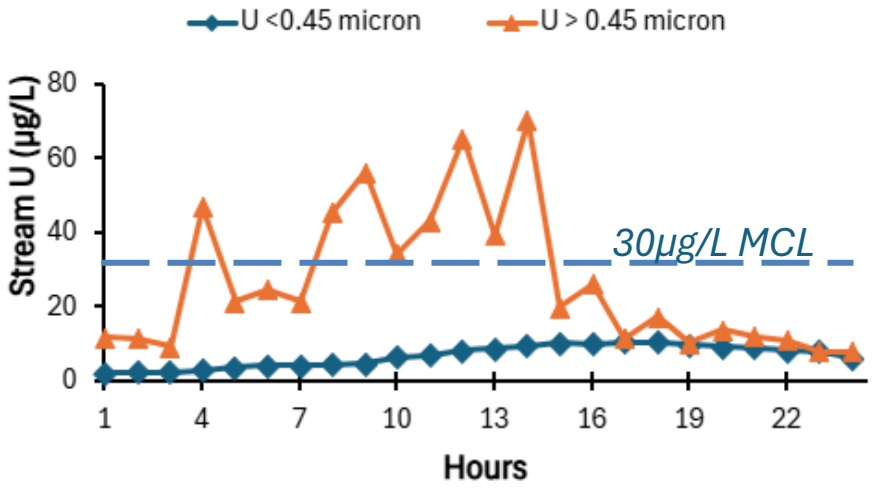
6 rain events

- *Rainfall = 0.7 to 10 cm/event*
- *Flow rate = 0.07 to 2.1 m^3/sec*
- *Total U_{stream} = 4 to 120 µg/L U*

Suspended solids collected on 0.45µm filters during rain event







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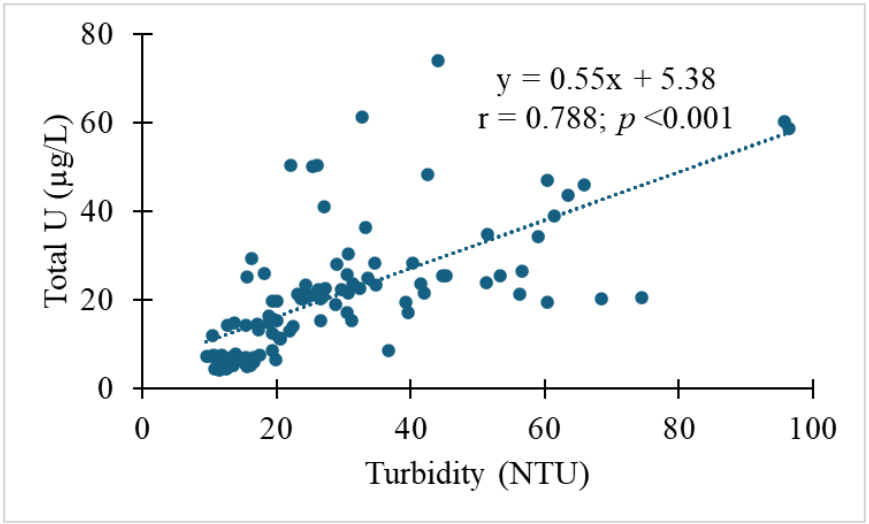
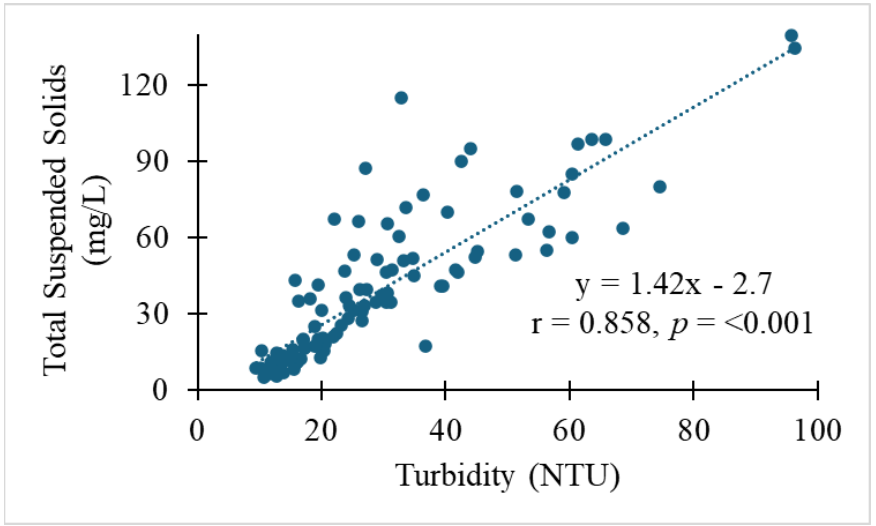
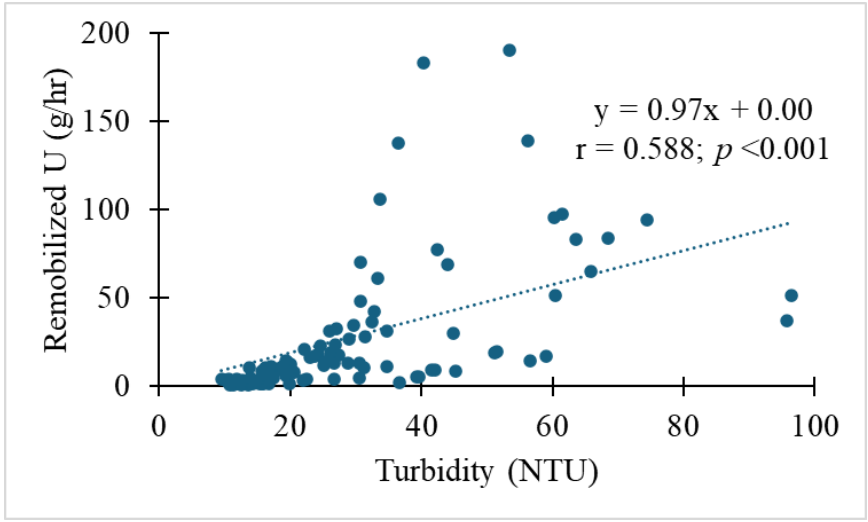
Stream U: Turbidity

$$U_{Total} = U_{>0.45\mu m} + U_{<0.45\mu m}$$

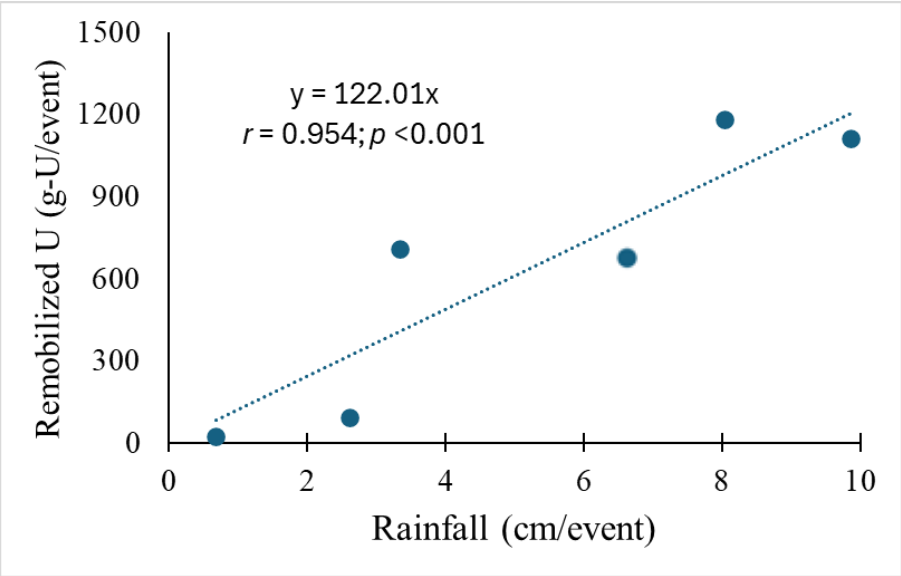


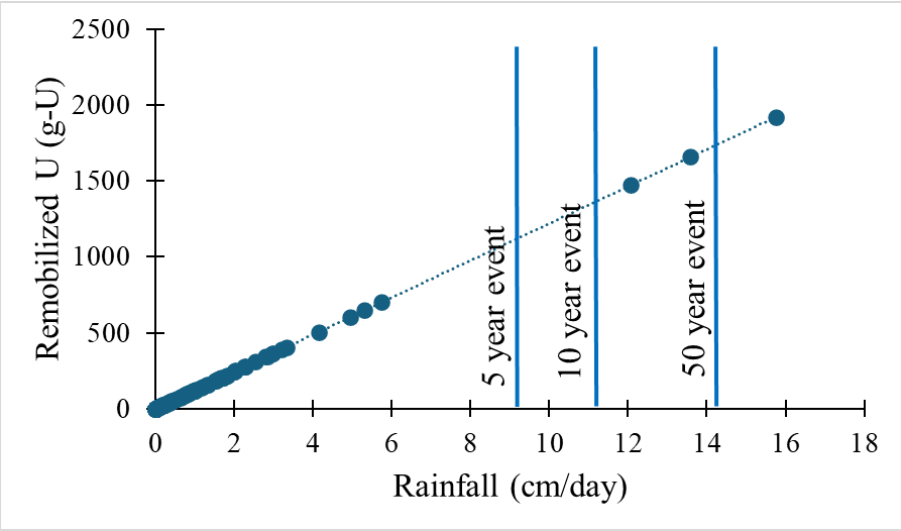


$$[U_{RemobilizedHr}]\frac{g\,U}{hr} = [U_{Total}]\frac{g\,U}{L} \times [Flow\ rate]\frac{L}{hr}$$



Stream U: Remobilized U vs. Rainfall





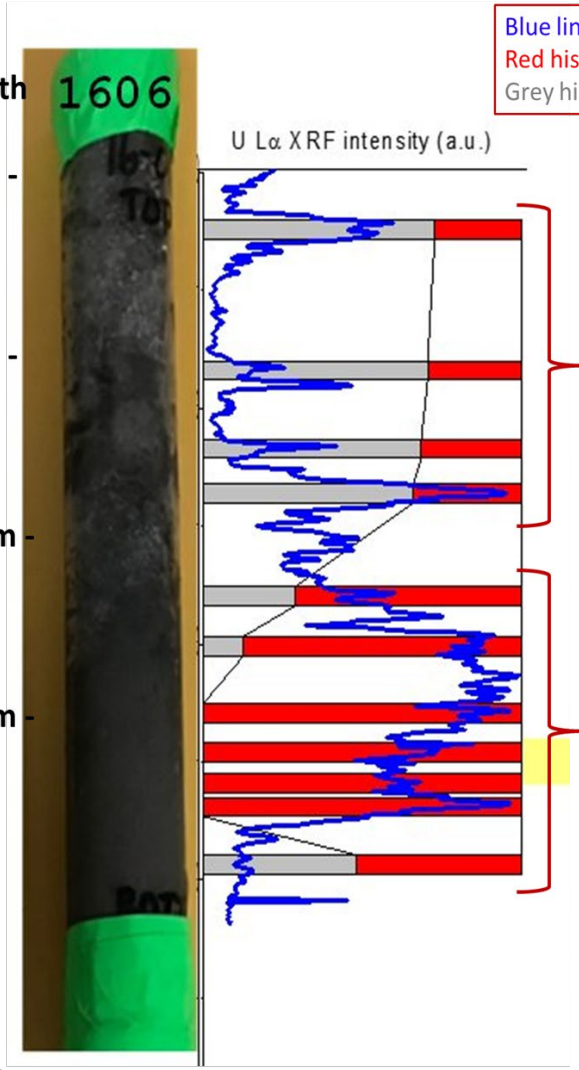
Between 1969 and 2025, ~900 kg U was estimated to be remobilized by the stream, which is equal to 2.2% of the total 43,500 kg released by the facility.

Kaplan et al. 2025 Sci Total Environ (accepted)

Conclusions

- **Long Term Stewardship** of 43,500 kg U, 94% remains in wetland & 2.2% remobilized in streams after 50 years
- **Resilience**: Wetland attenuation of contaminants is dependent on their delicate balance of hydrology and biogeochemistry. Significant anthropogenic or climatic changes to wetlands, such as flooding, forest fires, or land use, will disrupt this balance.

Sediment U: Geochemistry

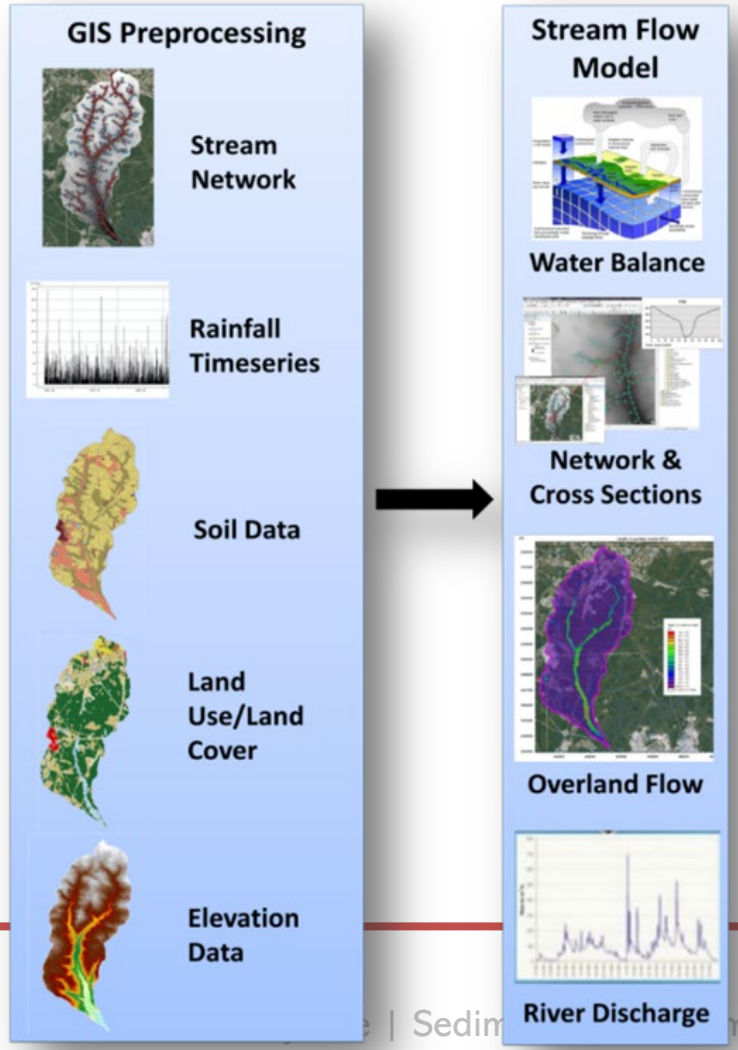


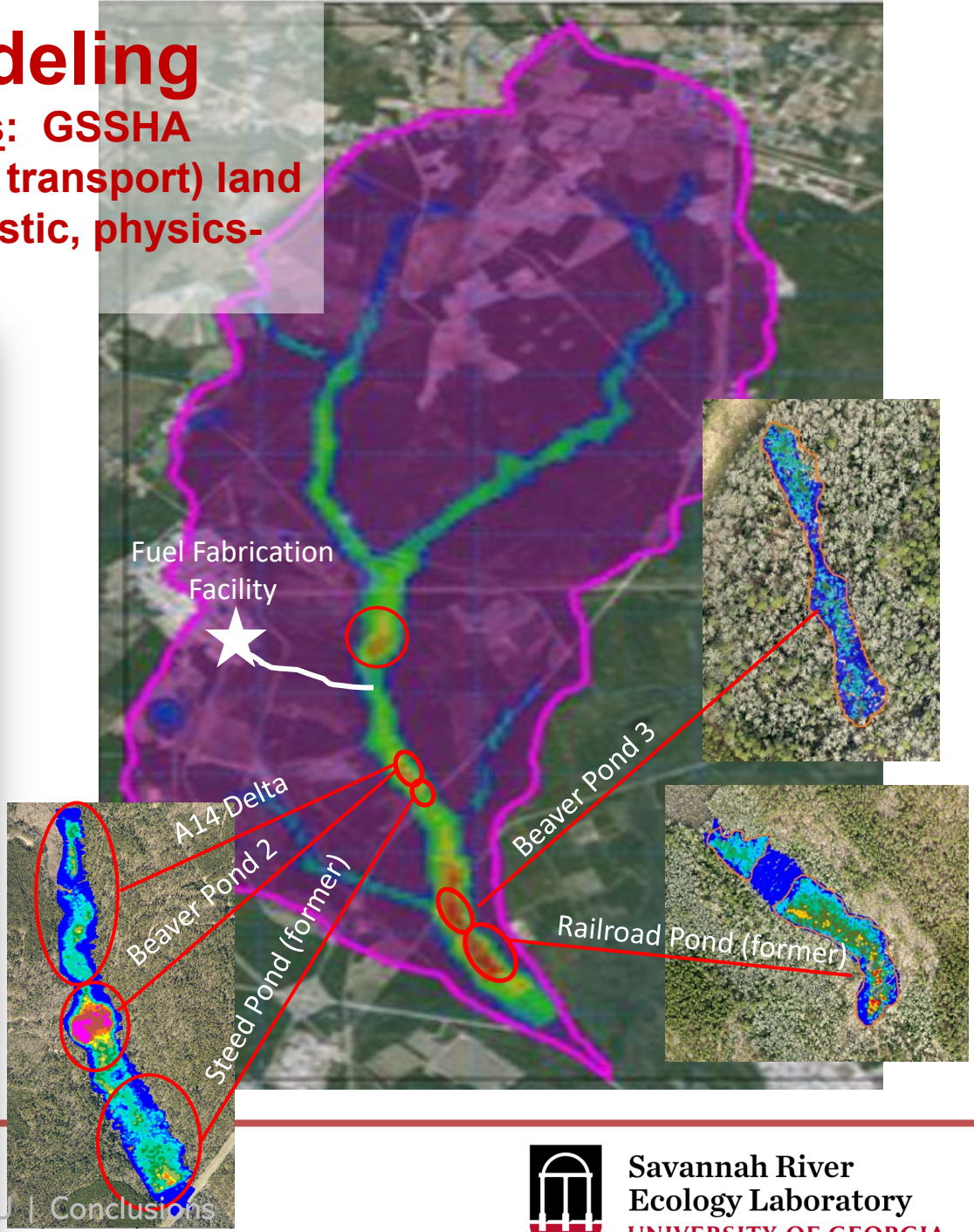
- Accumulation of U in the top 5-10 cm
- In drier or near-surface environments the predominant valence state is U^{VI}.
- Conversely, in saturated sediments that are not directly exposed to air the predominant valence state is stabilized as U^{IV}
- Speciation has implications on modeling U transport in the environment

Boyanov et al. 2024
DOE-OS ESS PI's Meeting

Stream-U Land Modeling

U.S. Army Corp Engineers models: GSSHA (hydraulic) & HEC-RAS (hydraulic transport) land models, deterministic or probabilistic, physics-based





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