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Quantifying Sediment Transport and Fate in Small Streams Using Rare Earth Elements as Tracers

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Lets just say that excess sediment is a bad thing.....

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So… we apply BMPs to try to stop the sediment….

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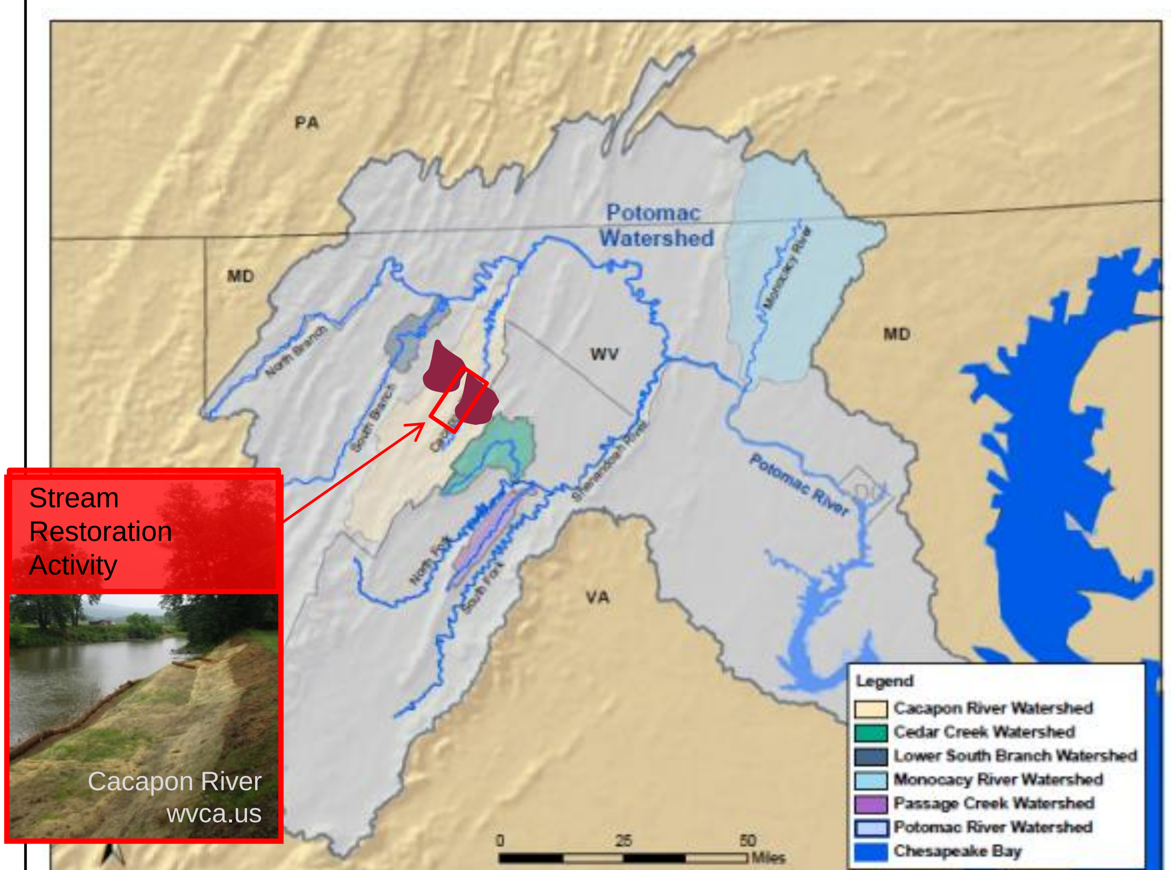
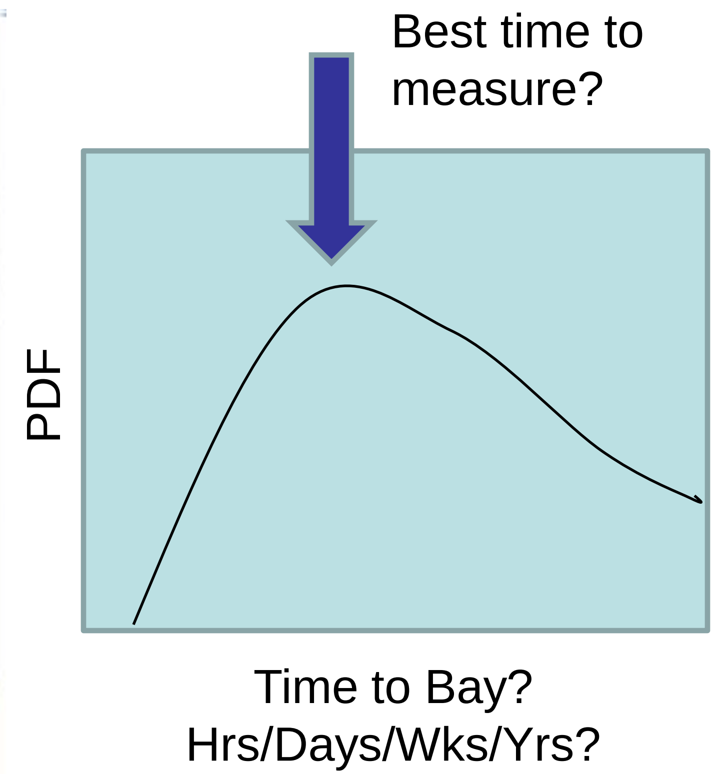
But… when should we expect to see improvements in downstream waterbodies?



Map by Potomac Conservancy March 2011.



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Our goal is to quantify this travel time (or lag time)… or at least start moving in that direction….

Where does it go?
How far does it go?
How long does it take to get there?
When will it improvement downstream?

~ 1000 m reach
Simple(r) System

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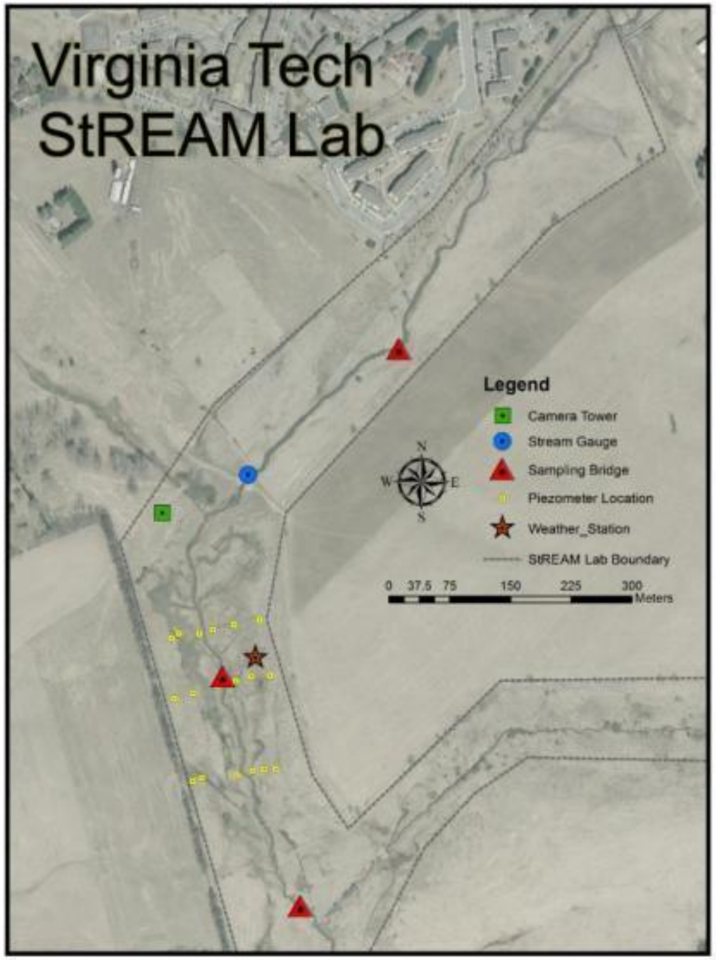
Study done @ VT StREAM Lab



http://streamlab.bse.vt.edu/

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Instrumentation

Full weather station

Porewater sampling

Storm sampling

Tracer injections

Datasondes

Sediment samplers

Well networks

Live cameras

Live data online

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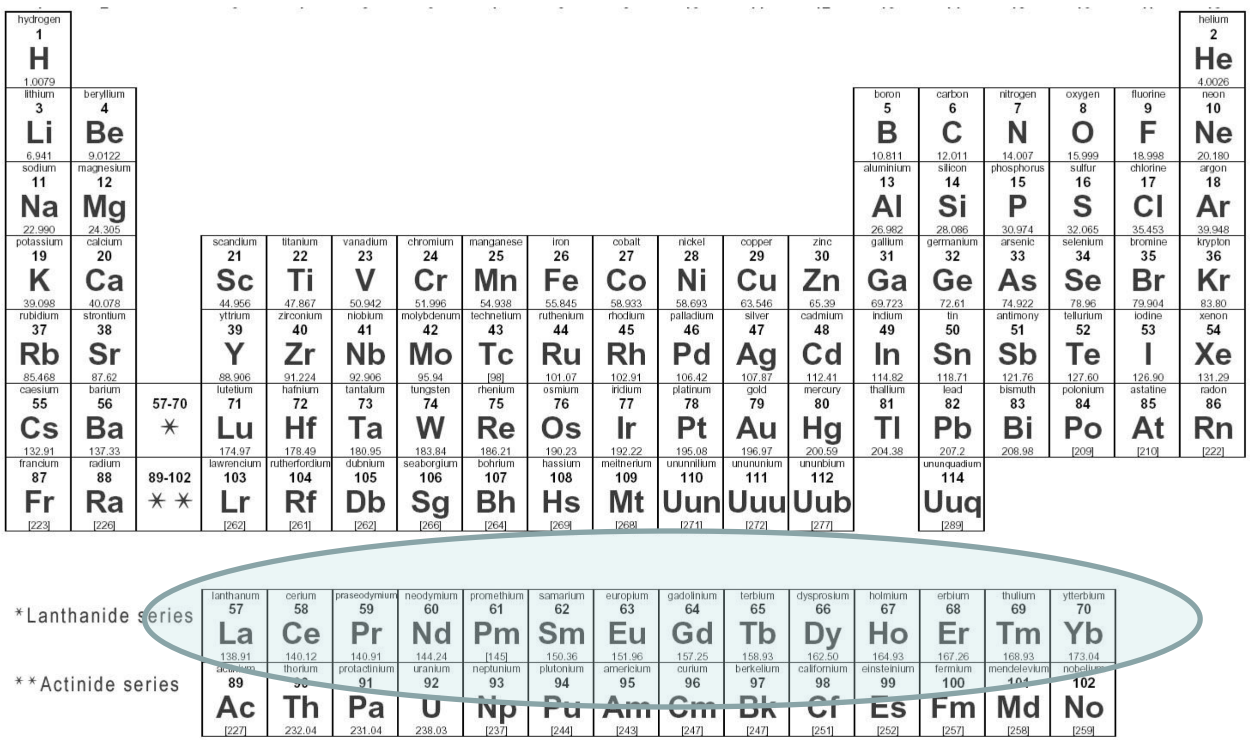
Can we use rare earth elements as sediment tracers to get at this?



http://www.bpc.edu/mathscience/chemistry/images/periodic_table_of_elements.jpg

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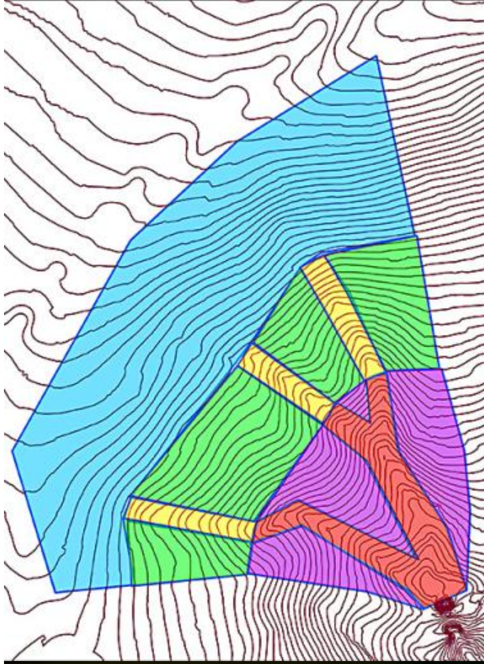
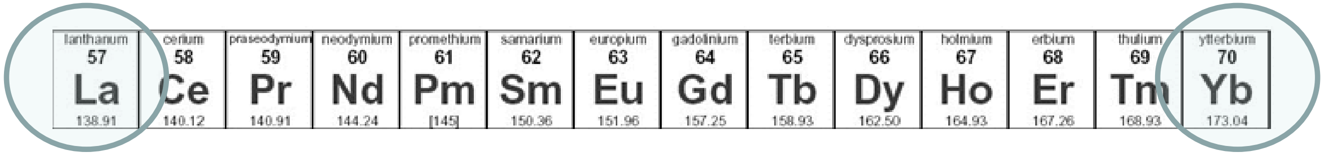
REEs as sediment tracers

- **REE s as sediment tracers**
  - Hill slope, plot and laboratory-scale erosion
  - Limited use in fluvial settings
- **An ideal tracer?**
  - Physical characteristics similar to sediment
  - Low detection limit
  - Multiple, unique signatures
  - Simple/inexpensive to create & detect
- **We performed isotherms for La and Yb**
  - Potentially 14 distinct tracers



http://www.ars.usda.gov/is/AR/archive/jun05/soil0605.htm



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REEE adsorption to stream bank sediments

- We performed isotherms using natural bank sediments
- Equal adsorption of La & Yb
- No desorption in stream water, < 0.3%
- Low background concentrations
  - Soil – La ~ 26 ppm; Yb ~ 1.5 ppm
  - Stream water- La and Yb <0.1 ppm

The stuff sticks and it stays stuck!

Created two unique tracers

- **Prepare REE-enriched tracer using La and Yb**
  - Mix a single REE with equal amounts of Soil 1 and 2
  - 4.8 kg soil
  - Equilibrate 3.5 – 8 weeks

	Lanthanum (ppm)	Ytterbium (ppm)
Bank Soil	26	1
La Tracer	**13,355**	1
Yb Tracer	20	**19,440**
Stream water	0.07	0.01

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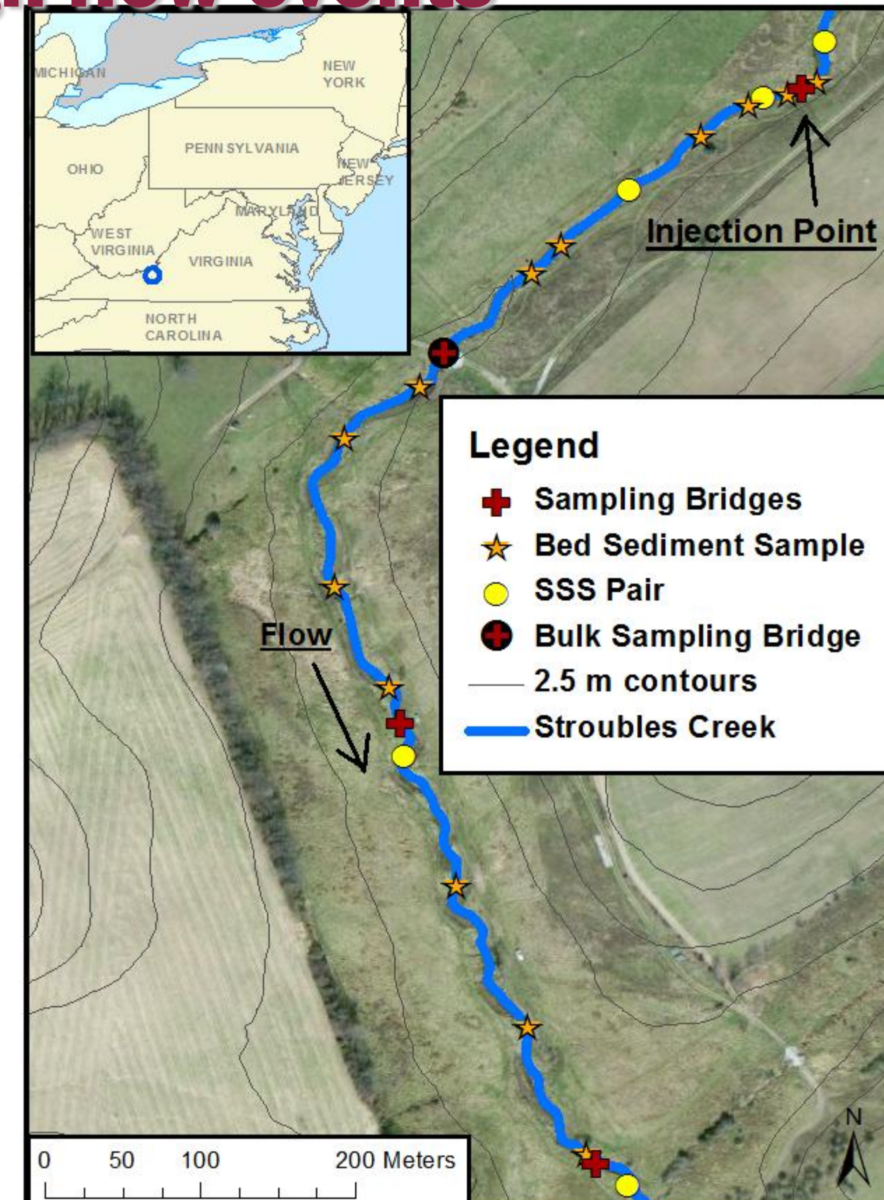
Field deployment of the REE tracer during high flow events

- 5-gallon bulk samples
- Suspended sediment samples (SSS)
- Bed sediment samples



ems

Sampled 7 high-flow events

- **Injected REE-labeled sediments**
  - Sampled from October 29 – 12/16/11
  - Injected REEs in Storms 1 and 3

Storm	REE Injected	Max Discharge ($m^3\ s^{-1}$)	Discharge at Injection ($m^3\ s^{-1}$)	Max Turbidity (NTU)	Turbidity at Injection (NTU)
1	La	0.37	0.20	25.7	14.8
2	-	0.64		48.4	
3	Yb	1.66	1.53	152.9	28.4
4	-	2.83		194.2	
5	-	6.58		169.4	
6	-	2.51		115.9	
7	-	0.53		59.6	

@ High Flows

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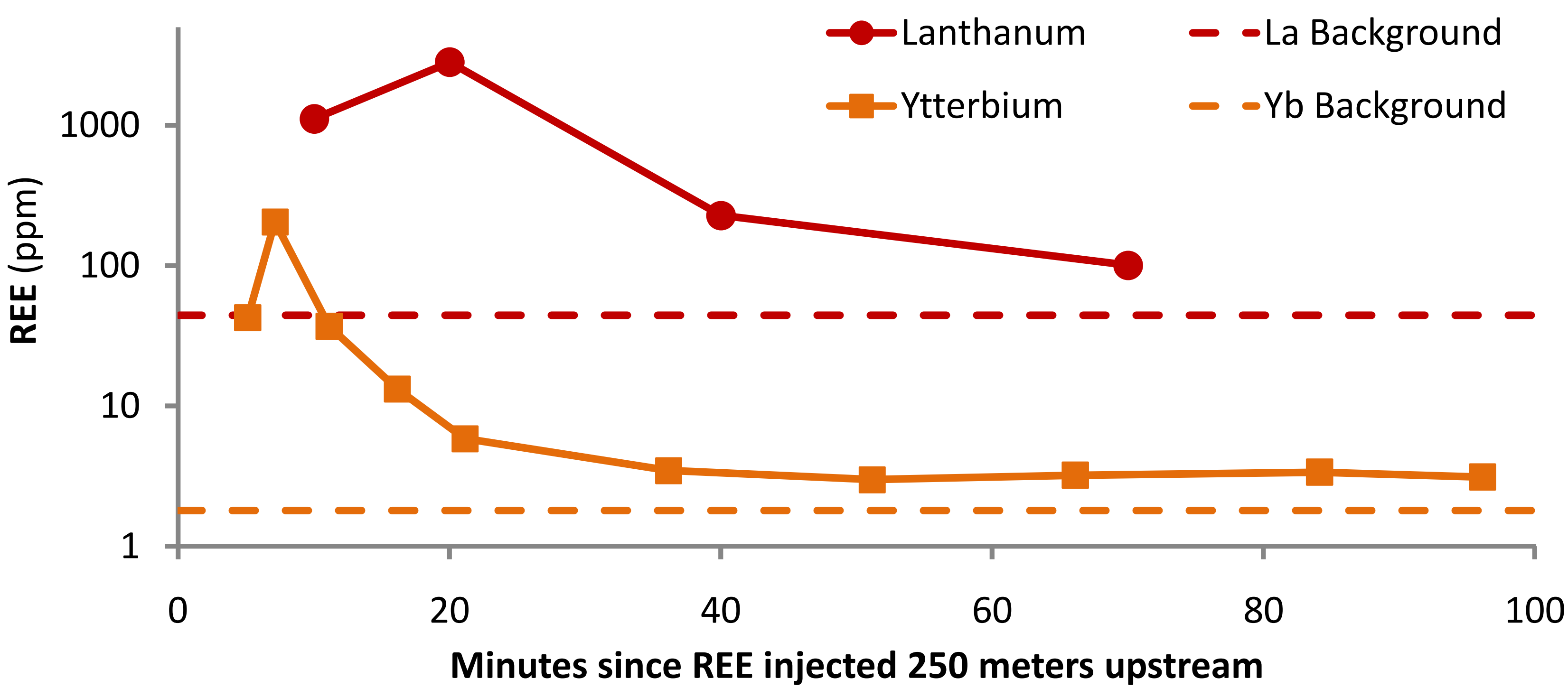
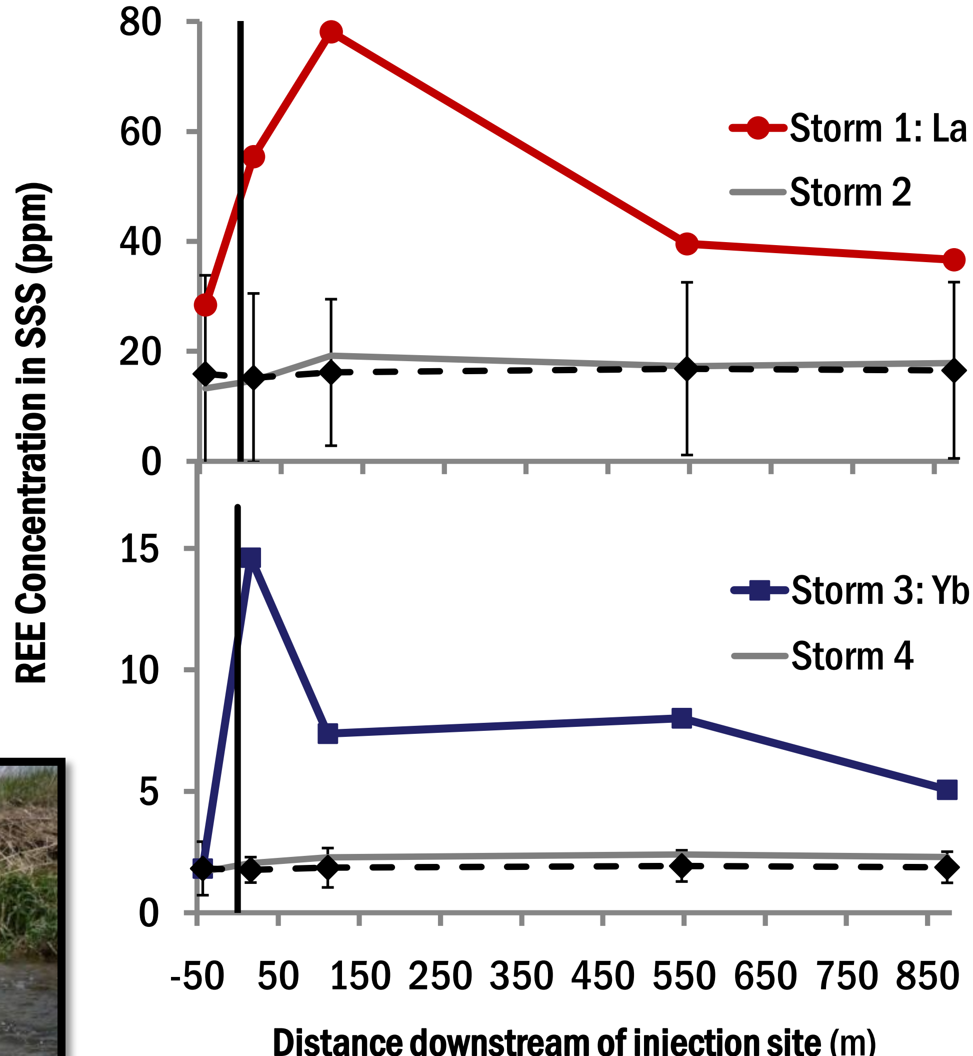
All 3 REEs detected at 250 m

- Bulk sampling at the concrete bridge
- All tracers were detected in the stream



Tracer detected at 875 m in SSS

- SSS are time-integrated
- La and Yb were detected at 875 m
- Minimal tracer re-suspension



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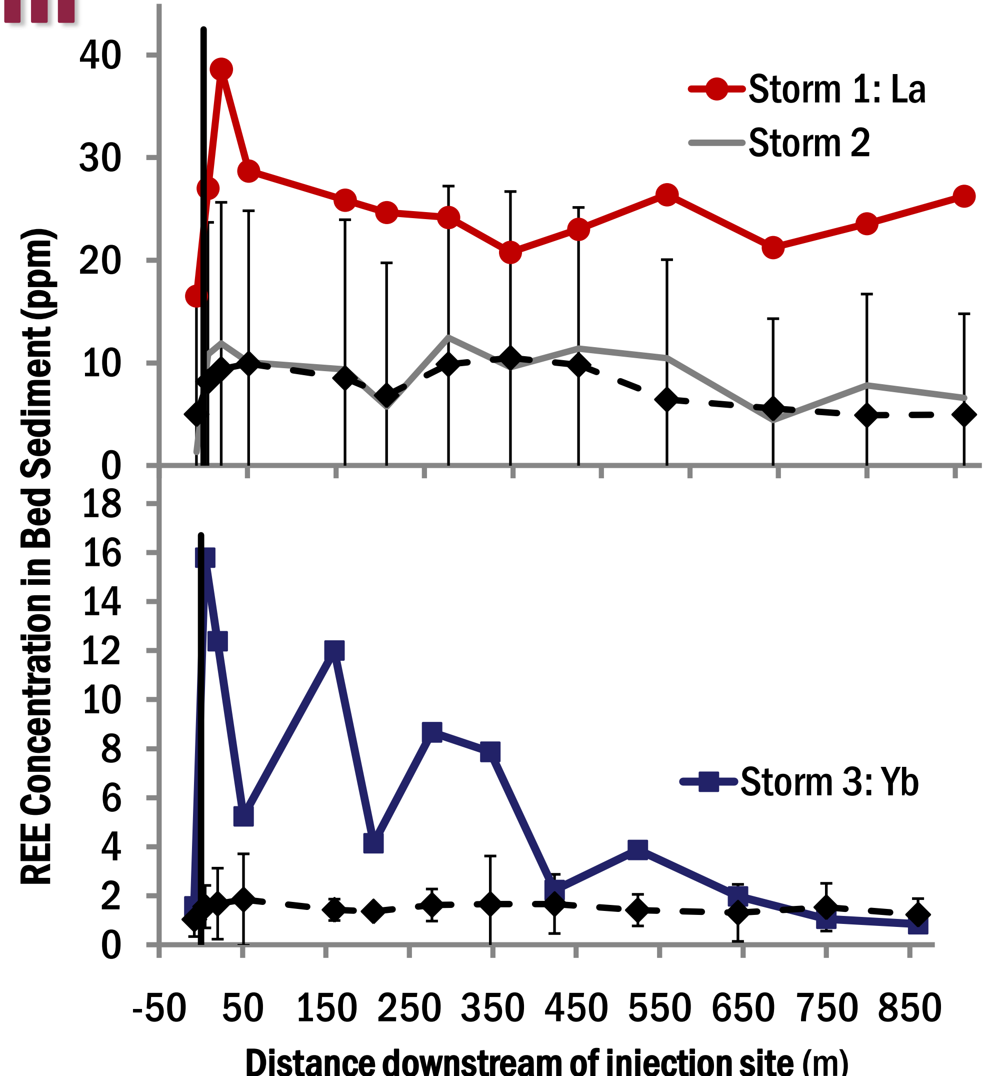
REEs in bed sediment at 875 m

- Samples collected 1-5 days after event
- La and Yb were successfully detected



REE-laced sediment can be tracked...

- Detected in bulk, SSS, and bed sediments
- REE tracer detected up to 875 m downstream
- REE-labeled tracer detection depends on
  - Background REE concentration
  - Enrichment level
  - Sediment load at time of injection
- REEs are stable, adsorb well to natural soils

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There were some challenges

- Varying high-flow events
- High-flows ALWAYS happen at night
- Clogging of the SSS
- Deposition sampling

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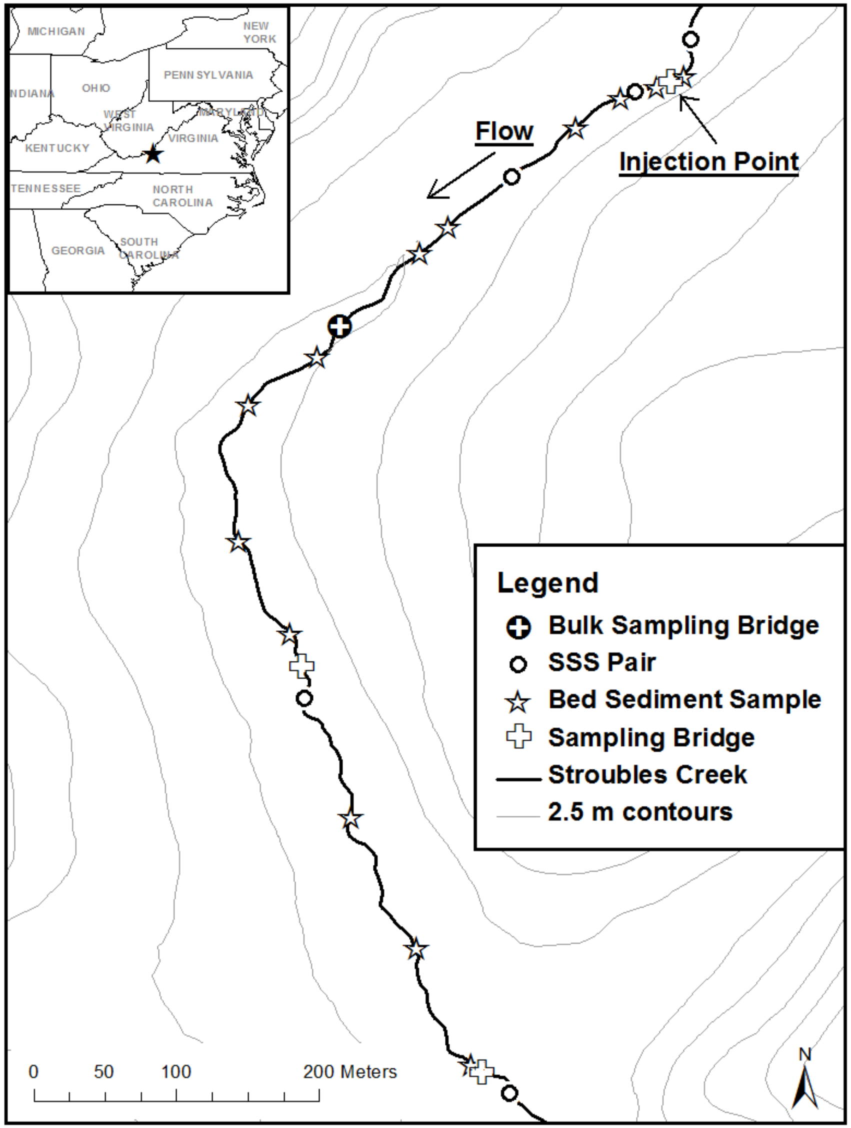
Now what?

- More "bulk" sampling longitudinally
- Inject/spray actual in-place bank sediments
- Pick apart the "lag time" mystery piece by piece
  - Where does it go?
  - How far does it go?
  - How long does it take to get there?
  - When would we see improvement downstream?



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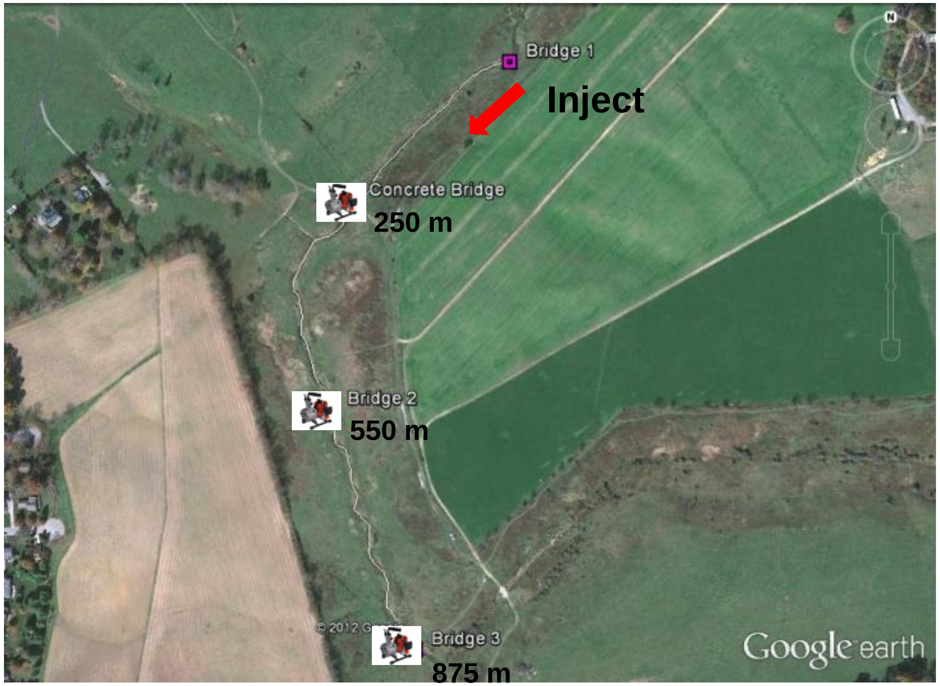
"Bulk" sampling spatially

- 3 bulk sample sites
- Already bought 2 new pumps
- ~156 "bulk" bucket samples
- Dysprosium injection ready
- An "event" would be nice....



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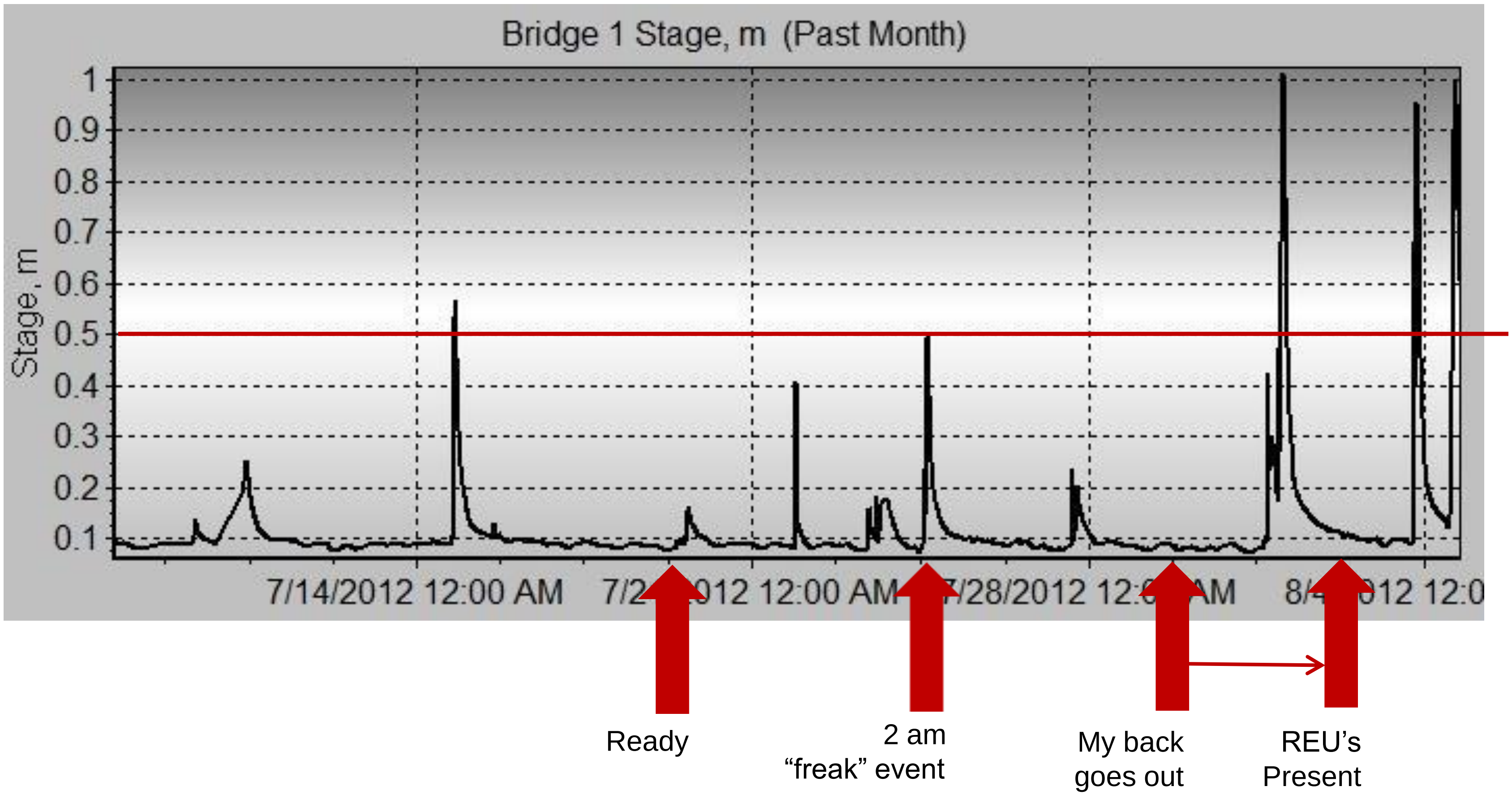
Need “event” and to be “ready” to do injection experiment



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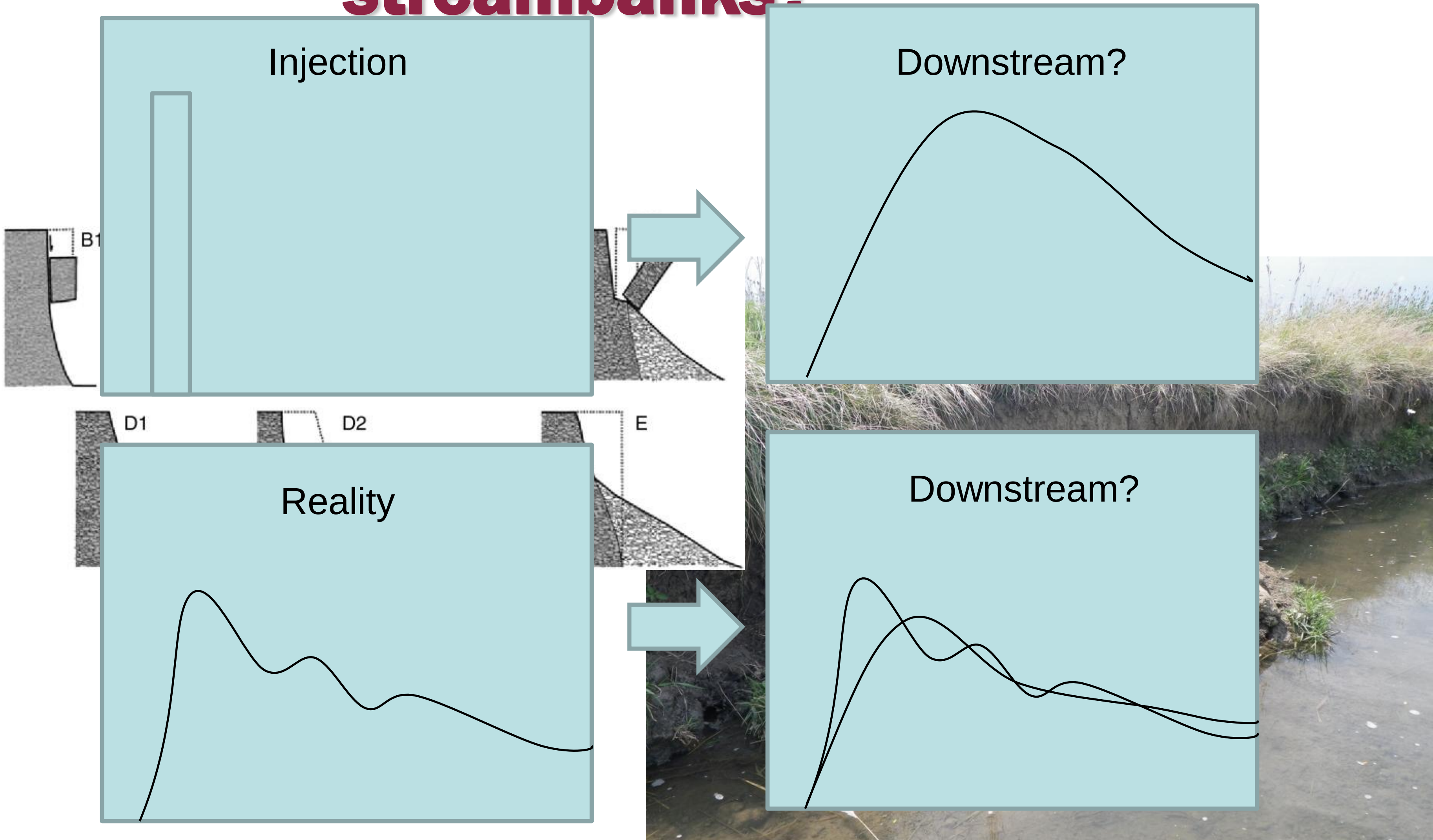
Injections on actual streambanks?



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Limits

- Detectability/enrichment/concentrations
- How far downstream can we find laced sediment
- At mercy of weather
- Manpower
- Only small piece of puzzle

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Acknowledgements

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- Nate, Luke, Emily and Katie
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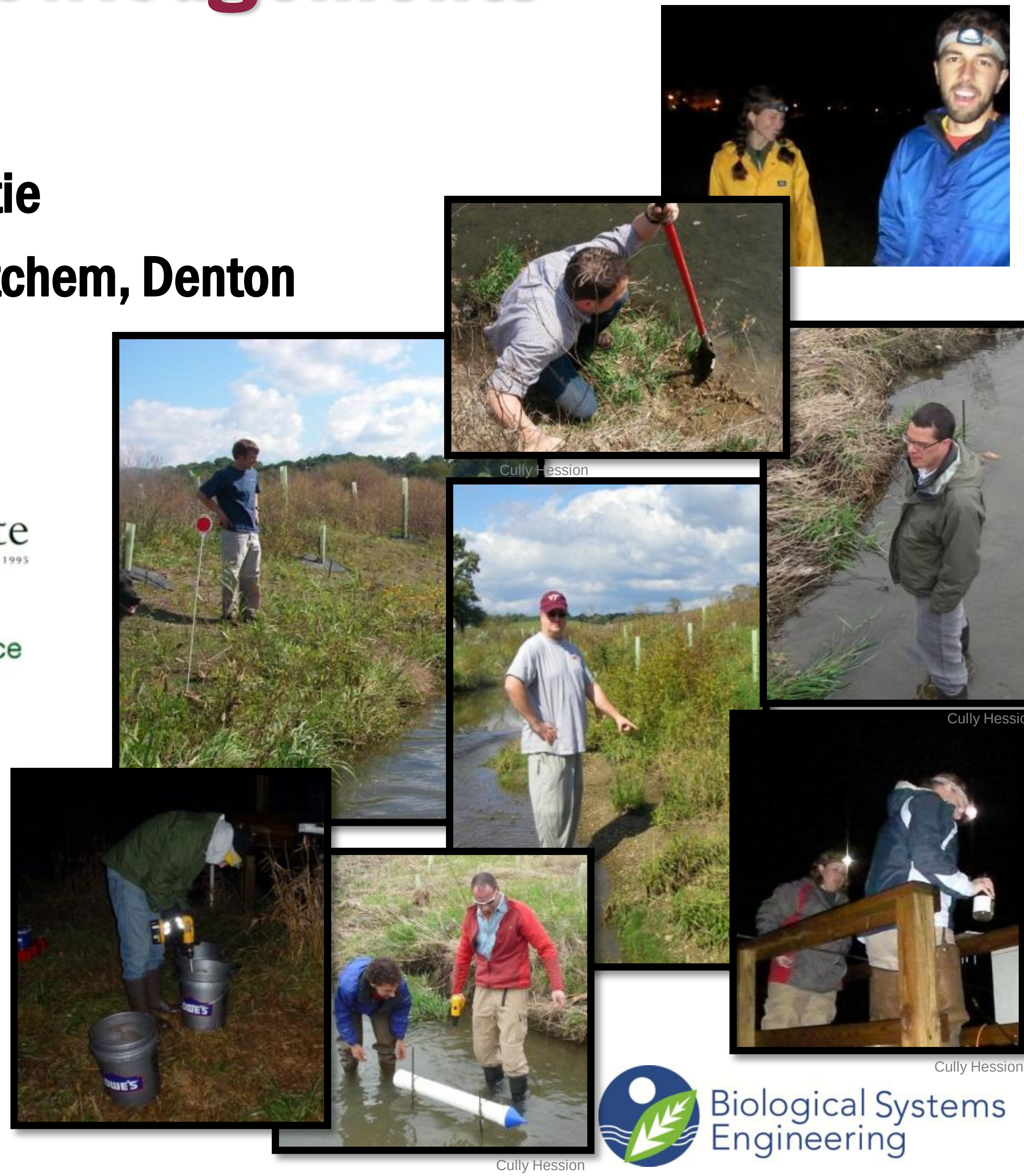
WORKING FOR THE SUSTAINABILITY OF THE MID-ATLANTIC HIGHLANDS SINCE 1995

USDA ars United States Department Of Agriculture
Agricultural Research Service

Virginia WATER RESOURCES Research Center

CENTER for WATERSHED STUDIES at VIRGINIA TECH



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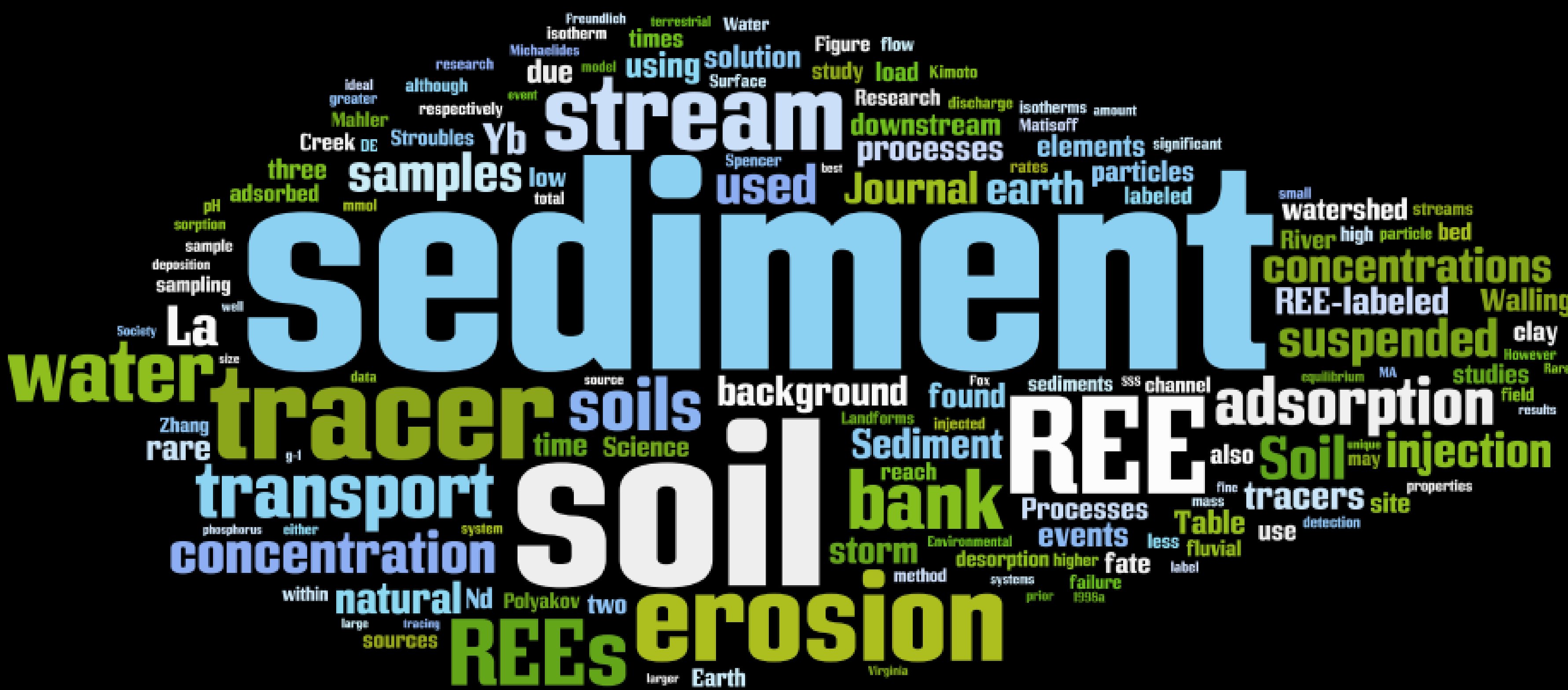
Questions . . .



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Dynamics of Water and Societal Systems An Interdisciplinary Research Program at the Virginia Tech StREAM Lab

NSF Research Experience for Undergraduates (REU)

Virginia Tech, Blacksburg, Virginia

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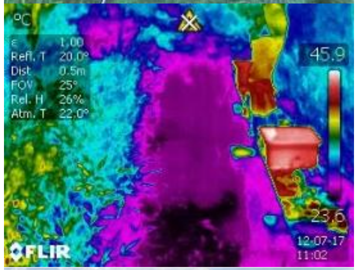
StREAM Lab NSF-REU 2012



- Community Knowledge, Attitudes, and Behaviors Towards Water Resources Within the Upper Stroubles Creek Watershed web
  - Charlotte Brown (UNC) & Jerod Myers (VT)
- A Multilevel Health Assessment of Stroubles Creek web
  - Sara Gokturk (VT) & Deandre Smith (Univ. Ark)
- Experimental Flooding of a Restored Floodplain within an Urbanized Watershed web
  - Katy Hofmeister (Hampshire) & Tyler Weiglein (VT)
- Spatial Assessment of Stroubles Creek using Macroinverts and TSS Measures web
  - Teneil Sivells (NC A&T) & Margaret Whitsell (LSU)
- Analysis of Stroubles Creek using SWAT and GIS web
  - Kevin Chu (UNC) & Adam Oliphant (TX State)

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