Long-term trends of specific conductance in waters discharged by coal-mine valley fills in Virginia, USA

Dan Evans, Carl Zipper, Pat Donovan & Lee Daniels

Effects of Total Dissolved Solids in Streams?





Mining and valley fills have been linked to elevated TDS in streams

Questions

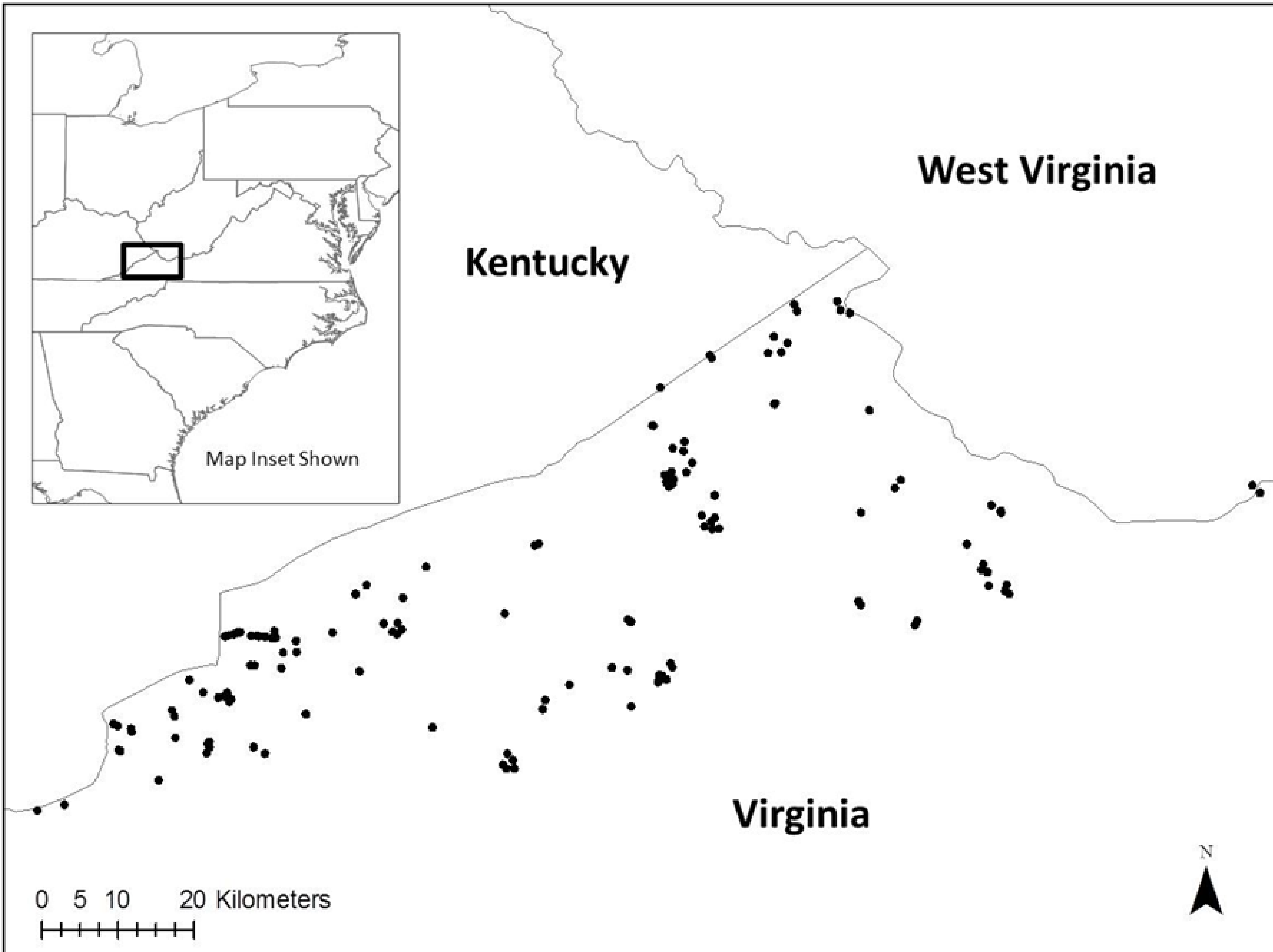
- Does TDS (specific conductance; SC) change during and after the valley fill construction?
- How long does SC stay elevated?
- What are the peak levels of SC?
- Does SC return to background levels? How long does it take?

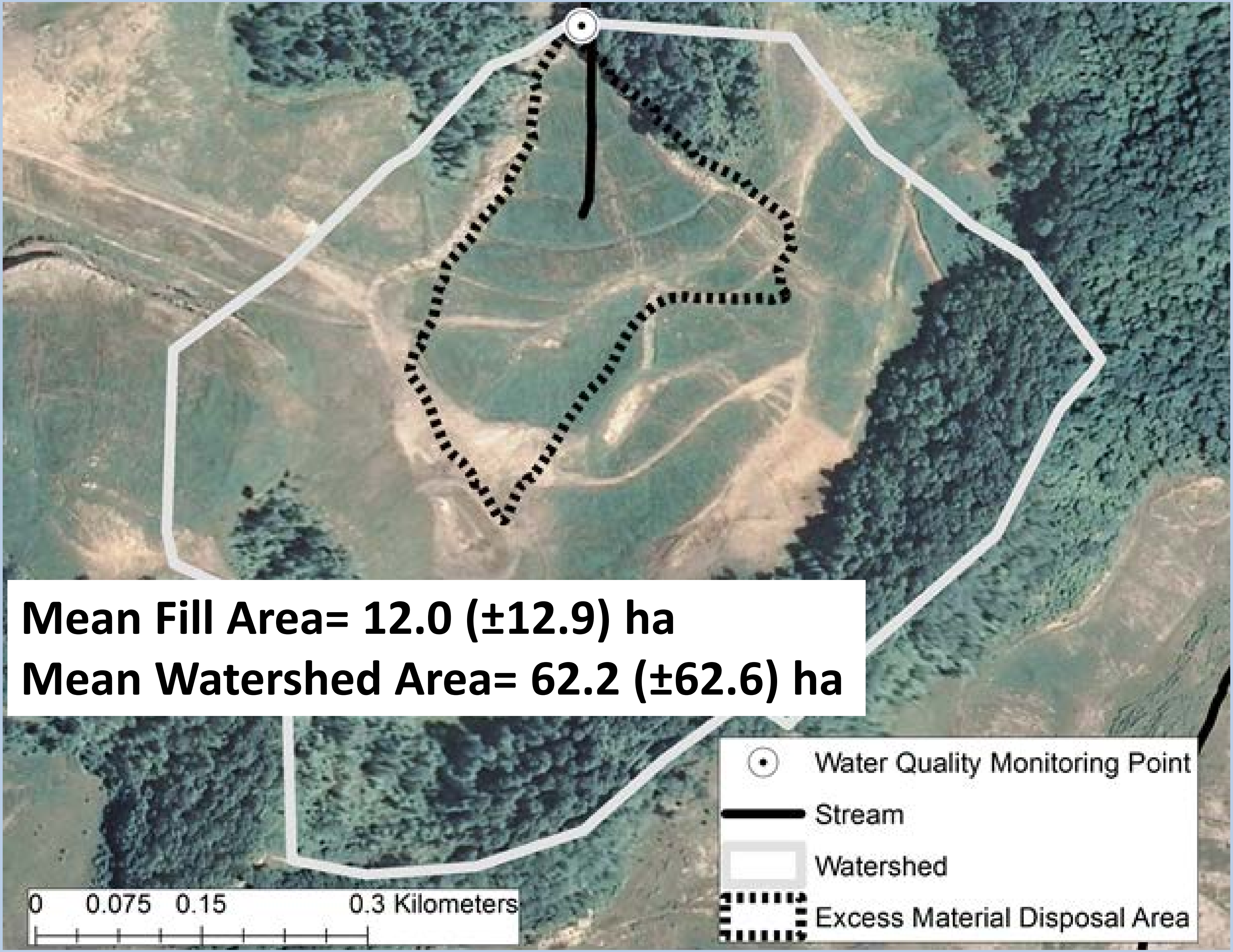
Our dataset is your dataset

- Publicly available water monitoring data from the Virginia DMME database.
- SC is monitored for each Virginia valley fill. Data are stored by Virginia DMME.
- Collected at underdrain outflow.
- Sampling often begins just before valley fill construction and continues for at least 5 years after completion.

Step 1. Valley Fill Selection

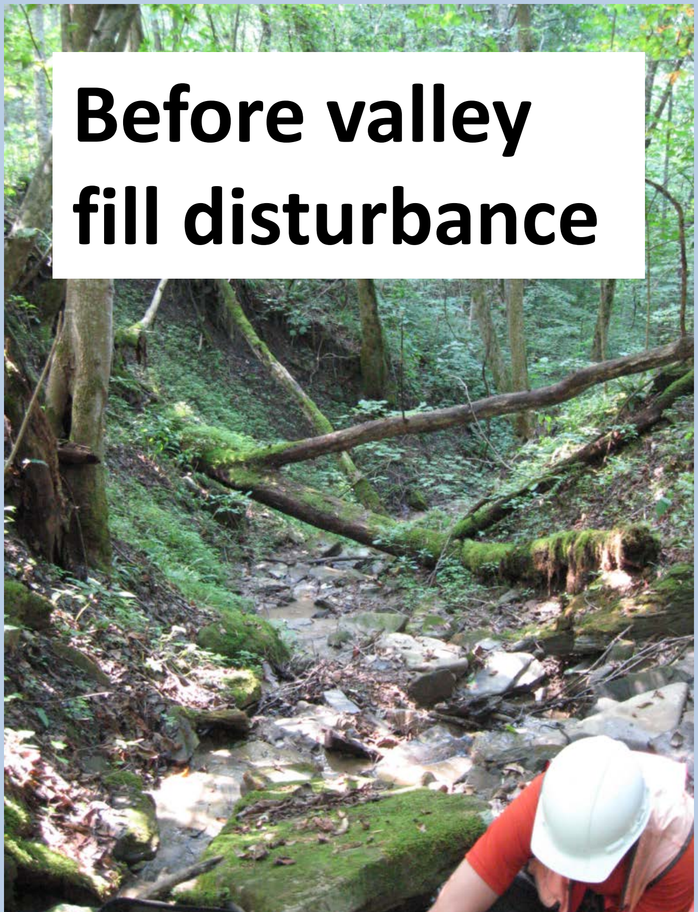
- Starting w/ full underdrain dataset
- Removed sites that
  - were not valley fills, had sorting or prep facilities, coal storage or permanent development.
  - did not have valley fill polygons describing the excess spoil material disposal area in the DMME database.
- Selected 137 valley fills with at least 20 samples and 1 year of sampling.


West Virginia
Kentucky
Map Inset Shown
Virginia
0 5 10 20 Kilometers
N



Mean Fill Area= 12.0 (±12.9) ha
Mean Watershed Area= 62.2 (±62.6) ha
Water Quality Monitoring Point
Stream
Watershed
Excess Material Disposal Area
0 0.075 0.15 0.3 Kilometers

Step 2. Breaking data set into disturbance periods for analysis



Before valley fill disturbance

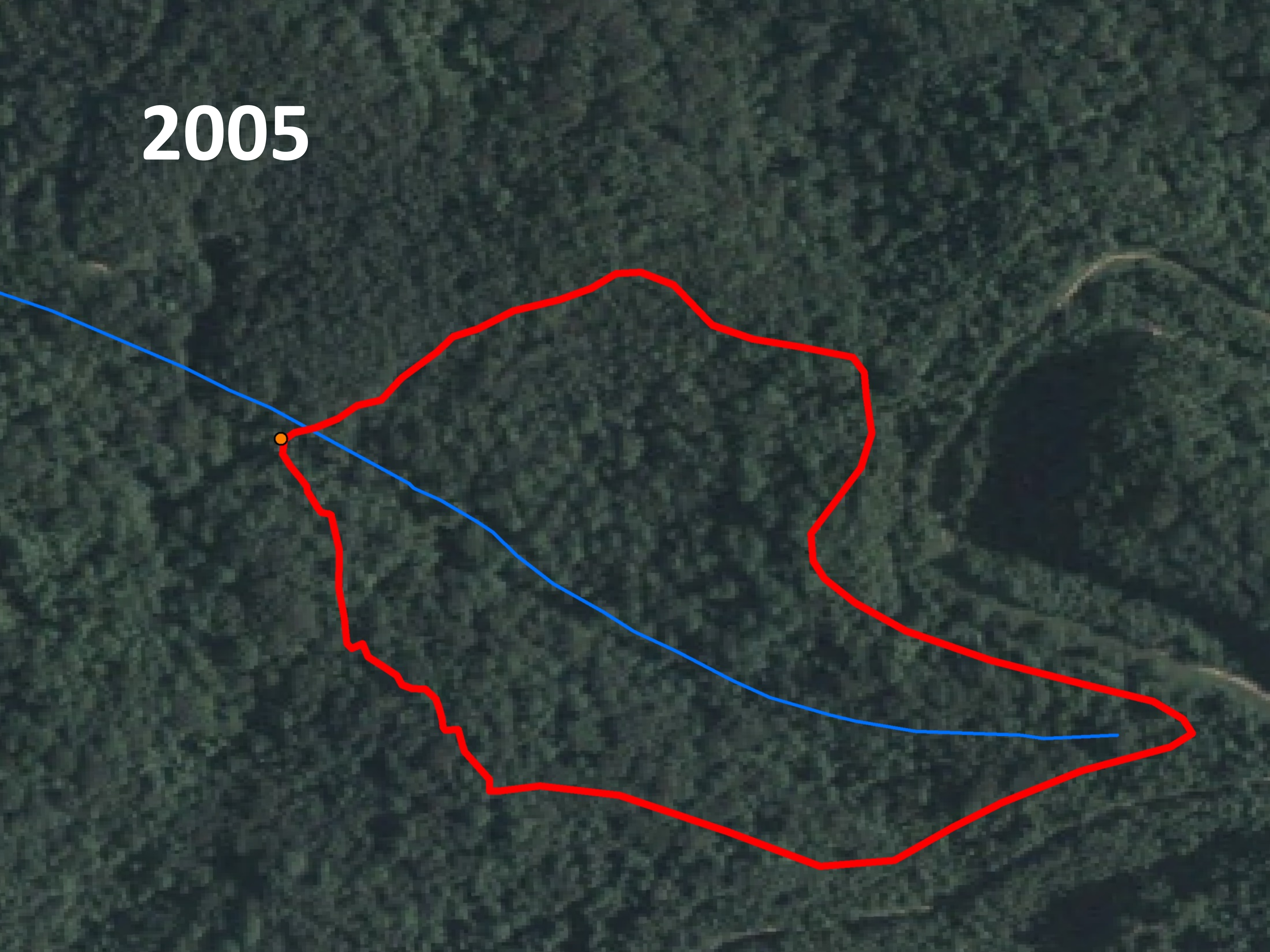
During valley fill disturbance

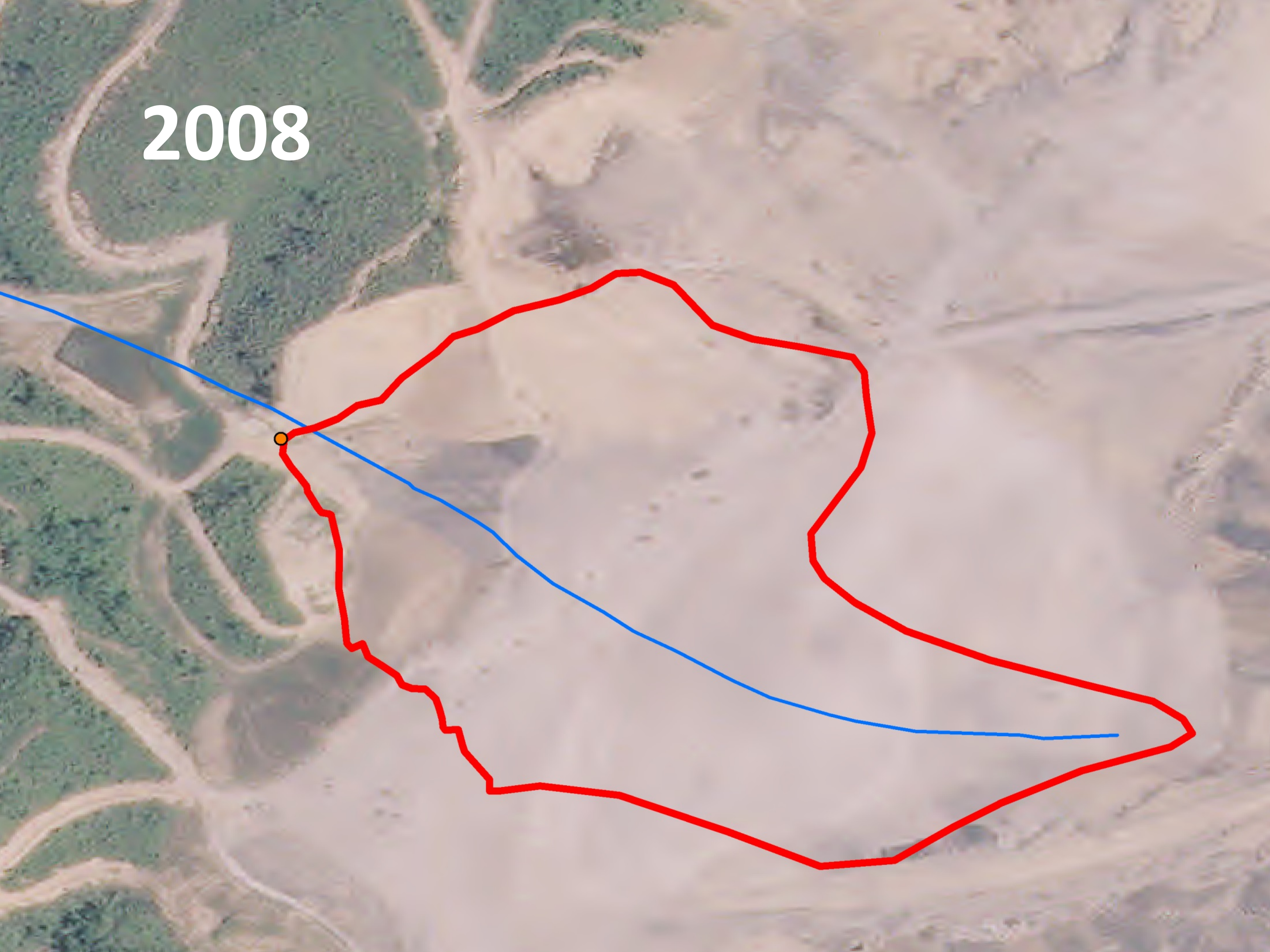
Post valley fill disturbance

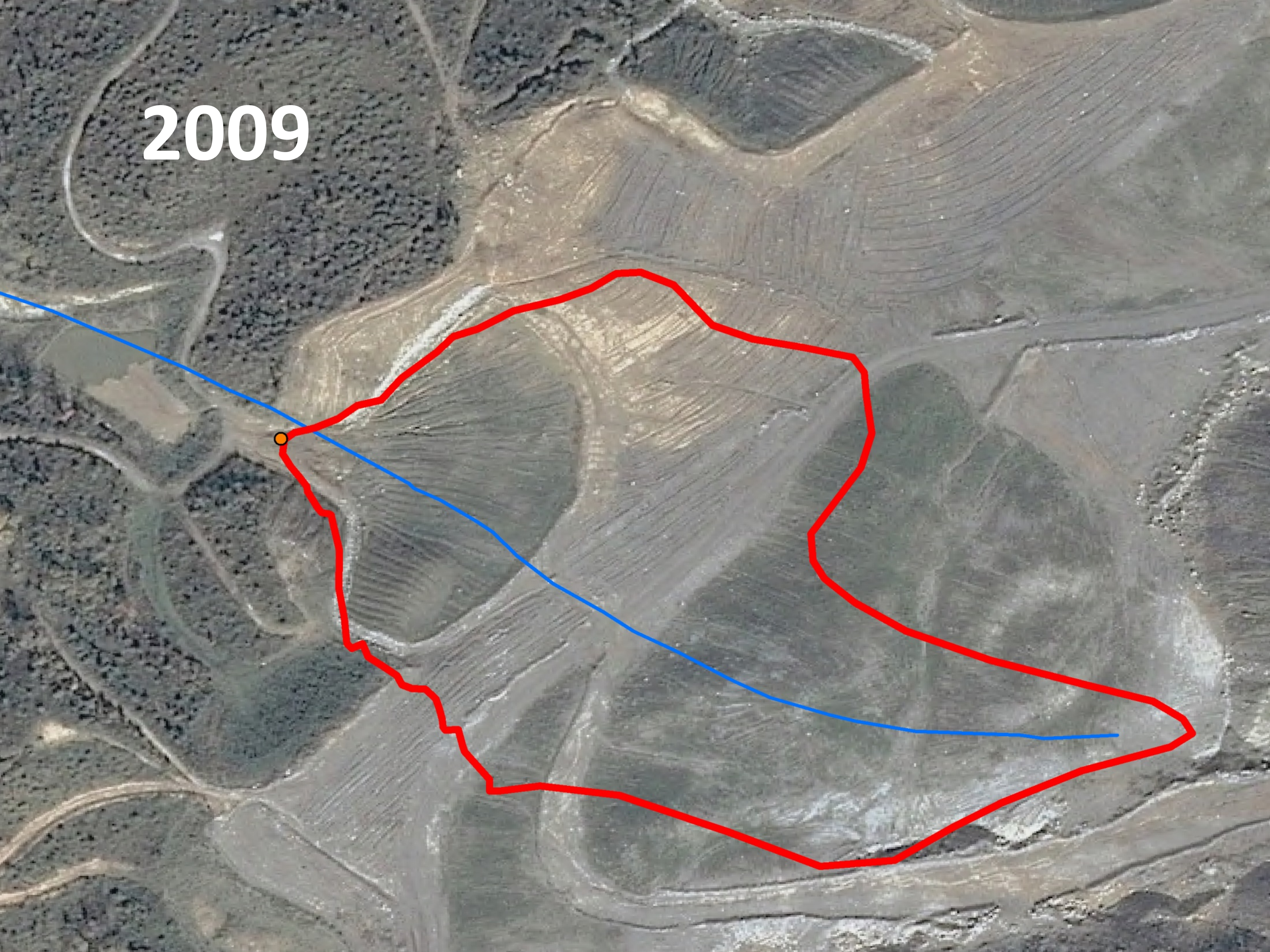
Estimating Disturbance Timelines

- Database was not adequate to estimate disturbance timelines.
- USDA-Farm Service Agency aerial imagery (1998,2003, 2005, 2008, 2009, and 2011).
- Bare ground estimates derived from Landsat images (1984 -2008) (Sen et al. 2012).
- We separated data for each valley fill into three disturbance periods.

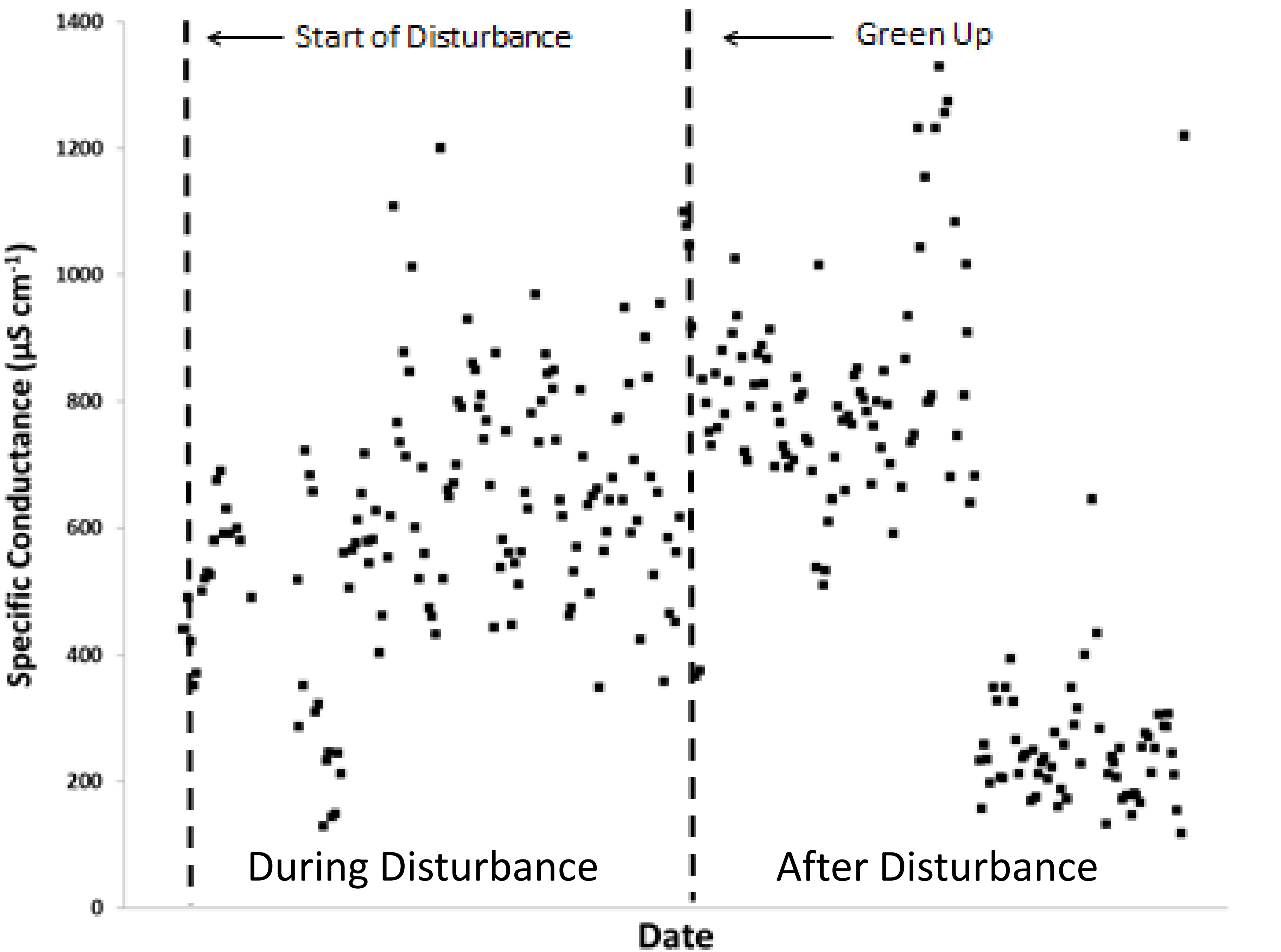

2003


2005


2008

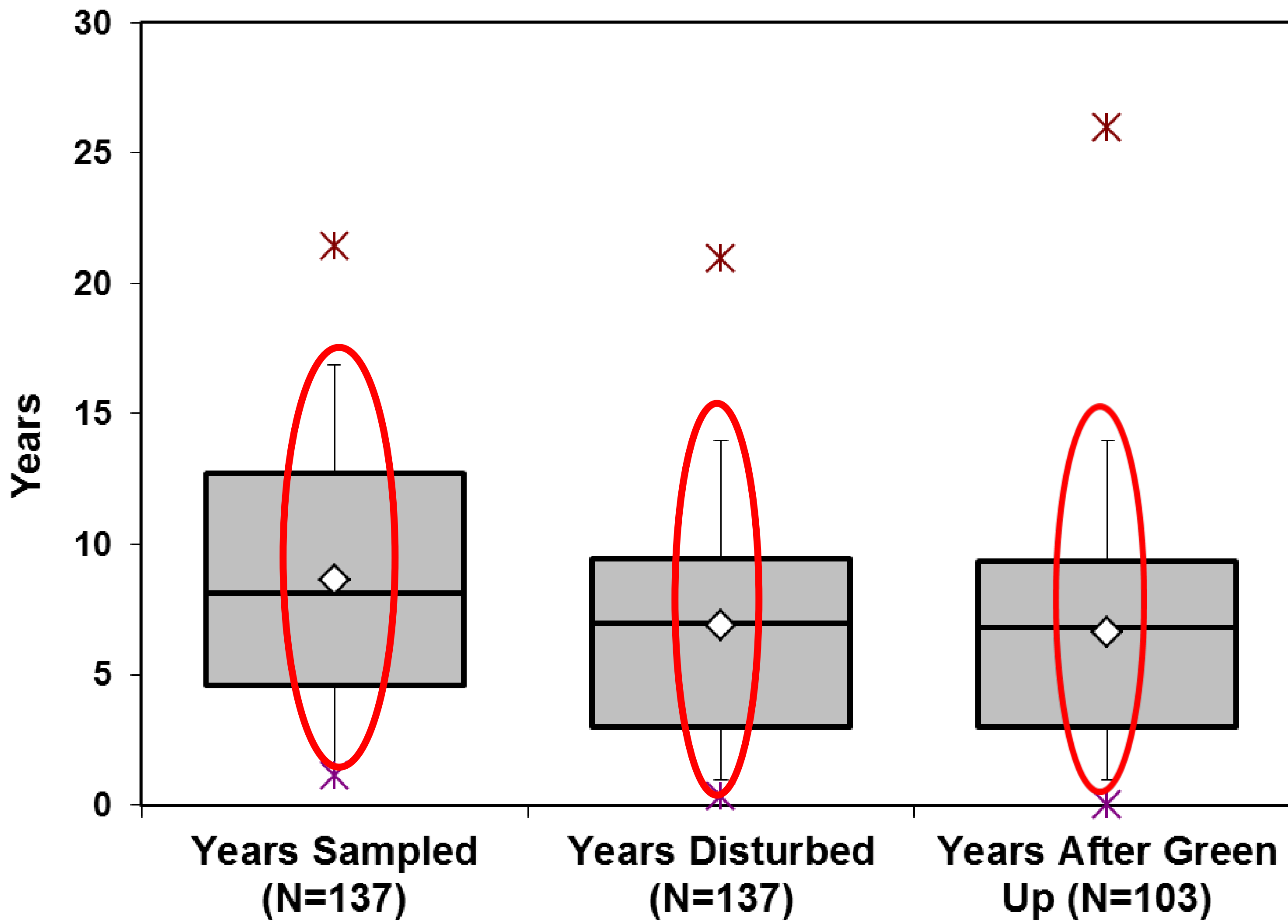

2009


2011

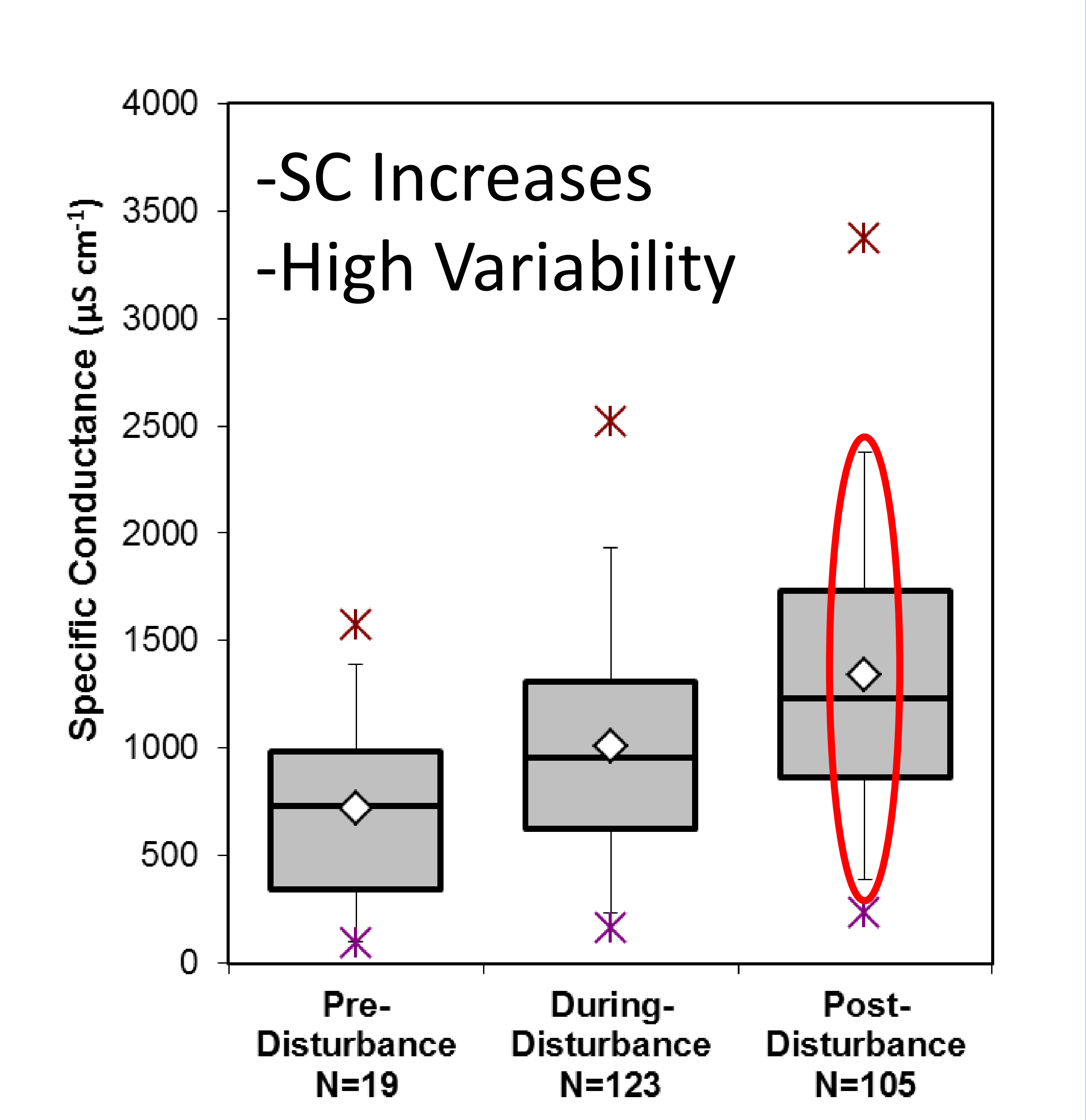


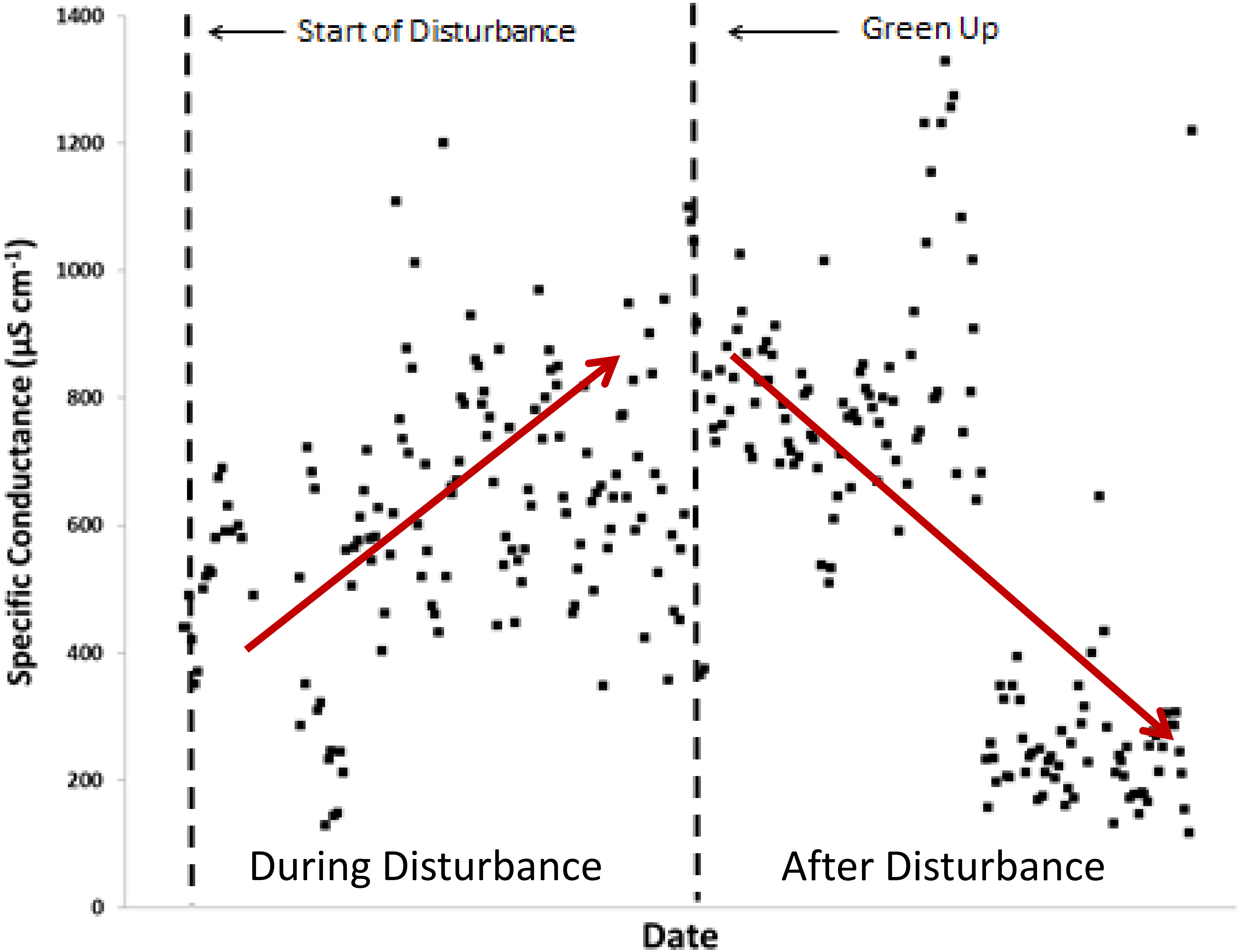
Start of Disturbance
Green Up
During Disturbance
After Disturbance
Specific Conductance (µS cm⁻¹)
Date
1400
1200
1000
800
600
400
200
0

- Mean of 160 samples (21-417)
- Mean of 19.2 samples yr^{-1} (3.2-26.3)



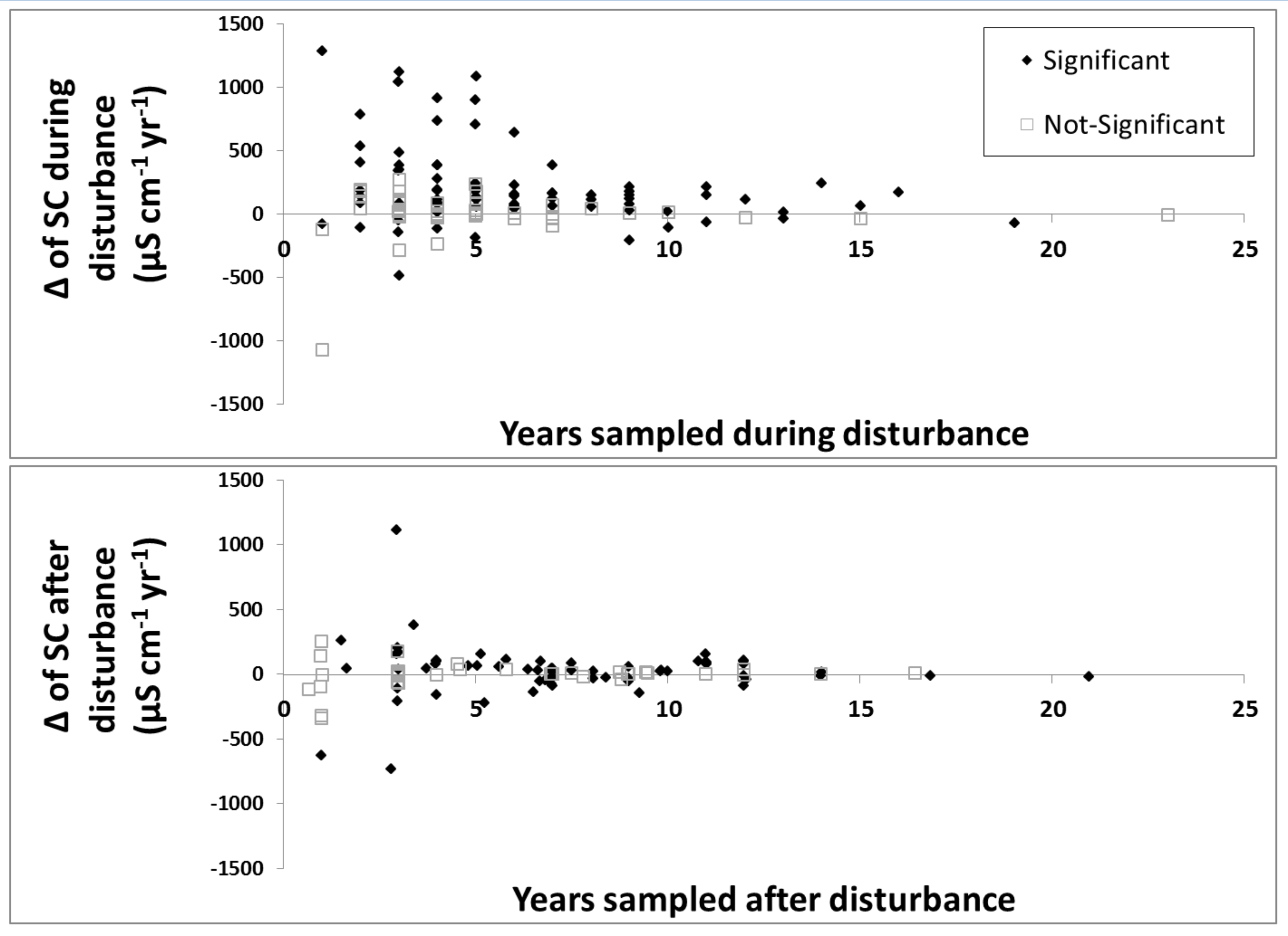
Results: Mean SC for VA Valley Fills



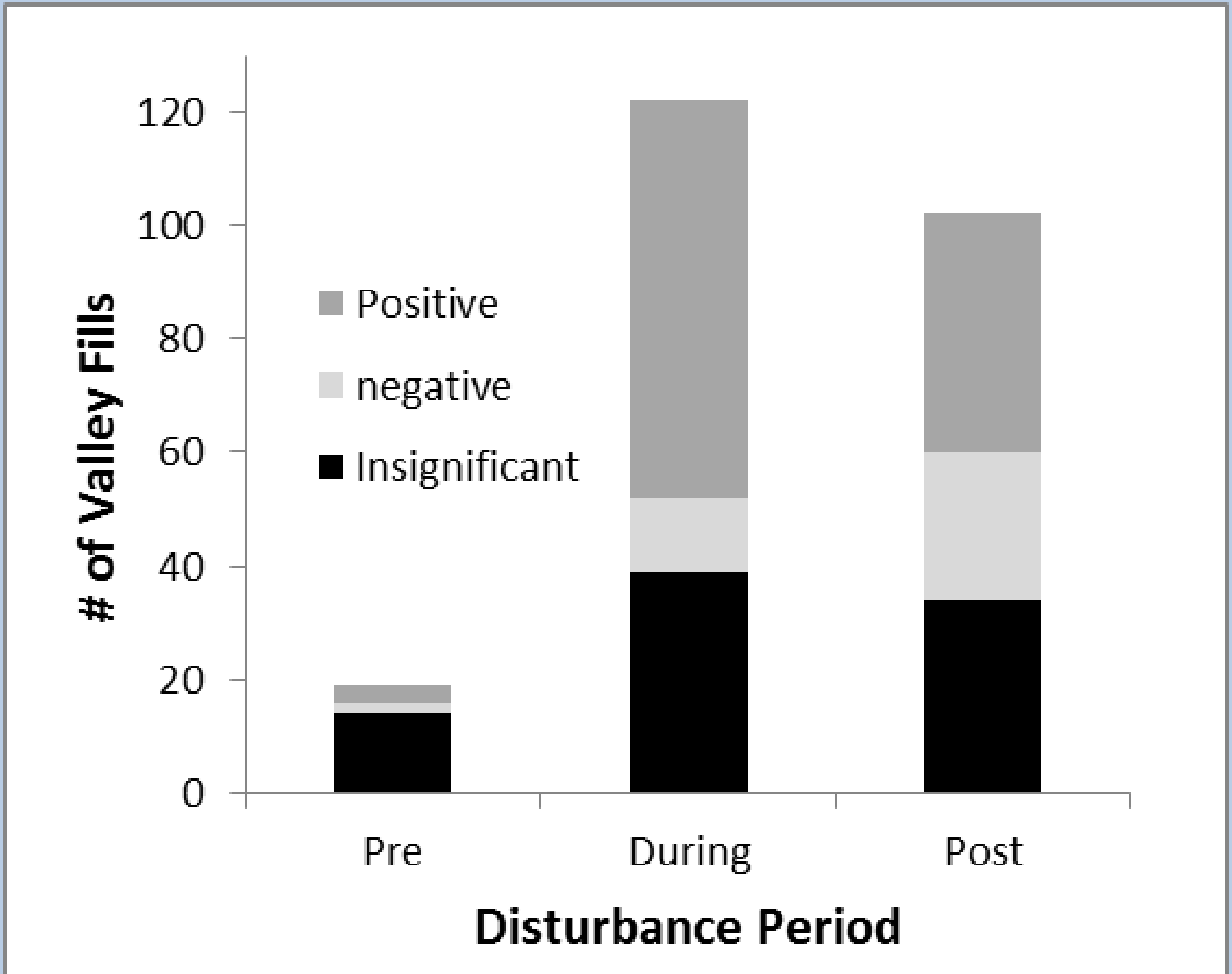


Start of Disturbance
Green Up
Specific Conductance (µS cm-1)
1400
1200
1000
800
600
400
200
0
During Disturbance
After Disturbance
Date

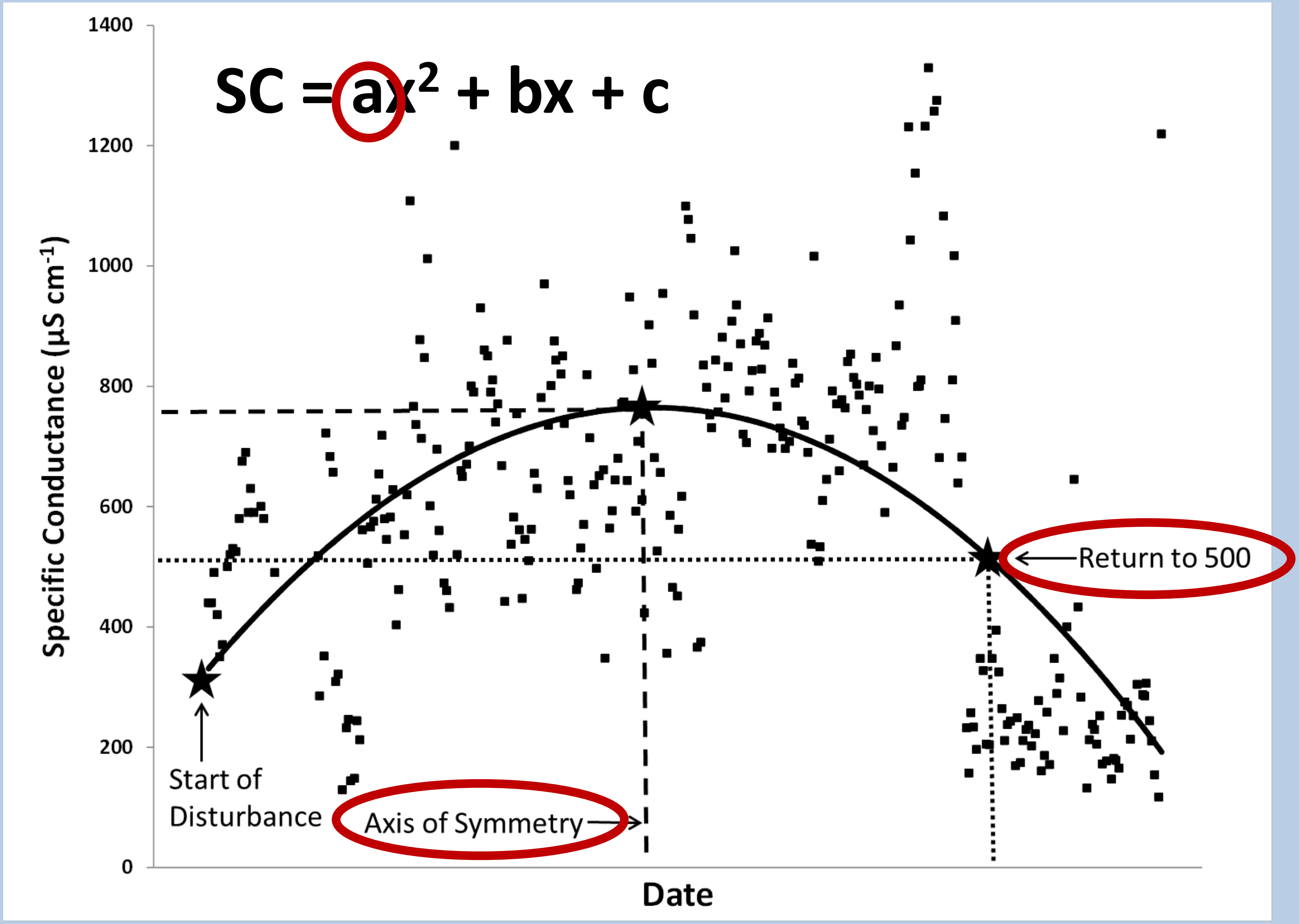
Linear Analysis

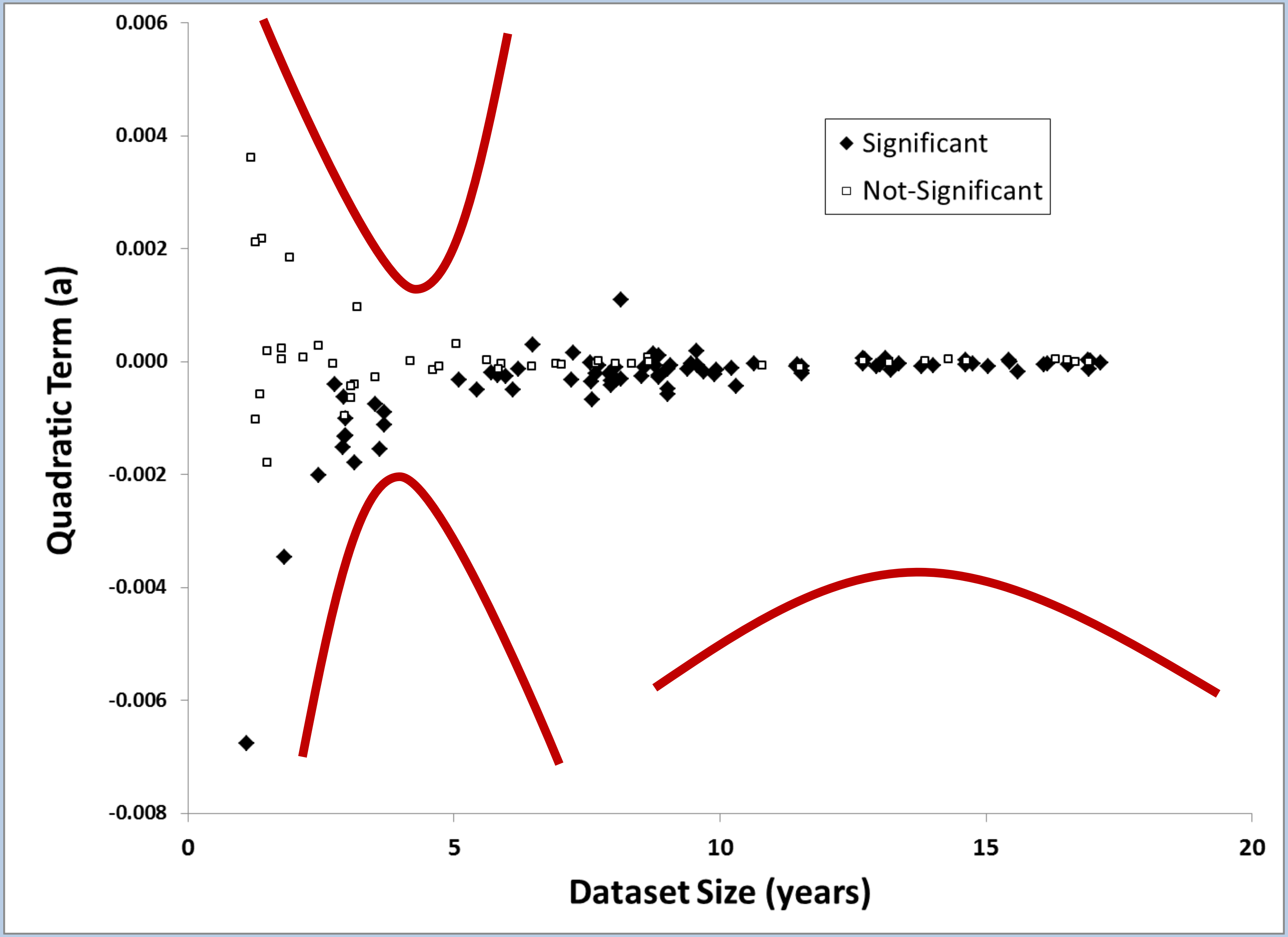


Spearman correlations: SC vs. Time



Can we model the peak of SC?
Can we project the return to background levels?





- **77 out of 137 valley fills datasets had significant negative quadratic terms (convex form)**

Projecting Future SC levels

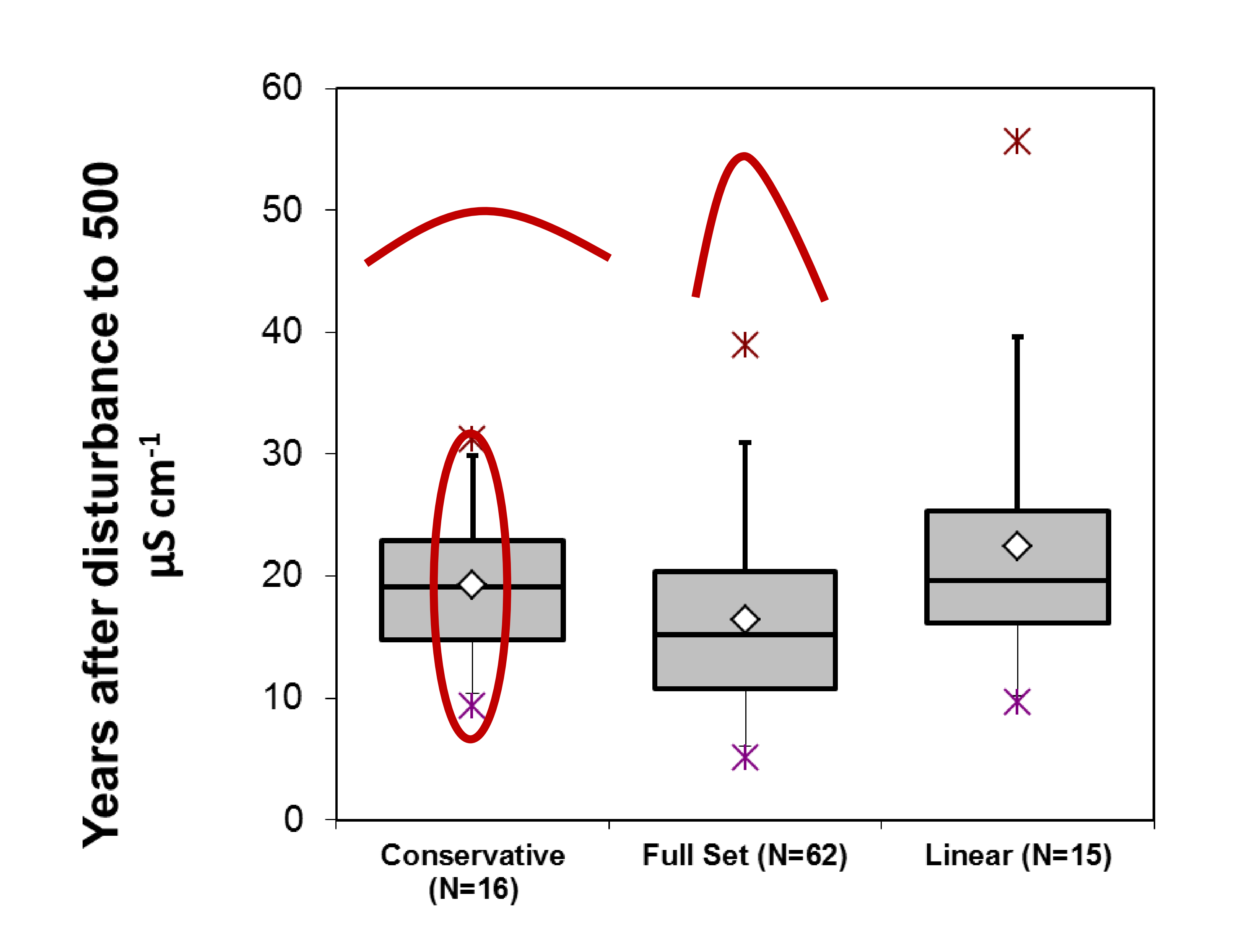
- Of the 77 valley fills with significant negative quadratic terms, 62 had achieved green up.

- Of the 62, 16 valley fills had at least 5 years of data past the quadratic peak.

- These 16 valley fills are used for more conservative projections.

	Years After Disturbance to Axis of Symmetry		Specific Conductance at Axis of Symmetry (µS cm^{-1})		Years after Revegetation to Axis of Symmetry	
	Subset (*N*=16)	Full Set (*N*=62)	Subset (*N*=16)	Full Set (*N*=62)	Subset (*N*=16)	Full Set (*N*=62)
Min	2.5	2.5	542	541	-4.3	-4.3
Max	16.1	17.3	3237	3823	9.2	12.8
Mean	9.5	8.5	1464	1706	2.8	3.6
Median	10.2	7.8	1358	1580	2.9	3.7
SD	3.7	3.7	696	760	3.4	3.3

Projected Recovery



Years after Revegetation to 500 μS cm^{-1}

- 12.5 ± 7.6 years for conservative dataset (N=16)
- 11.5 ± 7.5 years for full dataset (N=62)

What is causing all the variability?

- **Forward Stepwise Regression (*N*=137) (*a*=0.10)**
- **Dependent: Mean SC during and after revegetation**
- **Independent:**
  - -Valley fill area (ha)
  - ~~-Watershed area (ha)~~
  - -Max watershed bare ground (%)
  - ~~-Mean watershed bare ground (%)~~
  - -% of watershed deep mined
  - -# of years the watershed was disturbed
  - -Fraction of upper geologic layer dominated by sandstone
  - -# of years of data after revegetation

R^2= 18% and 14%

Conclusions

- Data show that SC is generally increasing during disturbance.
- SC continues to increase for several years after green-up. High variability.
- Projected ~19 years (average) after initial disturbance for return to 500 $\mu S\ cm^{-1}$. High variability and only 77 of the 137 valley fills.
- Variability suggests that there are site or engineering factors that affect TDS production.

Thank You to:

- Virginia DMME, Greg Baker for providing data acquisition and expertise.

- Sen et al. (2012) for providing NDVI analysis data for our study area.

Questions?

This study was sponsored by the Appalachian Research Initiative for Environmental Science (ARIES). The views, opinions and recommendations expressed herein are solely those of the authors and do not imply any endorsement by ARIES employees, other ARIES-affiliated researchers or industrial members. Information about ARIES can be found at http://www.energy.vt.edu/ARIES ”