Chemical and Biological Responses in the North Fork of Clear Creek Following Remediation of Acid Mine Drainage Inputs

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Acknowledgements

Investigating Biogeochemical Controls on Metal Mixture Toxicity Using Stable Isotopes and Gene Expression

National Institute of Environmental Health Sciences

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NiPERA NICKEL HEALTH AND ENVIRONMENTAL SCIENCES

International Copper Association Copper Alliance

RioTinto

Zinc ...essential for life

Co-PIs & Students

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Colorado State University

W. Clements & Chris Kotalik

University of Florida

C. Vulpe and Dani Cucchiara

Overall Study Objectives/Approaches

We wish to better understand how metal mixtures affect aquatic toxicology and metal bioavailability and how the presence of metal mixtures influence the remediation effectiveness for mining impacted waters

We are using a laboratory and field based-approach.

Laboratory studies of mixture toxicity utilize *D. magna*, with mortality, metal uptake (measured and computed by BLM), and gene expression as endpoints.

Bioavailability of metals from sediments utilize ^{65}Cu isotope labeling with snails as the test organism.

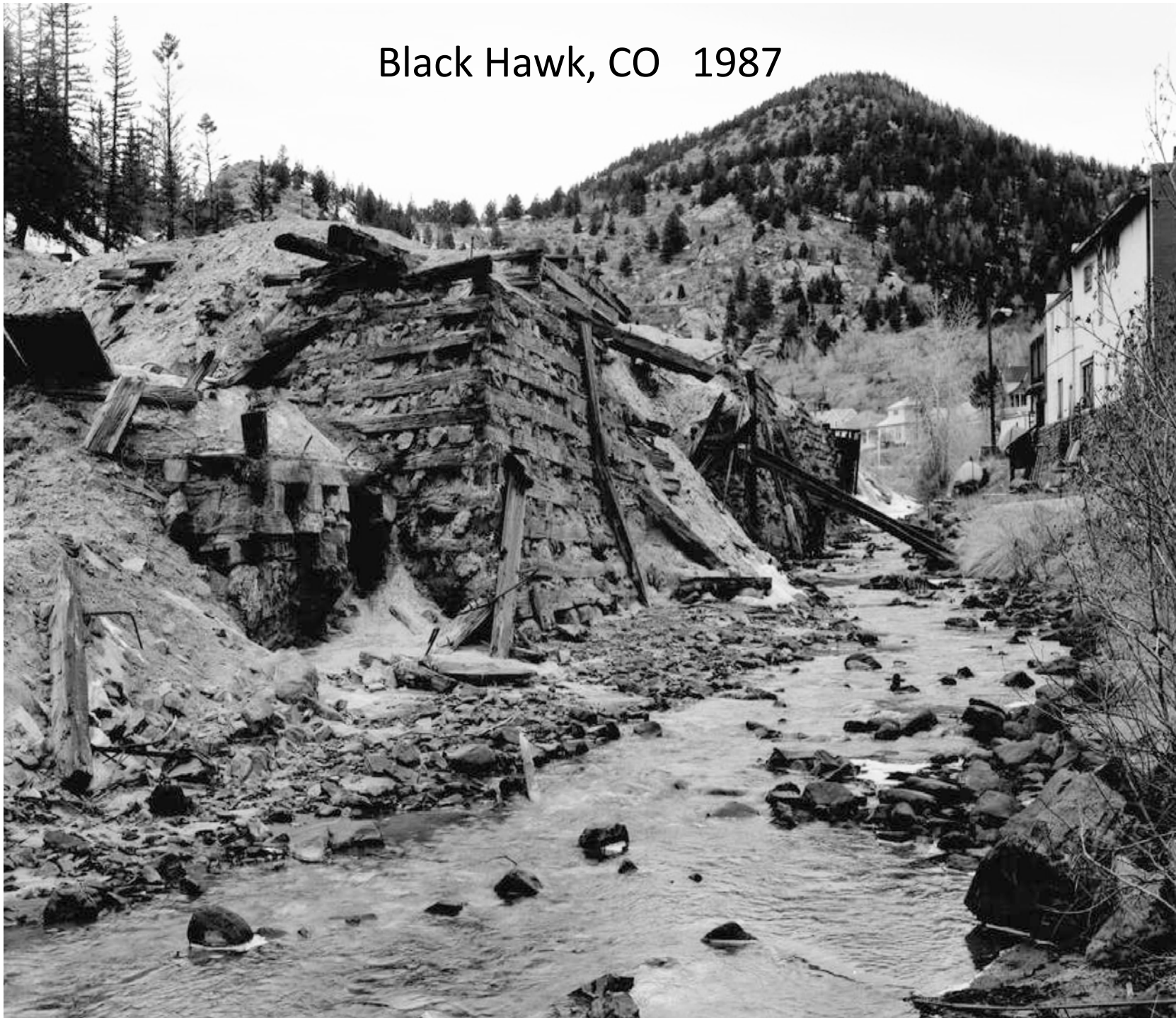
We are directly measuring the biological and chemical responses to remediation of the mining effluents **(todays presentation).**

Talk Outline

- Background
- Site Description/hydrology
- Water Chemistry Response
- Biological Recovery
- Outreach
- Summary

Introduction

- North Fork of Clear Creek (NFCC) located 50 km west of Denver, Colorado USA
- Mining activity 1850s – 1950s
- Acid mine drainage (AMD) and mining solid wastes (sulfide weathering)
- **Mixtures of toxic metals (Cu, Zn) enter stream effecting water column and sediment chemistry**
- Stream life highly impacted (absent)



Armoring

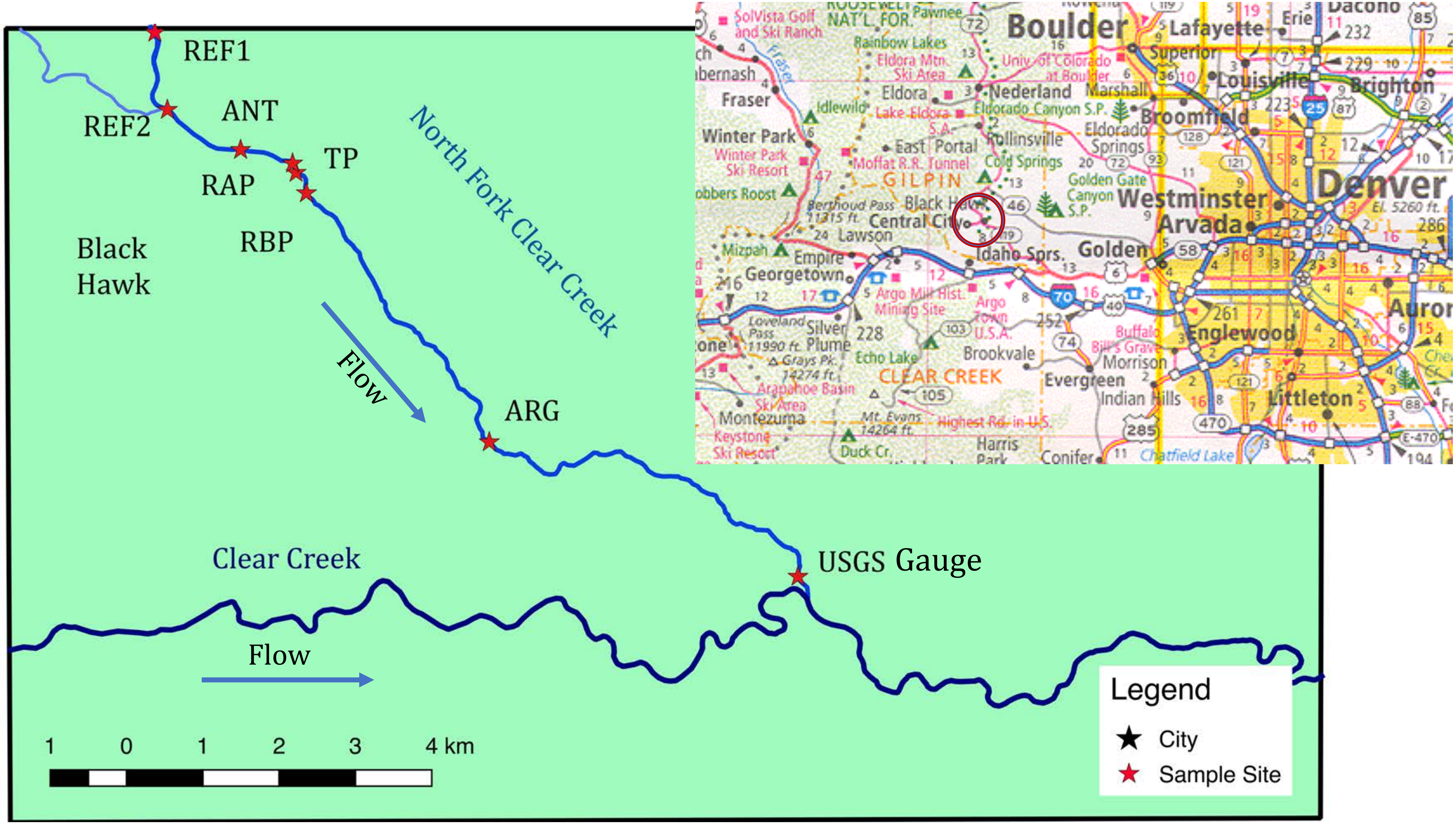
Aquatic Life ?

Flocculant bed and suspended sediments

Dissolved metals

Treatment Plant

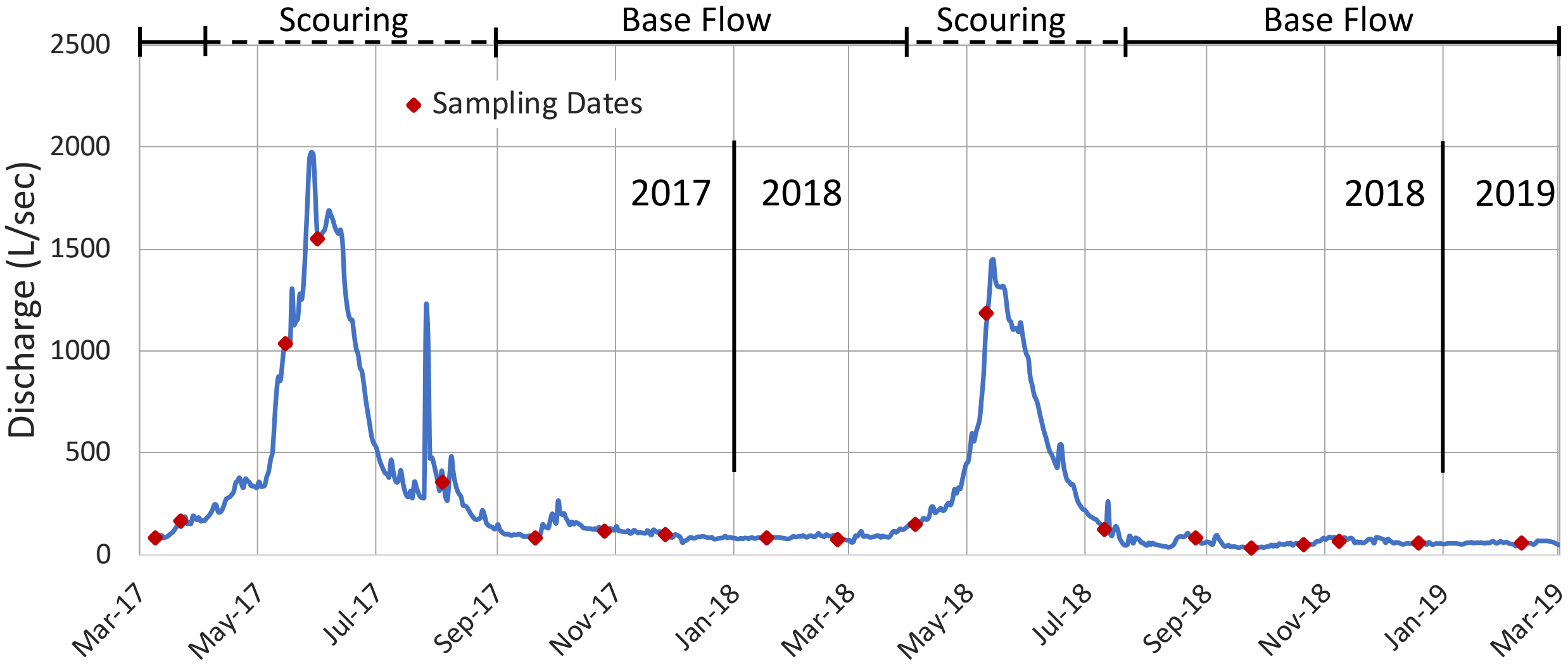
- High Density Sludge
- Operational March 2017
- Capture and treatment of two point sources of AMD entering stream
  - Gregory Incline and National Tunnel
- Initial cost of $19.66 million


REF1
REF2
ANT
RAP
TP
RBP
Black Hawk
North Fork Clear Creek
Flow
ARG
USGS Gauge
Clear Creek
Flow
1 0 1 2 3 4 km
Legend
City
Sample Site

Research Goals (Chemistry)

- Monitor water chemistry and biology pre- and post-remediation
- Understand effectiveness of treatment plant in decreasing total metal loading in stream
- Understand geochemistry of changes in water chemistry (dissolved) since implementation of remediation
- Evaluate potential aquatic toxicity of dissolved metals

Discharge


Scouring
Base Flow
Scouring
Base Flow
Sampling Dates
2017
2018
2018
2019
Discharge (L/sec)
2500
2000
1500
1000
500
0
Mar-17
May-17
Jul-17
Sep-17
Nov-17
Jan-18
Mar-18
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19

Visual Improvement in Stream Appearance March-October 2017 @ Downstream Site

March 23 | May 1 | May 16 | August 29 | October 27

March 28: treatment of one source begins, periodic shutdowns occur, second source treatment begins in July

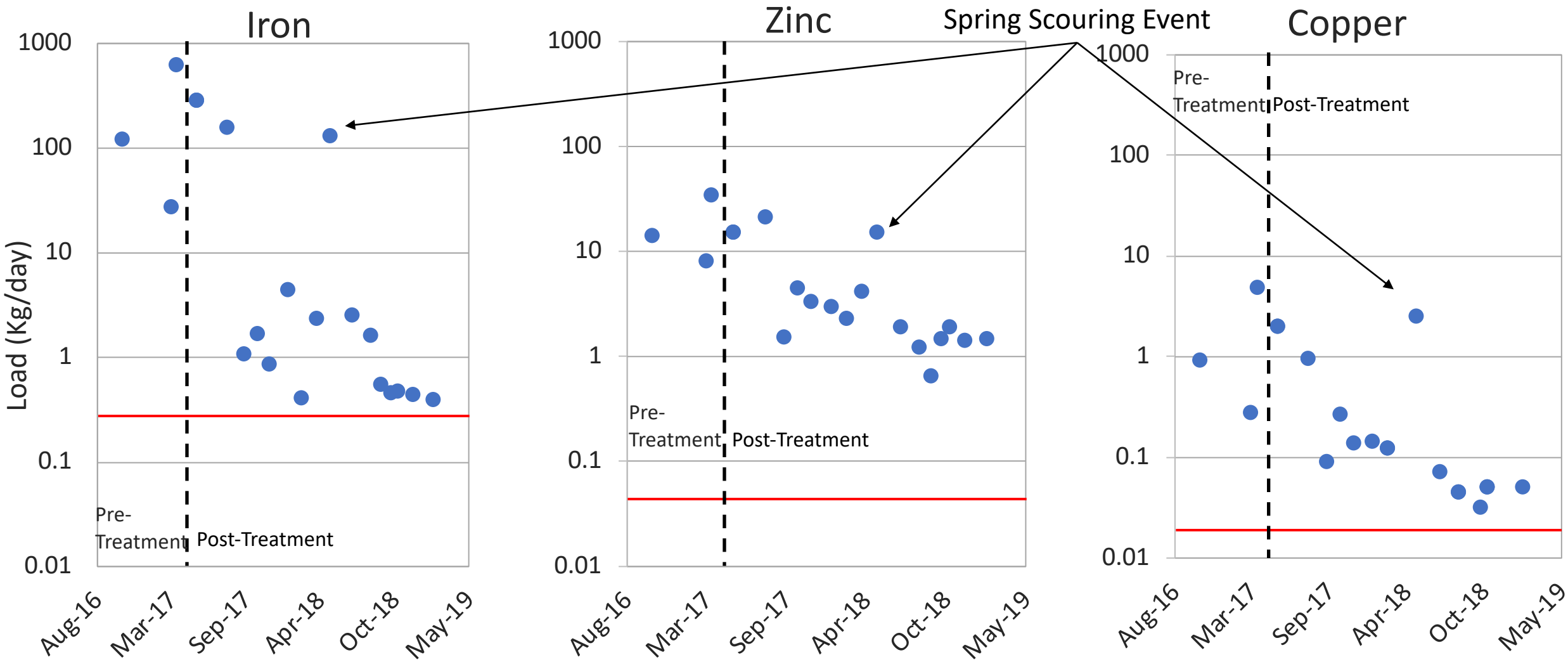
September 15: 24/7 treatment begins

Decrease in Total Metal Loading

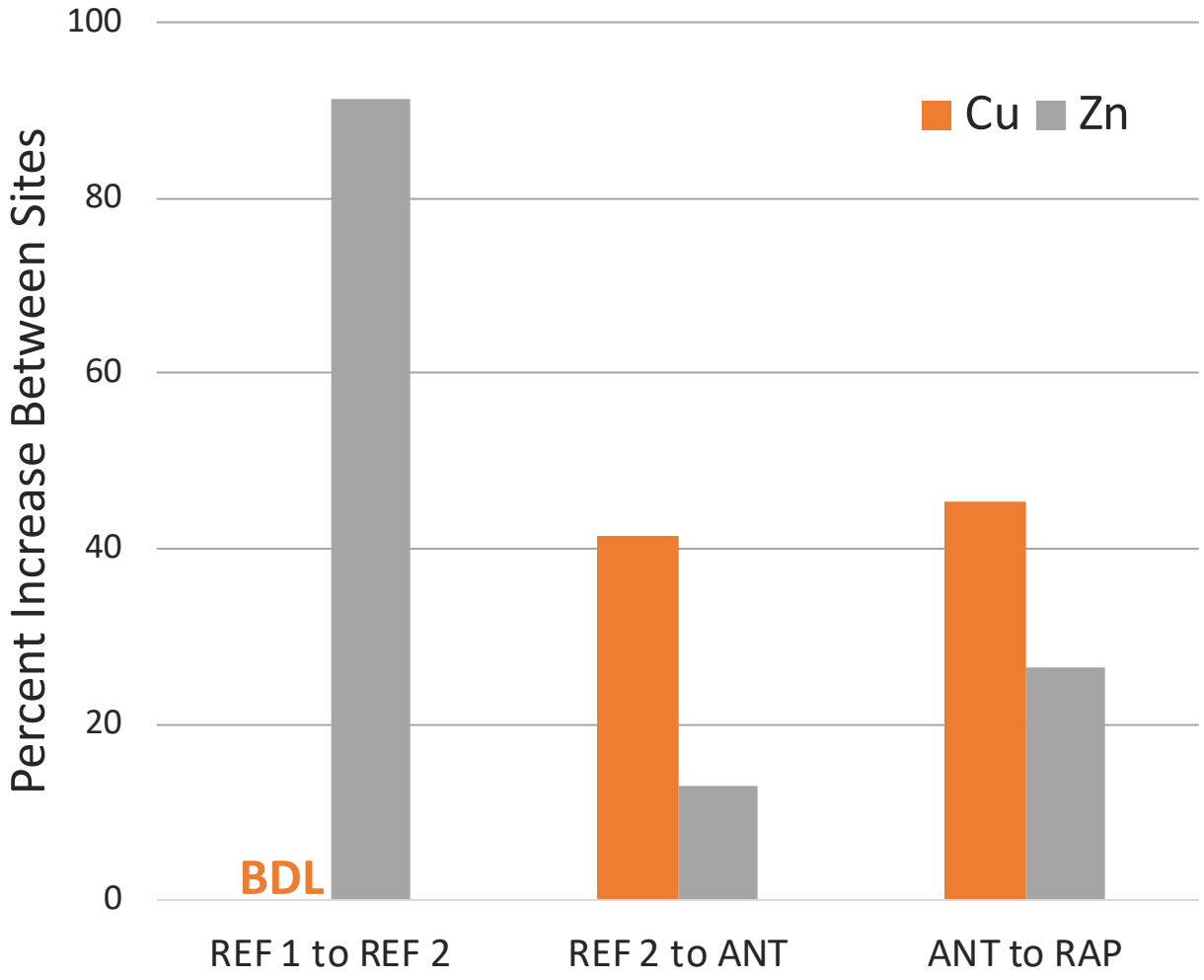
Decrease by factor of 1600

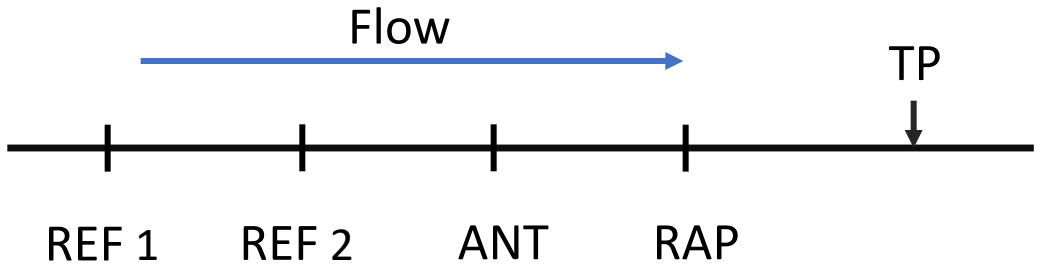
Decrease by factor of 50

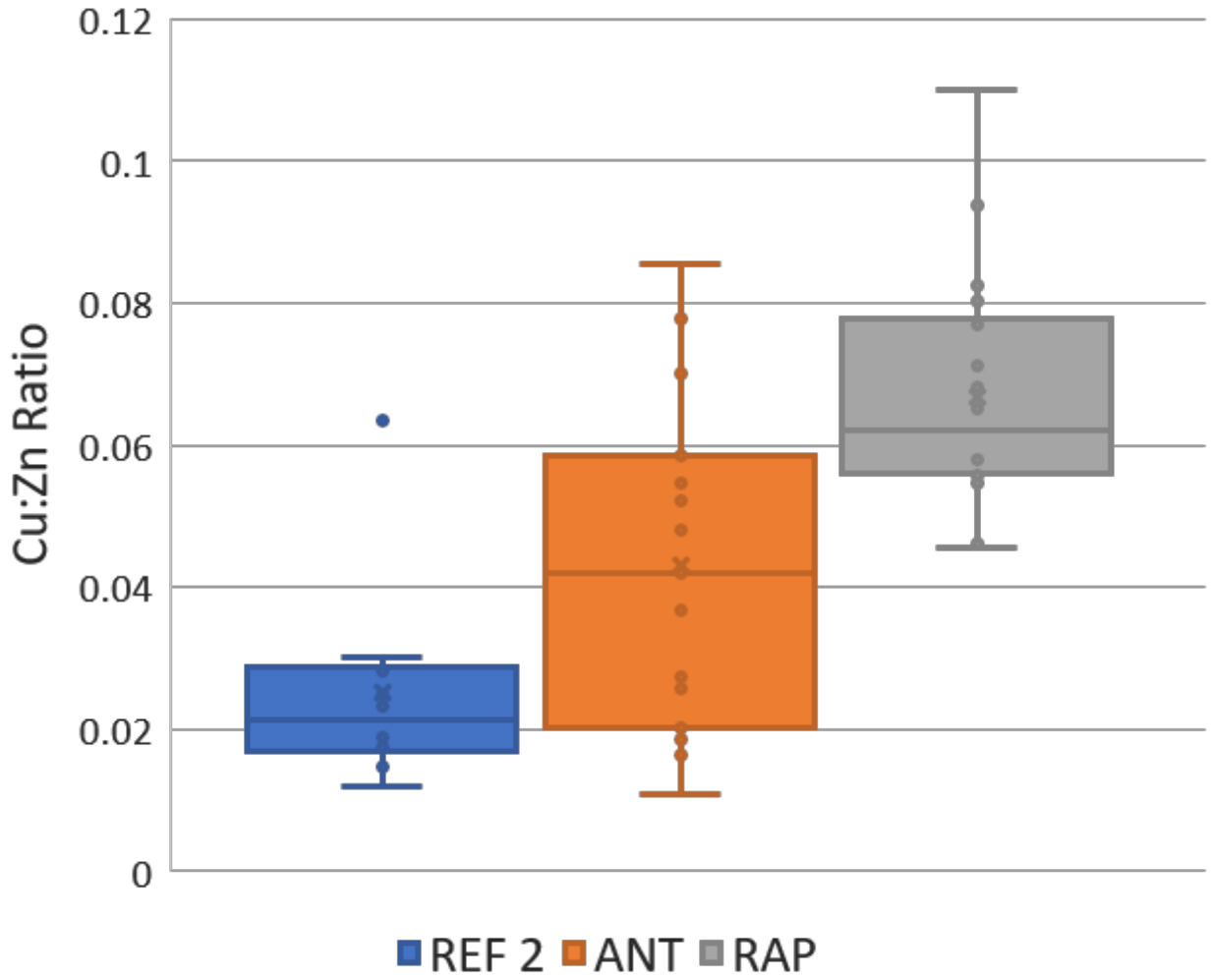
Decrease by factor of 150



Multiple Remaining Sources with Differing Metal Compositions







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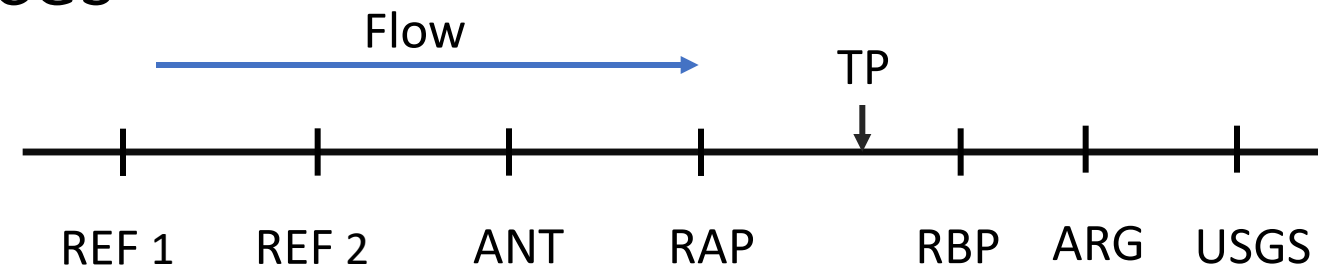
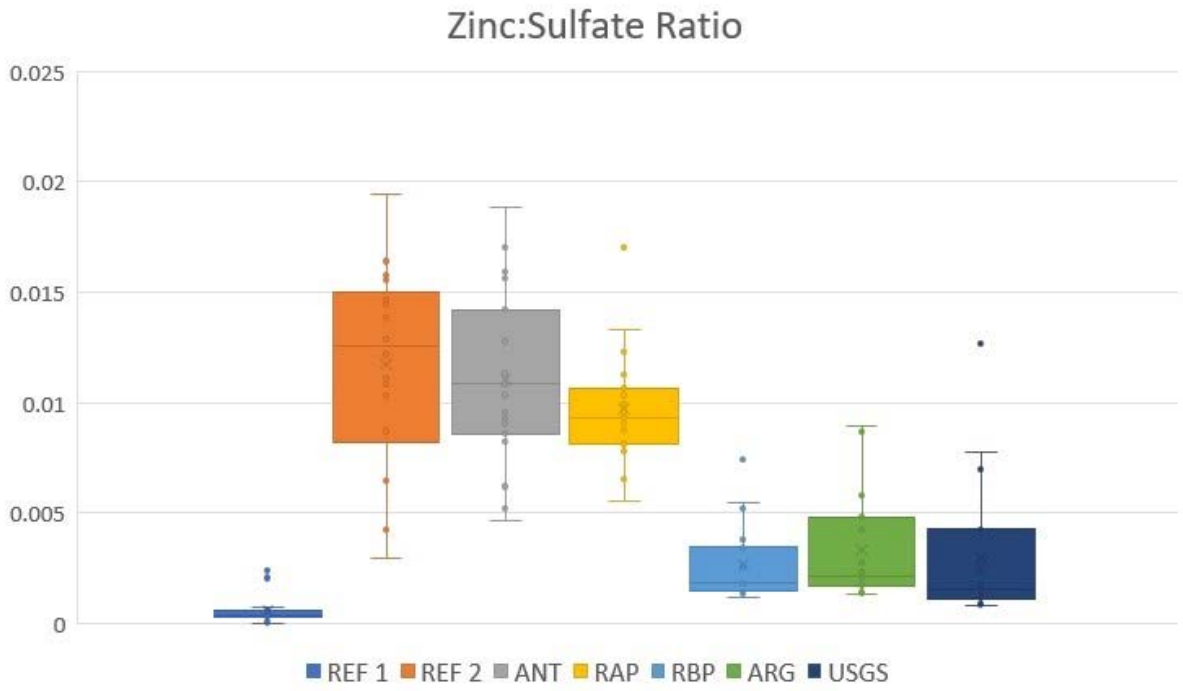
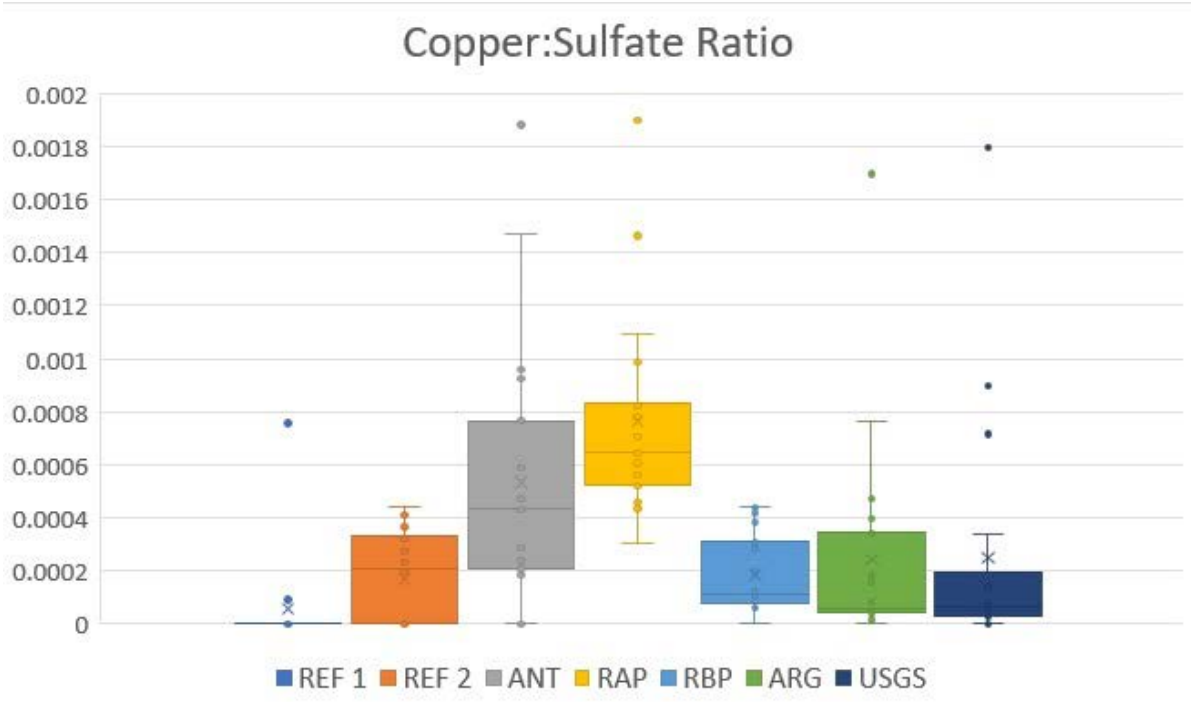
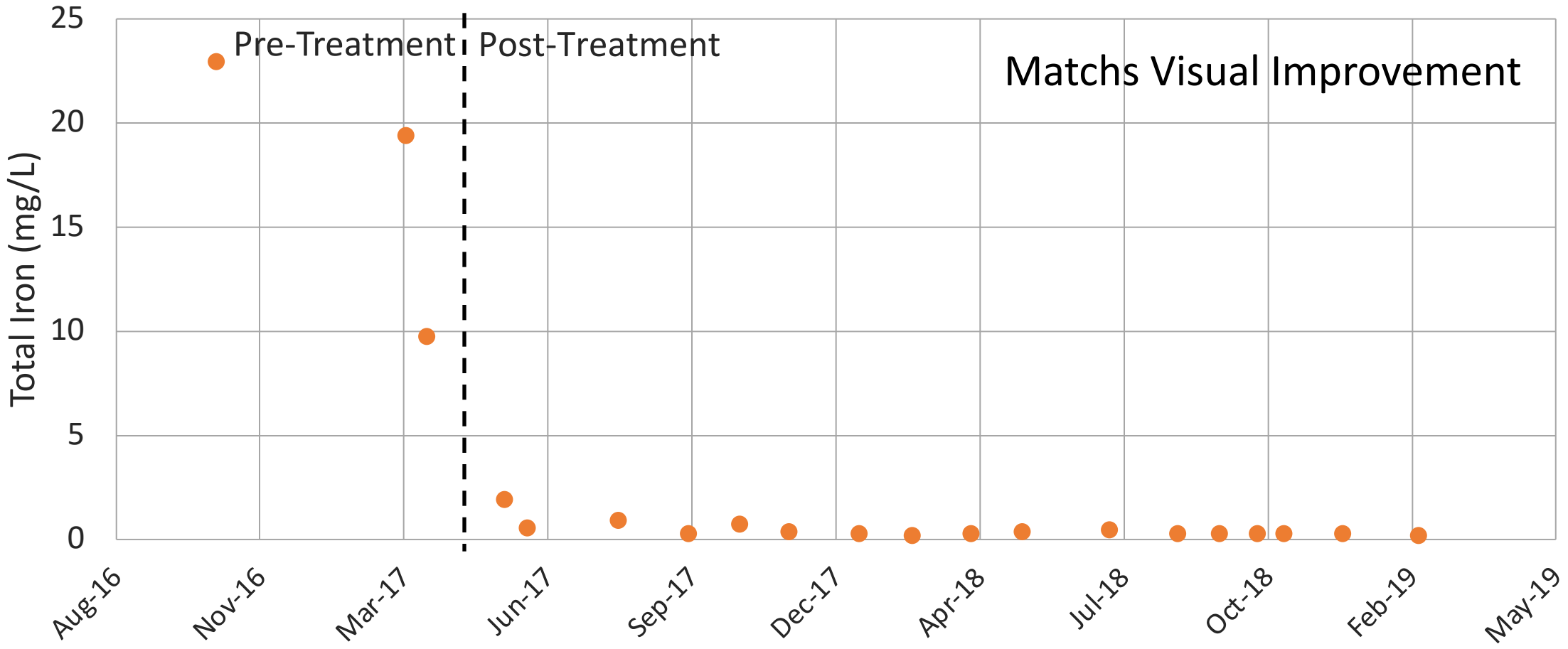


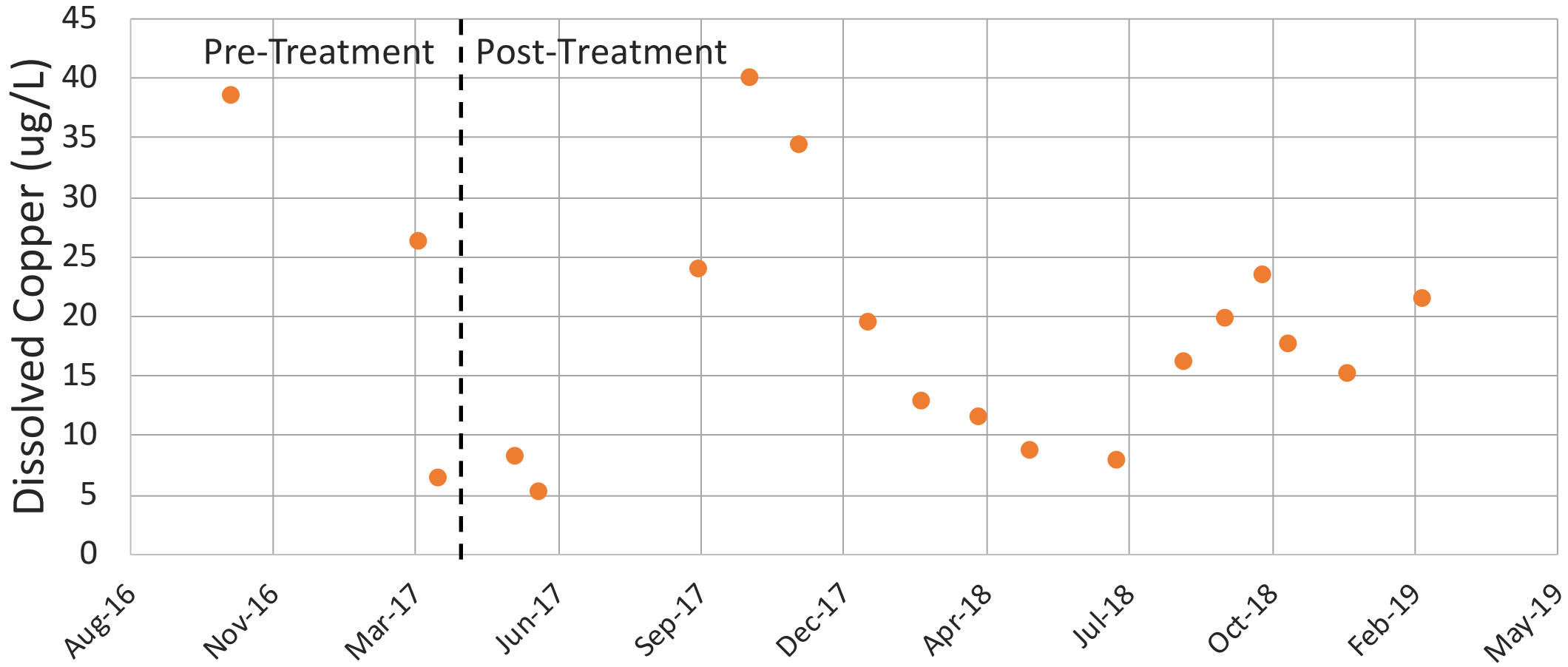




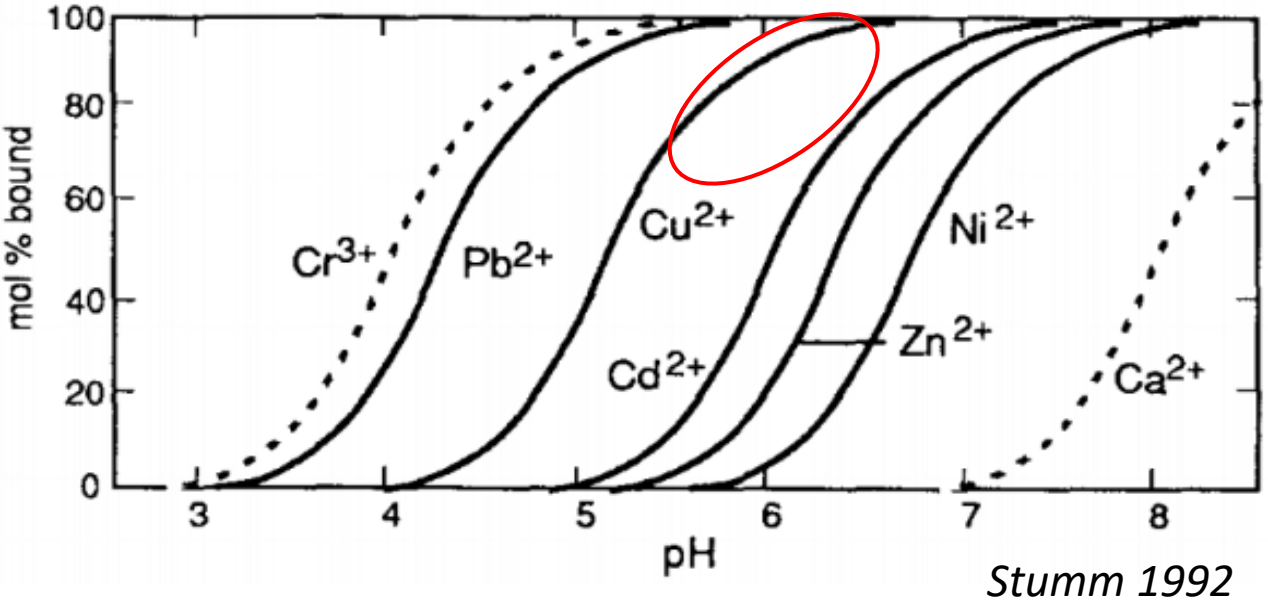
Total Iron Concentration: Near Complete Removal



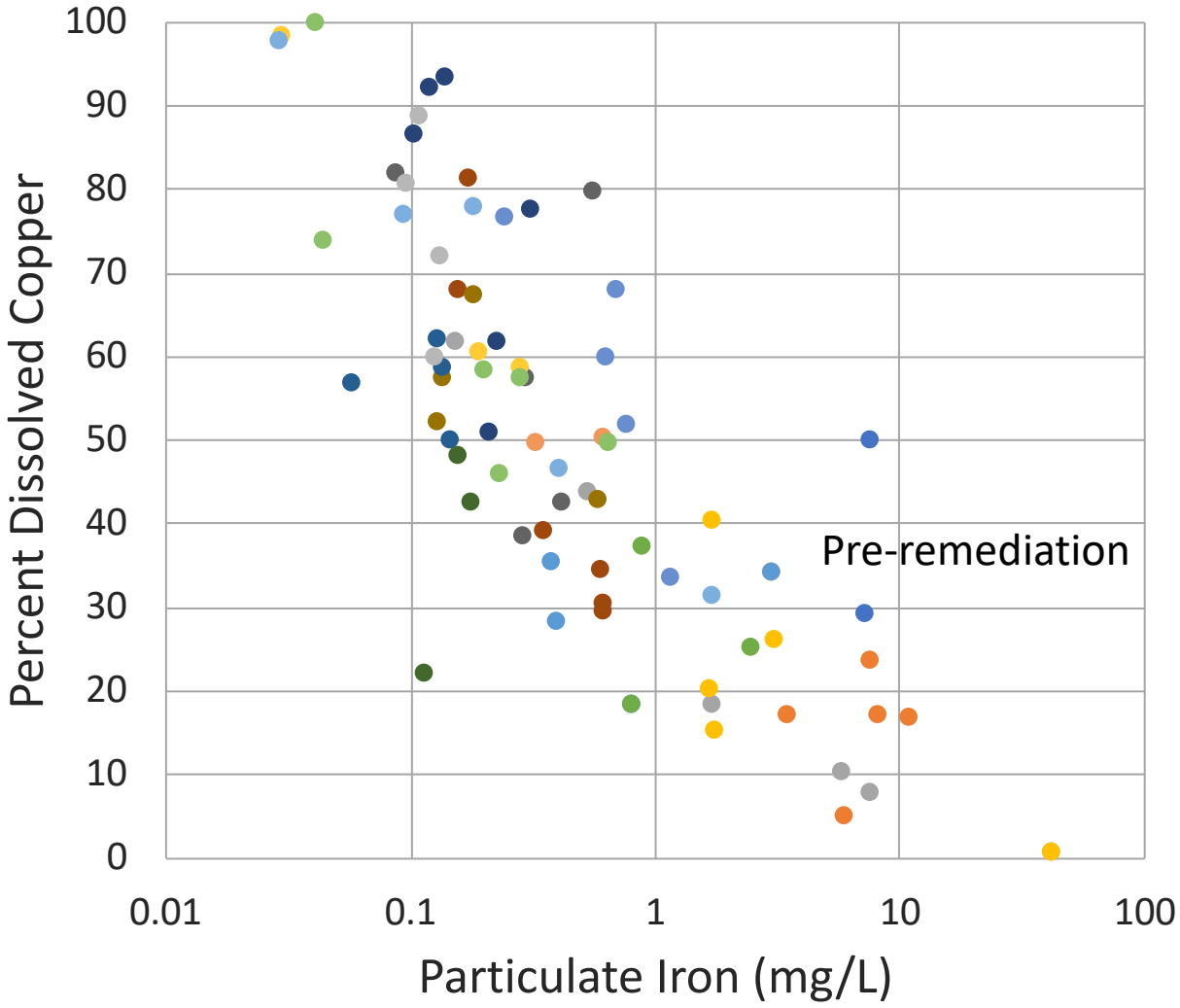
Only Partial Lowering of Dissolved Copper



Particulate Iron is Your Friend For Copper



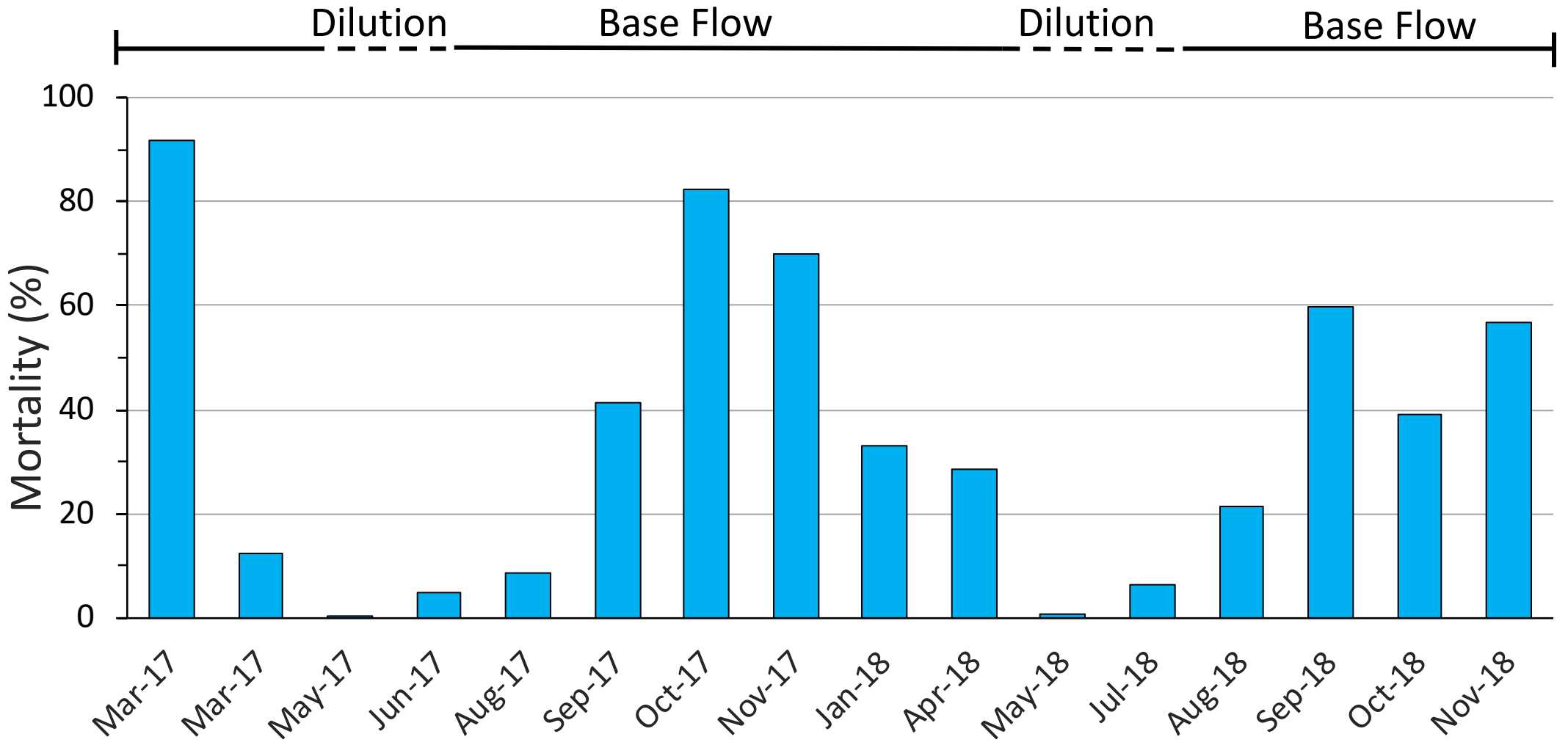
Stumm 1992



Predicted Toxicity of Instream Cu + Zn to *Daphnia magna*

- Based on measured dissolved Cu and Zn in stream
- Cu and Zn EC50s taken from previous 48-h lethality tests with *D. magna* neonates (EC50 = 50% mortality conc.)
- Toxic units
  - $TU_{Cu} = [Cu]/EC50_{Cu}$
  - $TU_{Zn} = [Zn]/EC50_{Zn}$
  - $\Sigma TU = TU_{Cu} + TU_{Zn}$
- Predicted mortality = f(ΣTU)

Predicted Toxicity of Instream Dissolved Copper and Zinc (considering effects of multiple metals)

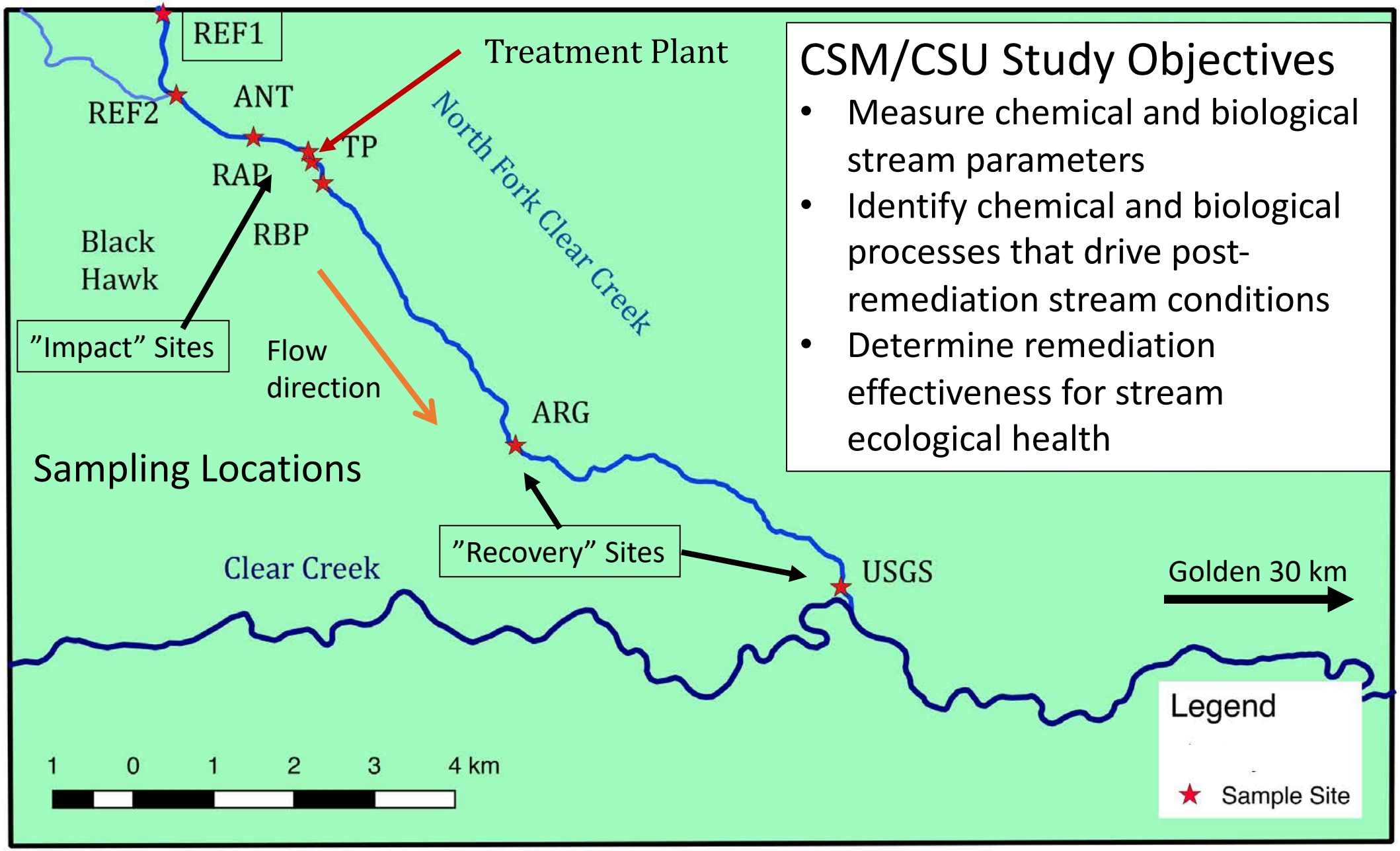


Chemistry Conclusions

- Total Copper, Iron, and Zinc loads have decreased to different degrees since treatment began
- Multiple and variable sources of uncaptured metals continue to enter NFCC in variable ratios
- Particulate Iron is your friend for Copper but not Zinc
- Predicted toxicity of Zinc and Copper to *Daphnia* magna remains elevated post remediation
- Cannot treat what we do not capture

Field Biomonitoring Hypotheses for AMD Remediation

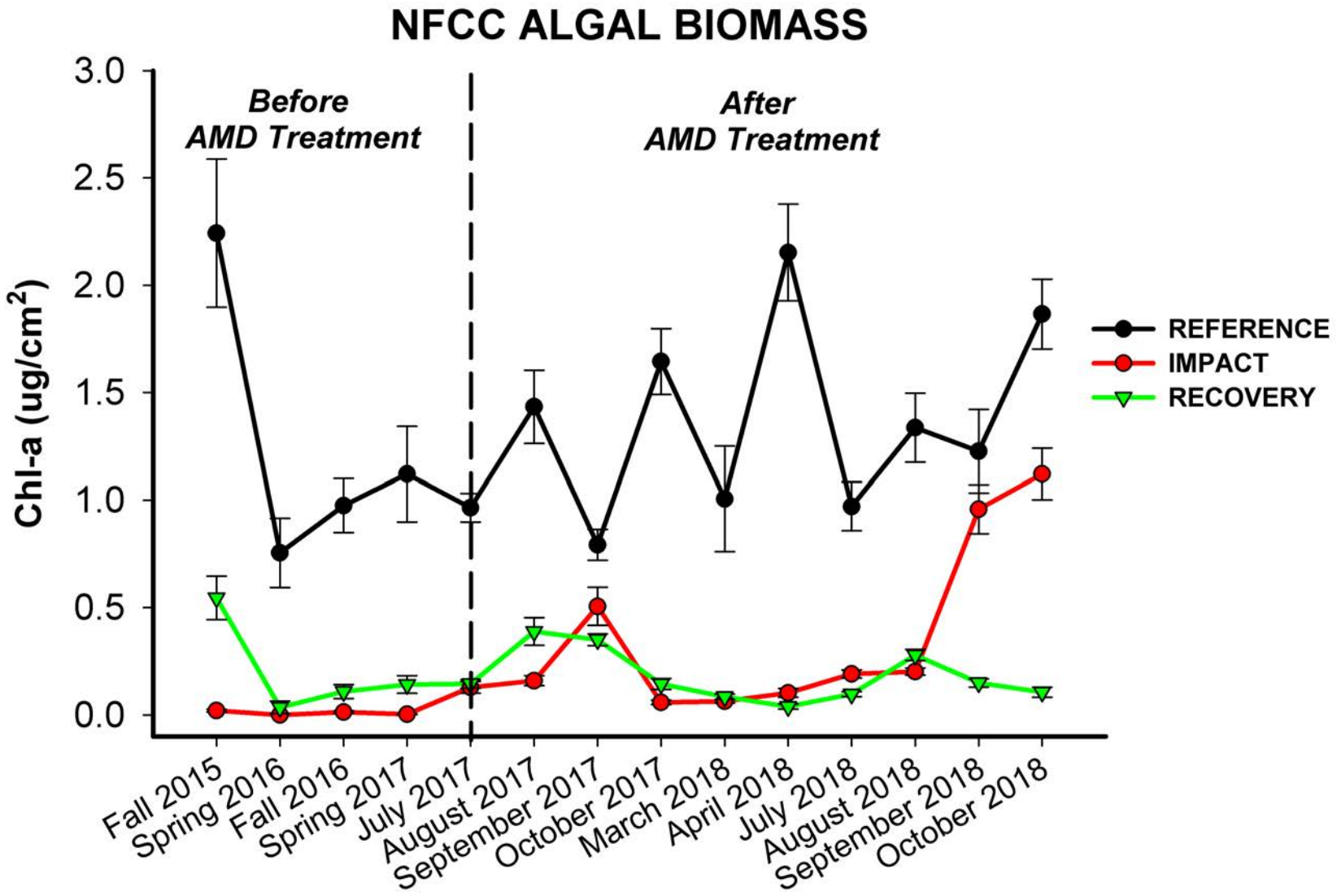
- H(1): Algal biomass will increase
- H(2): Benthic macroinvertebrates will increase in abundance and taxa richness
- H(3): Benthic and emerging adult biomass will increase
- But how quickly?



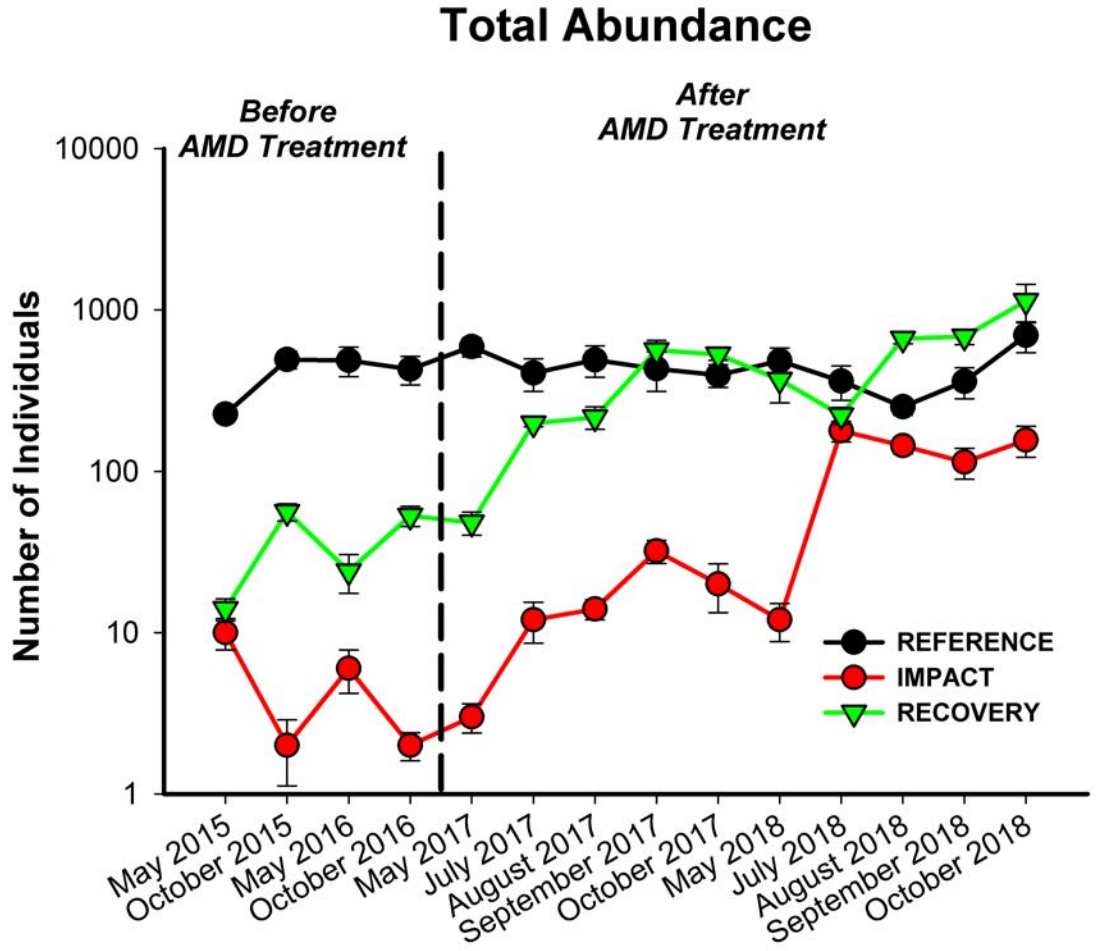
CSM/CSU Study Objectives

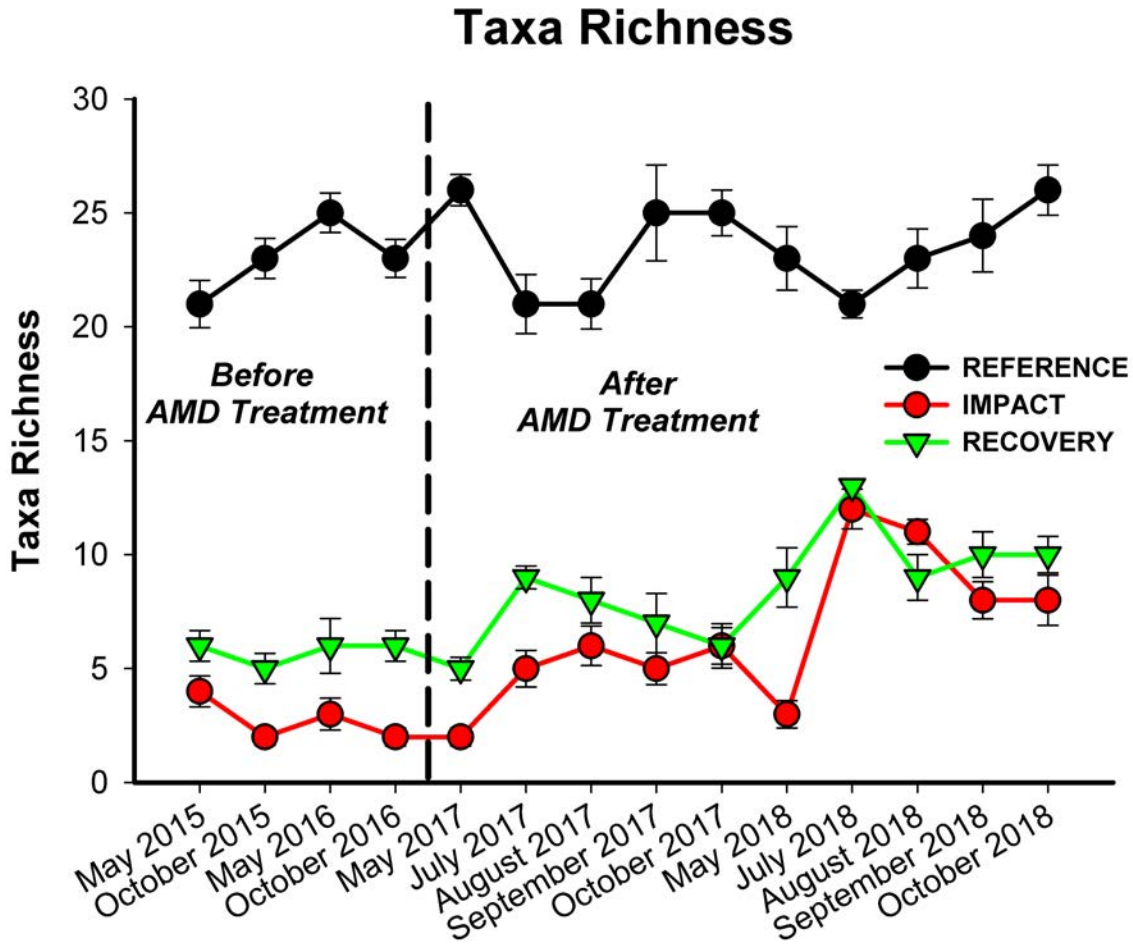
- Measure chemical and biological stream parameters
- Identify chemical and biological processes that drive post-remediation stream conditions
- Determine remediation effectiveness for stream ecological health

North Fork Clear Creek, Colorado
Algal Colonization

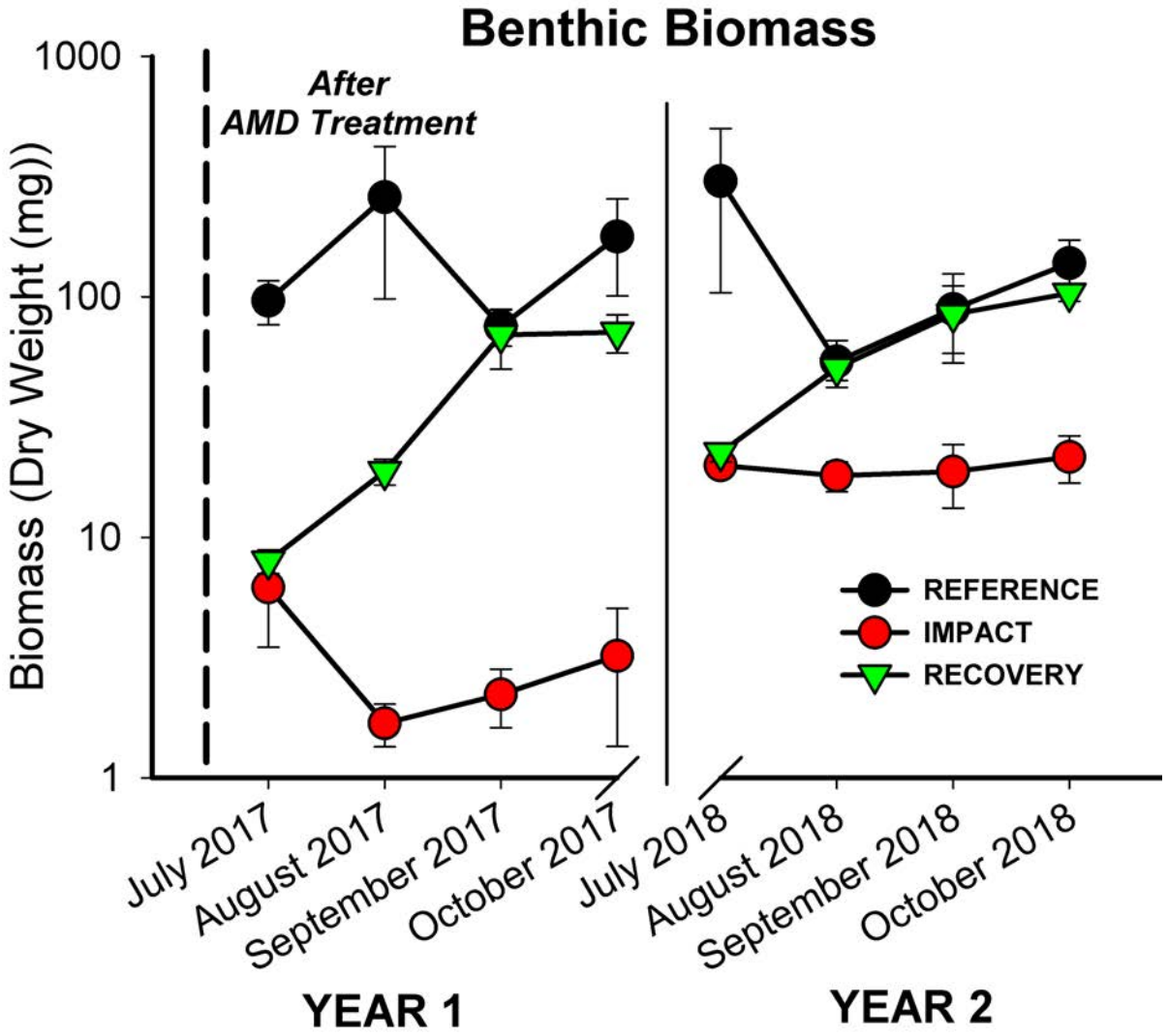


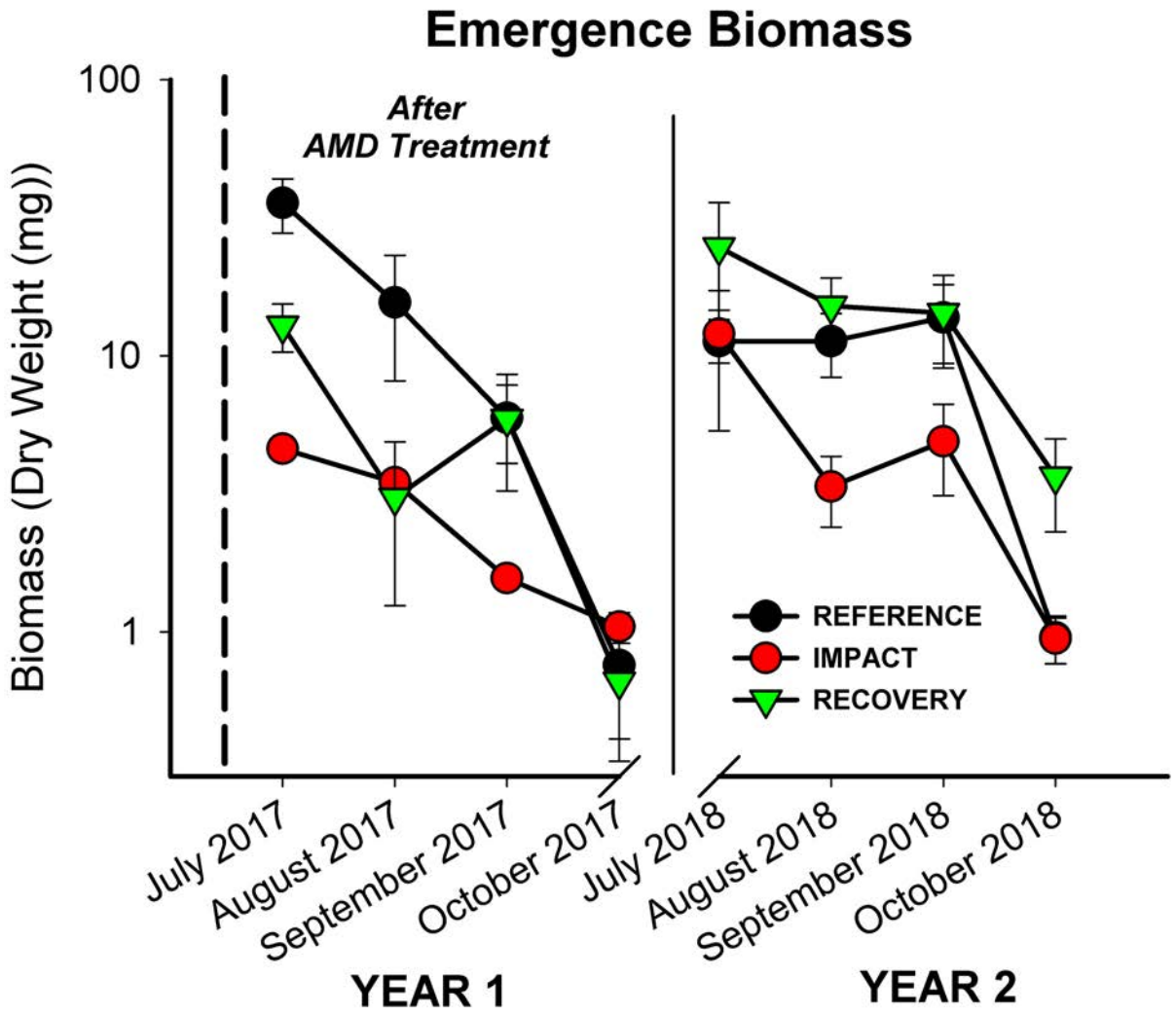
North Fork Clear Creek, Colorado
Larval Colonization





North Fork Clear Creek, Colorado
Benthic vs Emergence Biomass





Field Biomonitoring
Results and Conclusions to date--

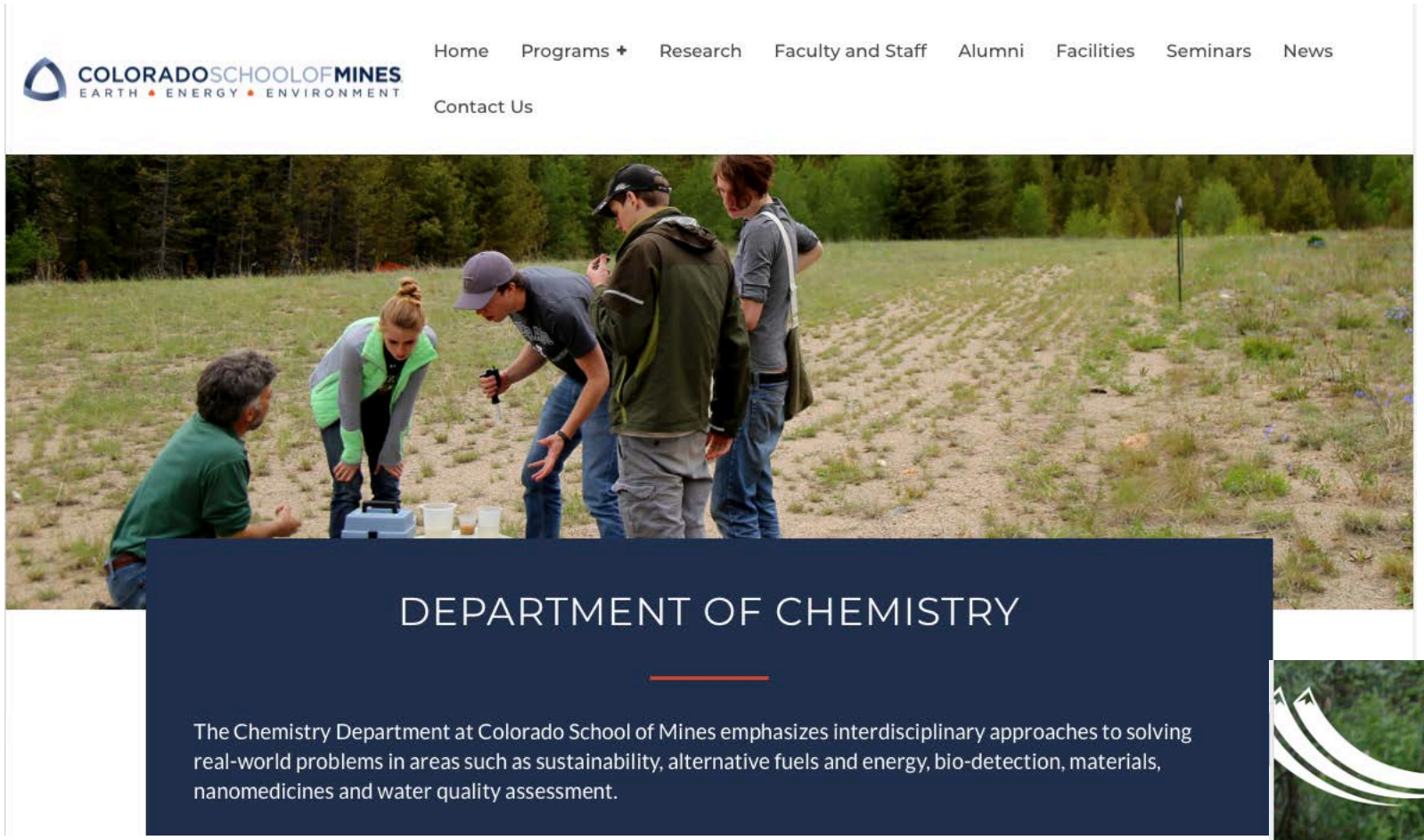
- Discrepancies in algal colonization at AMD remediation sites, likely due to top-down control by grazer aquatic insects
- Increased abundance and taxa richness at downstream sites, but richness is still far below Reference site observations
- Benthic and adult emergence biomass improved at downstream sites from Year 1 to Year 2. This suggests increased benthic production and increased subsidy export to terrestrial environments following remediation

Outreach to Local STEM K-12 Schools
CSM Summer programs engineering

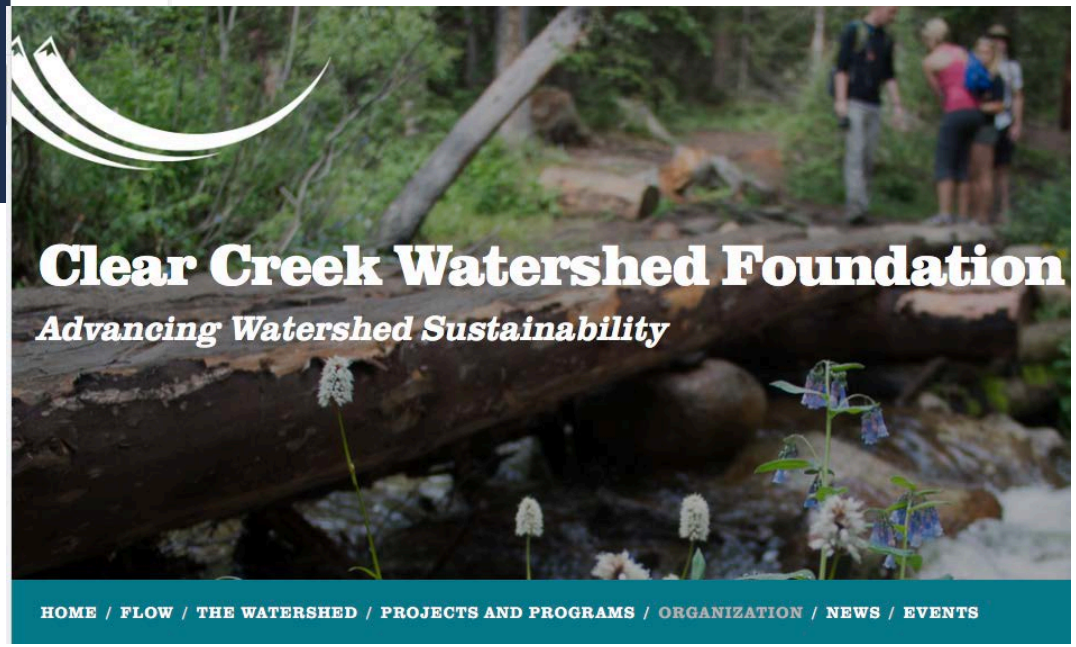
Impacts on Aquatic Life

Treatment

Sources



CSM Environmental Chemistry Field Session



Site investigations for local stakeholders

Questions