Collaborative efforts to characterize a watershed impacted by abandoned mines using metal loading tracer dilution tests

A case study for the Lefthand Creek Watershed, Colorado

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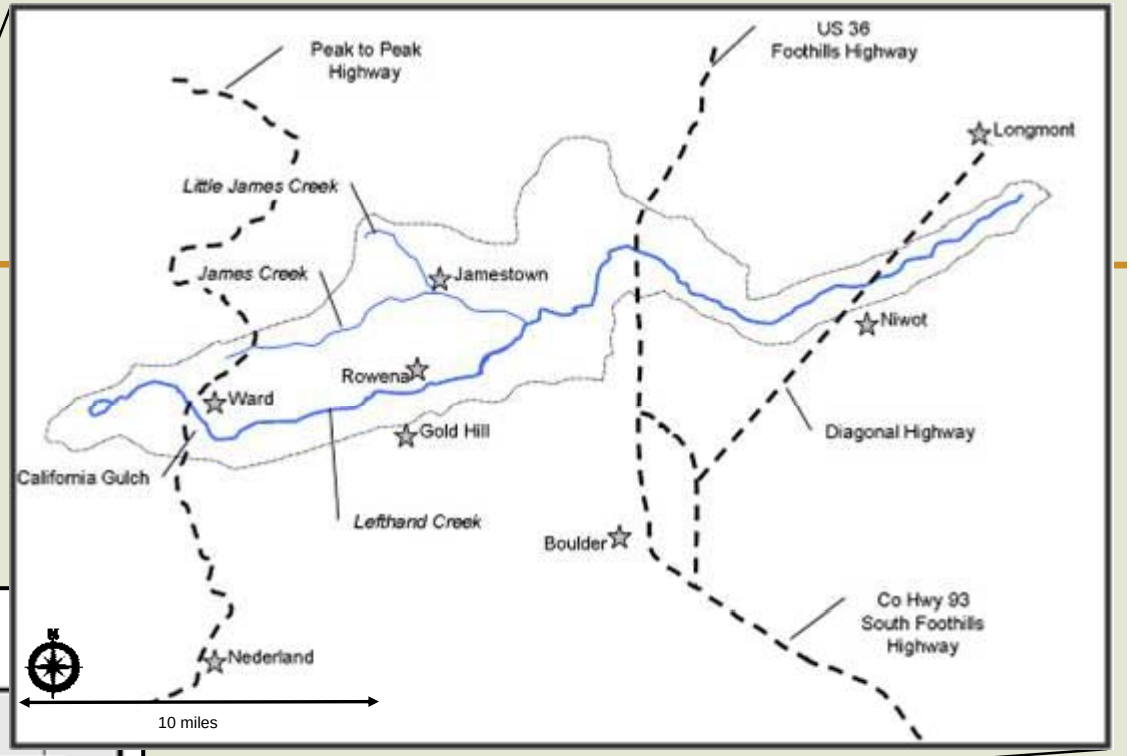
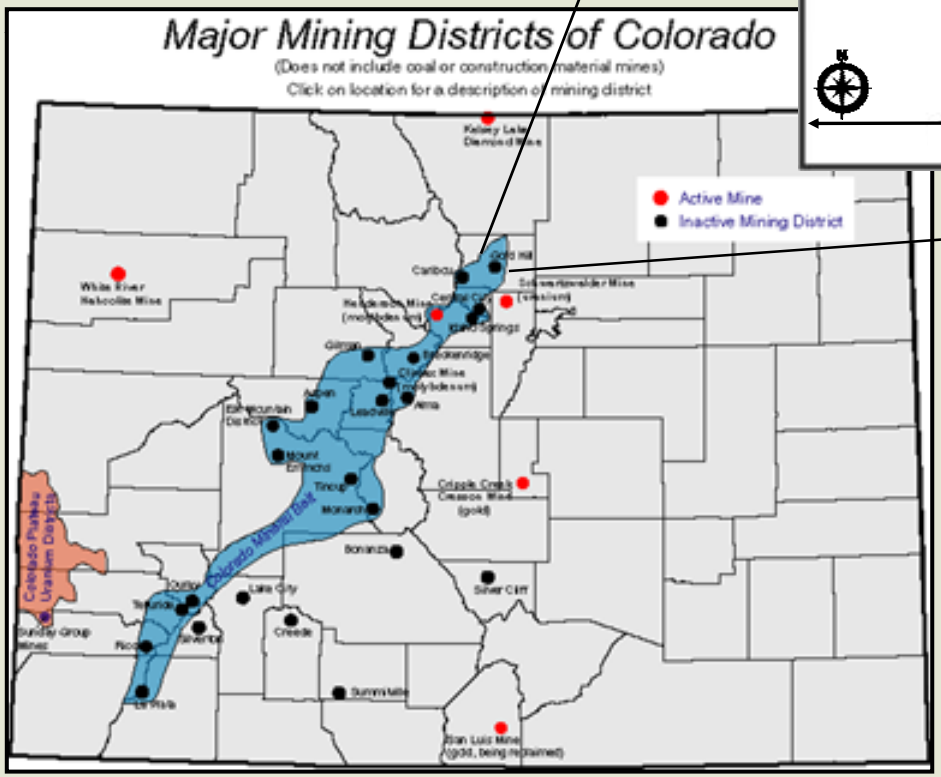
Study Area


Peak to Peak Highway
US 36 Foothills Highway
Longmont
Little James Creek
James Creek
Jamestown
Niwot
Rowena
Ward
Gold Hill
Diagonal Highway
California Gulch
Lefthand Creek
Boulder
Co Hwy 93 South Foothills Highway
Nederland
10 miles


Major Mining Districts of Colorado
(Does not include coal or construction material mines)
Click on location for a description of mining district
Active Mine
Inactive Mining District
Colorado Mineral Belt
Colorado Plateau Uranium Districts

Site History

- History: Hundreds of mines and mills operated from the mid-1800s to the late 1900s
  - » Brought settlers, railroad
  - » Mine sites abandoned when no longer profitable

Big Five Mill c. 1927, *The Cobb Collection*

The Slide Mine Mill 1890, *DPL X-61545*

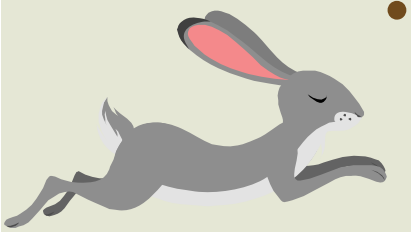
- Today: acid mine drainage (AMD) and metal contamination from mines and waste rock

Research Goals

- Identify and quantify sources of metal loading
  - Lefthand, James, and Little James Creeks
- Develop reliable baseline water quality data set

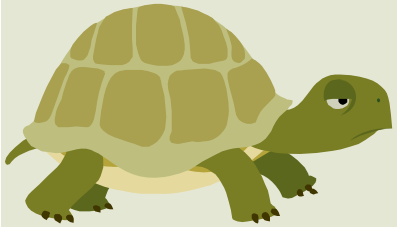
- Determine accurate and efficient sampling methods
  - Comprehensive understanding over large spatial area
  - Capture flow rates in very small streams

Methods – Overview



- Tracer tests & synoptic sampling
  - *Determine stream flow and metal concentration for a moment in time*

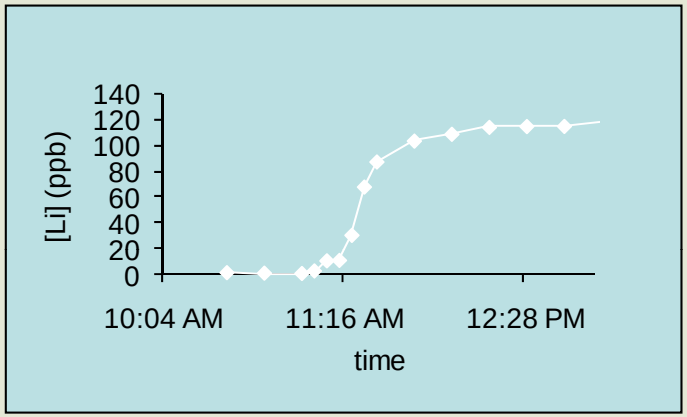
- Macroinvertebrate sampling
  - *Identify metals sources with a seasonal signal*



- Sediment sampling
  - *Identify metals sources with a long-term signal*

Methods – Tracer Tests

- Calculate stream discharge based on conservative (LiCl, NaCl) tracer dilution
  - Injection: known concentration, constant rate
  - Downstream: tracer concentration plateau
    - » Indicates even tracer distribution
    - » Synoptic sampling begins

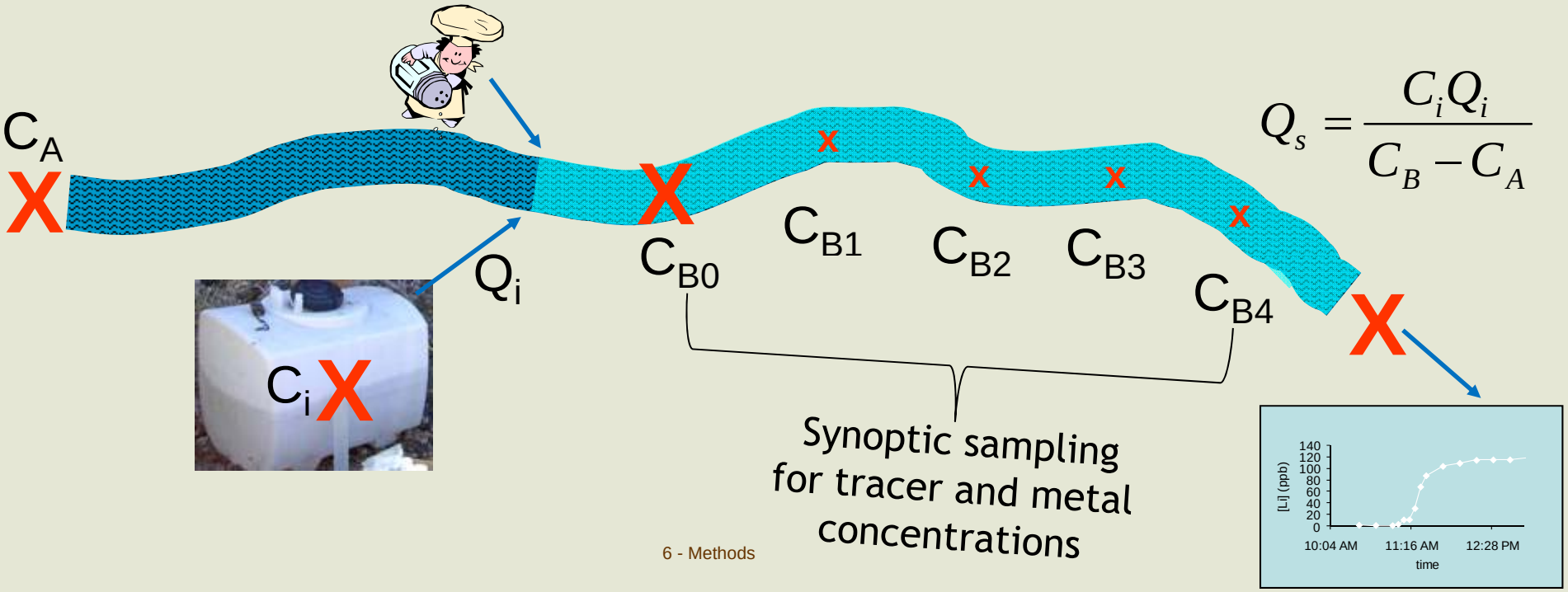


- Added NaCl pulse with LiCl injection
  - NaCl pulse spikes downstream conductivity
  - Field-measurable indicator of LiCl arrival at the most downstream sampling site

- Kimball *et al*. 2002, Kimball 1997

Methods – Synoptic Sampling

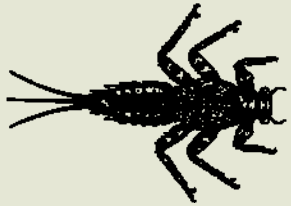
- A "snapshot in time" of concentrations and flows
  - High spatial frequency
  - Bracket key features: tributaries, adits, waste rock piles, etc.
- Metal Load = $\text{Flow}_{\text{tracer test}}$ x $\text{Concentration}_{\text{synoptic sampling}}$



$$Q_s = \frac{C_i Q_i}{C_B - C_A}$$

Methods – Macroinvertebrates

- Sample collection
  - » Composite samples from riffle areas
  - » 10 g biomass per station: Stoneflies, mayflies, caddisflies
  - » Oven-dried



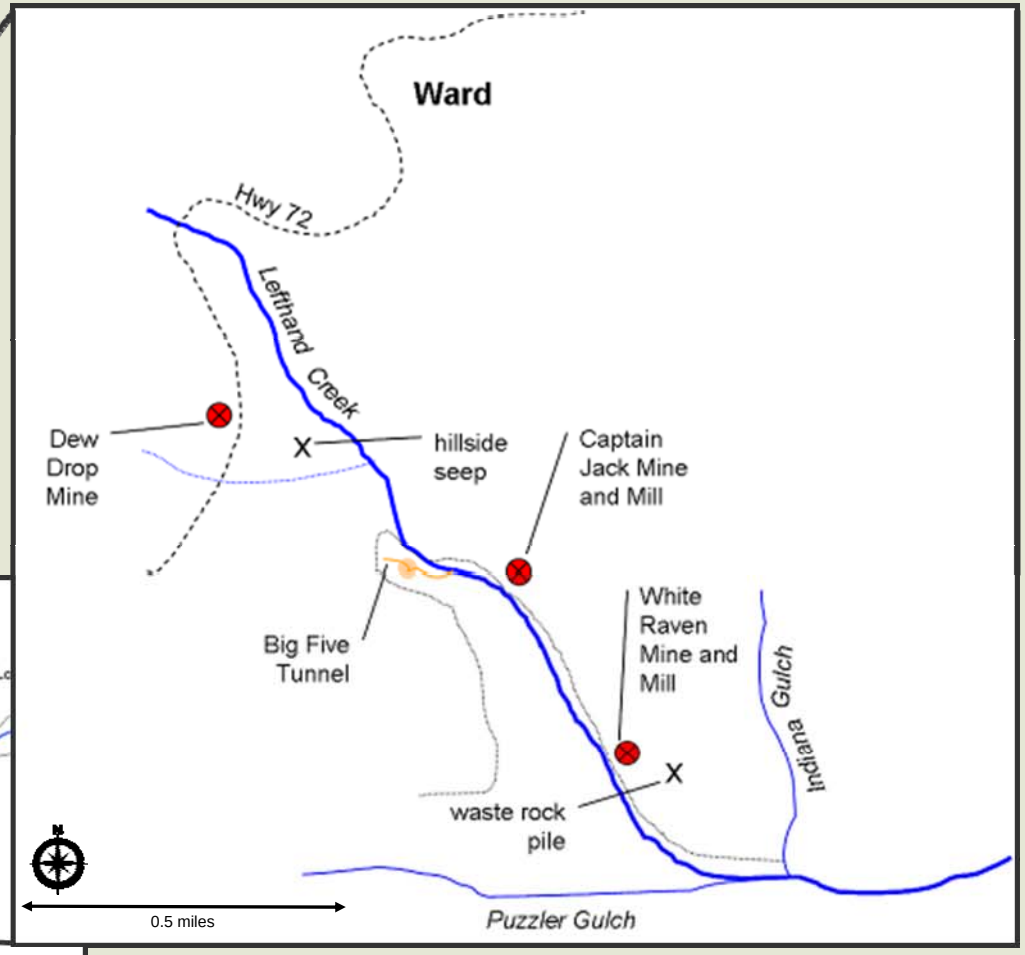
- Tissue digestion
  - — Extract metals associated with tissues and external coatings
    - » Warm (50ºC) 1.5M HCl leach solution, 6 hours
    - » H_2O_2 added to leach solution 1 hour
- Kiffney and Clements, 1993

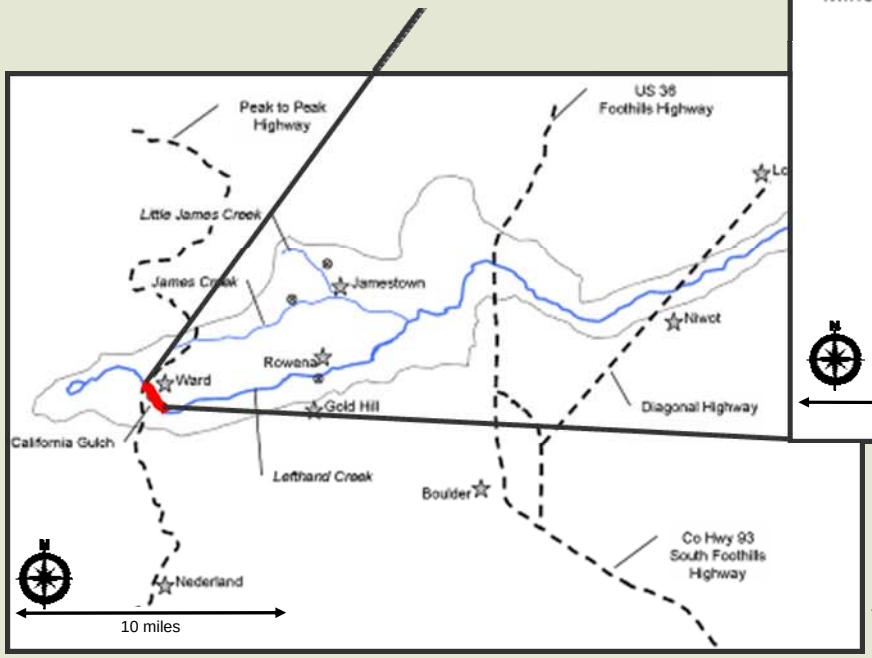
Methods – Sediments

- Sample collection
  - » Composite samples from in-stream depositional areas
  - » Oven-dried, sieved to isolate <63 µm size fraction
- Partial digestion
  - — Extract leachable metals associated with mineral coatings
    - » Warm (55ºC) 1.5M HCl, 30% H_2O_2 leach solution
- Church *et al*. 1997

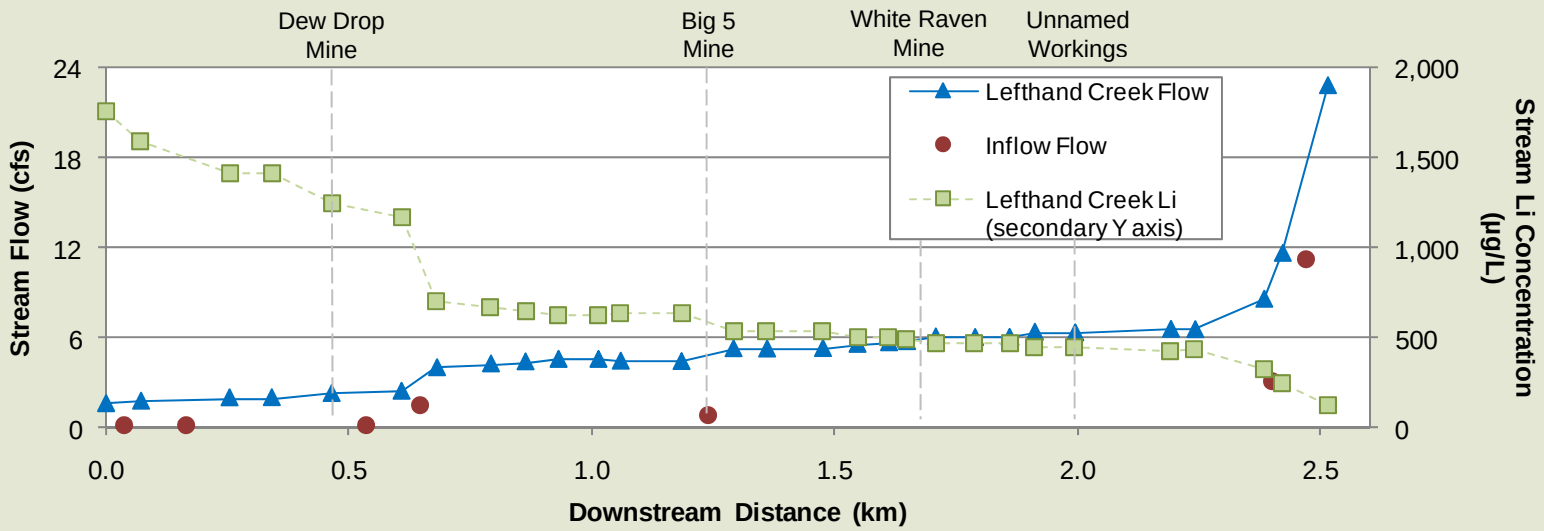
Case Study – Upper Lefthand Creek

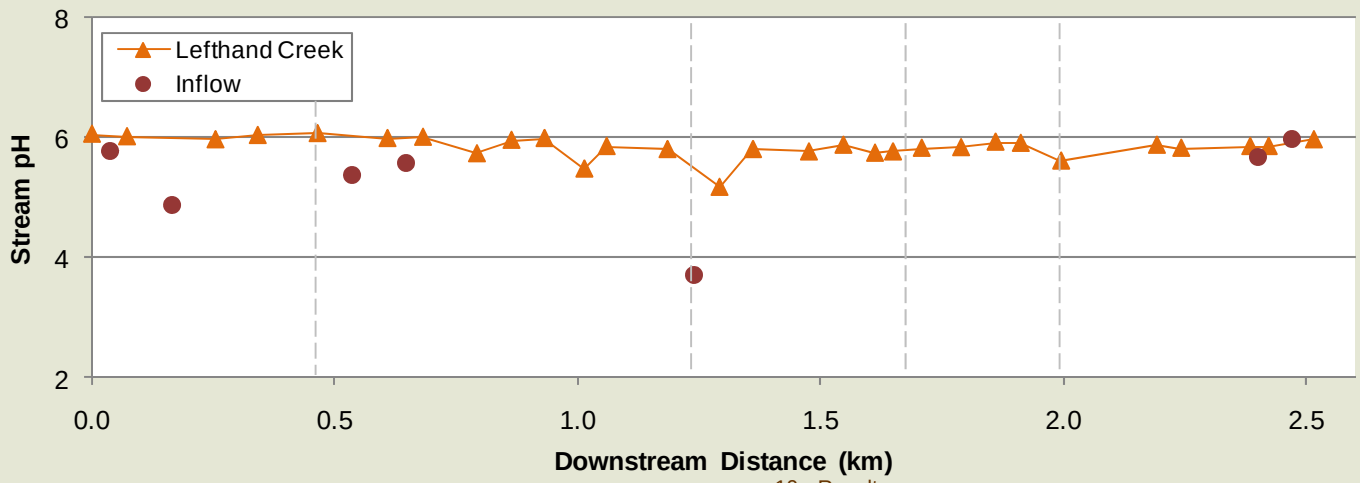
- Tracer tests & synoptic sampling, 5-21-2003
- Sediment sampling, 6-16-2003
- Macroinvertebrate sampling, 7-1-2004



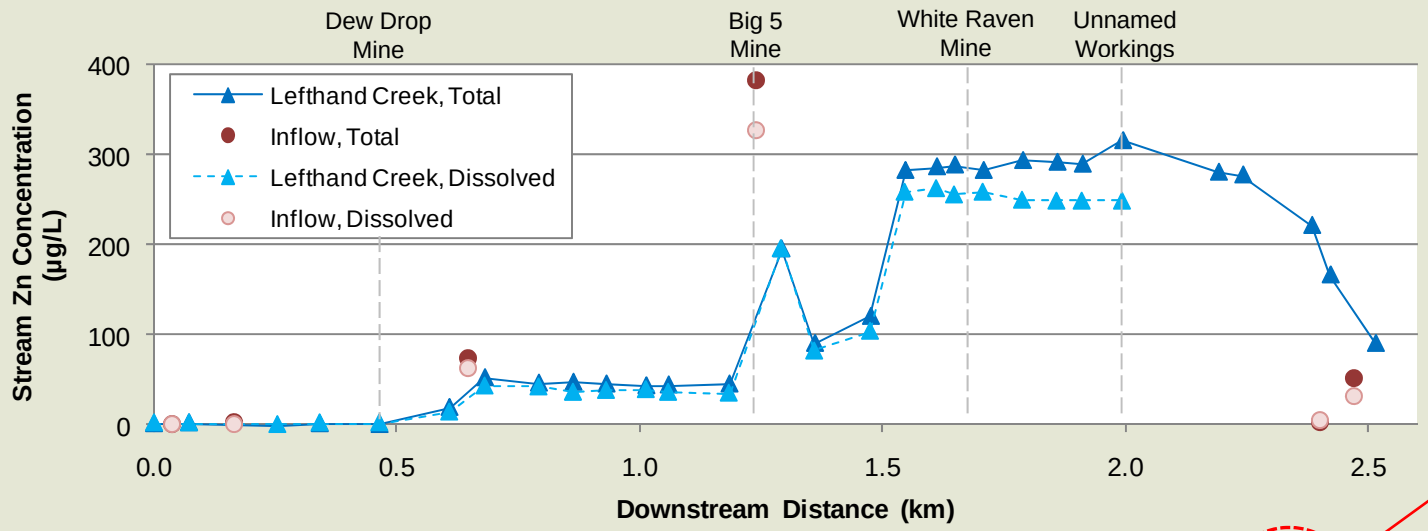


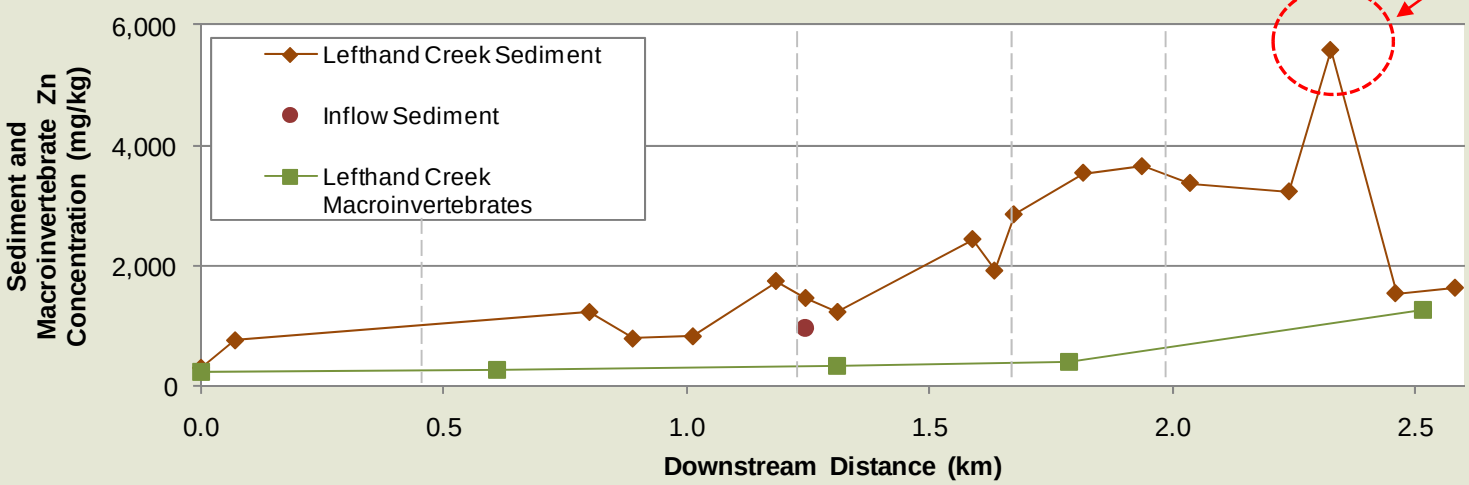
Results – Upper Lefthand Creek Flow and pH





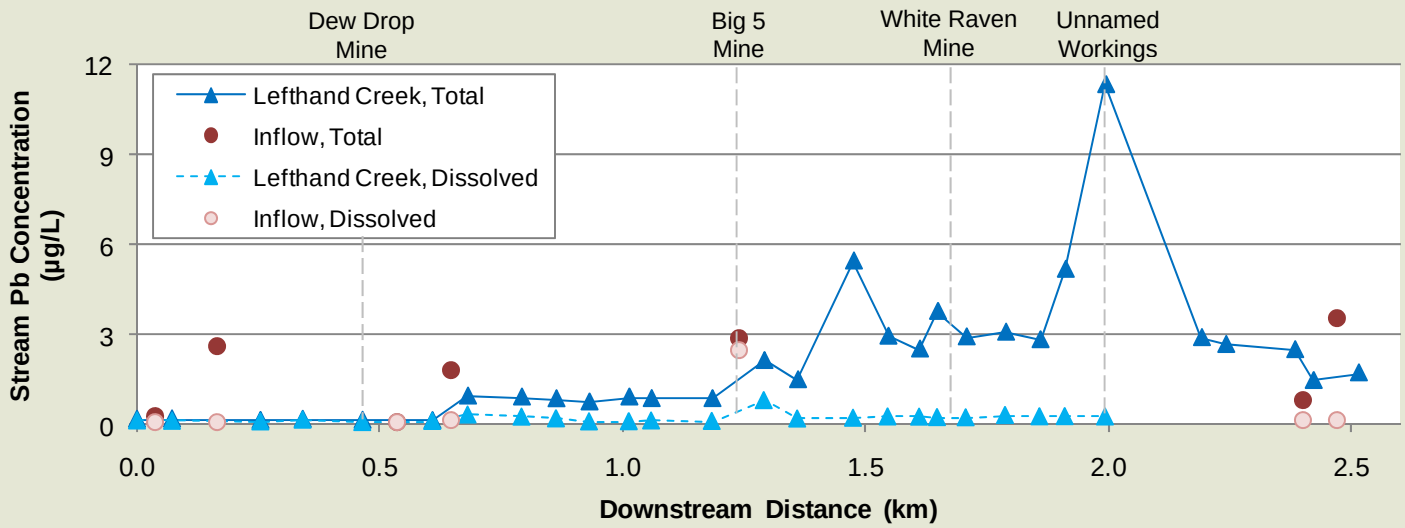
Results – Upper Lefthand Creek Zinc

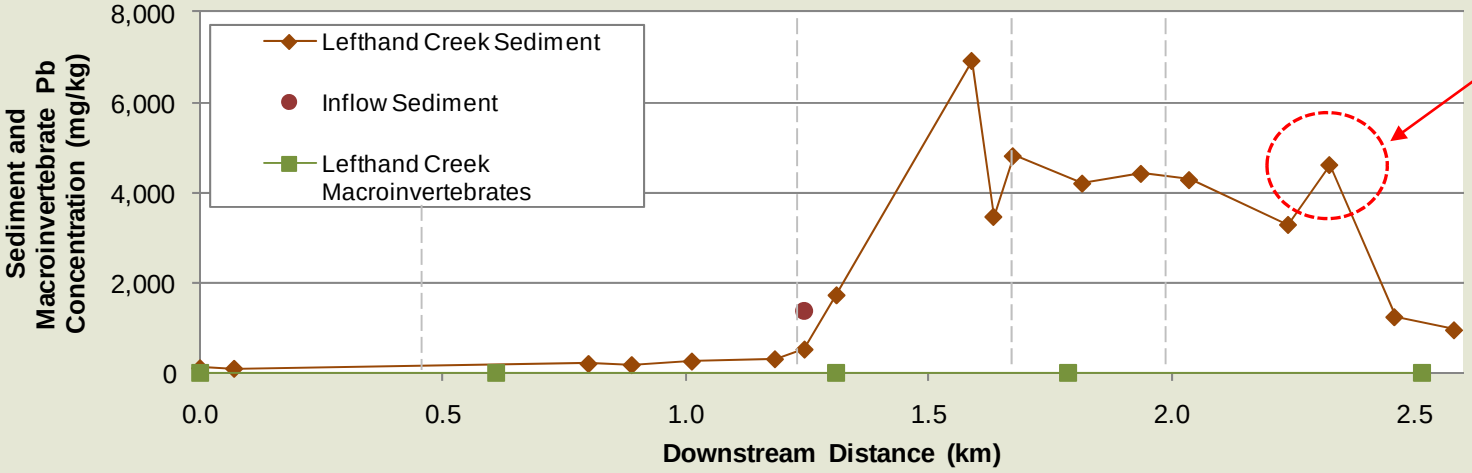




Sediment spike may be indicative of longer-term source not captured in 5-21-2003 synoptic sampling.

Results – Upper Lefthand Creek Lead





Sediment spike may be indicative of longer-term source not captured in 5-21-2003 synoptic sampling.

Outcome

- Tracer tests & synoptic sampling
  - » Identified and quantified sources of metals loading for a moment in time
    - — Efficient, spatially detailed, effective for small streams
    - — Requires multiple sampling events to capture temporal element
- Sediments
  - » Identified metals sources with a long-term signal not observed in synoptic sampling
- Macroinvertebrates
  - » Seasonal signal generally not evident
  - » Data interpretation difficult

Outcome

- Over $10 million in clean-up actions

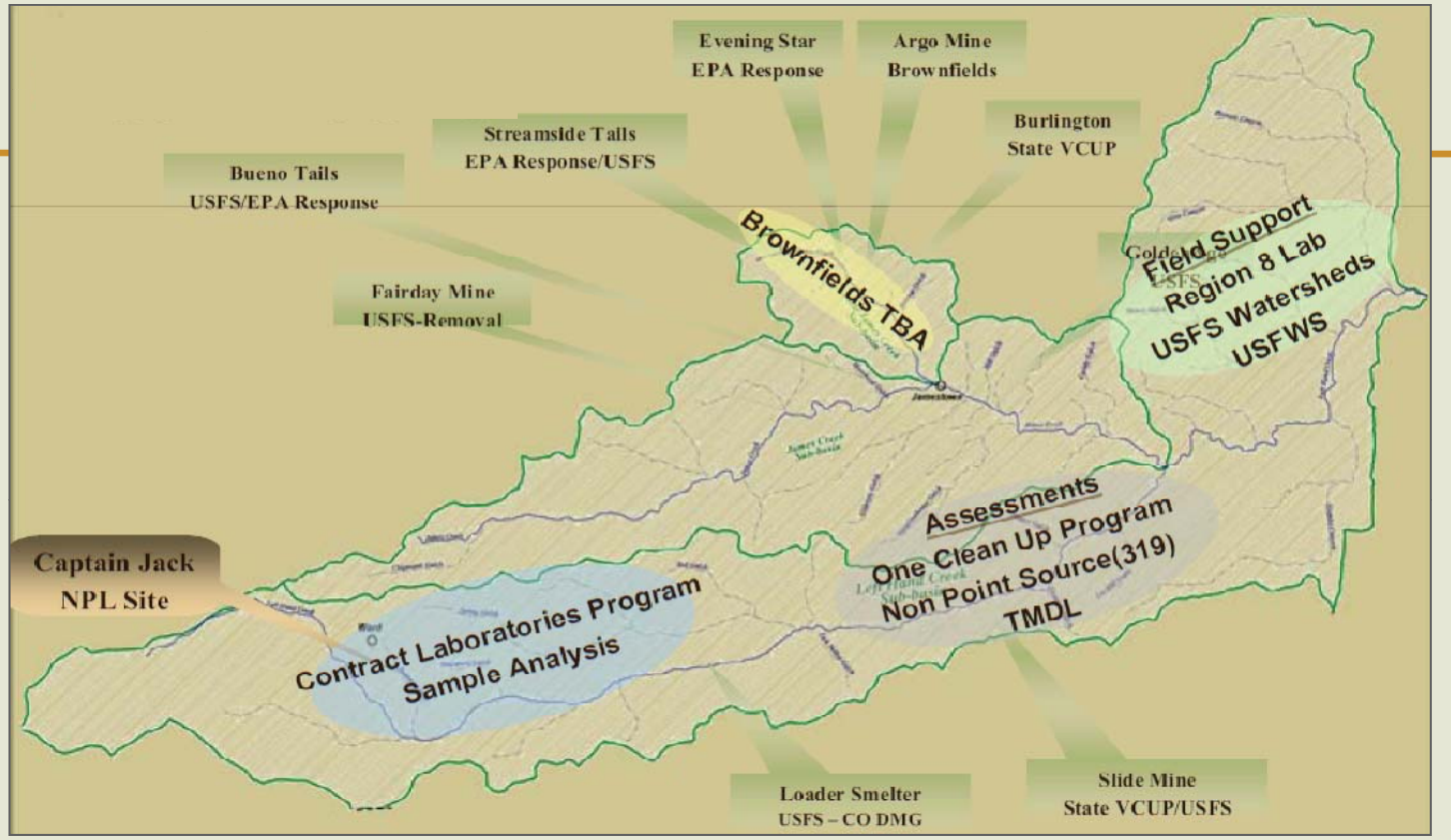


Image from K. Hernandez, EPA

- Future research
  - Repeat these studies
  - Did clean-up actions eliminate sources and reduce metals loads?

Collaboration

- Boulder County Health Department
- Boulder County Parks and Open Space
- CO Dept. of Public Health and the Environment
- CO Division of Minerals and Geology
- James Creek Watershed Initiative
- Left Hand Water District
- Lefthand Watershed Oversight Group
- US EPA Region VIII
- US Forest Service
- US Geological Survey
- University of Colorado
- Individual stakeholders, town governments, local consulting firms

References

Church, S. E., Kimball, B.A., Fey, D.L., Ferderer, D.A., Yager, T.J., and Vaughn, R.B., 1997. Source, transport, and partitioning of metals between water, colloids, and bed sediments of the Animas River, Colorado. United States Geological Survey. Open File Report 97-0151.

Kiffney, P.M. and Clements, W.H., 1993. Bioaccumulation of Heavy Metals by Benthic Invertebrates at the Arkansas River, Colorado. Environmental Toxicology and Chemistry, Vol. 12, p. 1507-1517.

Kimball, 1997. Use of tracer injections and synoptic sampling to measure metal loading from acid mine drainage. United States Geological Survey. Report FS-245-96.

Kimball, B.A., Runkel, R.L., Walton-Day, K., and Bencala, K.E., 2002, Assessment of metal loads in watersheds affected by acid mine drainage by using tracer injection and synoptic sampling: Cement Creek, Colorado, USA: Applied Geochemistry, v. 17, p. 1183-1207.

Questions?

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