# GROUNDWATER/SURFACE WATER INTERACTIONS

Characterization and Implications for Remedial Decision Making

Bonita Peak Mining District OU2

Ian Bowen

Hydrogeologist

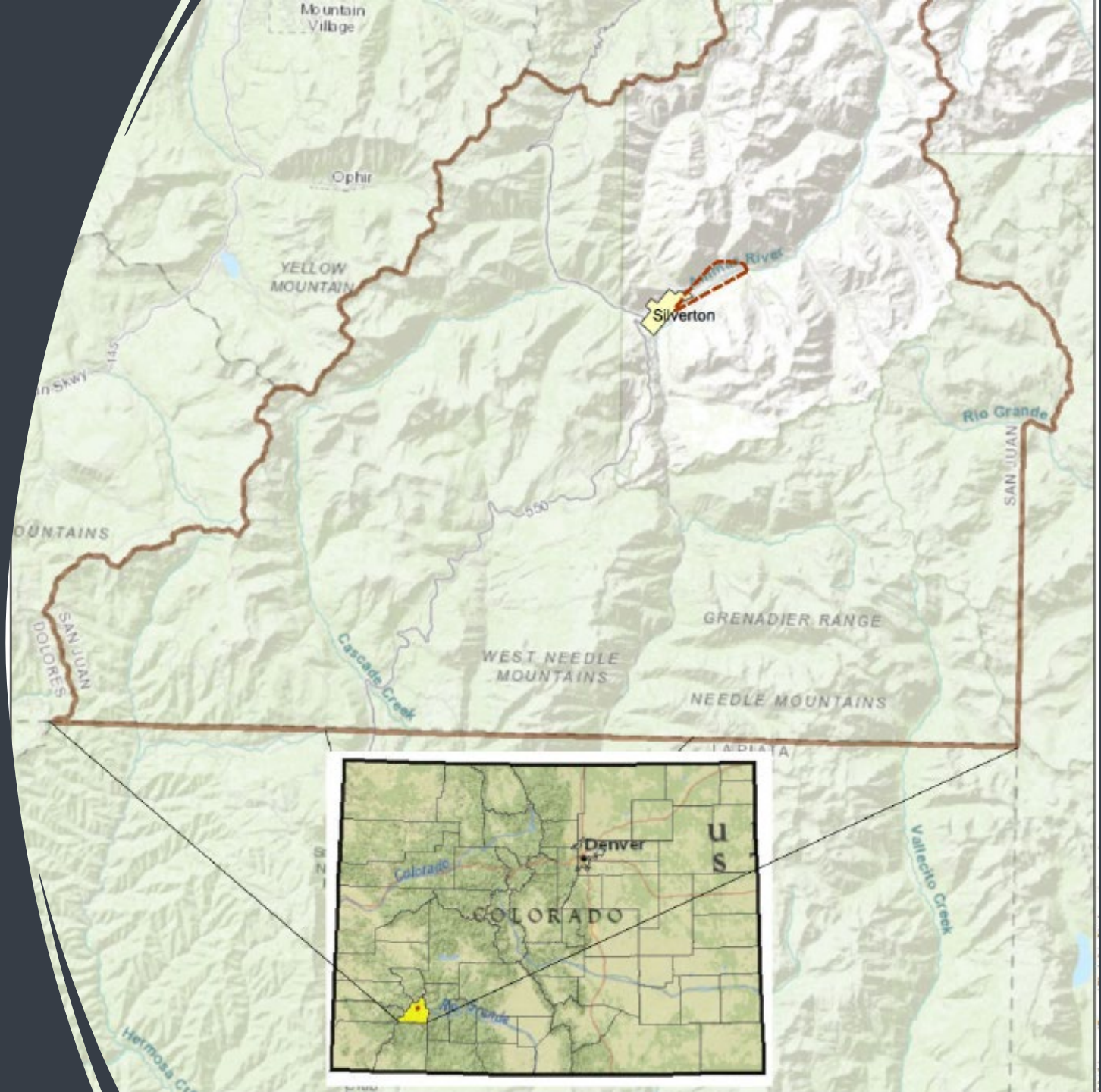
USEPA Region 8

# OUTLINE

- Site History
- Conceptual Site Model
- Data indicating GW/SW interaction may be significant
- Data needs
- Tools
- Results
- CSM updates/considerations
- Next Steps

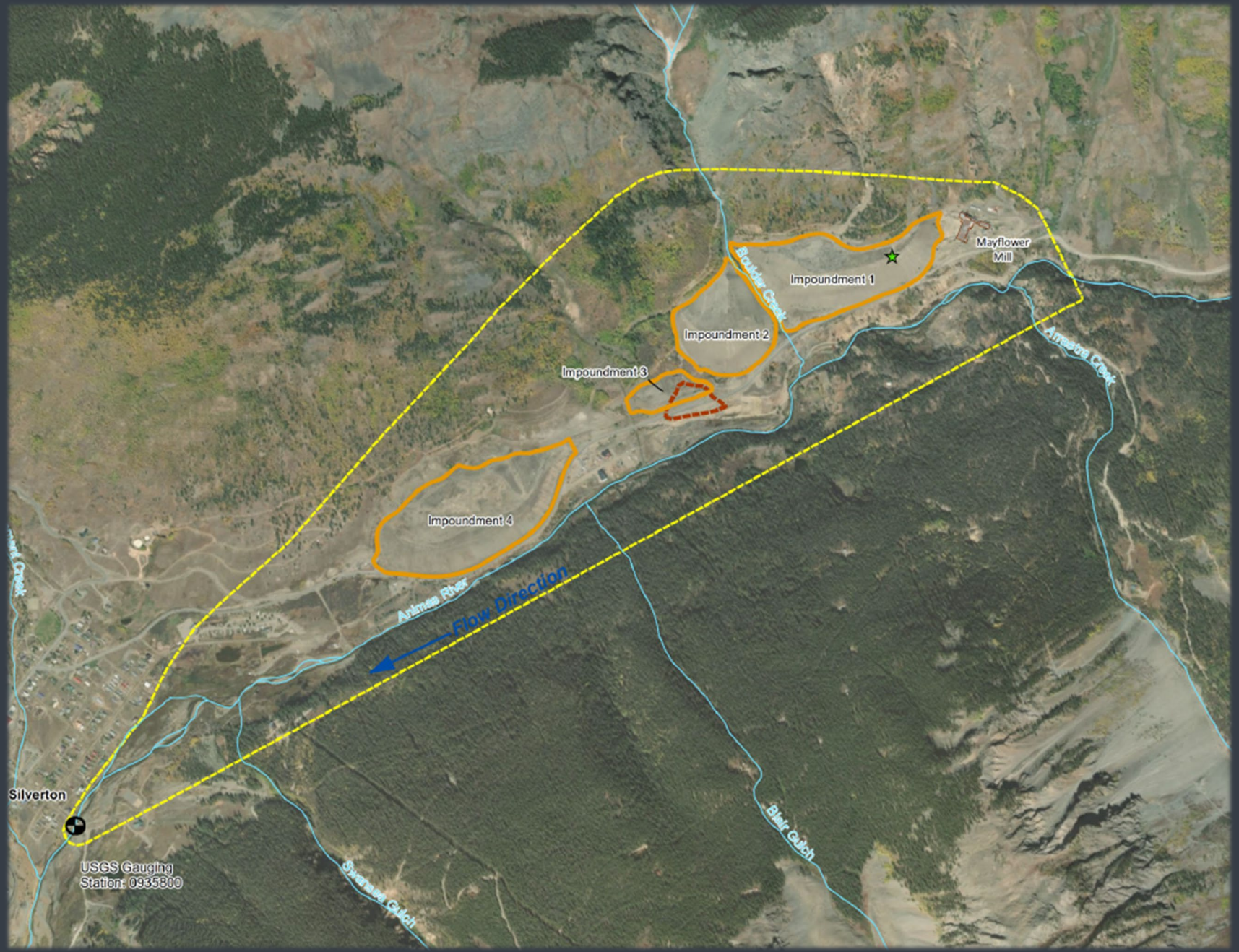
# BONITA PEAK MINING DISTRICT OU2

- Large mine waste repository
- Adjacent to Animas River



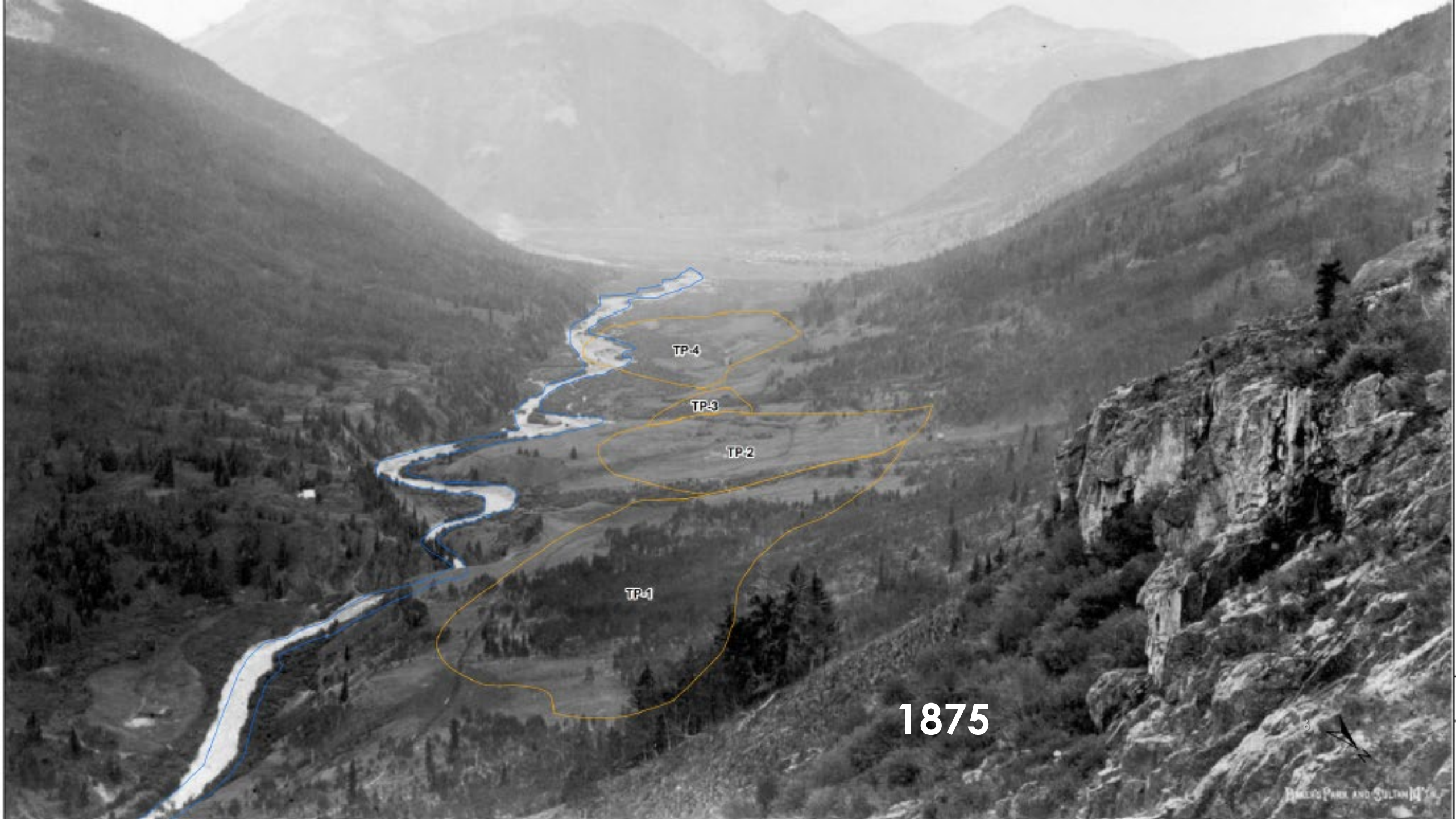
# MAYFLOWER MILL

- Flotation Mill
- 1929-1991
- Processed ore from >60 mines




# IMPOUNDMENTS

- 4 IMPOUNDMENTS
- IMPOUNDMENT 1 BUILT IN 1935
- IMPOUNDMENT VIA SLURRY

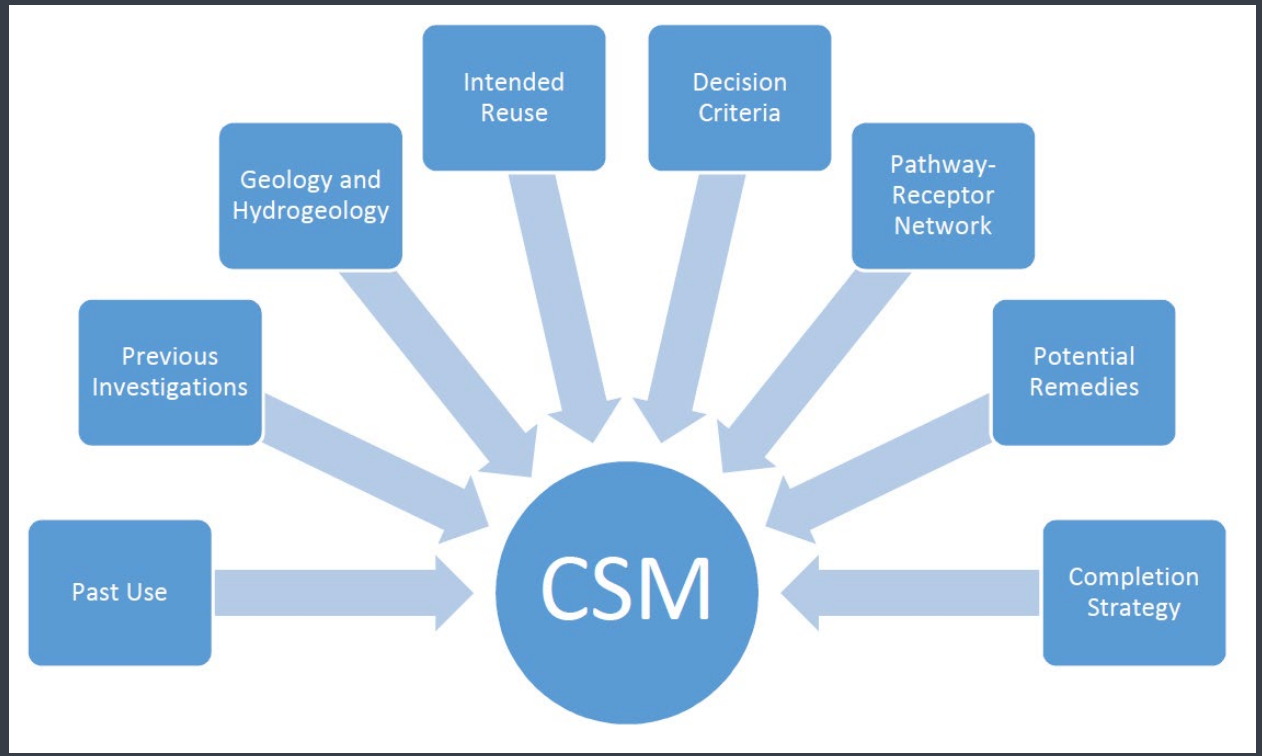

TP-4
TP-3
TP-2
TP-1
1875

June @ 9300’

June @ 10,000’

# CONCEPTUAL SITE MODEL

- PAST USE
- PREVIOUS INVESTIGATIONS
- MEDIA AND TRANSPORT (GEOLOGY AND HYDROGEOLOGY)

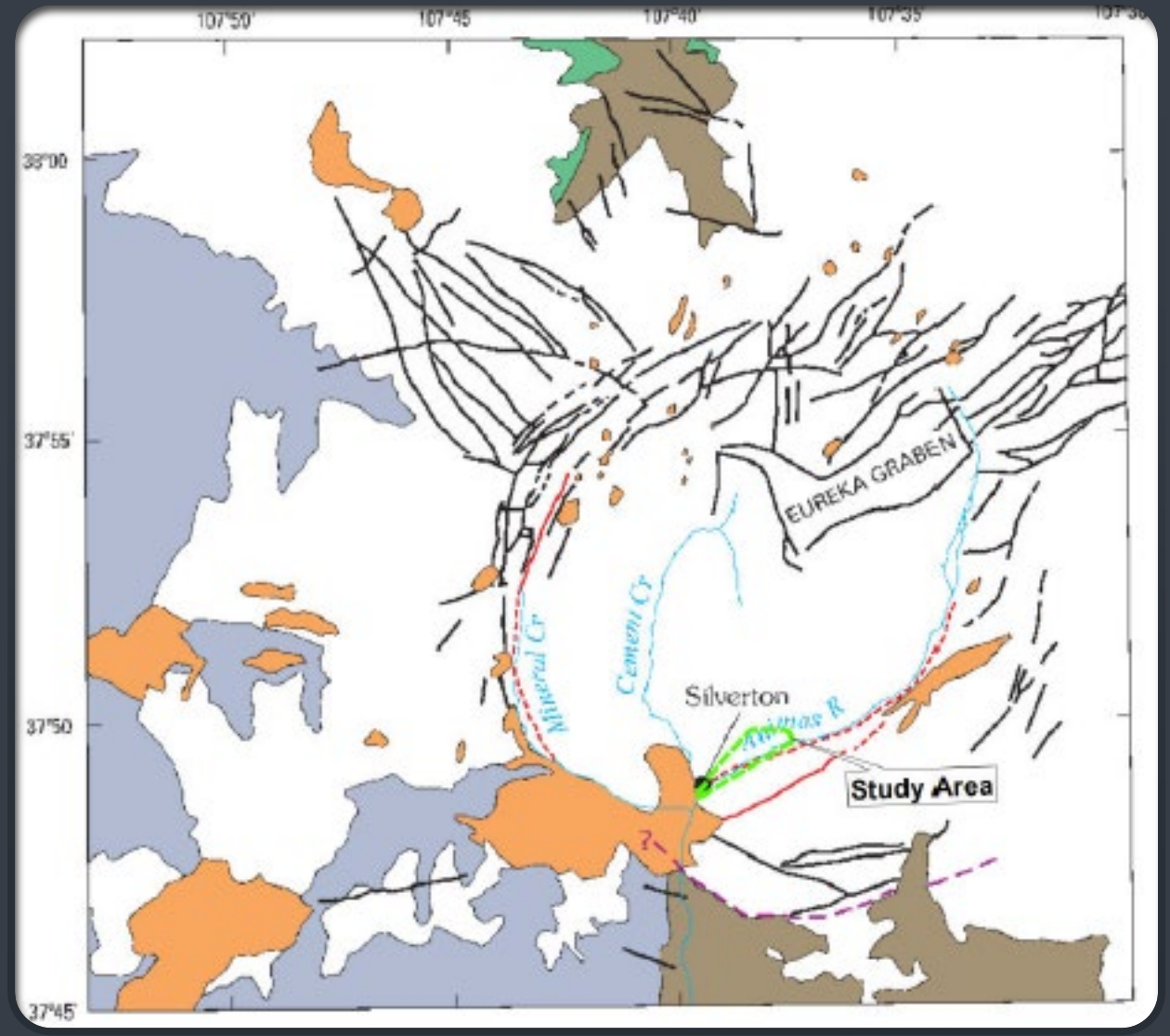


# GEOLOGY

"Caldera ring faults and associated veins of the Eureka graben and radial vein structures near the margin of the nested San Juan and Silverton Calderas are laterally and vertically continuous…"

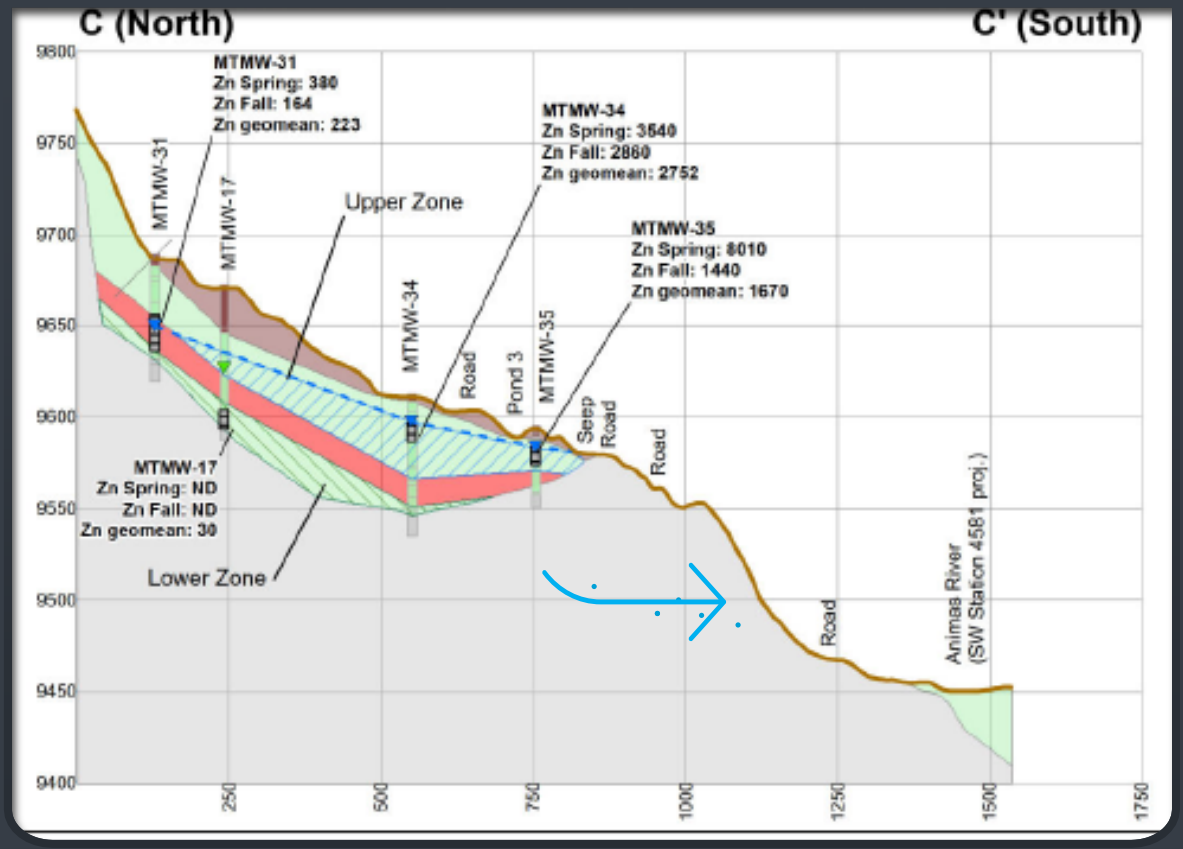
"Thus, these features may be important groundwater flow paths."

(Yager and Bove, 2007)



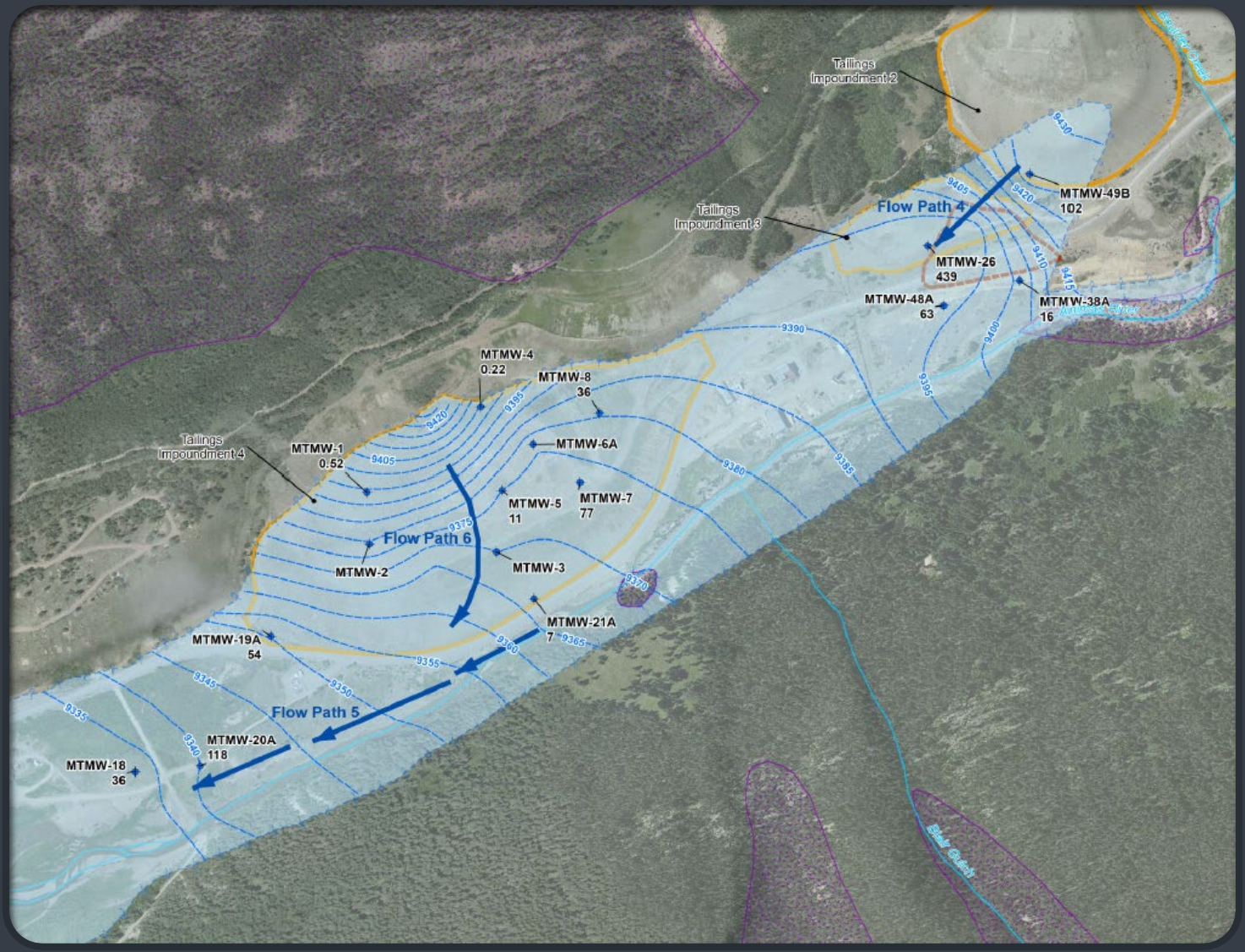
# GROUNDWATER SYSTEMS

- 3 AQUIFERS
- ALL LIKELY DISCHARGE TO SURFACE WATER
- NUMEROUS SIGNIFICANT SEEPS


# MILL AREA

- Perched Aquifer over bedrock
- Closed basin
- Bedrock seeps

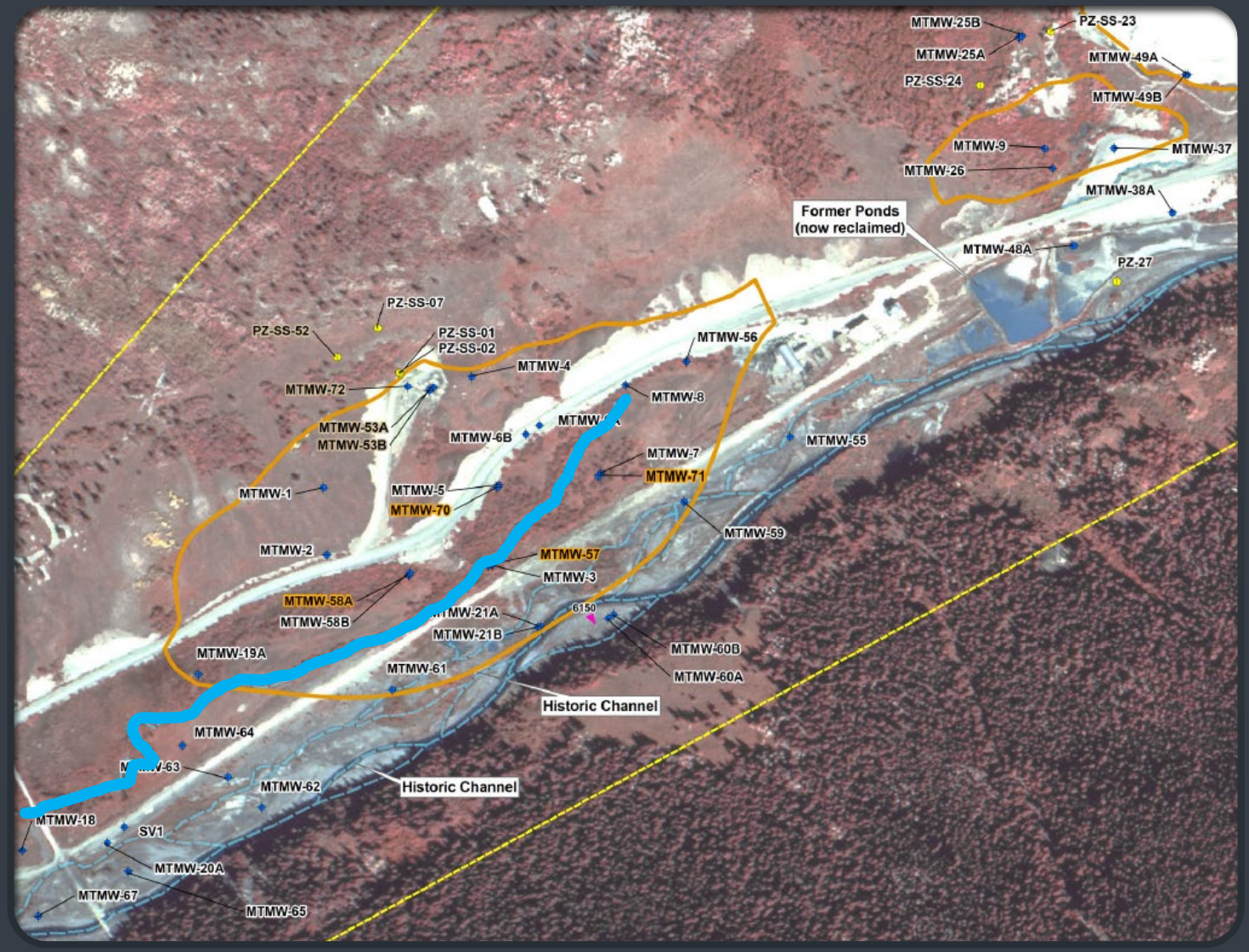



# WESTERN GROUNDWATER SYSTEM

# 1972

- Before realigning river (and road)
- Numerous spring creeks and side channels

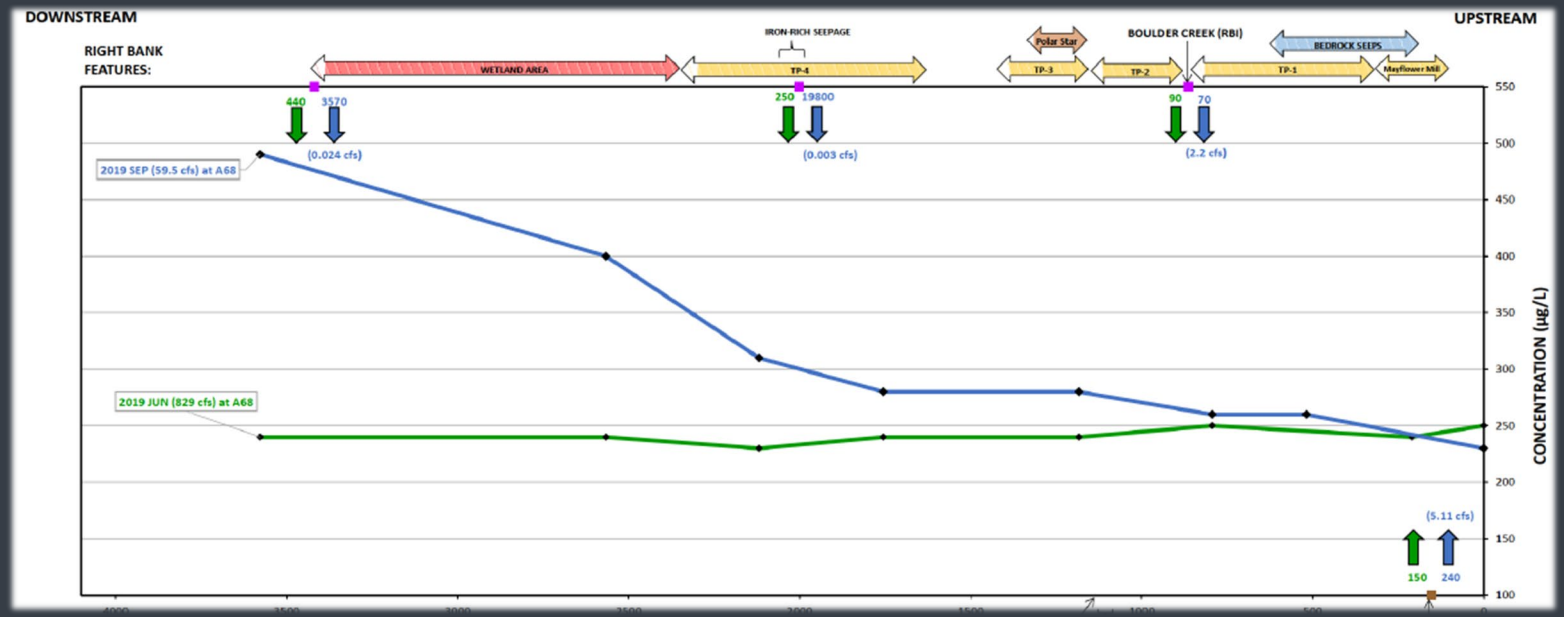
**Preferential Pathways!**



# PREVIOUS INVESTIGATION RESULTS

# SURFACE WATER ZINC CONCENTRATIONS

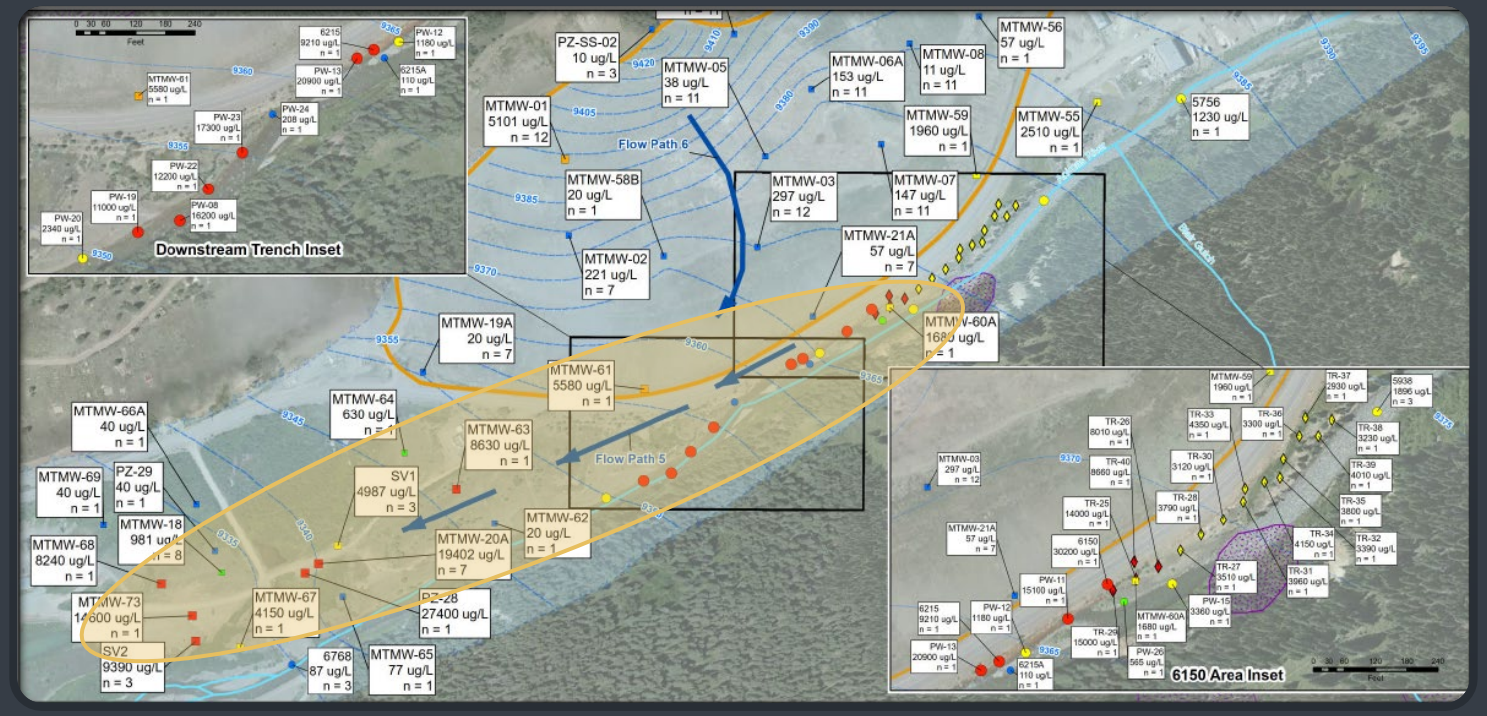
- SITEWIDE RISK DRIVER
- OVERALL GOAL TO DECREASE ZINC LOAD IN RIVER
- CONCENTRATIONS INCREASE NEAR OBSERVED SEEPAGE


FLOW

# GROUNDWATER ZINC CONCENTRATIONS

- GREATEST GROUNDWATER IMPACTS ALONG PREFERENTIAL PATHWAYS
- POREWATER IMPACTS NEAR KNOWN SEEPS

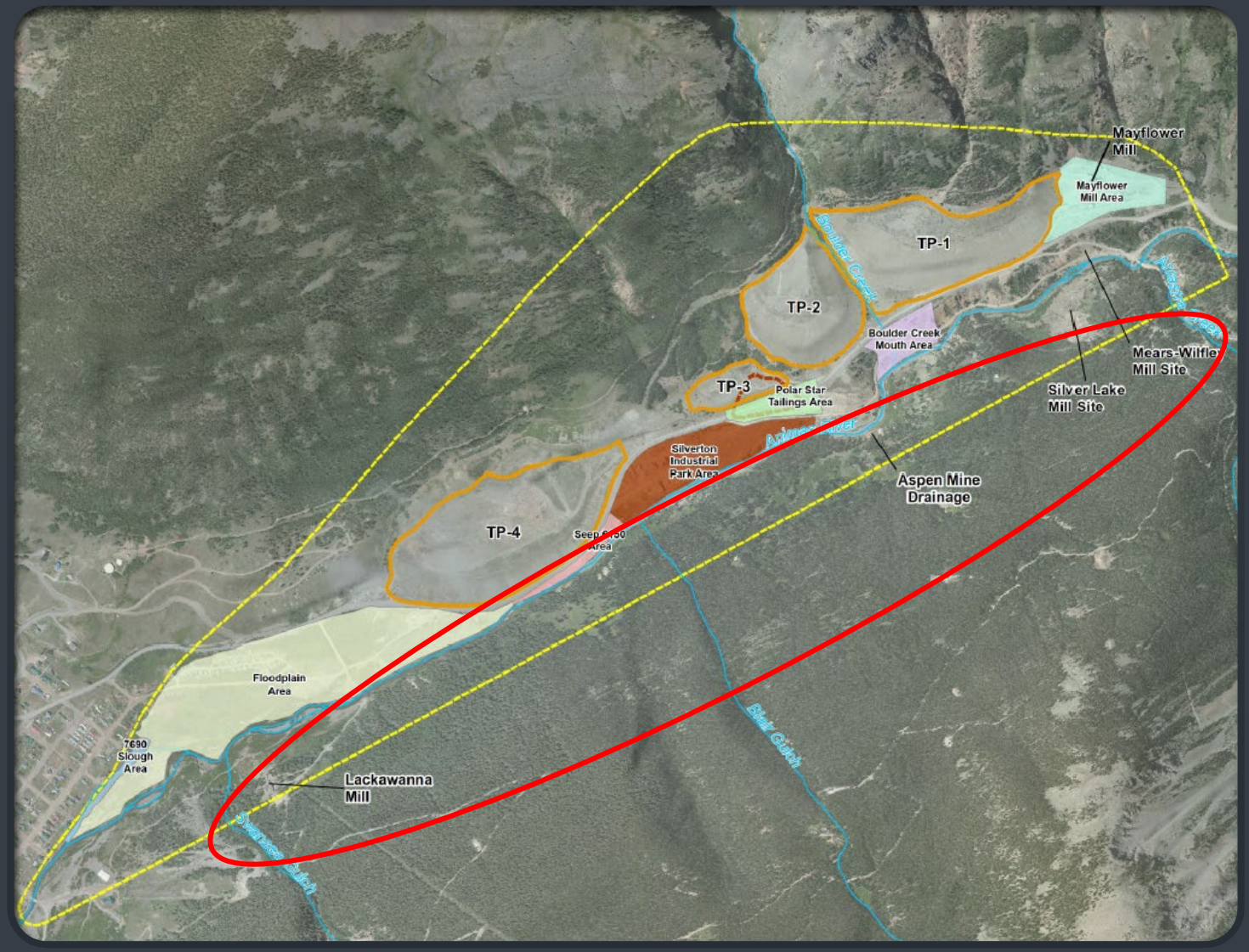



# DATA INDICATING GW/SW MAY BE SIGNIFICANT

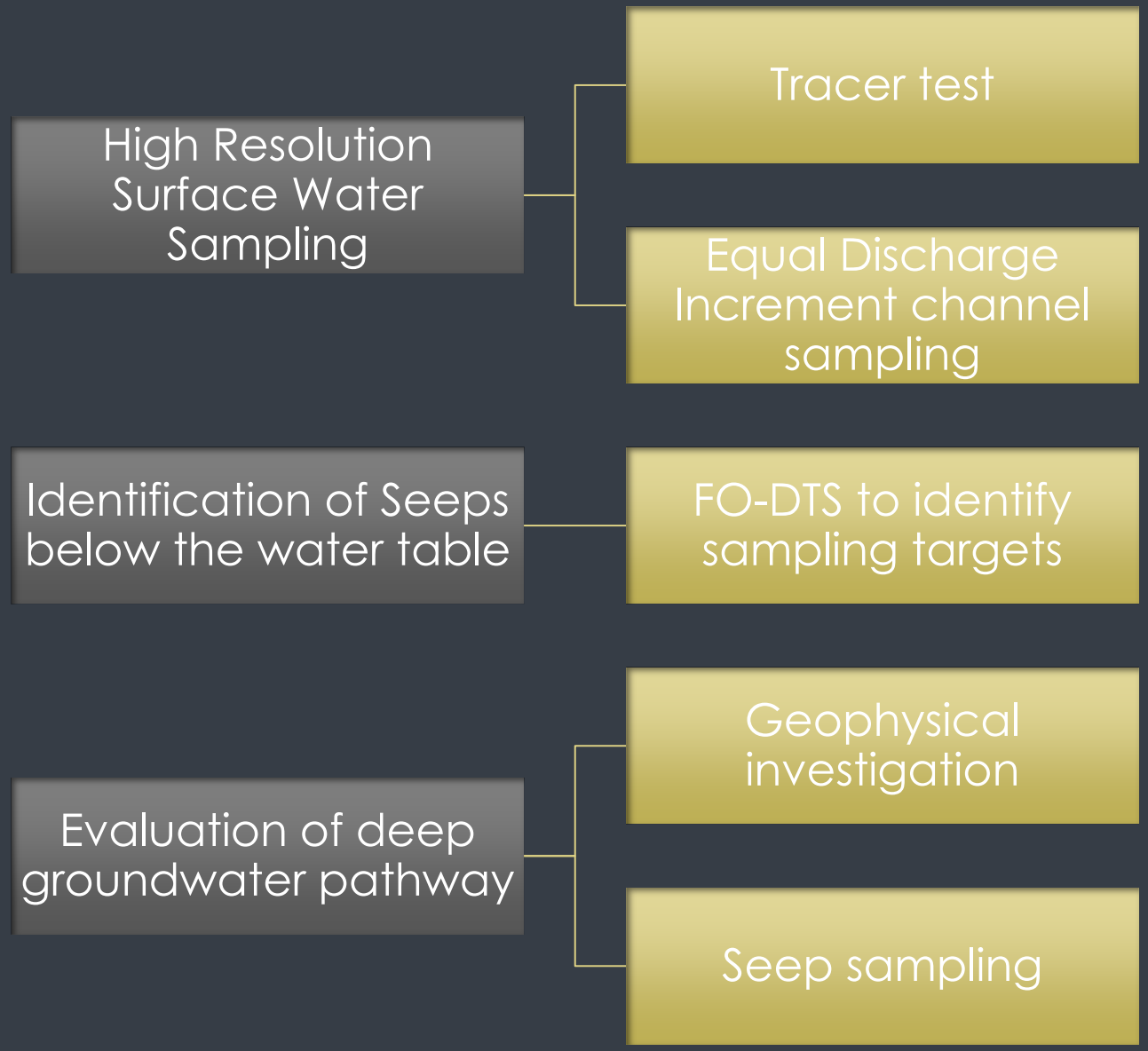
- Proximity
- Site History
- Faulting and fractured bedrock
- Seeps
- GW Potentiometric surface maps
- Surface Water Loading Profiles
- Groundwater Concentration Maps

# OTHER CONSIDERATIONS

- Other potential sources exist in study area
- Natural loading may be high (Background)
- Limited impacts in GW below impoundments

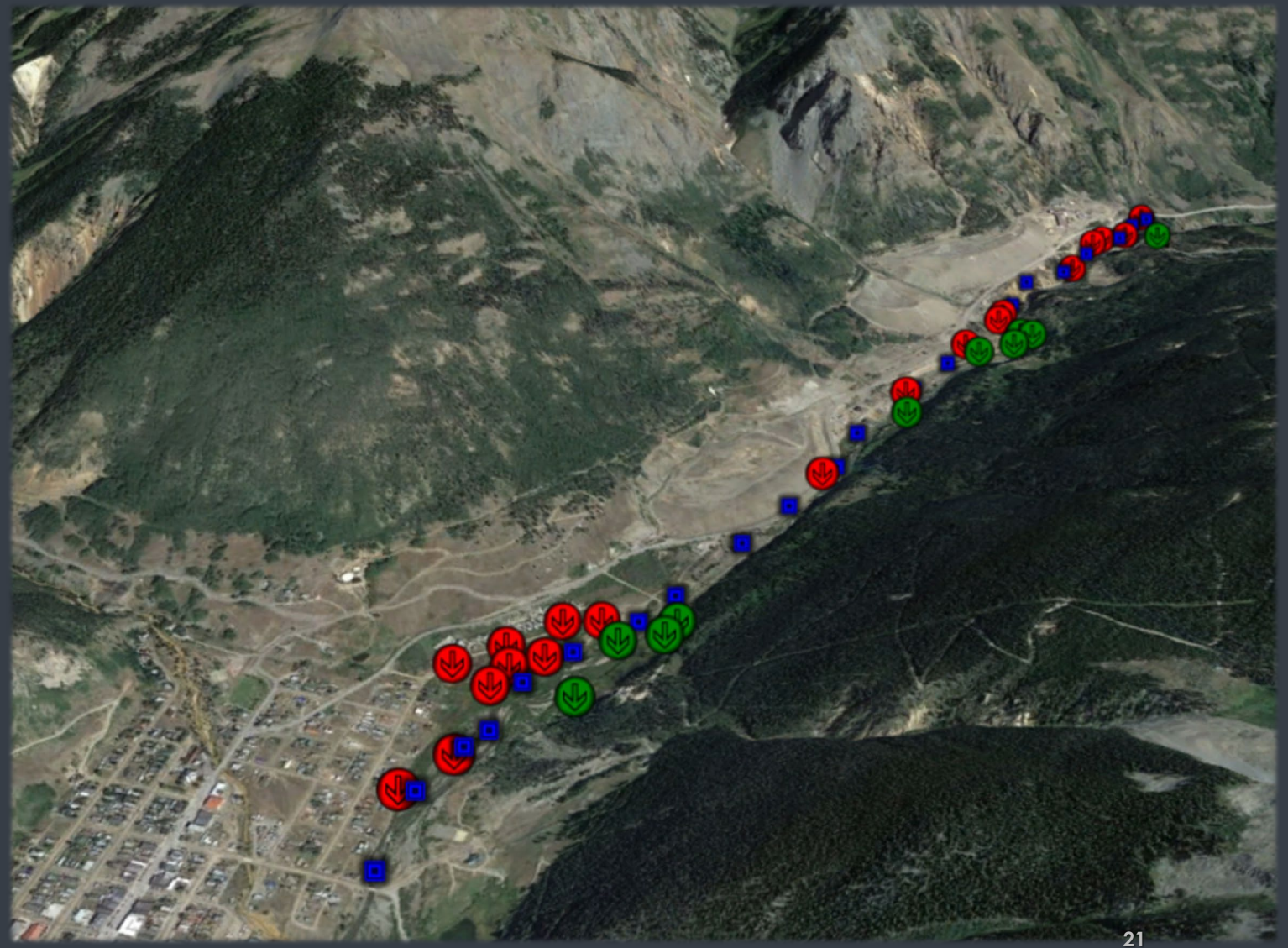


# DATA NEEDS


High Resolution Surface Water Sampling
Tracer test
Equal Discharge Increment channel sampling
Identification of Seeps below the water table
FO-DTS to identify sampling targets
Evaluation of deep groundwater pathway
Geophysical investigation
Seep sampling

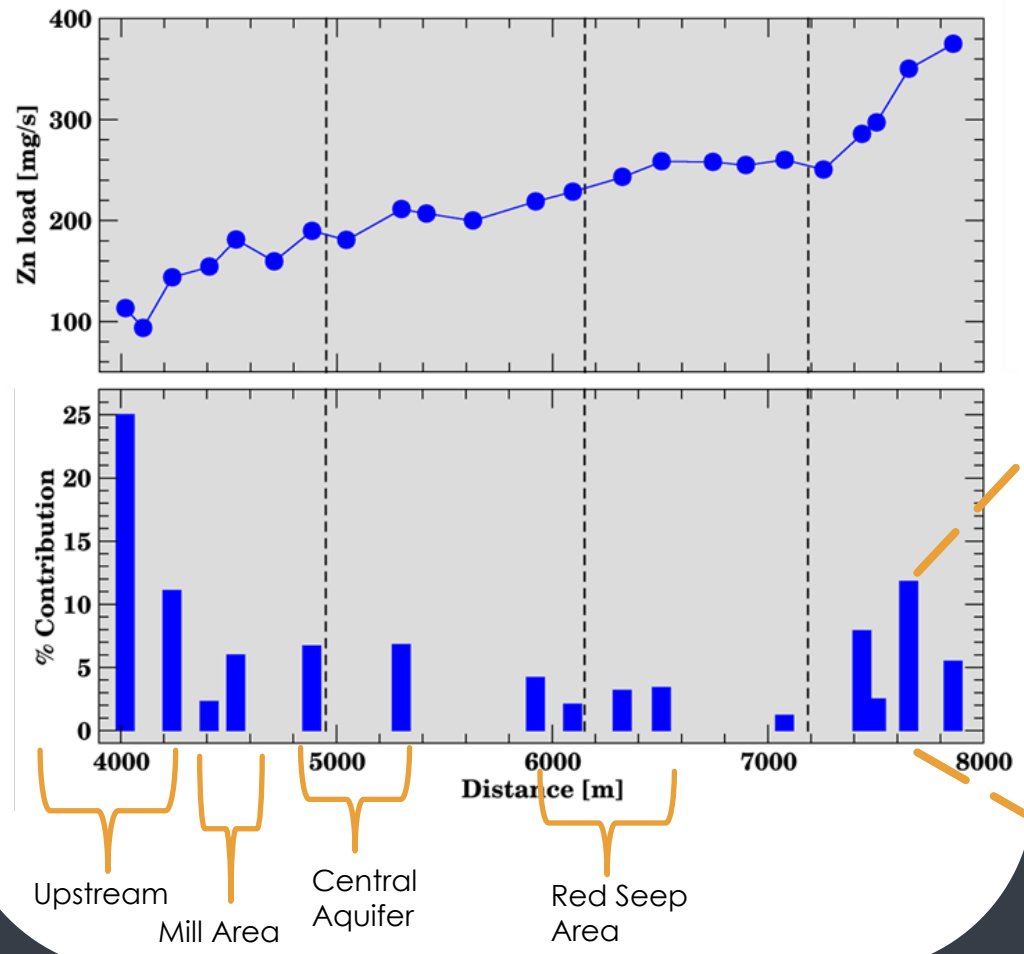
# TRACER TEST SAMPLING LOCATIONS

- Constant Bromide Tracer Injection
- Stream samples (Blue)
- Right Bank Inputs (red)
- Left Bank Inputs (Green)



# PRELIMINARY TRACER TEST RESULTS

## Preliminary Zinc Load



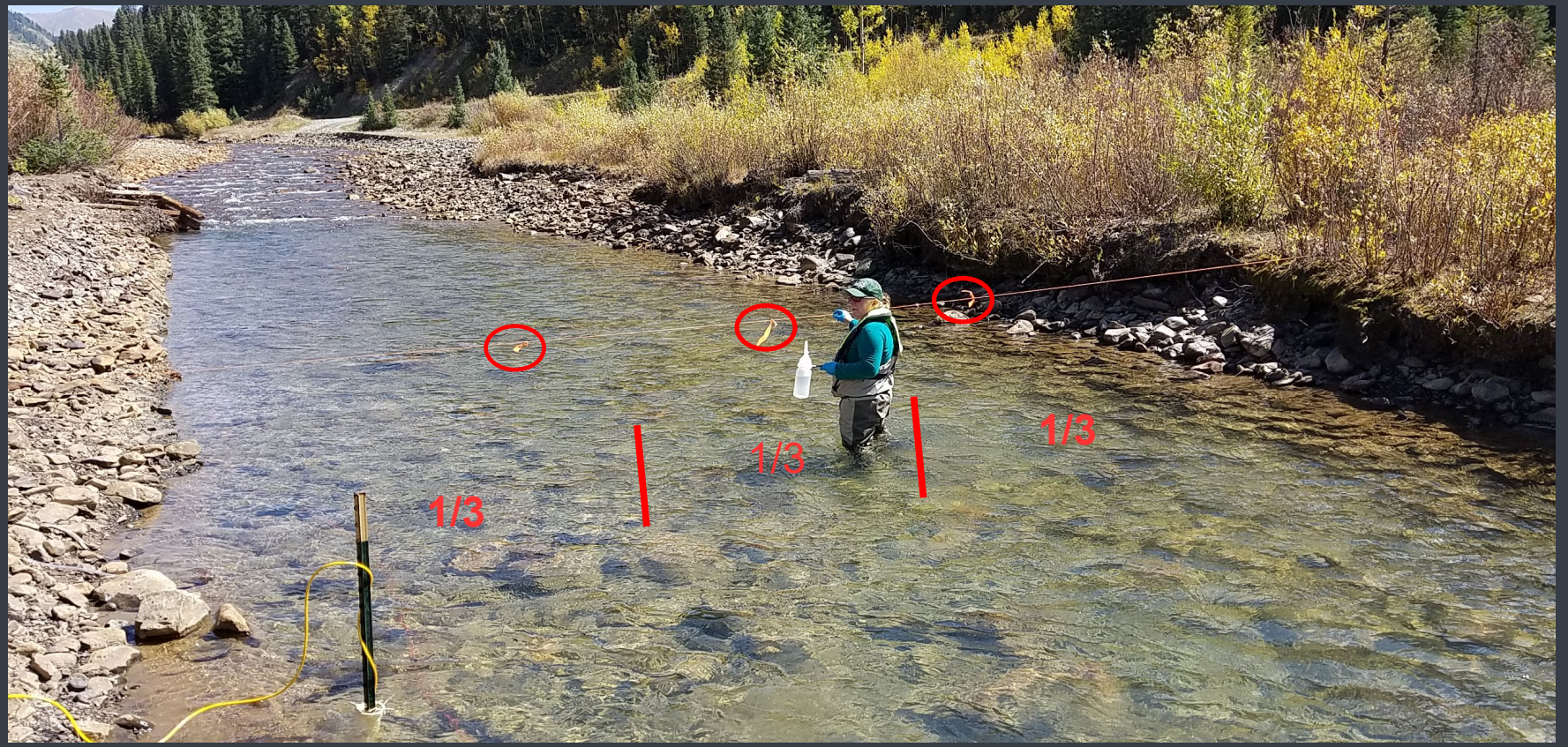



Slide Courtesy of Rob Runkel, USG

# Equal Discharge Increment Sampling

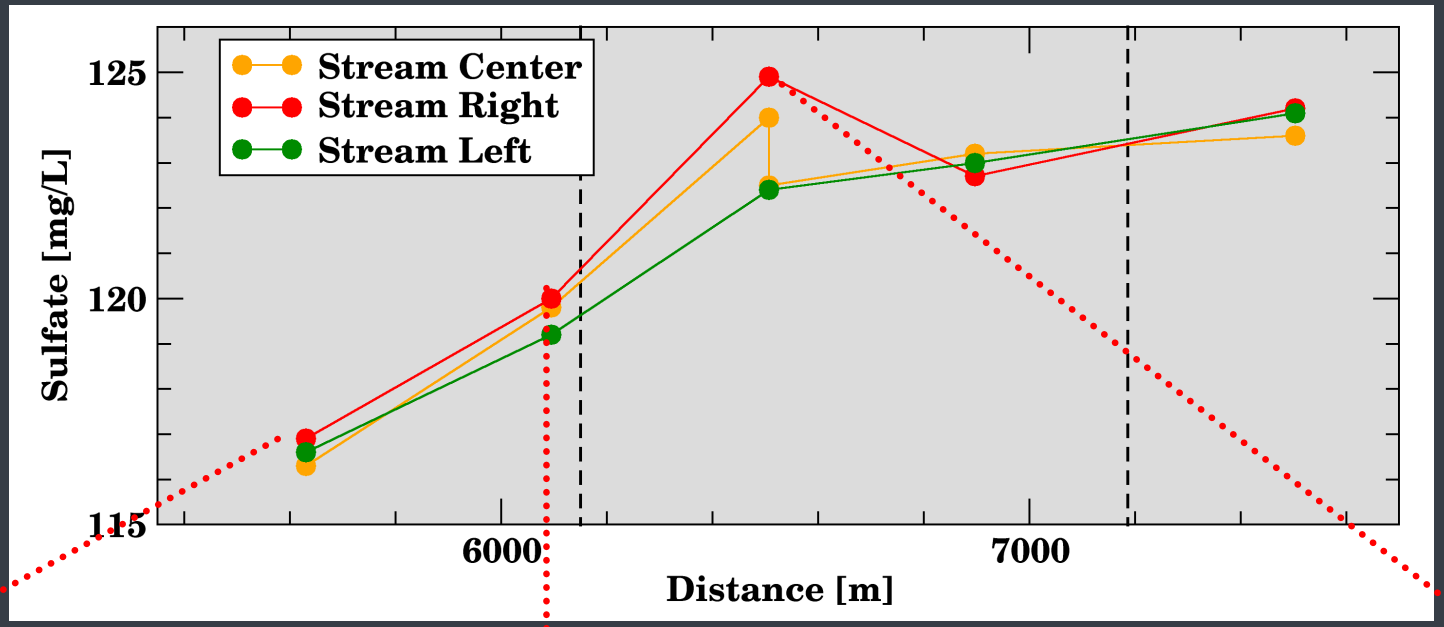
## Left Right or Center?


- divide transect into thirds based on streamflow
- sample at midpoint of each third (L, R, C samples)



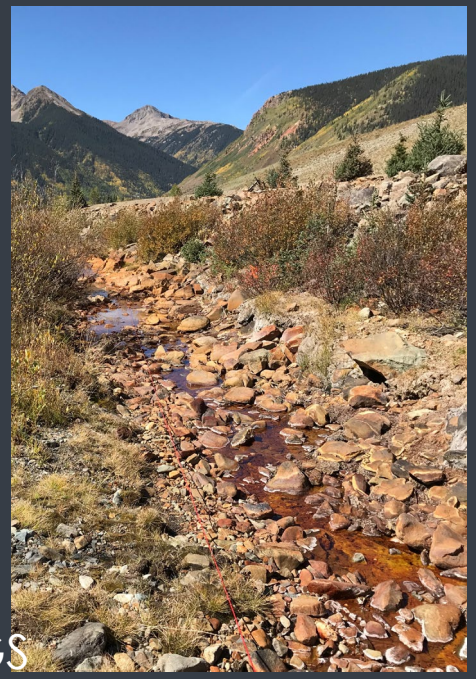

Slide Courtesy of Rob Runkel, USGS

# Equal Discharge Increment Sampling




Right Bank Seep
Zn = 27.4 mg/L

Red Seep
Zn = 19.1 mg/L

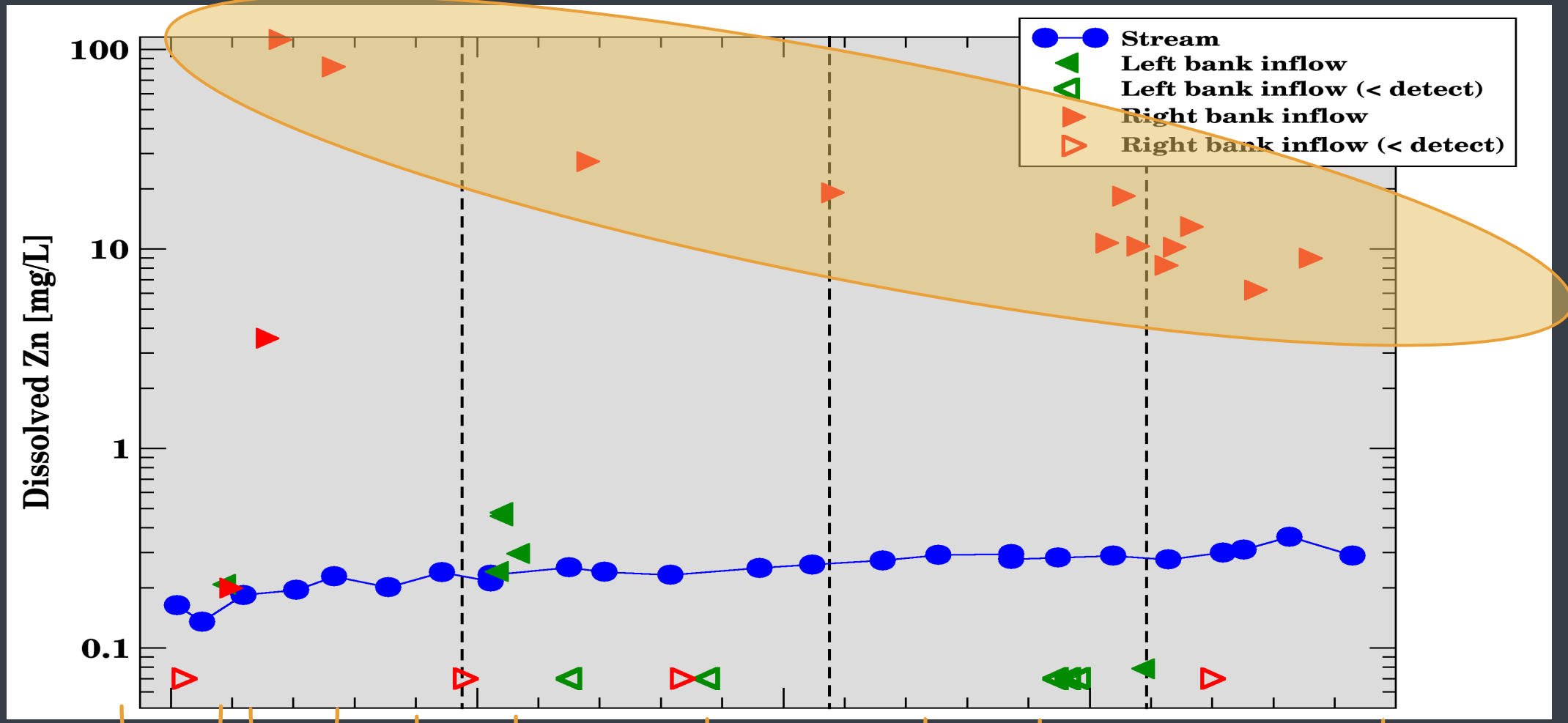


Flow

Central Aquifer
Groundwater?

Slide Courtesy of Rob Runkel, USGS

# High Resolution Sampling Results



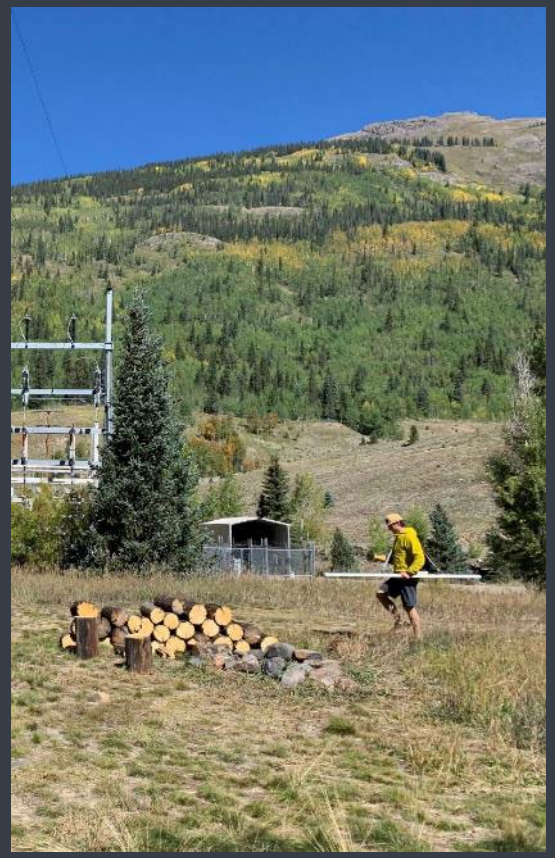



Slide Courtesy of Rob Runkel, USG

# GEOPHYSICAL CHARACTERIZATION APPROACH

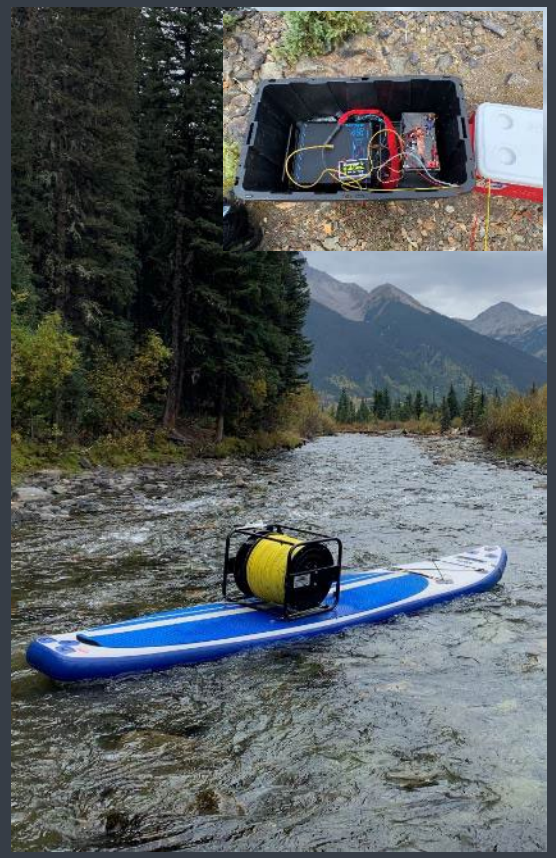
- Fiber Optic Distributed Temperature Sensor (Red/Green)
  - GW Discharge
- Electromagnetic Survey (White)
  - Bulk Electrical Conductivity
  - Fluids + Solids
- Magnetics Survey (White)
  - Ferrous materials
  - Solids

Data Release: Near-Surface geophysical data collected along streams near Silverton, CO, USA. 2020. DOI:10.5066/P97HDPAY



GEM2 FDEM

Geometrics G-858 Magnetometer

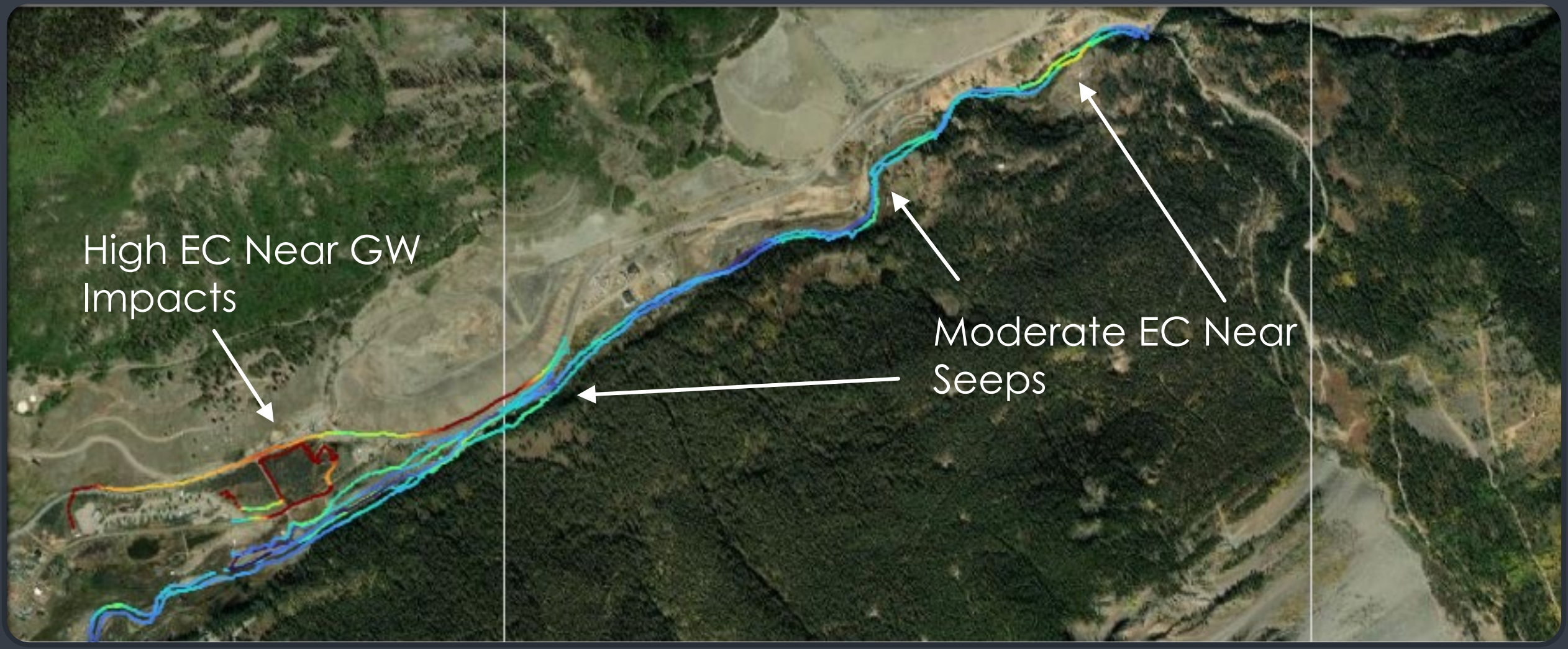


FO-DTS

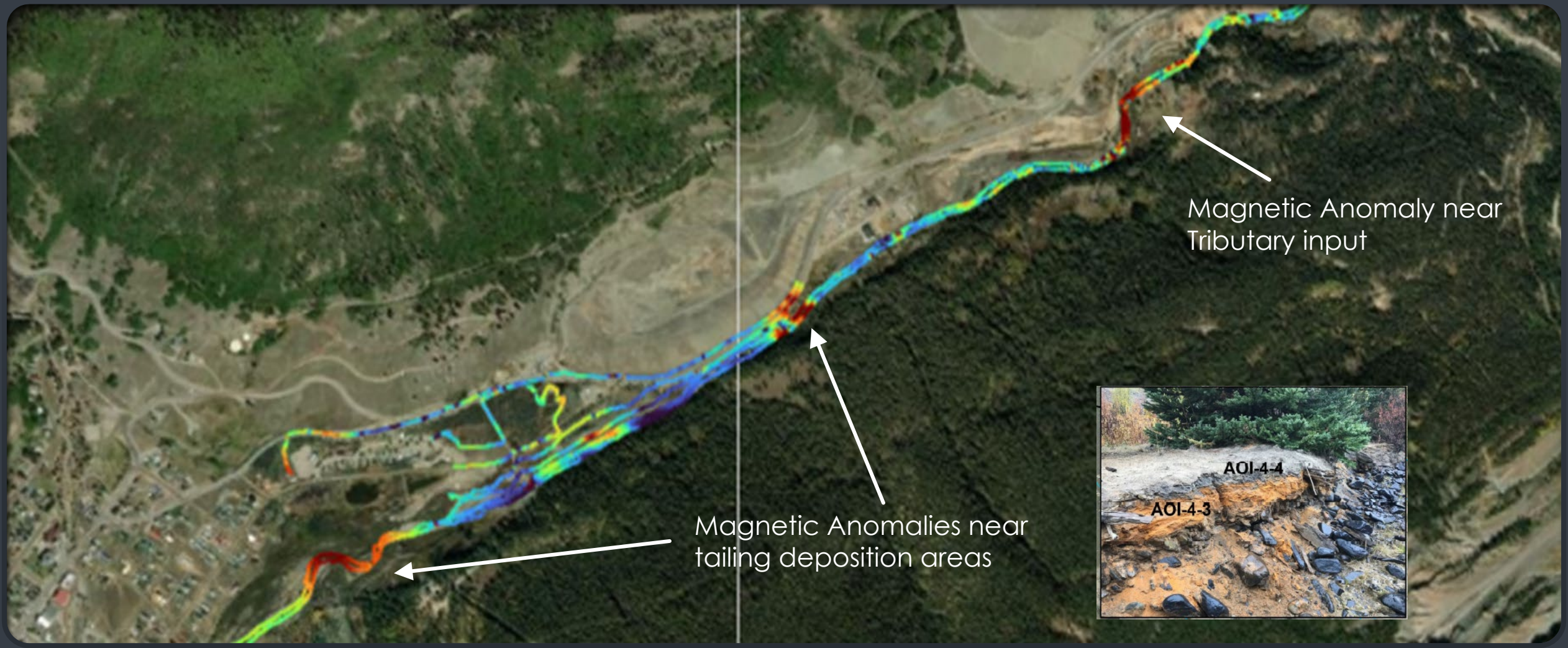


Slide Courtesy of Dale Werkema, EPA ORD

# GEM2 Apparent Electrical Conductivity



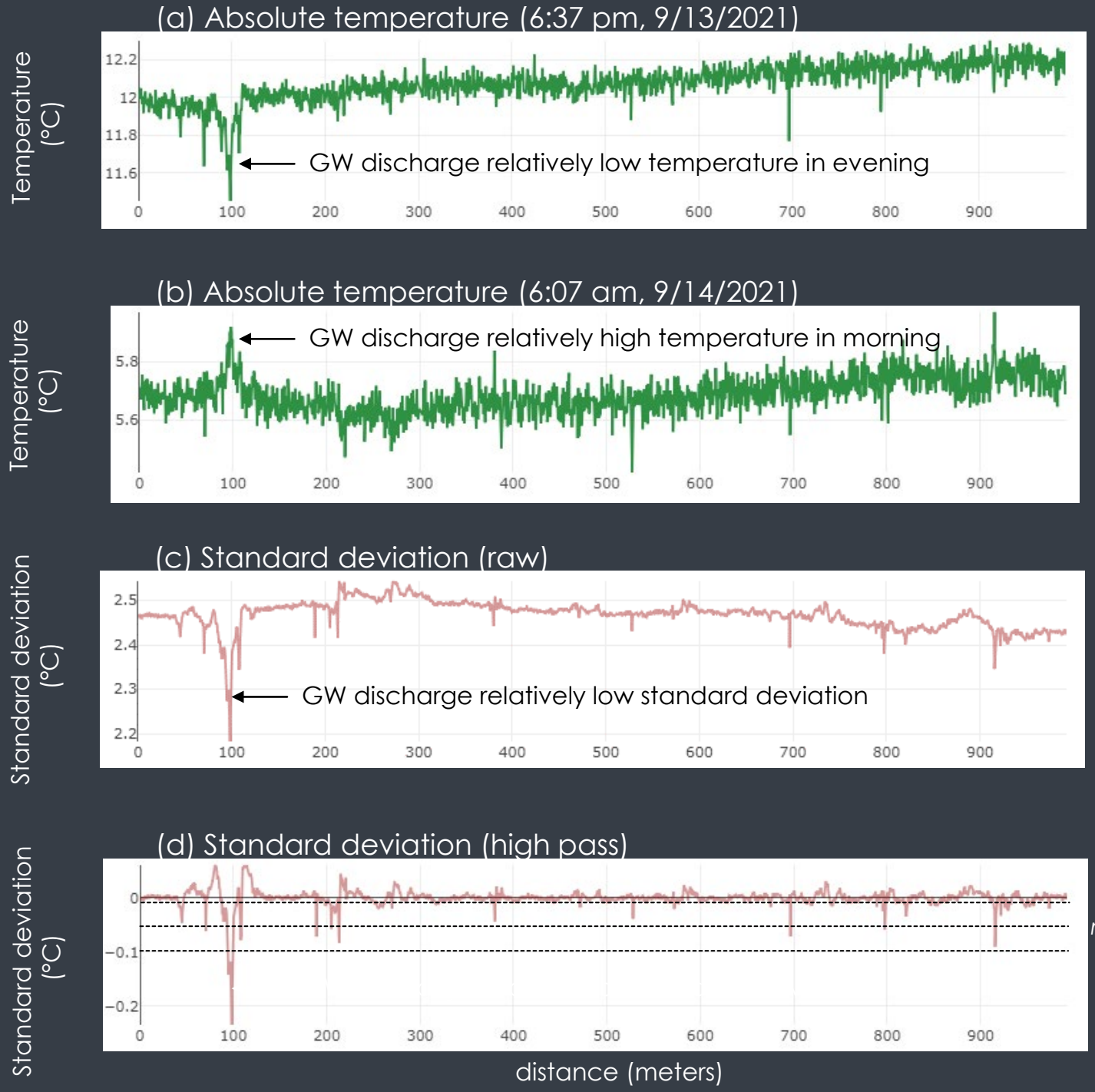
# Magnetic Susceptibility



# FIBER OPTIC-DISTRIBUTED TEMPERATURE SENSORS

- Temperature can affect glass fibers and locally change light transmission characteristics of the fiber
- Gives nearly continuous temperature measurements
- Identify heterogeneity in streambed and identify areas of enhanced seepage

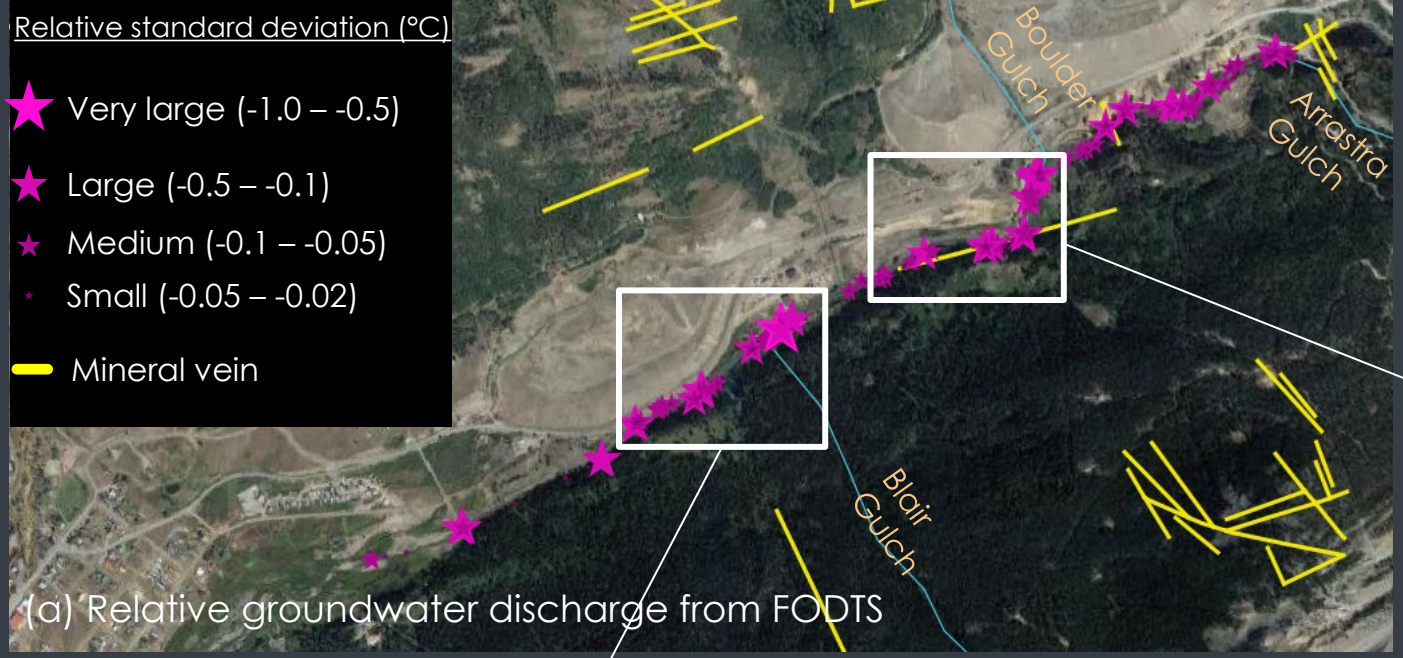
# FO-DTS Data Interpretation



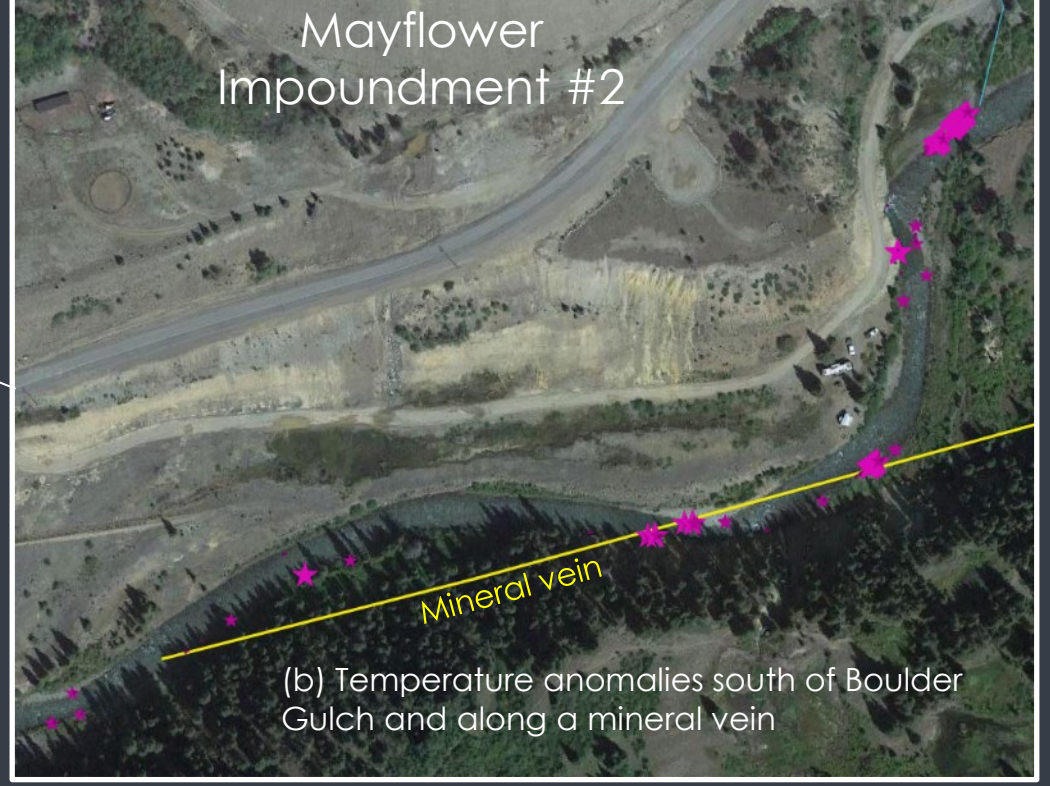

- GW Temperature is relatively constant
- SW temperature varies throughout the day
- Standard Deviation of temperature data is low near GW discharge zones
- Seep size can be inferred from standard deviation



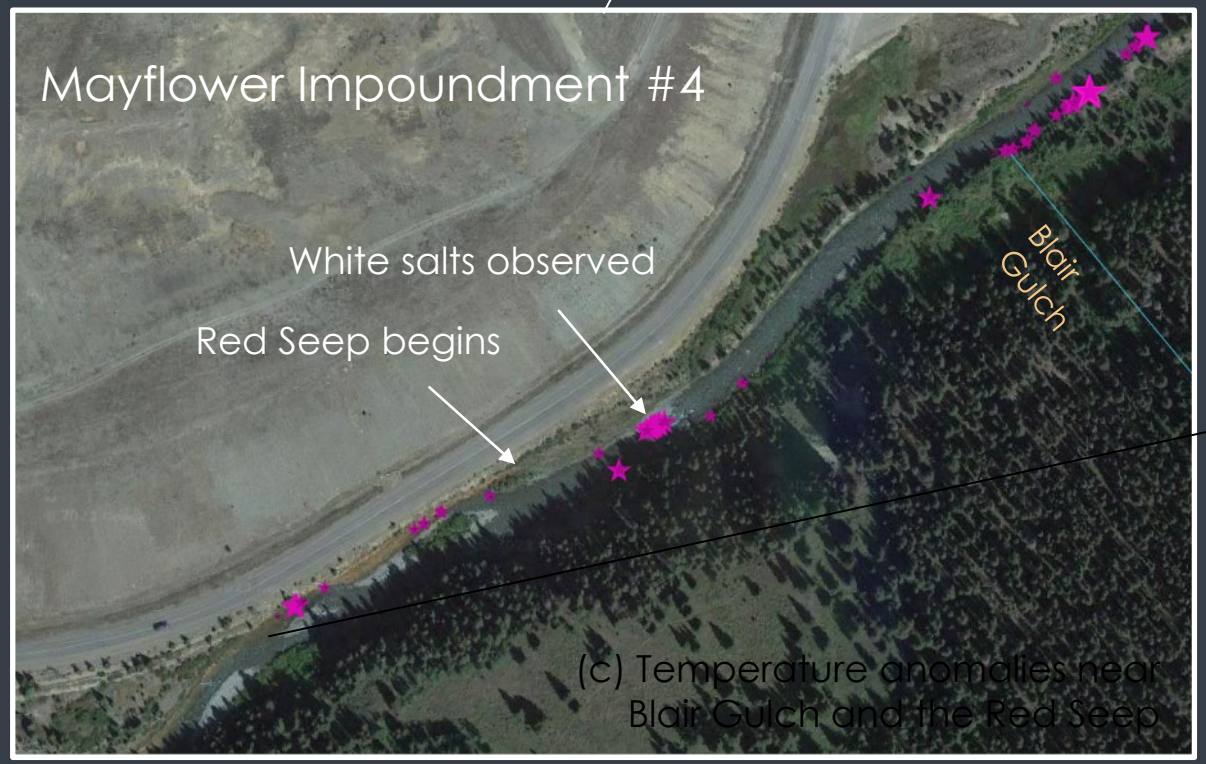
Slide Courtesy of Dale Werkema, EPA ORD



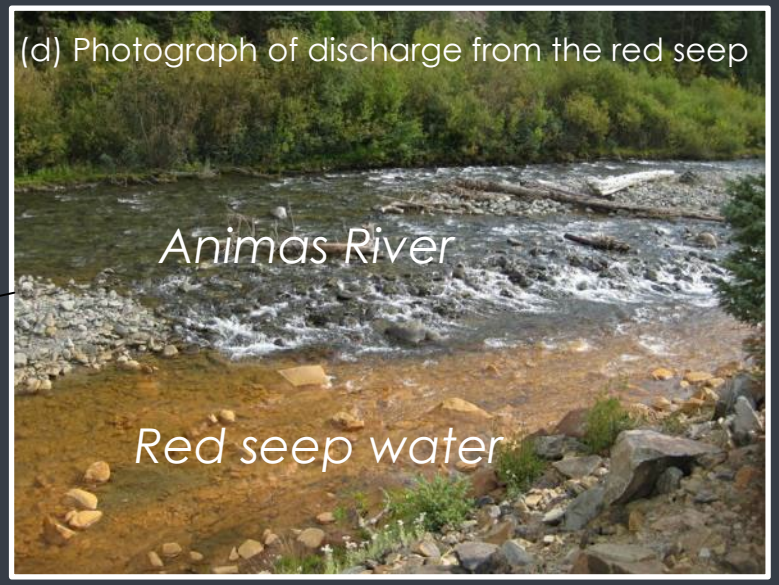

(a) Relative groundwater discharge from FODTS




(b) Temperature anomalies south of Boulder Gulch and along a mineral vein




(c) Temperature anomalies near Blair Gulch and the Red Seep






Slide Courtesy of Dale Werkema, EPA ORD

# UPDATED CSM

- Multiple lines of evidence suggest Impoundment 4 impacts GW and SW
- Mineral veins likely preferential GW discharge zones
- GW seeps are more prevalent above Impoundment 4
- North tributary transports large amounts of magnetic material (tailings)

# NEXT STEPS

SEEP SAMPLING

ADDITIONAL GW INVESTIGATION/DELINEATION

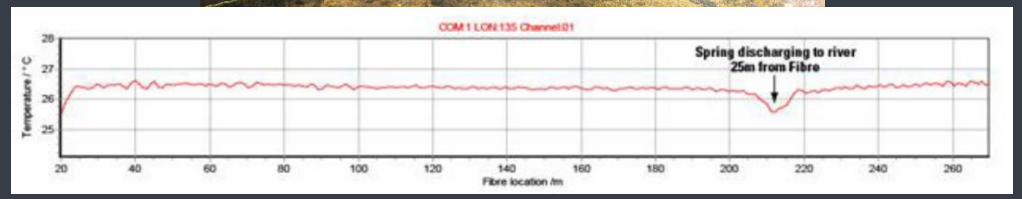
INVESTIGATION OF POTENTIAL TAILINGS DEPOSITION AREAS

# ACKNOWLEDGEMENTS


- Dale Werkema (EPA ORD)
- Neil Terry (USGS)
- Rob Runkel (USGS)
- Martin Briggs (USGS)
- Steven Dyment (EPA ORD)
- Field Team: Katie Krueger (EPA), Connor Newman (USGS), Jake Kurzweil (MSI), Carly Bonwell (MSI), Brett Trottier (USGS), David Rey (USGS), Katie Walton—Day (USGS), Johanna Blake (USGS), Alan Kirk (USGS), Lotian Buss (USGS)
- EPA Site Team: Jess Duggan, Athena Jones, James Hou, Joy Jenkins, Christina Progess, Mike Fischer, Rob Parker
- Techlaw
- CDM Smith
- Mountain Studies Institute
- Alpine Water Resources
- Sunnyside Gold Corporation
- Formation Environmental

# STREAMFLOW

# Fiber Optic Distributed Temperature System (FODTS)



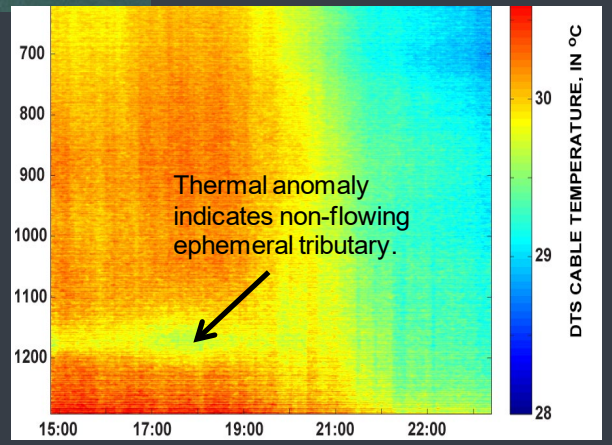


**STRENGTHS:**

- Direct temperature measurement of streambed (not possible with thermal infrared)
- High spatial resolution (~0.25 to 1 m linear)
- High precision (0.01 °C) potential
- Large scale (10 km possible, <5 km common)
- Continuous measurement (in time and space)
- Continuous data download (no retrieval/disturbance)

**LIMITATIONS:**

- Fiber is glass – can be damaged
- Deployment can be labor-intensive
- DTS systems are costly ($25-50K)
- Require calibration and field verification with conventional measurements; georeferencing




Voytek, E.B., Drenkelfuss, A., Day-Lewis, F.D., Healy, R., Lane, Jr., J.W. and Werkema, D., 2013



Slide Courtesy of Dale Werkema, EPA ORD