Improving Remediation Planning through Effective Mine Material Delineation

Formosa Mine Superfund Site, Douglas County, OR

Mark Nelson PG
Nicholas Anton PE
Howard Young LG

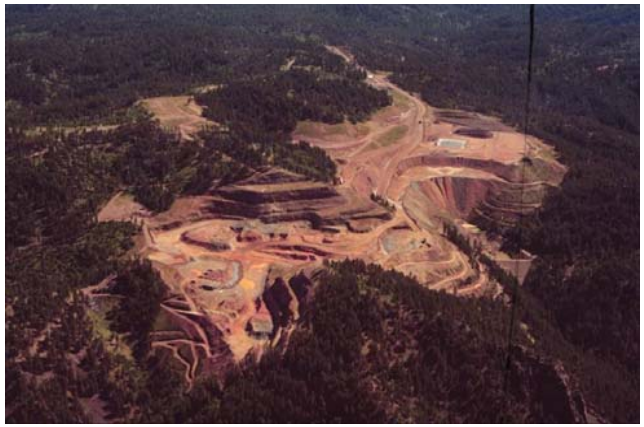
April 2012

CDM Smith

Why would one delineate mine materials?

Mine Remediation Projects

- Understand potential connections between suspect source materials and observed water quality effects
- Delineate problematic materials
- Support remedial action decisions



Cause?

Active Mine Projects

- Manage potential environmental liabilities
- Comply with environmental regulations

Effects?

What are mine materials?

Tailings

Spent ore

Highwalls

Waste rock

Mine Materials are potential source materials for dissolved metals in surface water and groundwater

Effective Mine Material Delineation

Mine Remediation Projects

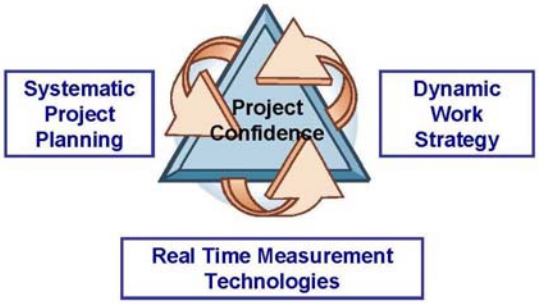
- Supports
  - Accurate alternative assessment
  - Reasonable cost estimates
  - Sound remedial action decisions
  - Effective remedial designs
  - Successful remediation
- Data often support multi-million dollar decisions

Active Mining Projects

- Supports
  - Mine permitting activities
  - Environmental management
  - Successful reclamation
- Manages potential environmental liabilities
  - Clean Water Act, CERCLA
  - Various state environmental laws

Approach to Data Collection and Analysis

- Rapid field geochemical characterization
  - Triad approach
    - Save costs throughout project lifecycle
    - Utilize field tools for real time measurement
    - Conduct laboratory verification
  - Components
    - Lithological examination, field paste pH, FPXRF
    - Real time geospatial database
    - Coupled laboratory analysis
      - Acid base accounting
      - Extraction tests
      - Total metals analysis
- Weight of evidence statistical approach



Approach can be applied at various project phases and in various levels of detail

- Reconnaissance Phase
  - Quick field survey
  - Limited or no laboratory verification
  - Qualitative data analysis
- Site Characterization Phase
  - More detailed surveys
  - Laboratory verification
  - Statistical data analyses
- Reclamation or remediation phase
  - Confirmatory sampling
  - Detailed surveys
  - Lab verification
  - Statistical data analysis

Formosa Mine- West Encapsulation Mound Waste Rock Dump

Formosa is a good example of a comprehensive site characterization phase program

Interdisciplinary Field Team

- Geologist
  - Identifies mineralized rock based on lithology, alteration, and mineralization
  - Guides dynamic work strategies based on geology and other visual indicators of mine materials
- Environmental scientist
  - Collects field paste pH and FPXRF measurements
  - Collects samples for laboratory analysis
- Field technician
  - Collects GPS data using a resource grade instrument (<1m accuracy)

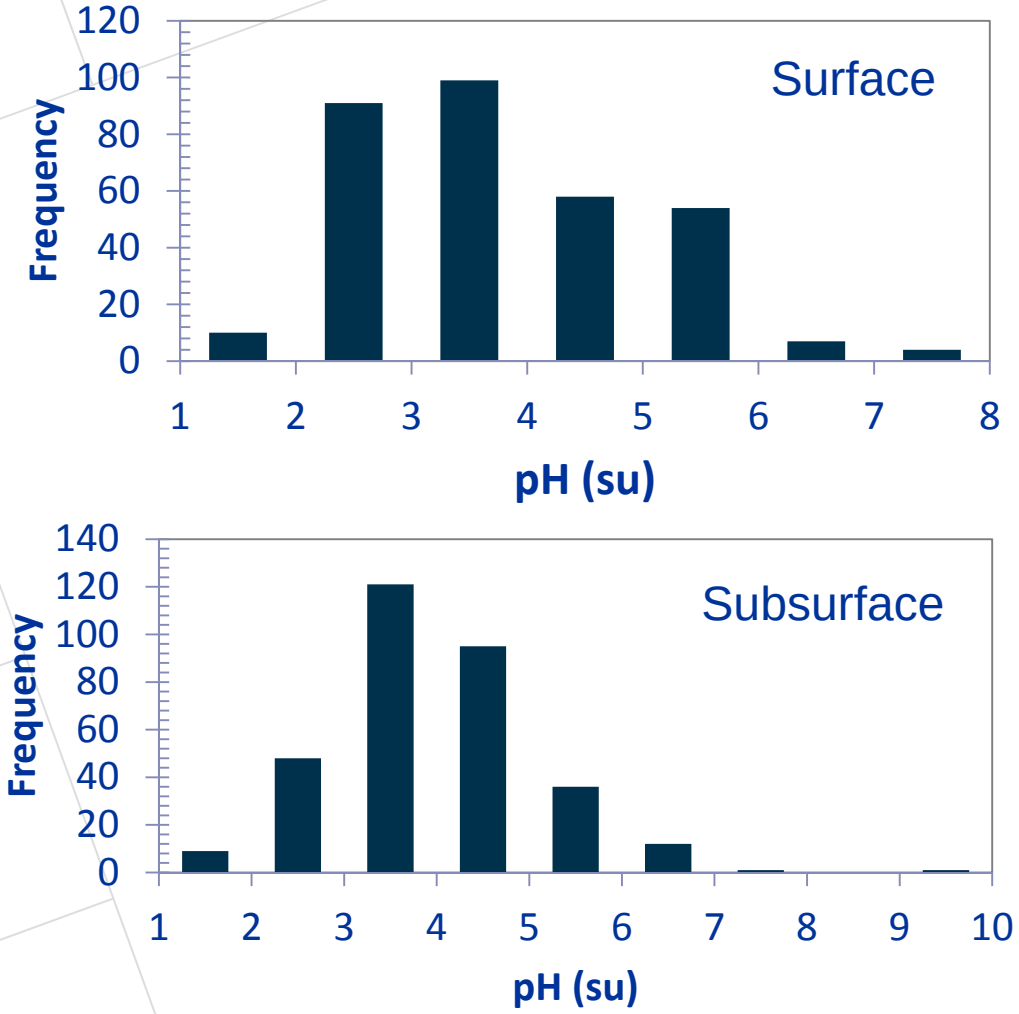
Coupled Laboratory Analyses

- Acid base accounting
  - Modified Sobek (1978) method
  - Estimates propensity of sample to generate ARD in the future
- Extraction Tests
  - Modified Synthetic Precipitation Leach Procedure
  - Estimates propensity of sample to leach metals and metalloids when exposed to percolating water
- Total Metals Analyses
  - Provides information regarding “total” content of selected metals and metalloids
- SEM-EDS mineralogical analysis
  - Provides information on mineralogy of samples to support ABA data interpretation

Putting it All Together

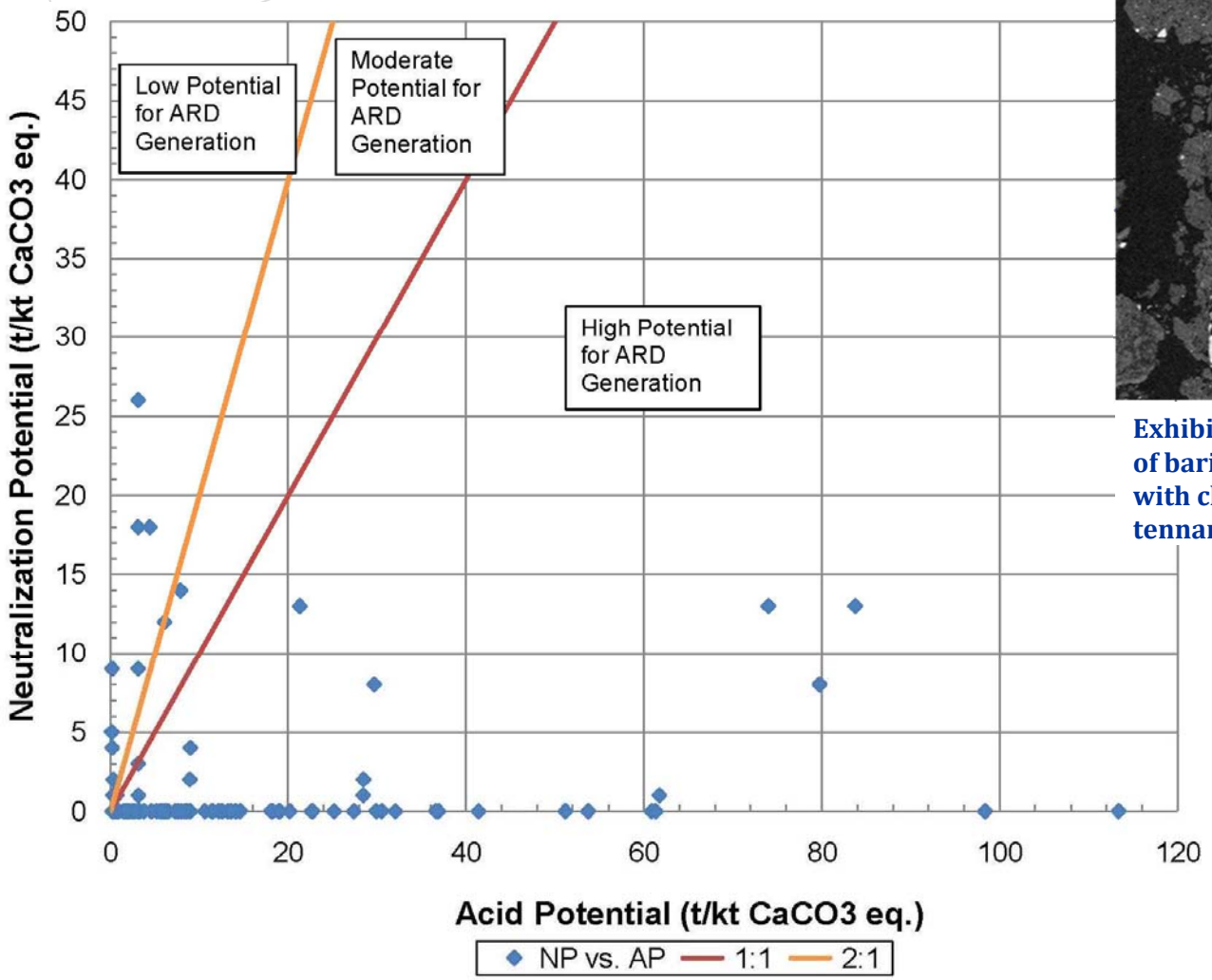
- Goals
  - Identify mine materials that are causing water quality problems
  - Delineate the areal extent, depth and volume of these materials
- Weight of Evidence Approach
  - No one laboratory analysis can answer the study questions
  - Sound answers are developed with weight of evidence approach
  - Components
    - ARD potential
    - ML potential
    - Metals concentrations

Field Paste pH Data



- pH measured in a paste of fine grained sample and DI water
- Measures products of previous sulfide oxidation and acid generation
- Only appropriate for weathered mine materials
- Data show Formosa mine materials to be moderately to strongly ARD generating

Laboratory Acid Base Accounting Data



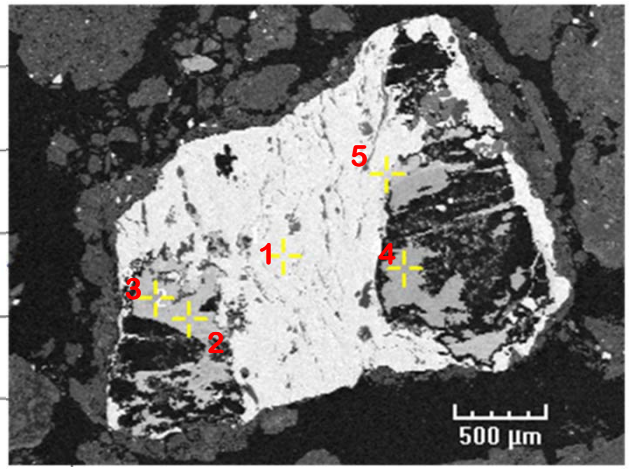
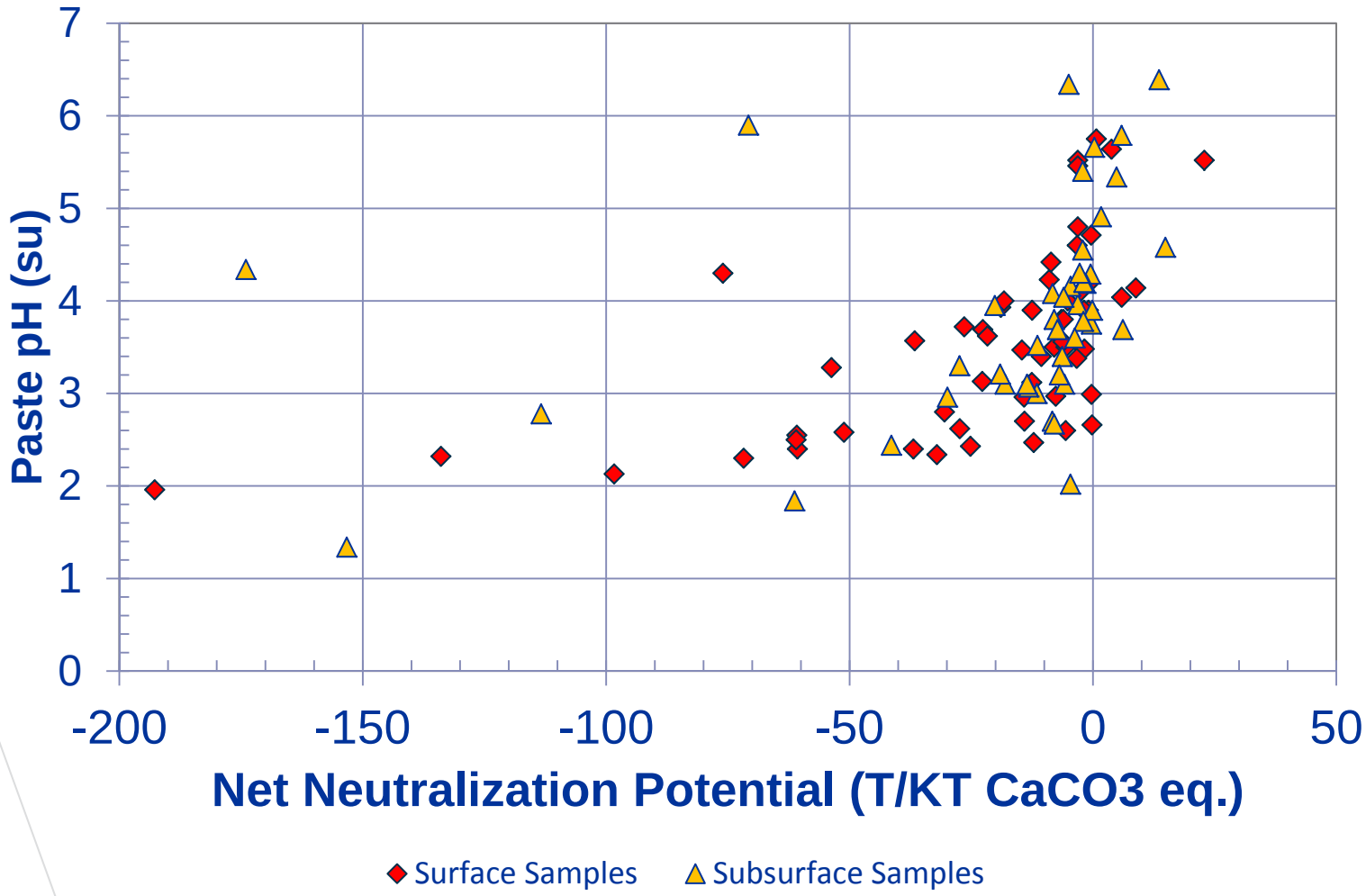


Exhibit 3.3-1. SEM-EDS photomicrograph of barite mineral grain (1), associated with chalcopyrite (2 and 3), pyrite (4), and tennantite (5).

Mineralogical data used to improve ABA interpretation

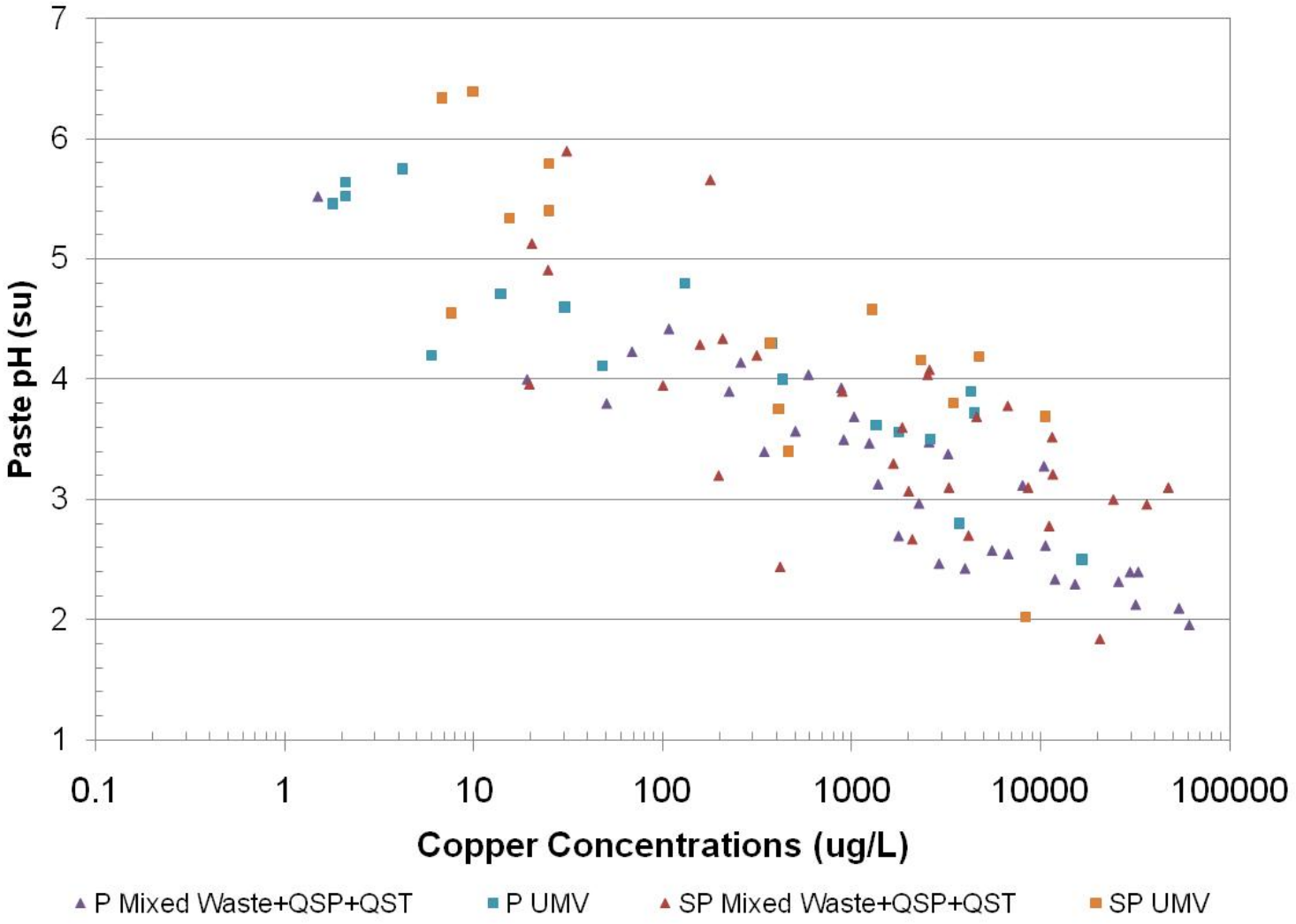
Comparison of Field Paste Ph with ABA



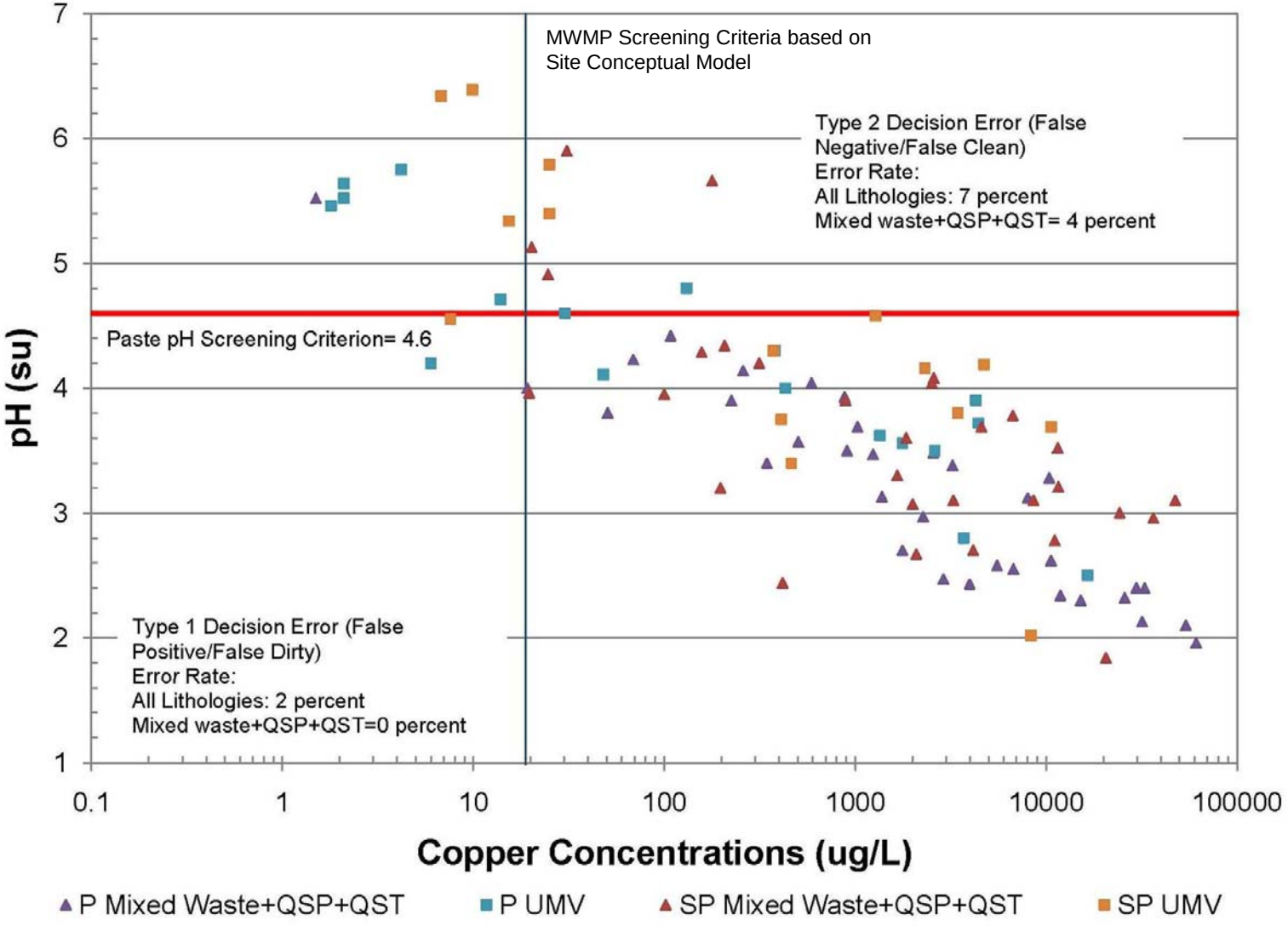
Extraction Tests

- Evaluates metals and metalloids that are rinsed from the sample when it is exposed to water
- Bottle roll or column rinse tests
- Generally use deionized water or simulated precipitation as an extraction fluid
- Examples
  - Synthetic Precipitation Leach Procedure (EPA Method 1312)
  - Meteoric Water Mobility Procedure (ASTM Method E2242-07)
  - USGS Field Leach Test
- Modified SPLP extraction tests used at Formosa
  - Reduced water to rock ratio as compared with standard SPLP

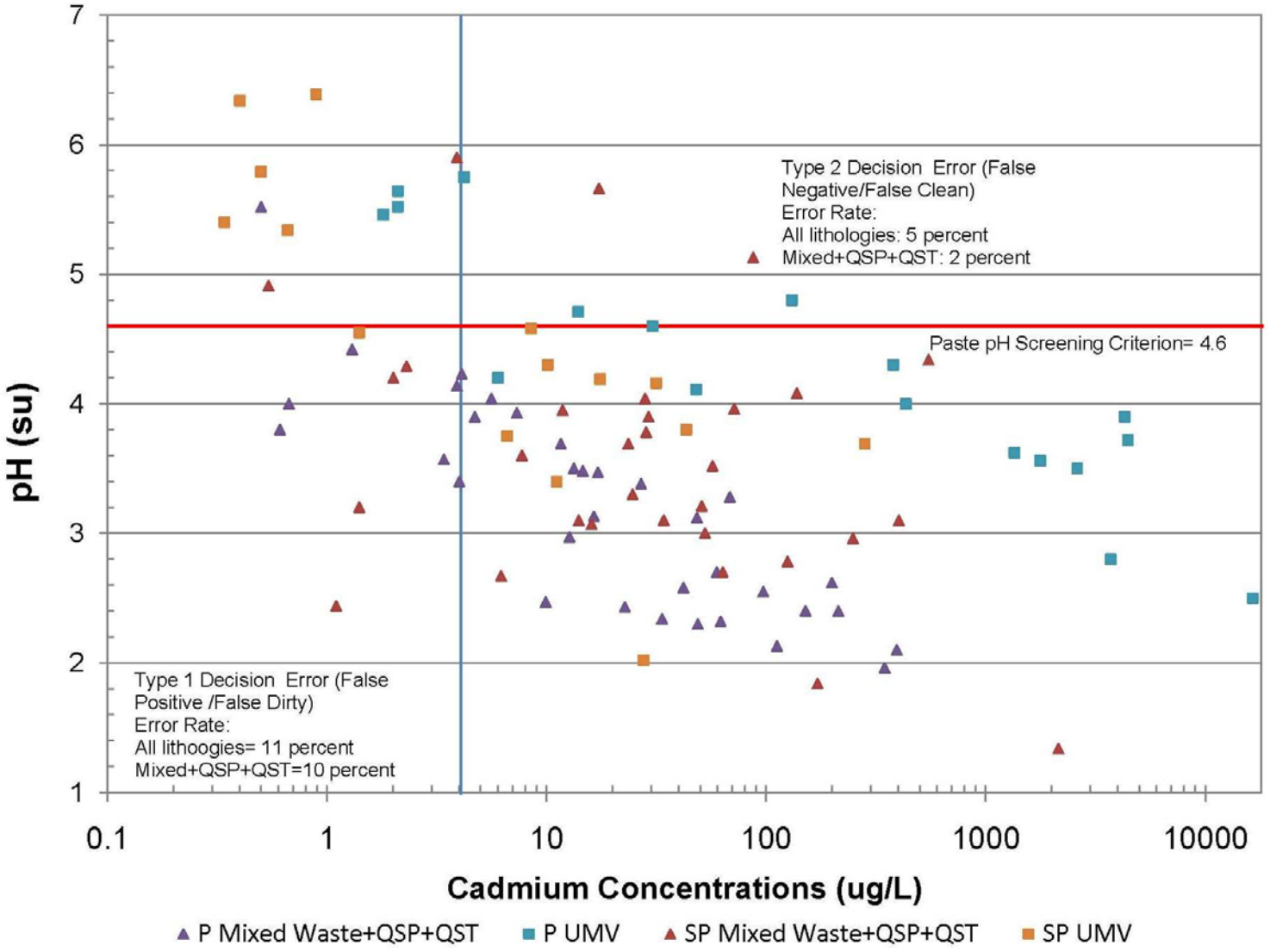
Modified SPLP vs. Paste pH- Cu



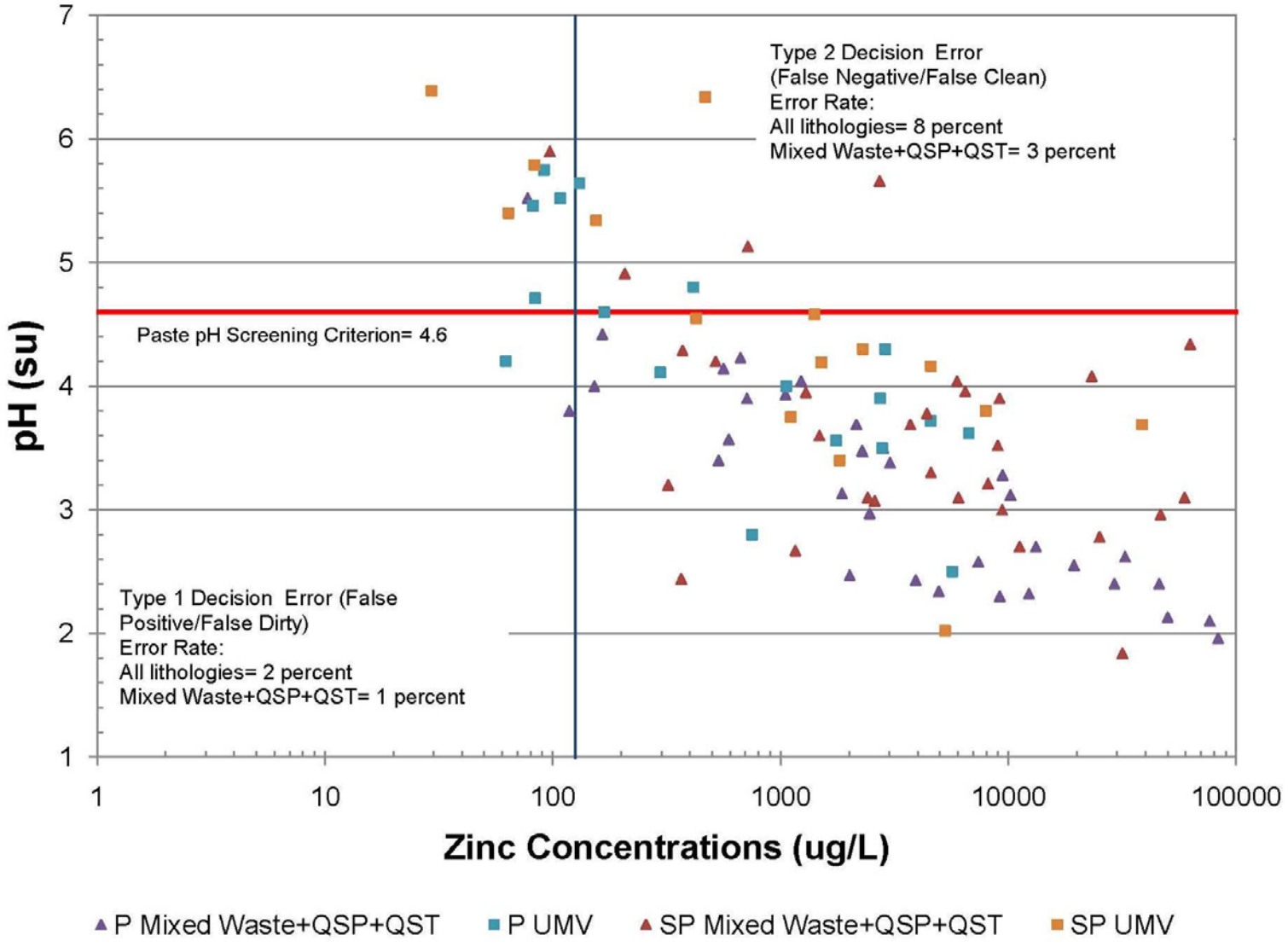
Development of Field Paste pH Criterion- Cu



Development of Field Paste pH Criterion- Cd



Development of Field Paste pH Criterion- Zn



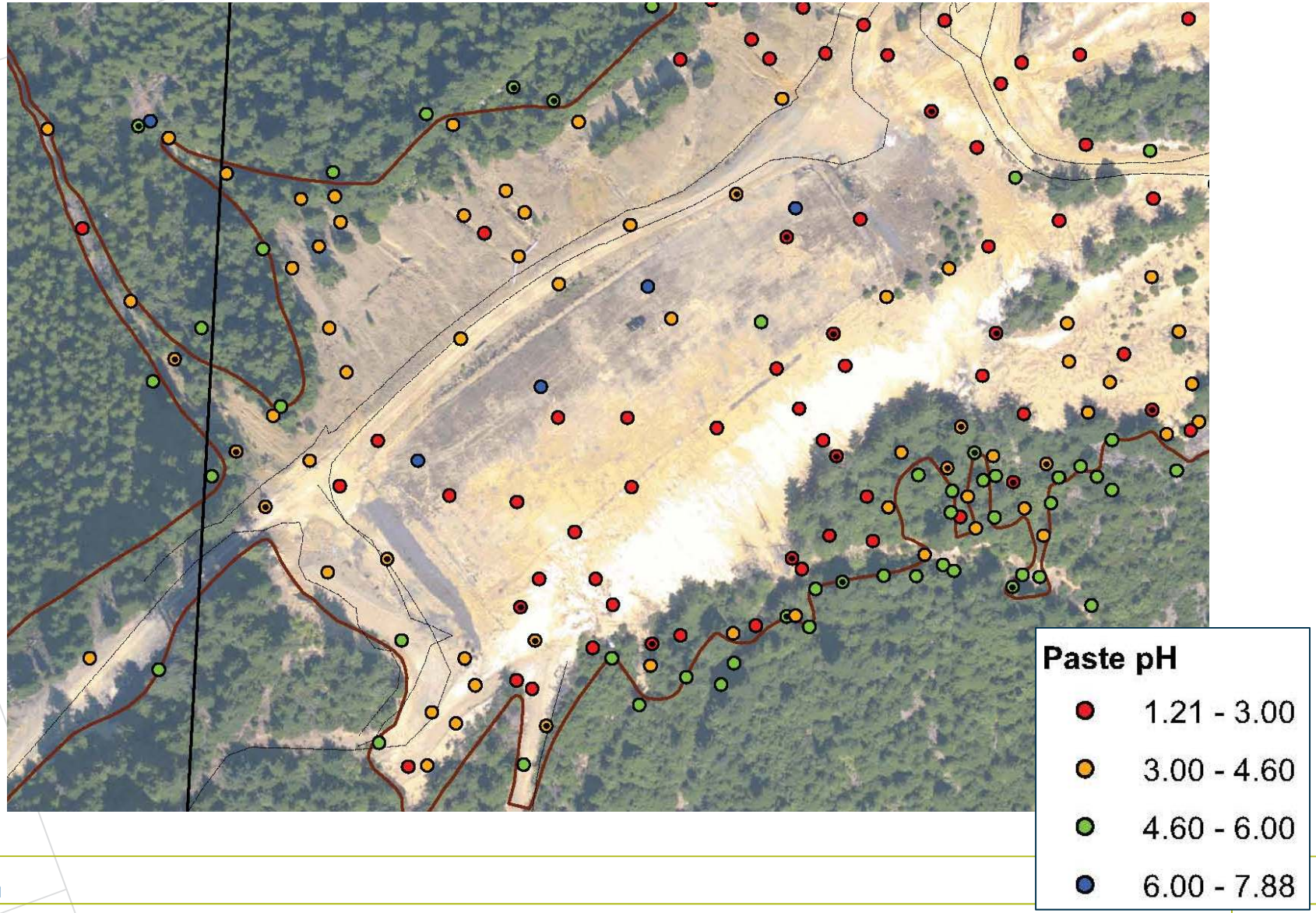
Analysis of Field Paste pH Criterion

Decision Error Rates
Field Paste pH Criterion: 4.6 su

	Paste pH		Paste pH+ Lithology	
Analyte	False Negative (%)	False Positive (%)	False Negative (%)	False Positive (%)
Cadmium	5	11	2	10
Copper	7	2	4	0
Zinc	8	2	3	1

Weight of Evidence Approach Improves Decision Error Rate

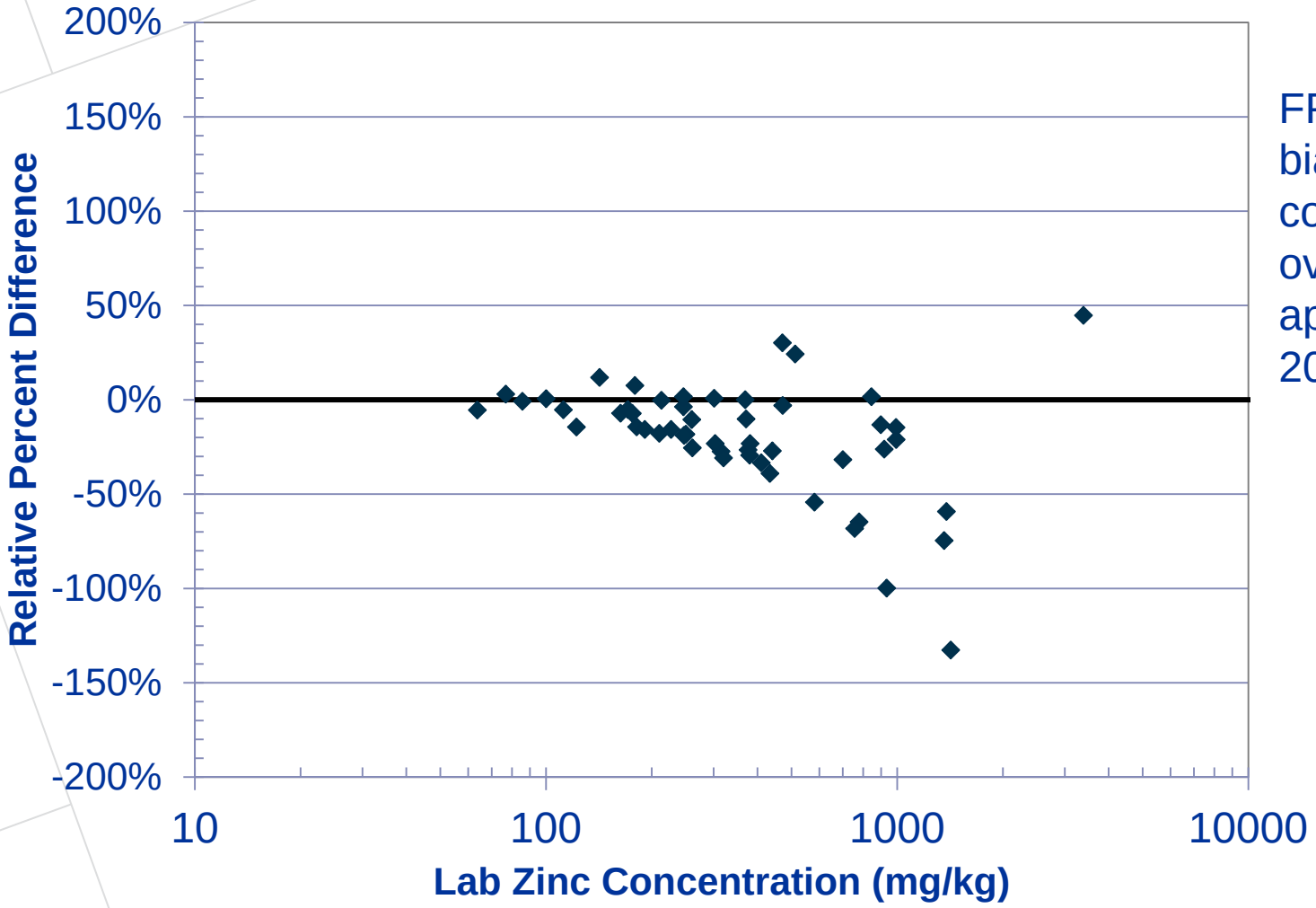
GIS Analysis based on Field Paste pH Criterion



Use of Field Portable XRF

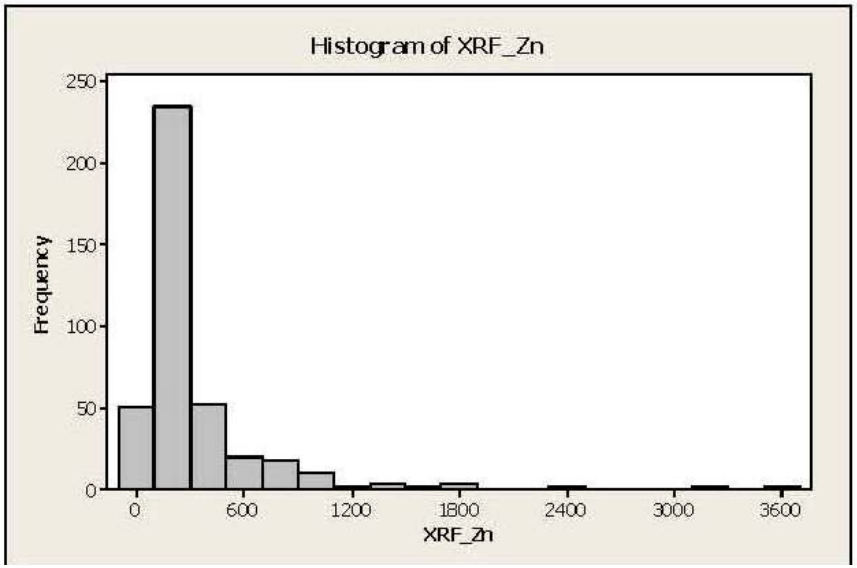
- Useful to measure total metals concentrations
- Total metals concentrations do not necessarily correlate to potential water quality effects
- Used at Formosa to evaluate boundary between mine materials and natural soils
- Samples prepared in the field using disposable -1.5 mm sieves
- XRF data validated with laboratory check samples

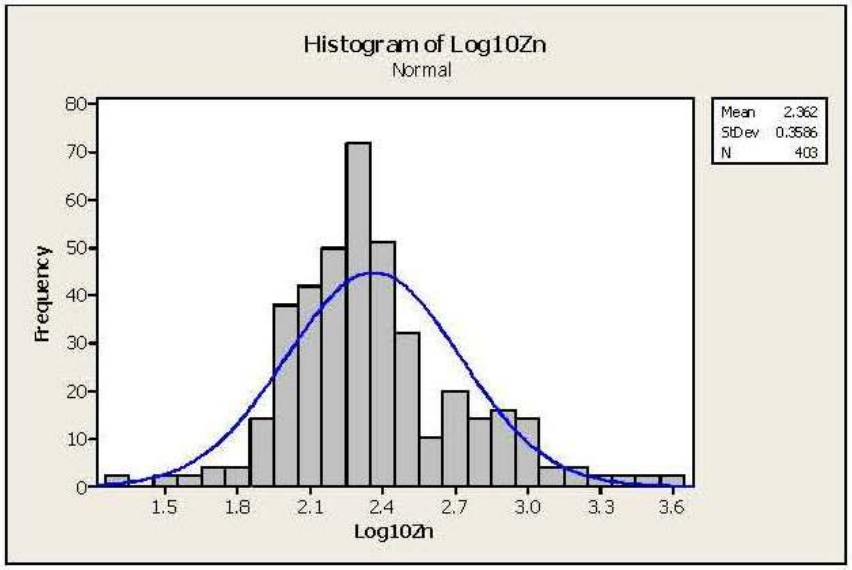
FPXRF Accuracy- Zn



FPXRF data biased low at concentrations over approximately 200 mg/kg

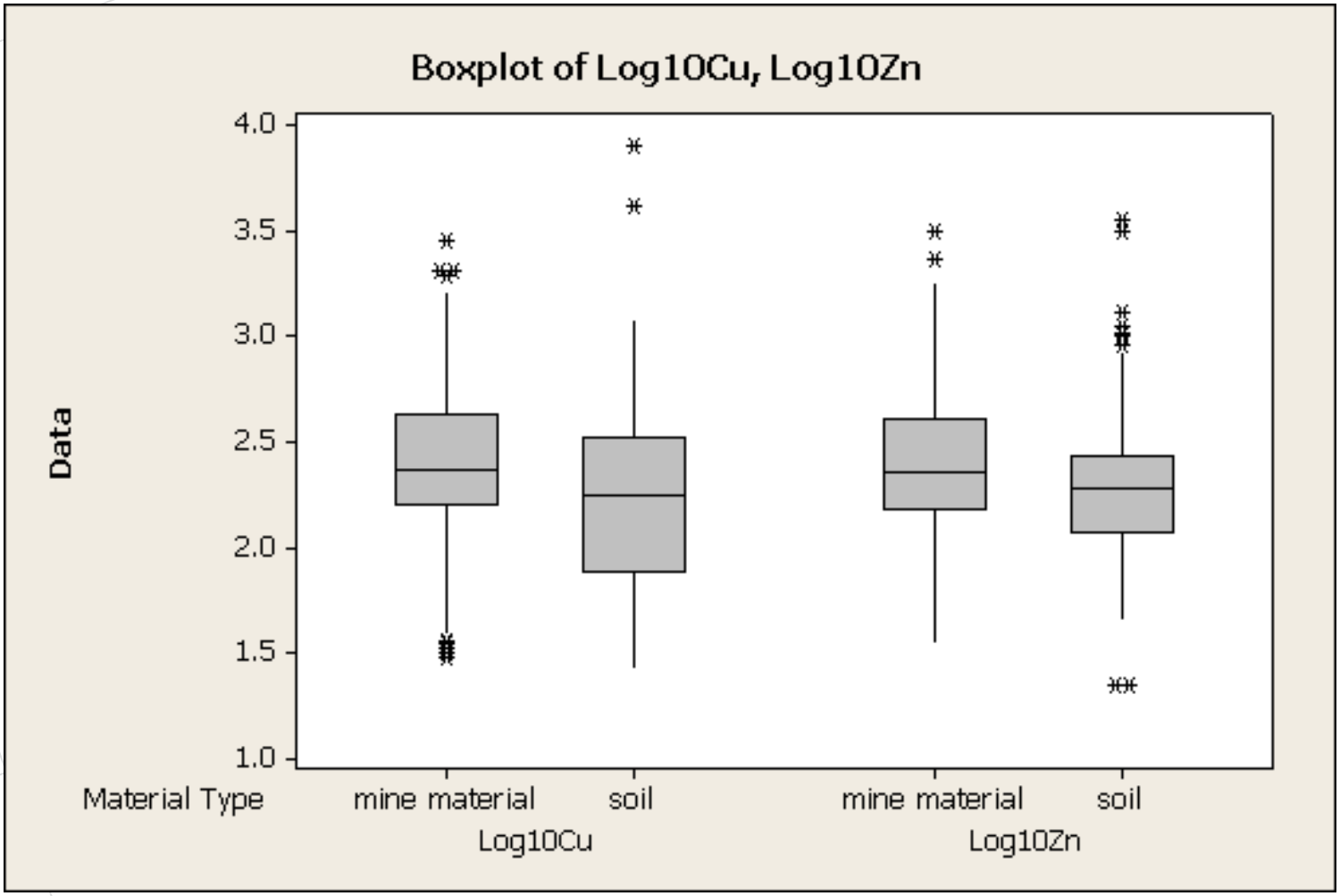
Formosa FPXRF Data- Zn



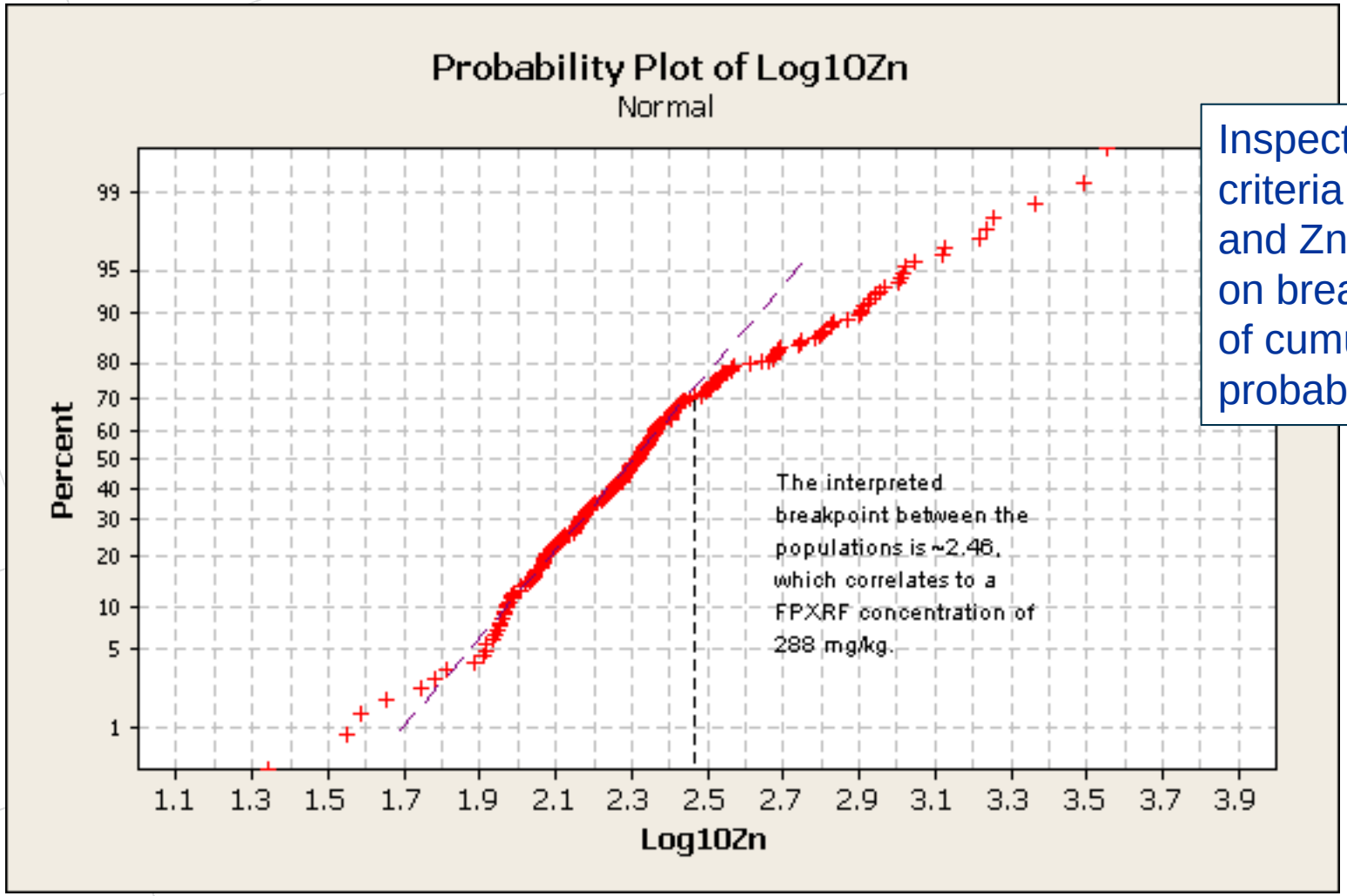


- Data are positively skewed
- Log transformation suggests bimodal distribution
- Hypothesized to be related to sampling of the geological boundary between mine materials and natural soils

Formosa FPXRF Data

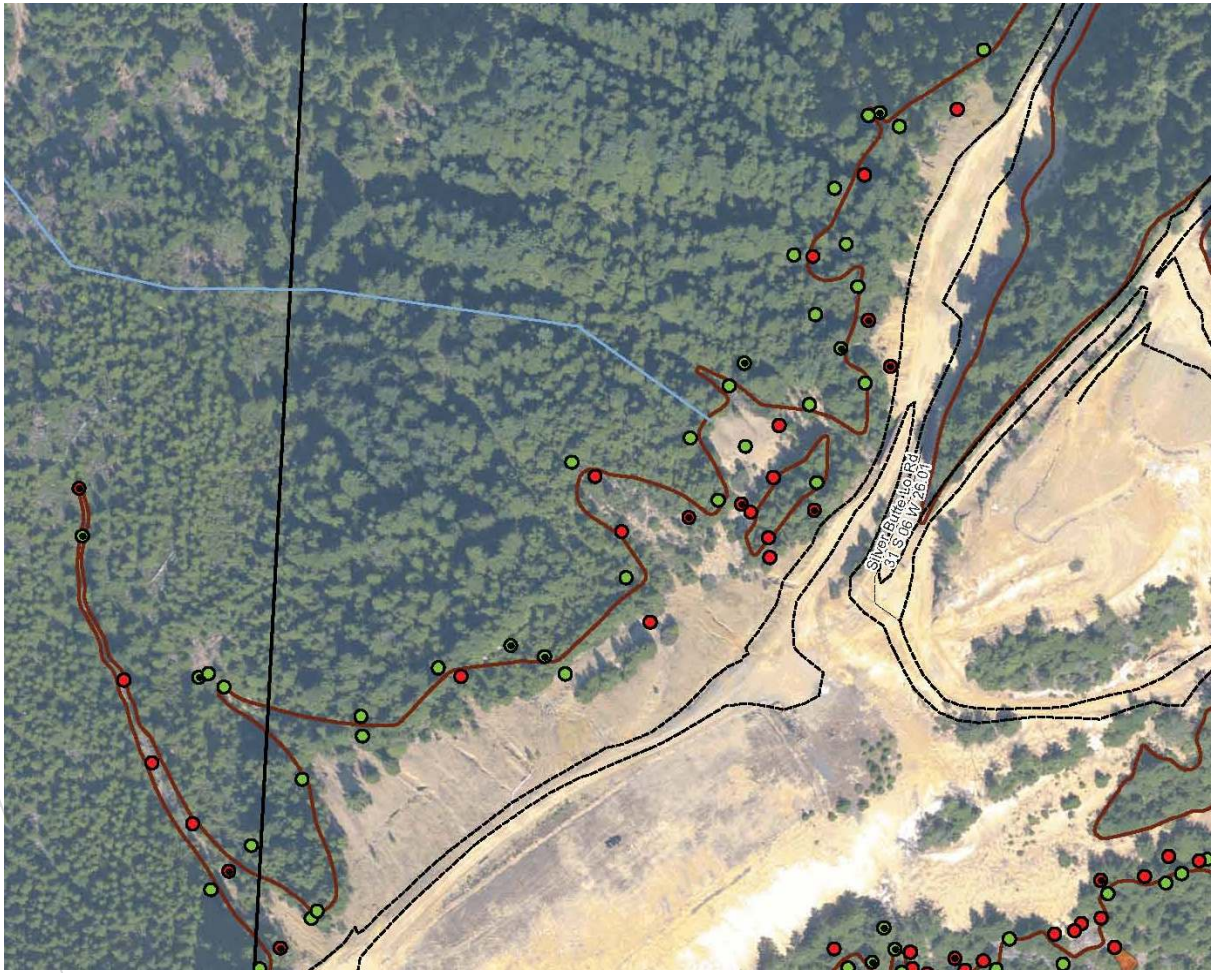


FPXRF Inspection Criteria



Inspection criteria for Cu and Zn based on breakpoint of cumulative probability plot

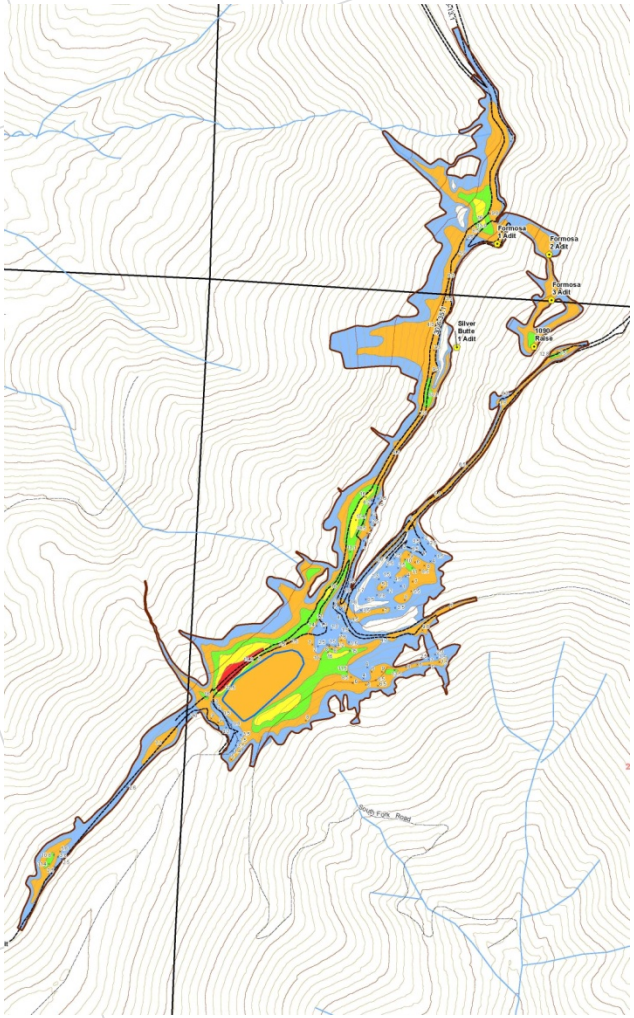
Application of FPXRF Inspection Criteria



Copper

- <190
- >=190

Adding the Third Dimension



- Depth shown as thickness isopachs
- 3-dimensional model generated in ArcGIS Spatial Analyst to support volume estimation
- Depth and volume characterized in sufficient detail to support feasibility study analyses

What Did We Learn?

Study Questions

- ARD potential?
- Metals leaching potential?
- Horizontal and vertical extent?
- Volume?

Study Conclusions

- ARD generating mine materials identified
- Mine materials that leach metals delineated
  - Evaluated with respect to CSM
  - Known and acceptable decision error rates
- Areal extent, depth and volume defined

Conclusions

Rapid field geochemical characterization performs well at answering study questions

Method applicable at various project phases and in various levels of detail

Provides for efficient and detailed characterization, while managing investigation costs

- Thanks to our partners!
  - US EPA
  - US Bureau of Land Management
  - Oregon DEQ
  - USGS