Waste Pile and Water Sampling

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Assessing the Toxicity Potential
of Mine-Waste Piles Workshop
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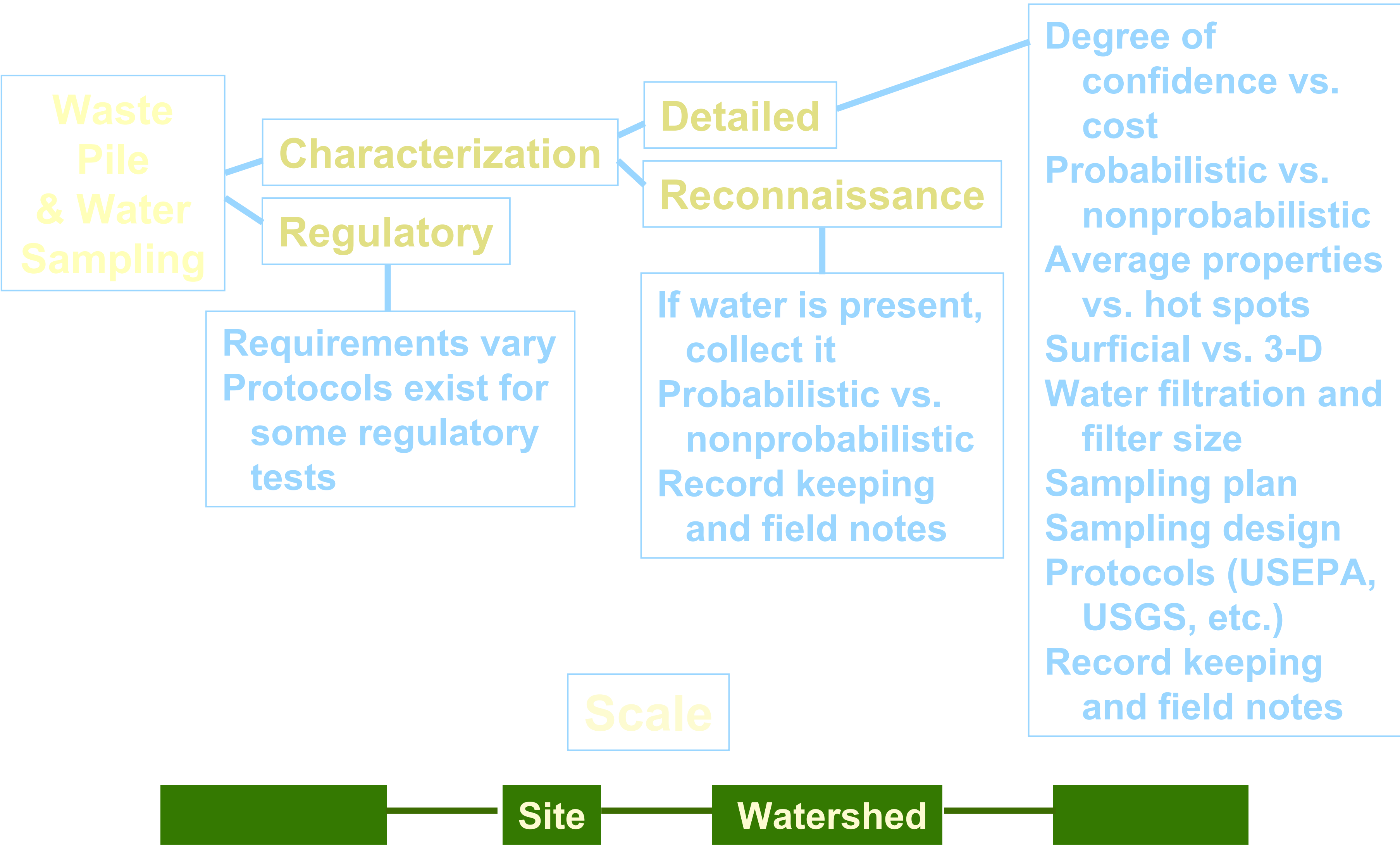
U.S. Department of the Interior
U.S. Geological Survey

Flow Chart for Ranking and Prioritization



What? Why?

- What to sample
  - Define target population
- Reasons for sampling
- Question(s) to be answered
- Desired degree of confidence in the answer(s)

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Examples of Questions

- Are there hot spots?
- What is the average behavior of a mine-waste pile?
- Are these two waste piles different?
- Are concentrations above baseline conditions?
- Is a remediation approach working?

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Target Population

- Defined by objectives of study
- Must be identified prior to sampling
- Scale of observation matters

Desired Degree of Confidence

- Must be identified prior to sampling
- Low degree of confidence can lead to erroneous data and flawed decisions
- High degree of confidence can be expensive

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Precision versus Accuracy

Precise, unbiased, and accurate

Precise, biased, and inaccurate

Imprecise, biased, and inaccurate

Imprecise, unbiased, and inaccurate

Sampling Concerns

- Sampling error
- Precision requirements
  - Field sampling methods and equipment
  - Sample preparation
  - Laboratory subsampling
  - Analyses
- Sample containers
- Sample preservation and storage
- Sample holding times

Sampling Error

- Improper collection
  - Target population
  - Sampling location
  - Spatial or temporal changes
  - Sampling media
  - Sampling tools
  - Sample containers
- Contamination
- Sample preservation and storage
- Inadequate sample mass

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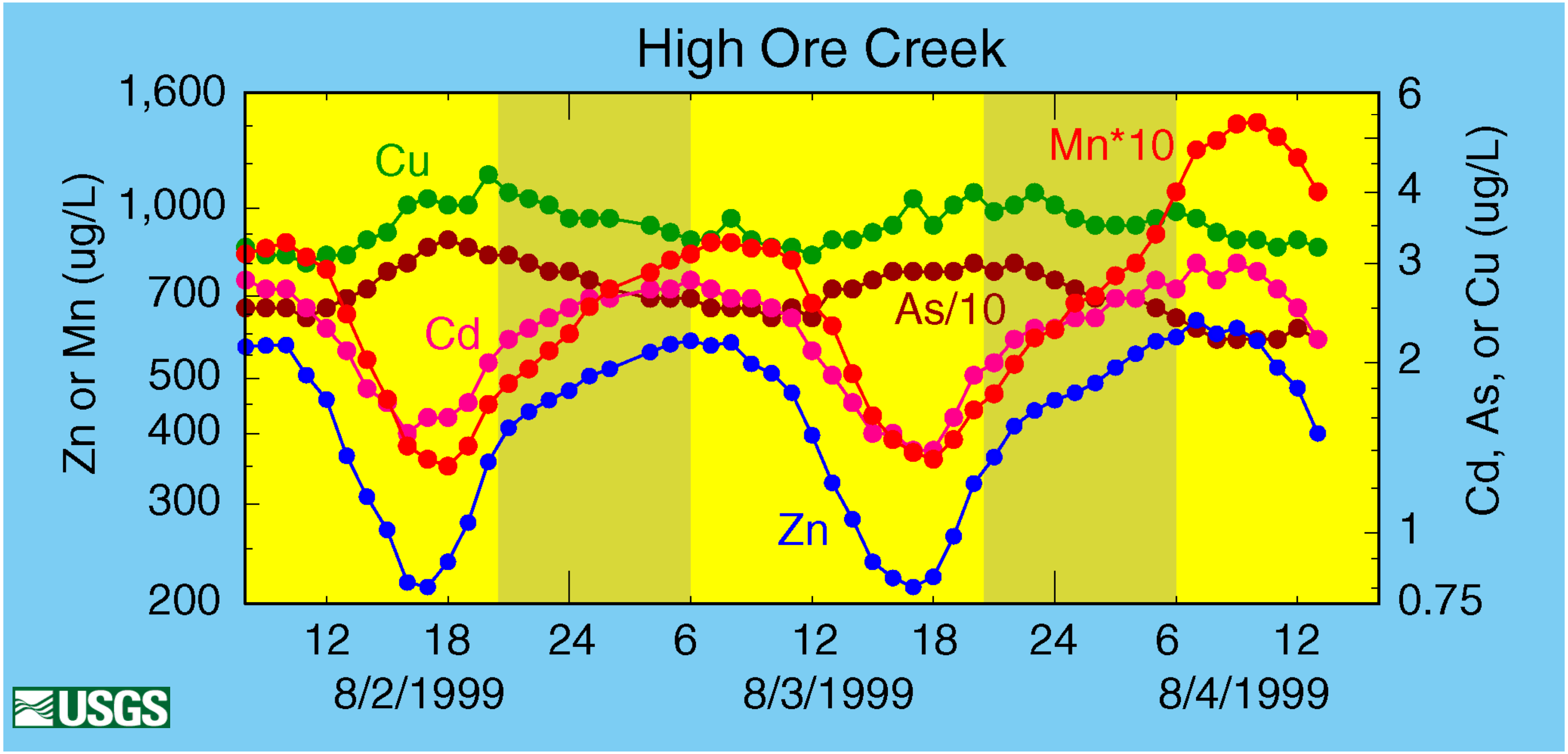
Sampling Error Example—Diel Cycling

(from Nimick, 2001)



Arsenic	Cadmium	Manganese	Zinc	Copper
22-33 ug/L	1.4-3.0 ug/L	35-142 ug/L	214-634 ug/L	3.0-4.3 ug/L
50%	110%	306%	196%	43%

Fundamental Error

- The source of most sampling errors
- Cannot be eliminated, but can be estimated
- Due to the fact that not all particles have the same composition
- Results in variability and a lack of precision
- Particle size, sample mass, and degree of heterogeneity are important factors

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Particle size

Heterogeneity

Desired degree of confidence

Fundamental Error

- Mineralogical factor
- Liberation factor
- Shape factor
- Granulometric factor
- Maximum particle size
- Sample mass

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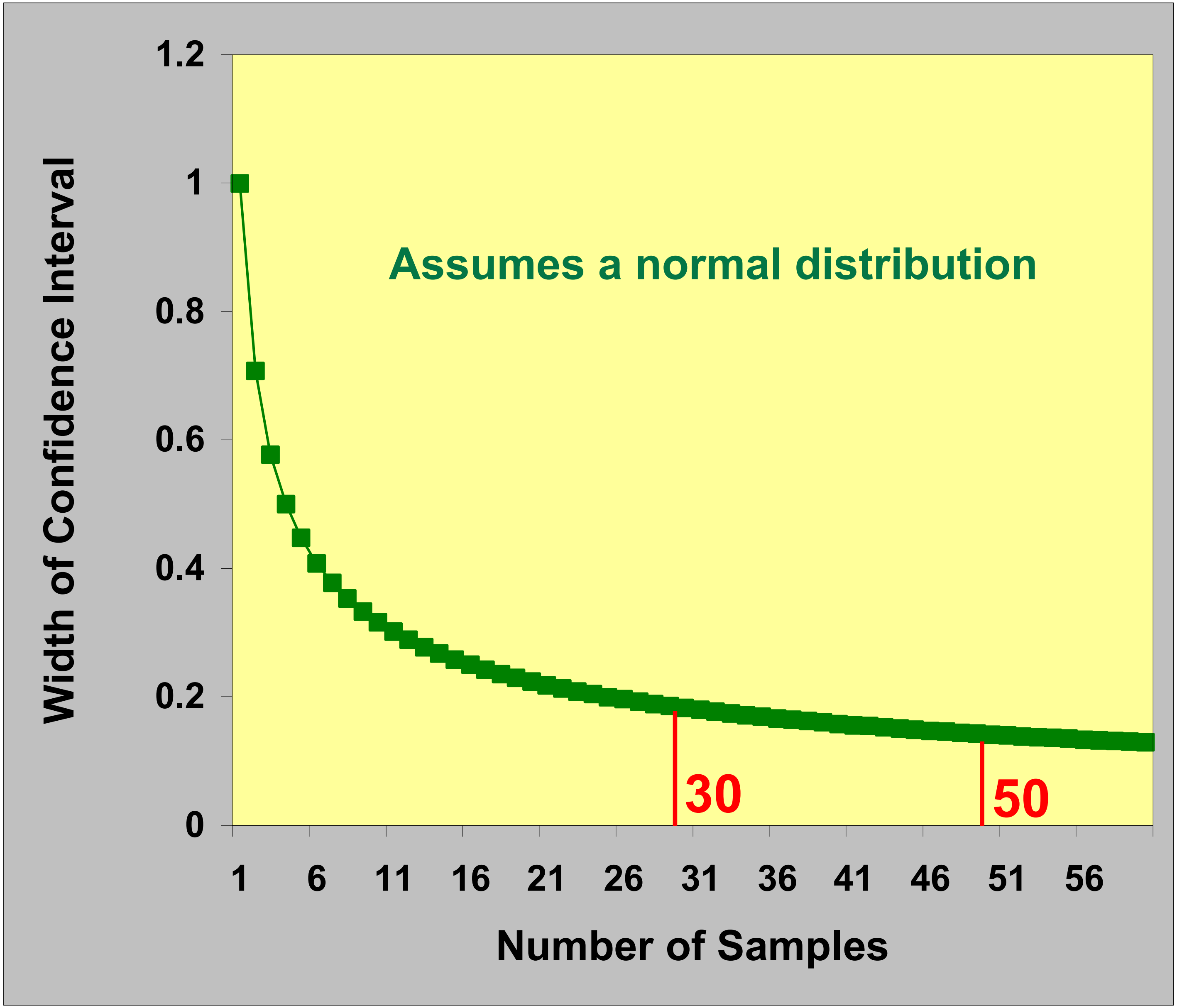
Grouping and Segregation Error

- Due to the fact that not all particles are randomly distributed
  - Size, shape, concentration
  - Temporal differences
  - Waste-pile segregation
- Can be reduced
  - Random sampling
  - Collection of multiple increments

How many samples?



Sampling Media

- Solid
- Liquid
- Biological
- Air

Choice of media depends on:

- Regulatory requirements
- Anticipated sources
- Transport mechanisms
- Receptors
- Climate

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Solid Sampling Objectives

- Assess potential for acid generation
- Assess potential for contaminant release
- Identify contaminant source(s)
- Provide input for modeling
- Determine lithologic variability
- Establish baseline conditions
- Meet regulatory requirements

Liquid Sampling Objectives

- Assess water quality
- Provide data for contaminant loading calculations
- Identify contaminant source(s)
- Provide input for modeling
- Use in toxicological testing
- Establish baseline conditions
- Meet regulatory requirements

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Biological Sampling Objectives

- Detect changes in community composition
- Trace contaminant pathways
- Provide input for modeling
- Use in toxicological testing or bioassays
- Establish baseline conditions
- Meet regulatory requirements

Air Sampling Objectives

- Monitor for hazardous gases, vapors, or particulates
- Monitor for combustible gases or vapors
- Monitor for oxygen deficiency
- Determine total suspended particulates
- Establish exposure levels
- Meet regulatory requirements

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Things to Keep in Mind

- **Focusing sampling activities *solely* on regulated constituents often results in incomplete or incorrect characterization, which could lead to *costly* problems later**
- **Most modeling requires complete information (e.g., Biotic Ligand Model, geochemical speciation models)**

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Sampling Methods

- **Probabilistic**
  (Each member of the target population has a known probability of being selected)
  - Random sampling
  - Systematic random sampling
  - Stratified random sampling

- **Nonprobabilistic**
  - Convenience sampling
  - Purposive sampling

Sampling Methods

➢ Adaptive sampling

- Sampling regions are selected based on values of the variables of interest observed during a sampling survey
- Because sampling is based on prior data, different estimators must be used in the adaptive sampling technique to guarantee lack of bias

Sampling Methods

- Composite sampling
  - Use when average values are of interest
  - Can significantly reduce analytical costs
- Hot spot sampling
  - Use when need to distinguish areas of different concentrations
  - Can result in expensive sampling and analytical costs

Mining Wastes Heterogeneity

Distributional

Morphological (size and shape)

Compositional

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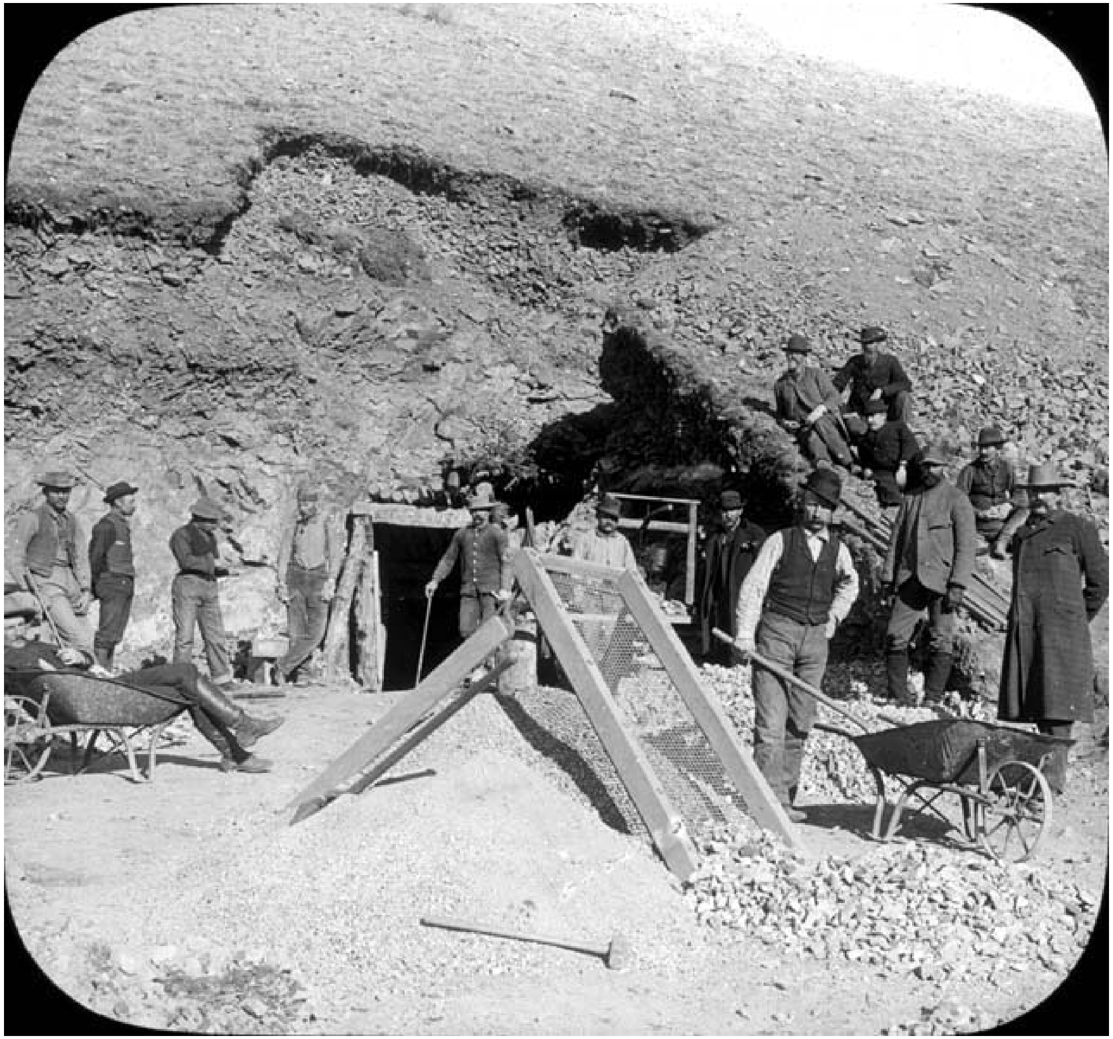
Mining Wastes Heterogeneity

3-D variation



Gold King Mine, Cripple Creek, Colorado

(*photo by William Henry Jackson; Western History/Genealogy Dept., Denver Public Library*)

Sampling Strategy for Screening Mining Wastes

- Screening and prioritizing for AML studies
- Regional or watershed-based assessments
- Average properties of mine-waste pile
- Statistically based
- Field friendly
- Cost effective

- Heterogeneity
  - Compositional, spatial, particle size
- Sampling errors

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Sampling Strategy for Screening Mining Wastes

- Surficial material (upper 15 cm)
- < 2 mm size fraction

- Pitard (1993)
  - Interplay between particle size and sample mass
  - Collect many small increments
  - Awareness of segregation mechanisms

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Sampling Strategy for Screening Mining Wastes

Divide mine-waste dump into at least 30 cells of roughly equal surface area

Collect a surficial sample from each cell (multiple samples from each cell if possible and a total weight of at least 100 g)

Combine cell samples into a mine-dump composite sample

Dry sieve the mine-dump composite sample to < 2 mm (final composite sample should weigh at least 1,000 g (1 kg) after sieving)

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Sampling Strategy for Screening Mining Wastes

Stainless steel trowel

Plastic bucket

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Sampling Strategy for Screening Mining Wastes

One 30-increment dump-composite sample collected using this sampling strategy contains as much information, relative to average value, as 30 individual grab samples at $^{1}/_{30}$ of the analytical cost

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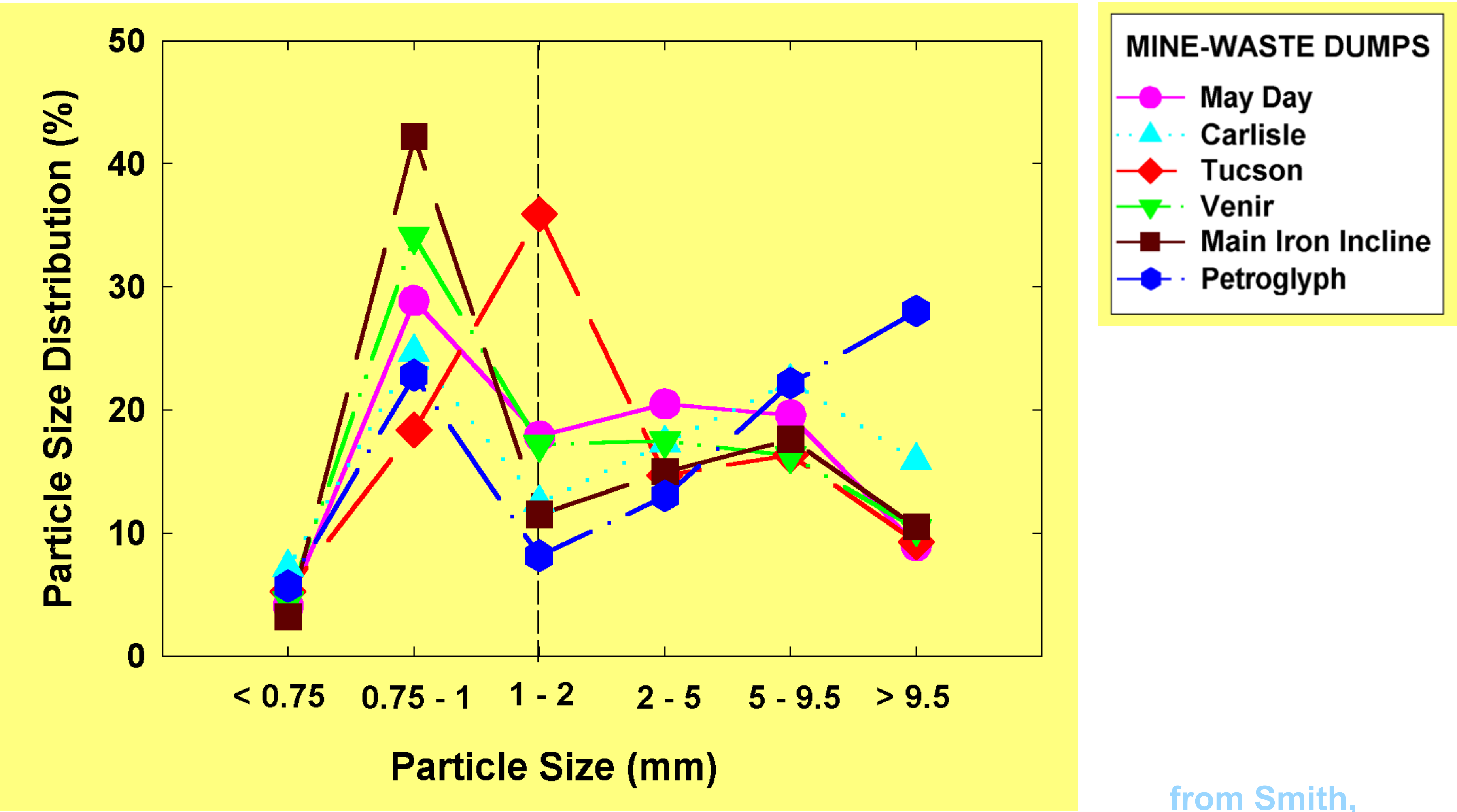
Sampling Strategy for Screening Mining Wastes

This sampling strategy could be adapted to the sampling of other target populations, such as

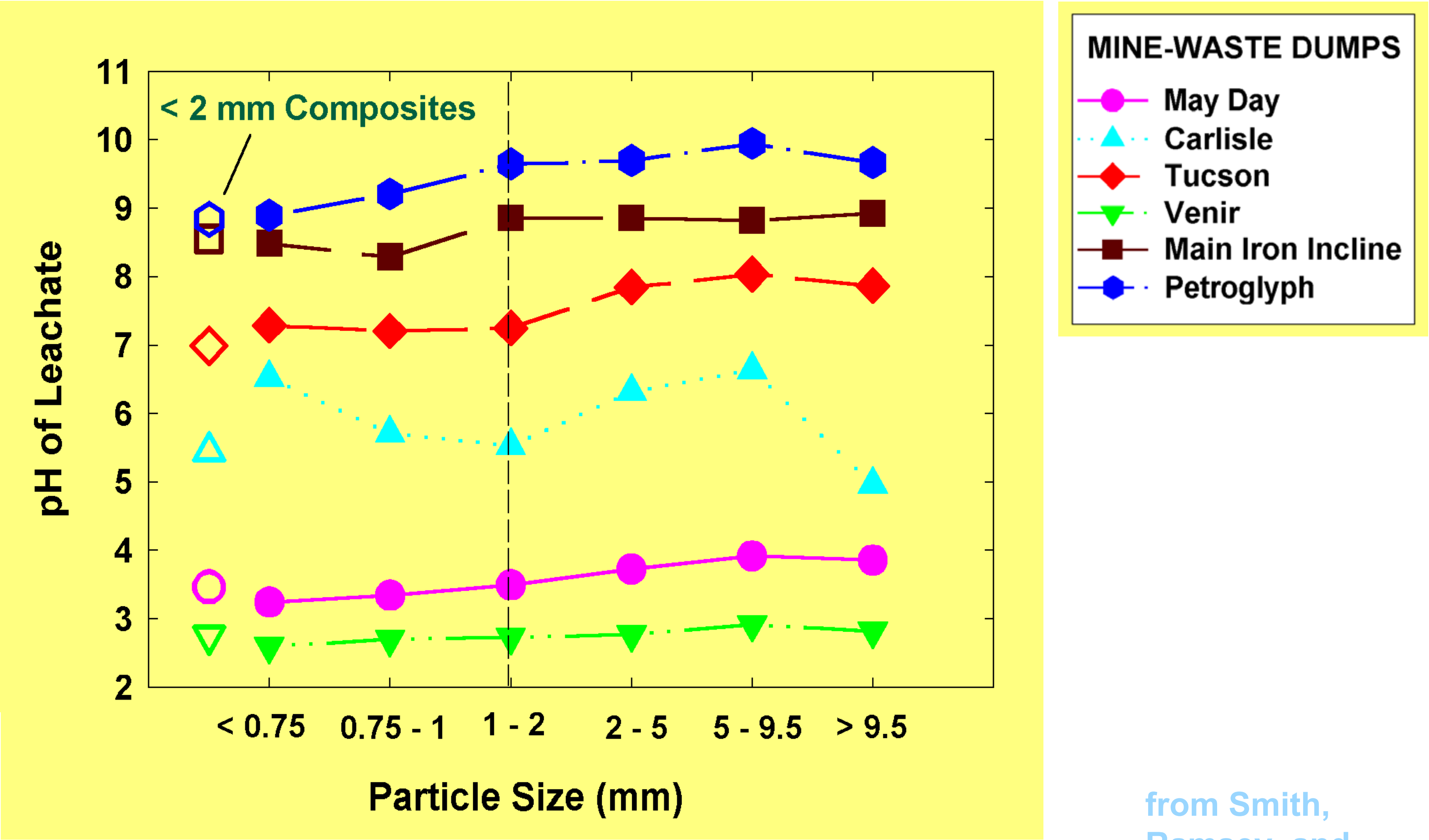
- Individual waste-dump lobe
- Pit bench
- Dump lift
- Geologic unit
- Other "operational" units

Particle Size Distribution



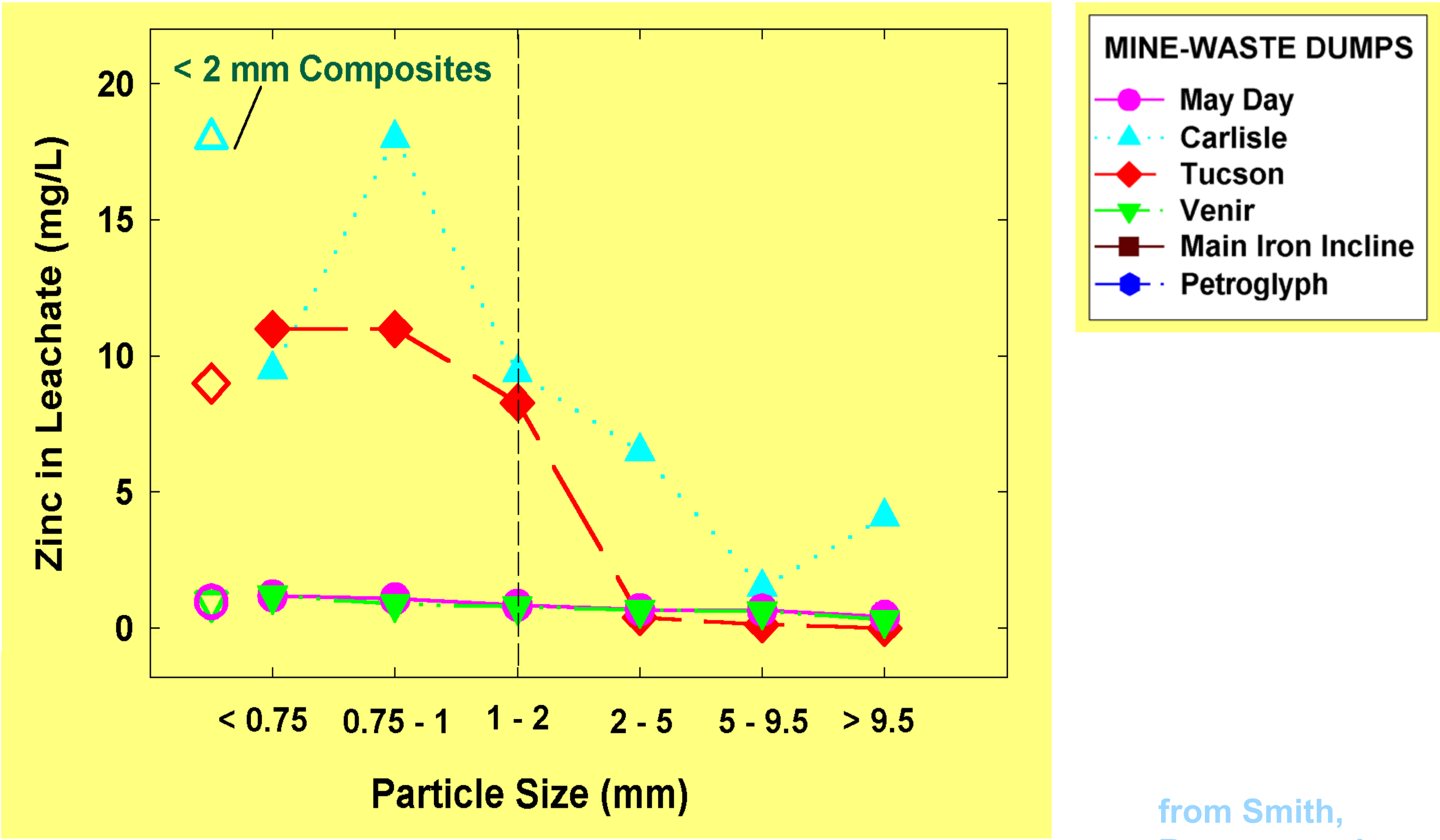
from Smith, Ramsey, and Hageman (2000)

pH versus Particle Size



from Smith, Ramsey, and Hageman (2000)

Zinc versus Particle Size



from Smith, Ramsey, and Hageman (2000)