



# Waste Pile and Water Sampling

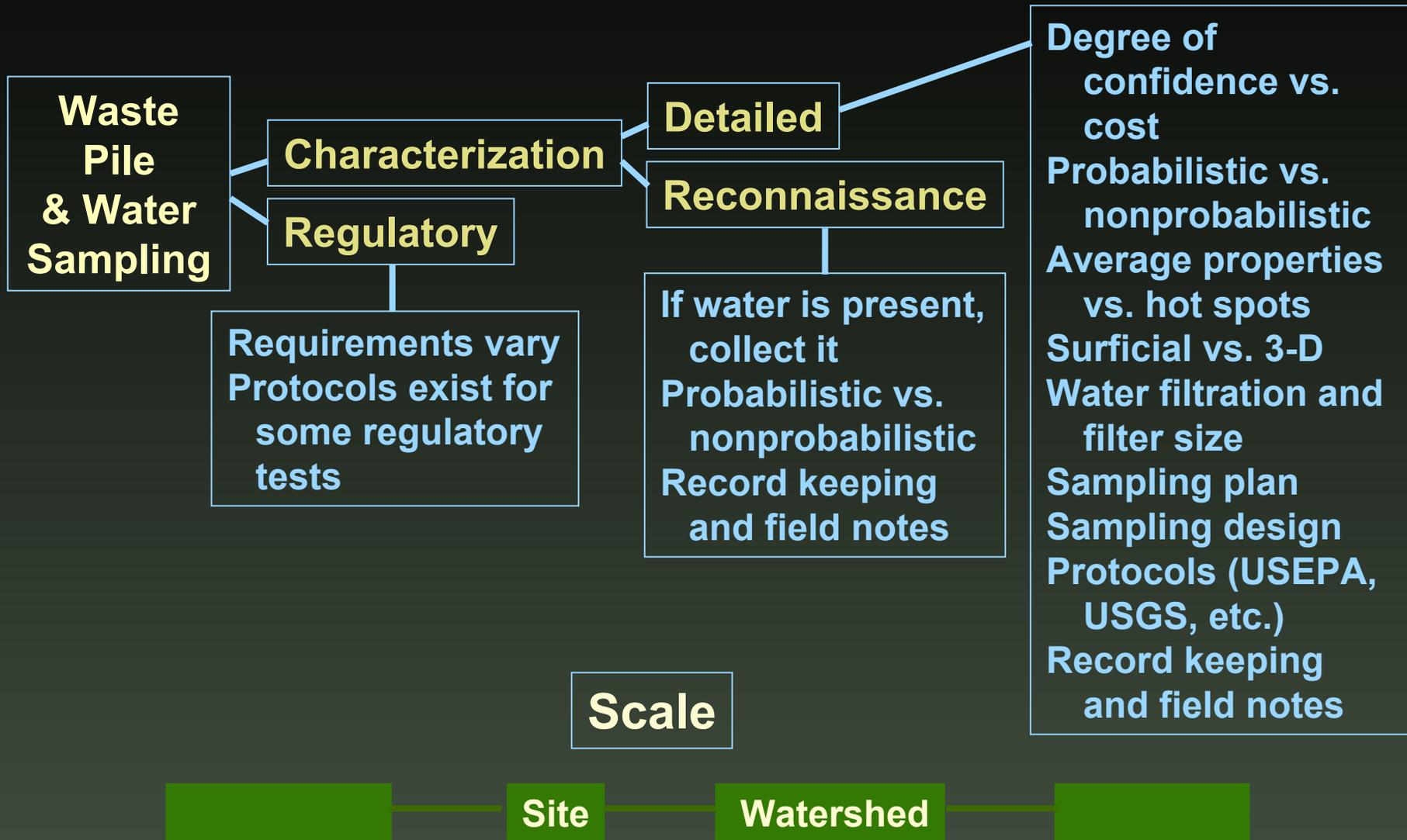
**Kathleen S. Smith, USGS**

**Billings Symposium / ASMR Annual Meeting**

**Assessing the Toxicity Potential  
of Mine-Waste Piles Workshop**

**June 1, 2003**

# 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)**

**You'll never know the true answer,  
but you can make a reasonable estimate**

# 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?**

# Target Population

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



**Target Population**

**Sample**

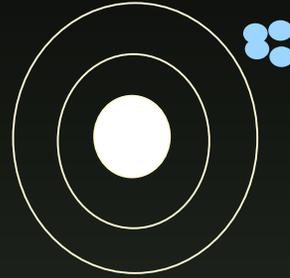
# Desired Degree of Confidence

- **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**

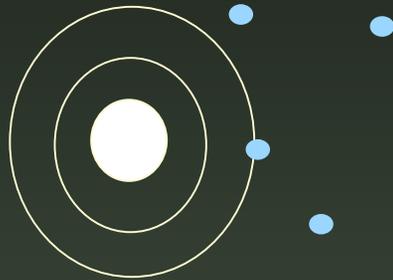
# Precision versus Accuracy



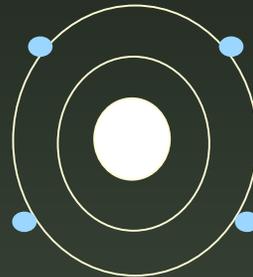
**Precise, unbiased,  
and accurate**



**Precise, biased,  
and inaccurate**



**Imprecise, biased,  
and inaccurate**



**Imprecise, unbiased,  
and inaccurate**

# Sampling Concerns

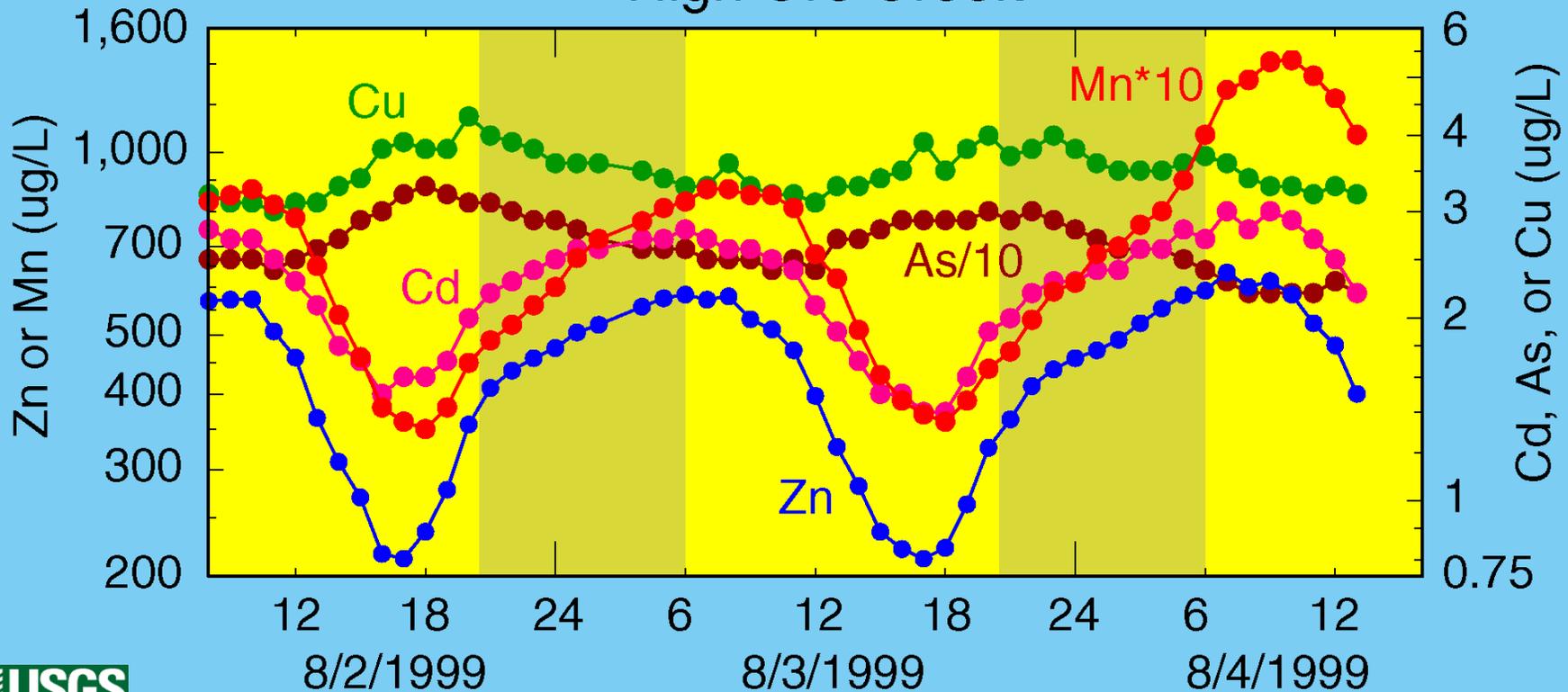
- **Sampling error**
- **Precision requirements**
  - **Field sampling methods and equipment**
  - **Sample preparation**
  - **Laboratory subsampling**
  - **Analyses**
- **Sample containers**
- **Sample preservation and storage**
- **Sample holding times**

# 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**

# Sampling Error Example—Diel Cycling (from Nimick, 2001)

High Ore Creek



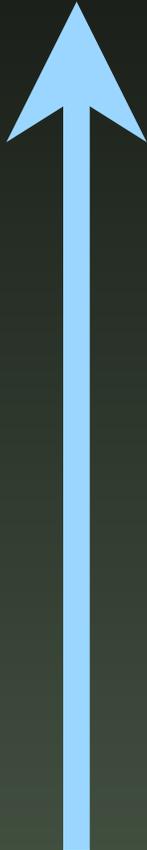
Arsenic	Cadmium	Manganese	Zinc	Copper
22-33 ug/L	1.4-3.0 ug/L	35-142 ug/L	214-634 ug/L	3.0-4.3 ug/L
50%	110%	306%	196%	43%

# Fundamental Error

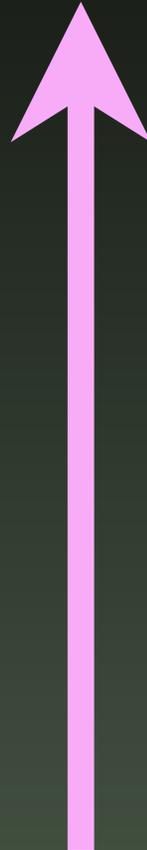
- **The source of most sampling errors**
- **Cannot be eliminated, but can be estimated**
- **Due to the fact that not all particles have the same composition**
- **Results in variability and a lack of precision**
- **Particle size, sample mass, and degree of heterogeneity are important factors**

# Need to collect more sample mass when

Particle  
size



Heterogeneity



Desired  
degree of  
confidence



# Fundamental Error

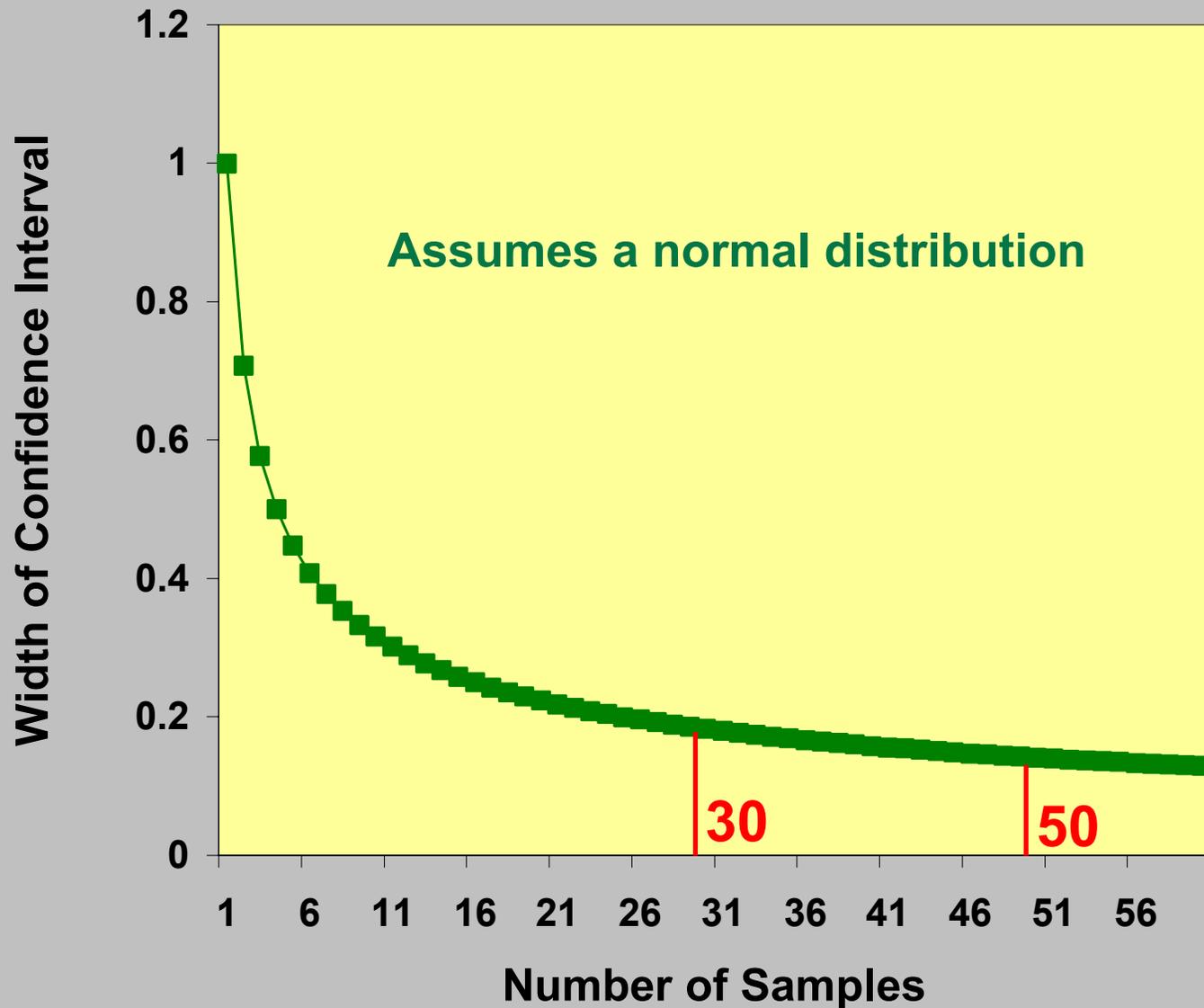
## Function of:

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

# 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**

# 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**

# 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**

# 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)**

# 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**



# 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

## Uses and Needs

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

## Concerns

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

# Sampling Strategy for Screening Mining Wastes

## Target Population

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

## Approach

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

Pitard, F.F., 1993. Pierre Gy's sampling theory and sampling practice: CRC Press

# 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)

# Sampling Strategy for Screening Mining Wastes



**Stainless steel  
trowel**

**Plastic bucket**

# Sampling Strategy for Screening Mining Wastes



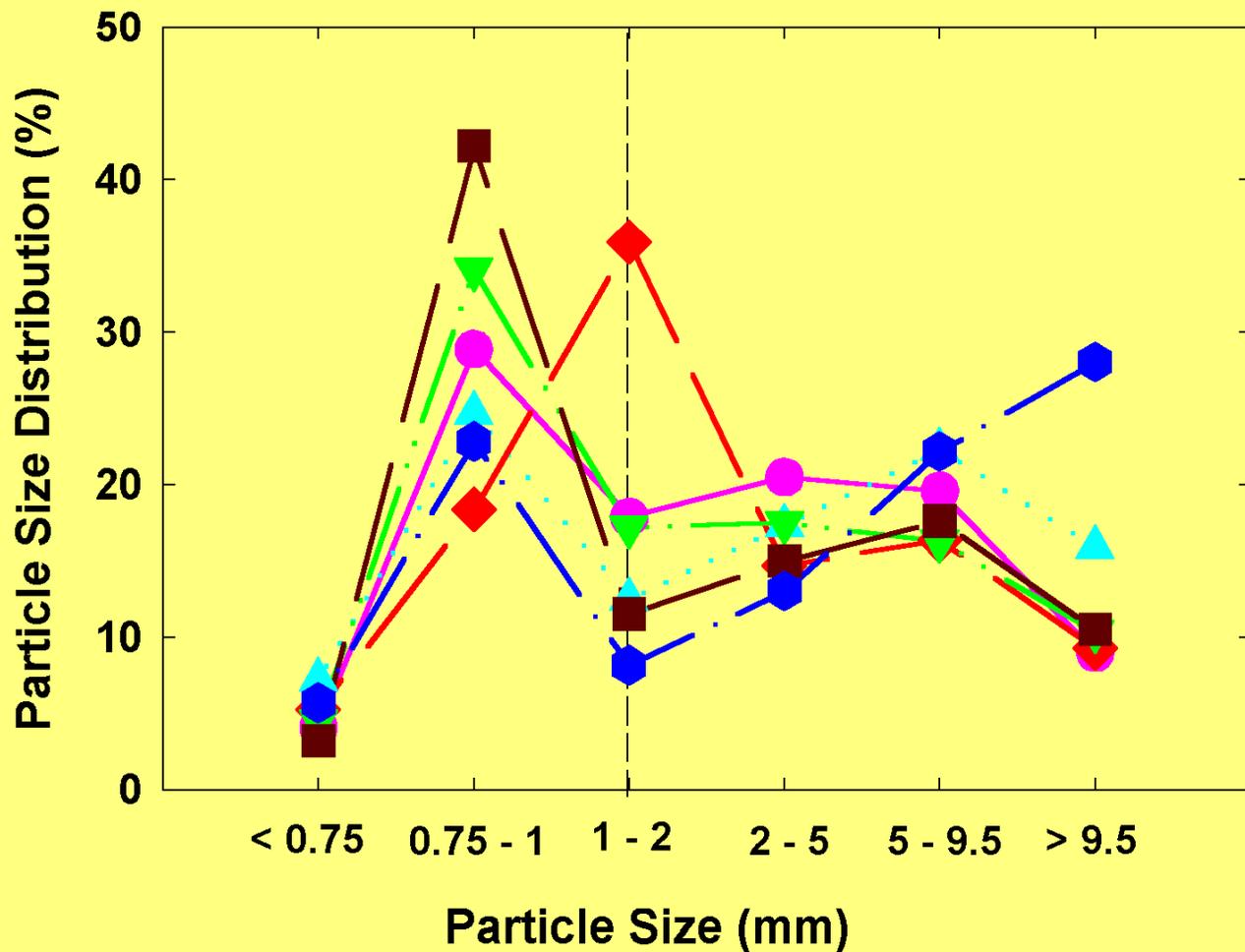
One 30-increment dump-composite sample collected using this sampling strategy contains as much information, relative to average value, as 30 individual grab samples at  $1/30$  of the analytical cost

# 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

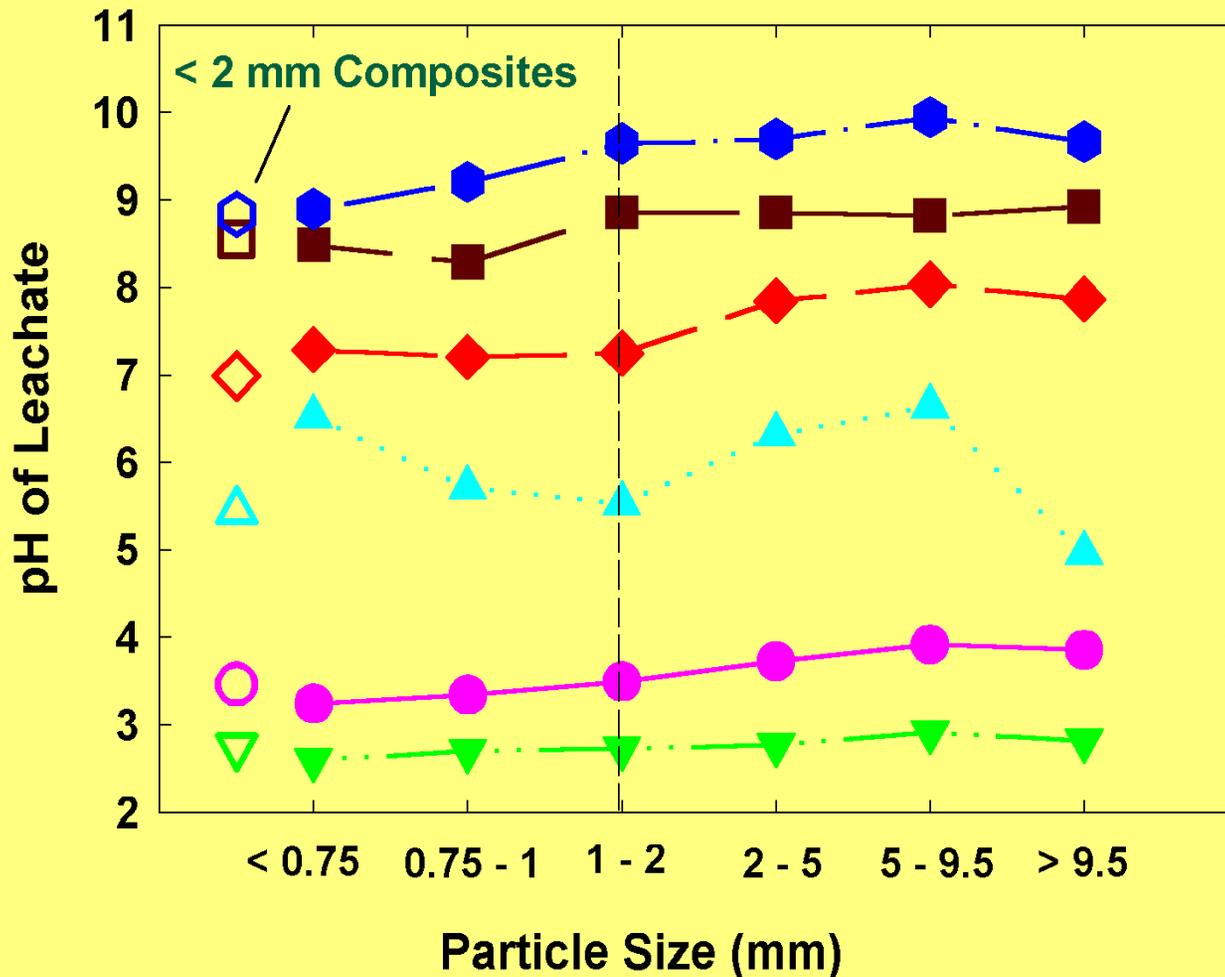


## MINE-WASTE DUMPS

- May Day
- Carlisle
- Tucson
- Venir
- Main Iron Incline
- Petroglyph

from Smith,  
Ramsey, and  
Hageman (2000)

# pH versus Particle Size

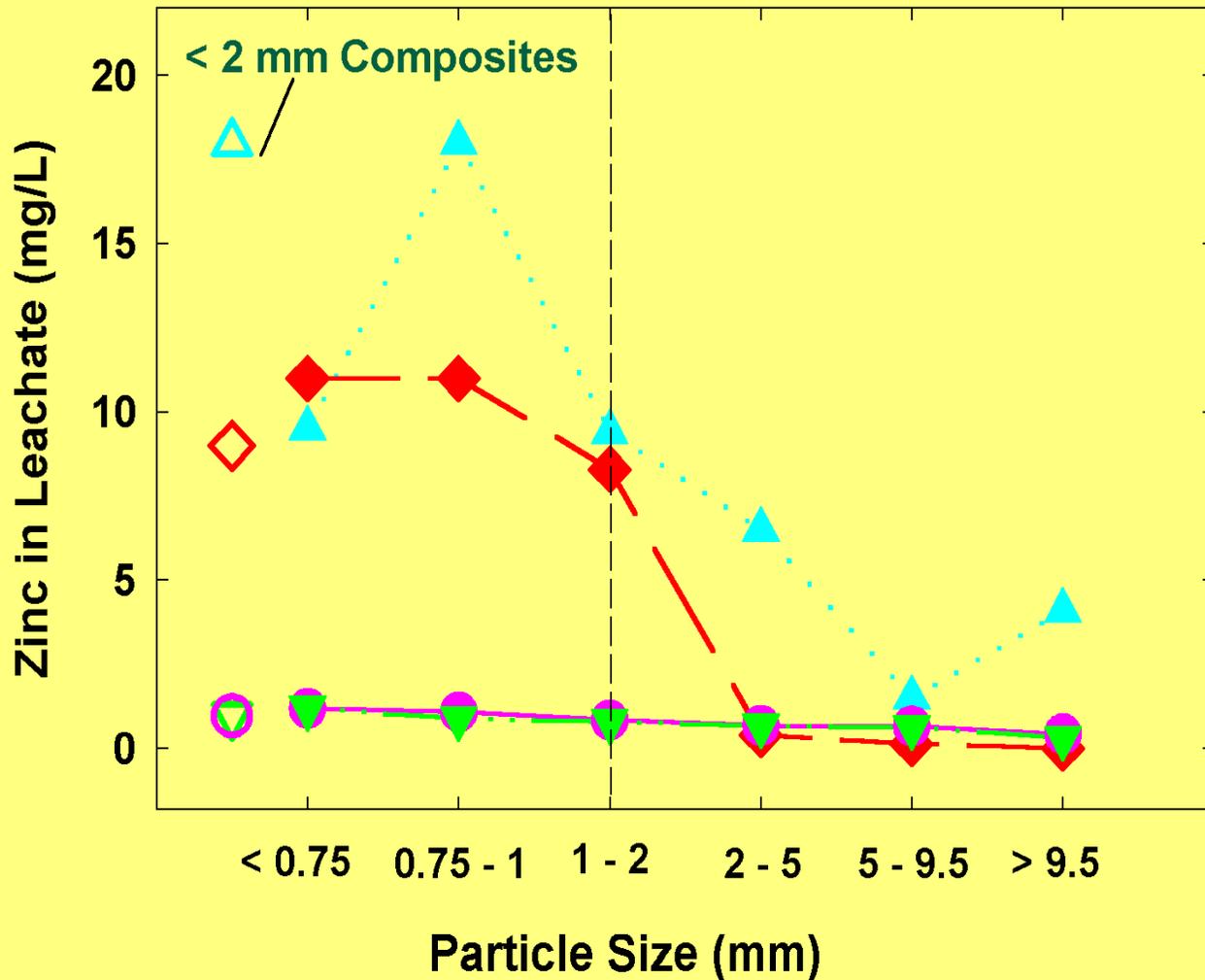


## MINE-WASTE DUMPS

- May Day
- Carlisle
- Tucson
- Venir
- Main Iron Incline
- Petroglyph

from Smith,  
Ramsey, and  
Hageman (2000)

# Zinc versus Particle Size



## MINE-WASTE DUMPS

- May Day
- ▲ Carlisle
- ◆ Tucson
- ▼ Venir
- Main Iron Incline
- Petroglyph

from Smith,  
Ramsey, and  
Hageman (2000)