Triad Overview
What It Is.   What It Is Not.

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FRTR Mtg, Washington, DC, December 1, 2003

The Triad approach is…

…a technical framework to incorporate 25+ years of experience and advancing science & technology into second-generation cleanup program policy & practice—

with the intent of improving confidence in project outcomes AND saving money over project lifetimes.

The Triad is NOT…

- …written in all caps (not an acronym!)
- …just about using field analytical! (Warning: Just using field analysis does not mean they used the Triad approach!!)
- …a way to justify using field analysis without using proper QC (MUST have data of known/documented quality!)
- …just about using a dynamic/flexible work plan (must actively manage decision uncertainty!)
- …a license to write vague work plans or escape regulatory oversight or accountability.

The Triad is about…

- Improving project quality by actively managing DECISION uncertainty using new tools & strategies
- Constructing accurate CSMs (as a primary Triad product!) to support cost-effective decisions
  - Done in real-time to cut lifecycle costs
  - Controlling sampling variables & tailoring QC to manage specific data-decision uncertainties
- Avoiding uncertainty in communications with logical solid documentation and unambiguous terminology
- Cultivating professional competence & multidisciplinary teams ("allied environmental professionals" that parallel medicine's "allied health professionals")

Problems with Current Remediation Model

- Little discussion or agreement on project goals and decision points before gathering data.
  May unknowingly work at cross-purposes.
- Data acceptable only if produced by regulator-approved methods/fixed-based labs. **Sampling and analytical uncertainties impacting data interpretation are ignored.**
- Budgets limit the number of lab samples, result is faulty understanding about contamination distributions.
  The CSM is incomplete.
- Incomplete CSM compromises reliability of site decisions and efficiency of remediation. **Resources wasted.**

Problems Exist Because Still Using a Cleanup Model based on 1980's Expectations

1980's Realities: Newborn programs & rudimentary science

- **Trying to understand issues one step at a time**
- **Could not predict…**
  - how contaminants behaved & distributed throughout the environment (i.e., the CSM)
  - what cleanup levels would be expected (to background?)
  - how cleanup might be accomplished (few remedial options)
  - how the site might be reused after cleanup (if at all)
  - what legal ramifications might arise
  - all potential uses of data when planning for data collection
- **Sparse service provider network**
- **Used simple models to reduce complexities to manageable components (e.g., assume homogeneity)**

But, Programs Have Evolved Since 1980's

- Regulatory & funding programs at federal, state, local levels to support cleanups
- Private sector now provides a range of analytical, engineering, insurance, and oversight services
- Land economics make site reuse a key driver
- Politicians expect that scientific & technical issues of site cleanup have been resolved
- Yet, programs often dissatisfied with quality of projects
  - Reports vague; no CSM; unable to defend decisions
  - Poor characterizations disrupt budgets & schedules
    - » Inefficient remedial actions
    - » Unexpected contamination discovered later
    - » Uncertainty can derail redevelopment

Science & Technology Have Also Evolved

- Better understanding of contaminated sites

Heterogeneity Rules! Simple models inadequate.

- Better cleanup technologies are available
  – Wider range of remedial options, **but** successful selection and deployment require accurate characterization

- Better investigation technologies are available
  – Provide reliable information that can capture heterogeneity and understand contaminant distributions (build accurate CSMs)

However, 1980's-style habits often raise barriers to adopting better technologies

Although programs and capabilities have evolved, many practices remain in 1980's-mode

In general, we still…

- plan projects as if unable to predict what the ultimate project goals might be
- budget and contract as if we expect all projects to cost the same, no matter what the site's technical or contaminant issues are
- plan for sampling as if we cannot predict contaminant locations, distributions, and behavior
- expect simplified models based on assumptions of homogeneity to work: 1) "analytical method quality = data quality"; and 2) classical statistics

The Triad Approach Moves Beyond 1980's Thinking

Triad Expects the Real-World to be Heterogeneous

Triad copes with heterogeneity by using:

1) Project-specific Conceptual Models

2) A 2nd-Generation Data Quality Model

3) Modern Tools & Work Strategies

Conceptual Site Model: THE Basis for Confidence in Project Decisions

- Correct decisions require accurate picture of site contamination
- This picture is called a **Conceptual Site Model (CSM)**
- A **CSM** = any format or tool(s) that let you represent, "**conceptualize**" or "**model**" **site** contamination issues & concentration populations to make predictions about

  nature, extent, exposure, and risk reduction strategies
- A sufficiently **accurate** CSM will distinguish populations based on whether **decisions** or outcomes **differ** enough to alter risks, costs, or remedial success. Sites often contain 2 or more populations. Separating them makes for **cost-effective decisions.**

Conceptual Site Model Elements

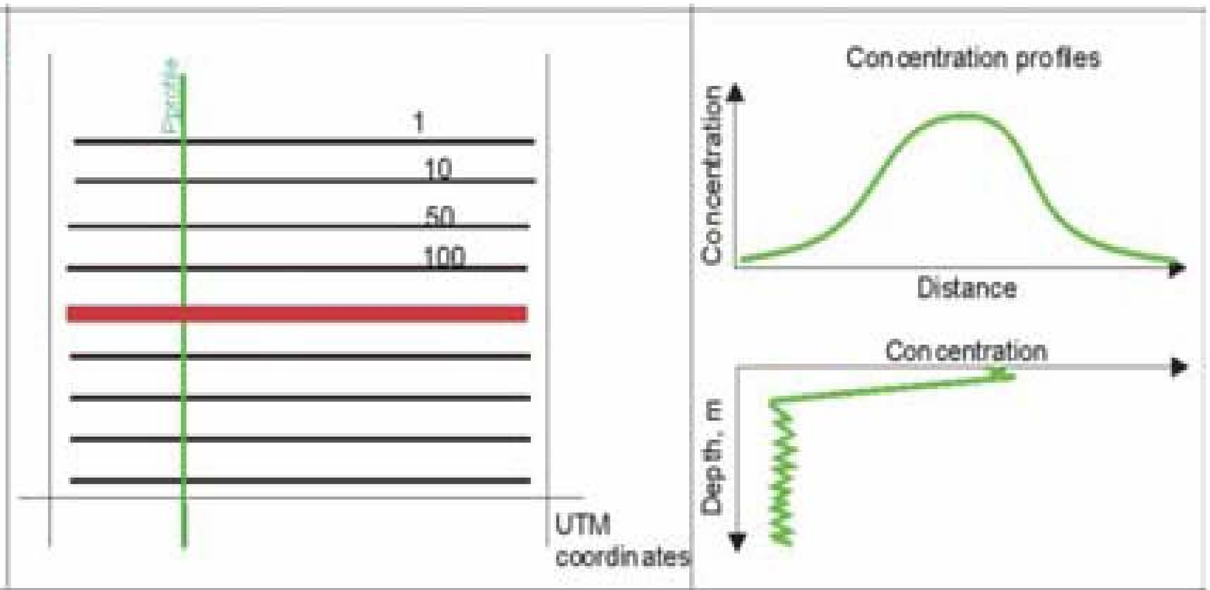
- Where is the contamination and how is it distributed?
- Contaminant patterns are created by
  - Contaminant **release** mechanism(s)
  - Contaminant **dispersal/migration/fate** mechanisms
- Risk to present or future receptors dependent on bioavailability & related issues (weathering, matrix binding, chemical species, degradation products)
- What risk reduction mechanisms are consistent with project constraints?

Urban Soil CSM Examples: Contrast Road vs. "Fill" Contaminant Distributions

Line Model

e.g. roads
railways

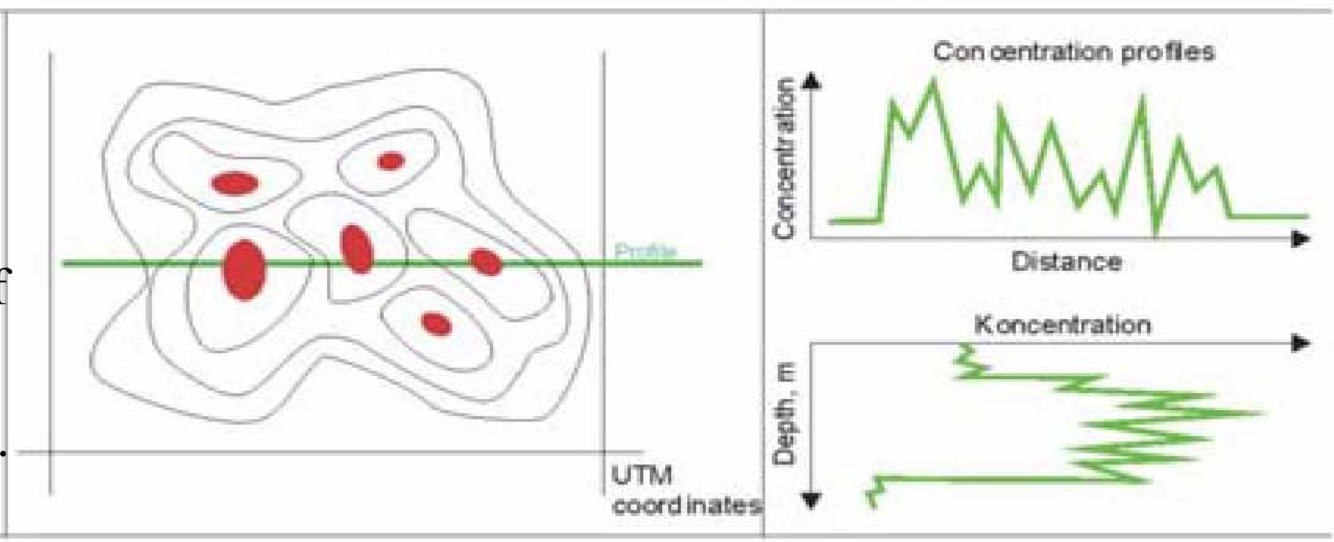
Soil impact from moving point sources aligned along a long linear element in the landscape, e.g. a road, railway.



Soil Fill Model

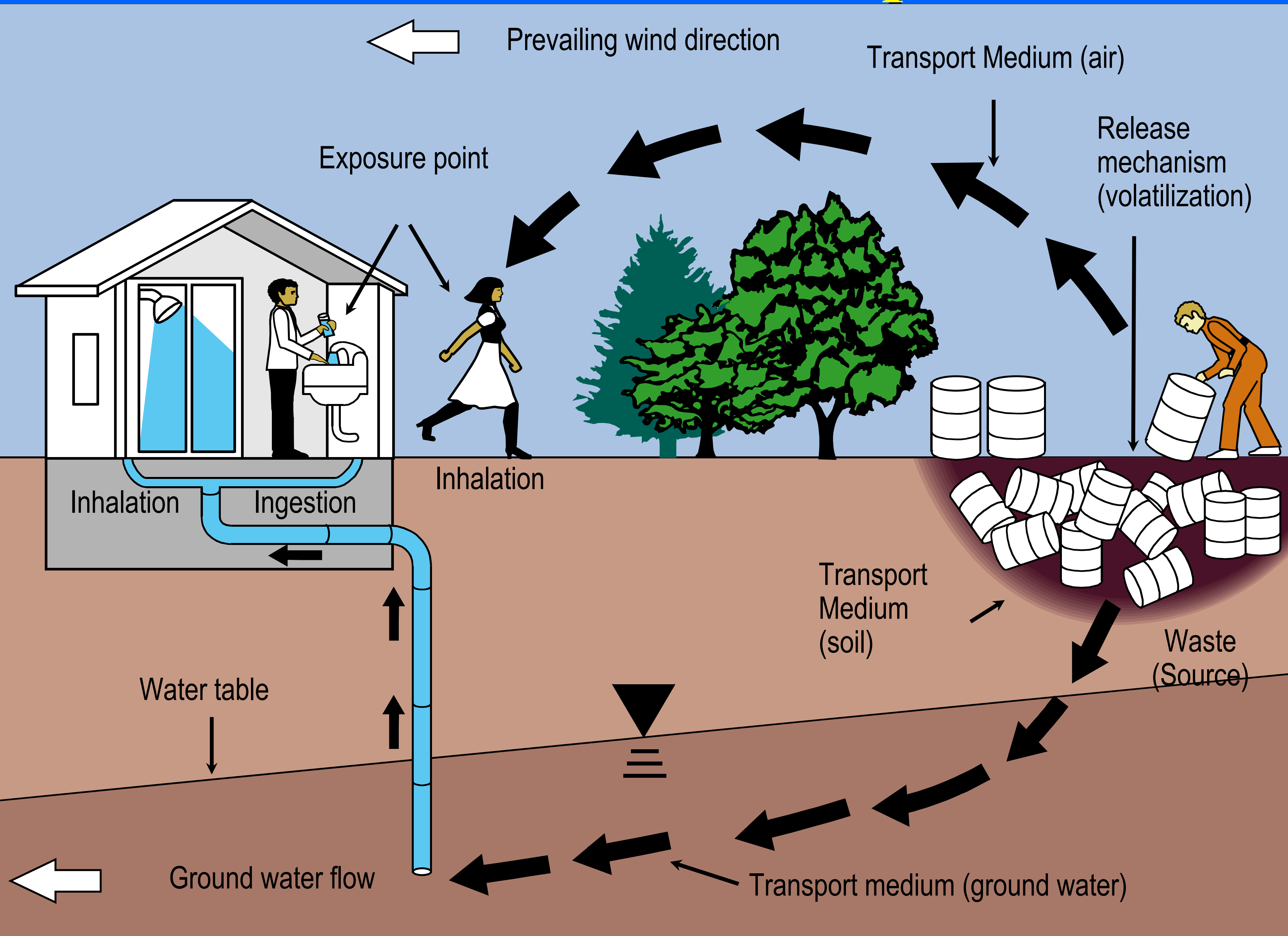
e.g. contaminated fill

Systematic dumping/filling with soil, waste, material of unknown origin variable and random load to the historic fill.



Falkenberg, et al., ConSoil (2003) Poster 1

Another CSM Depiction



2-D CSM Built from Direct-Push Sensor Data

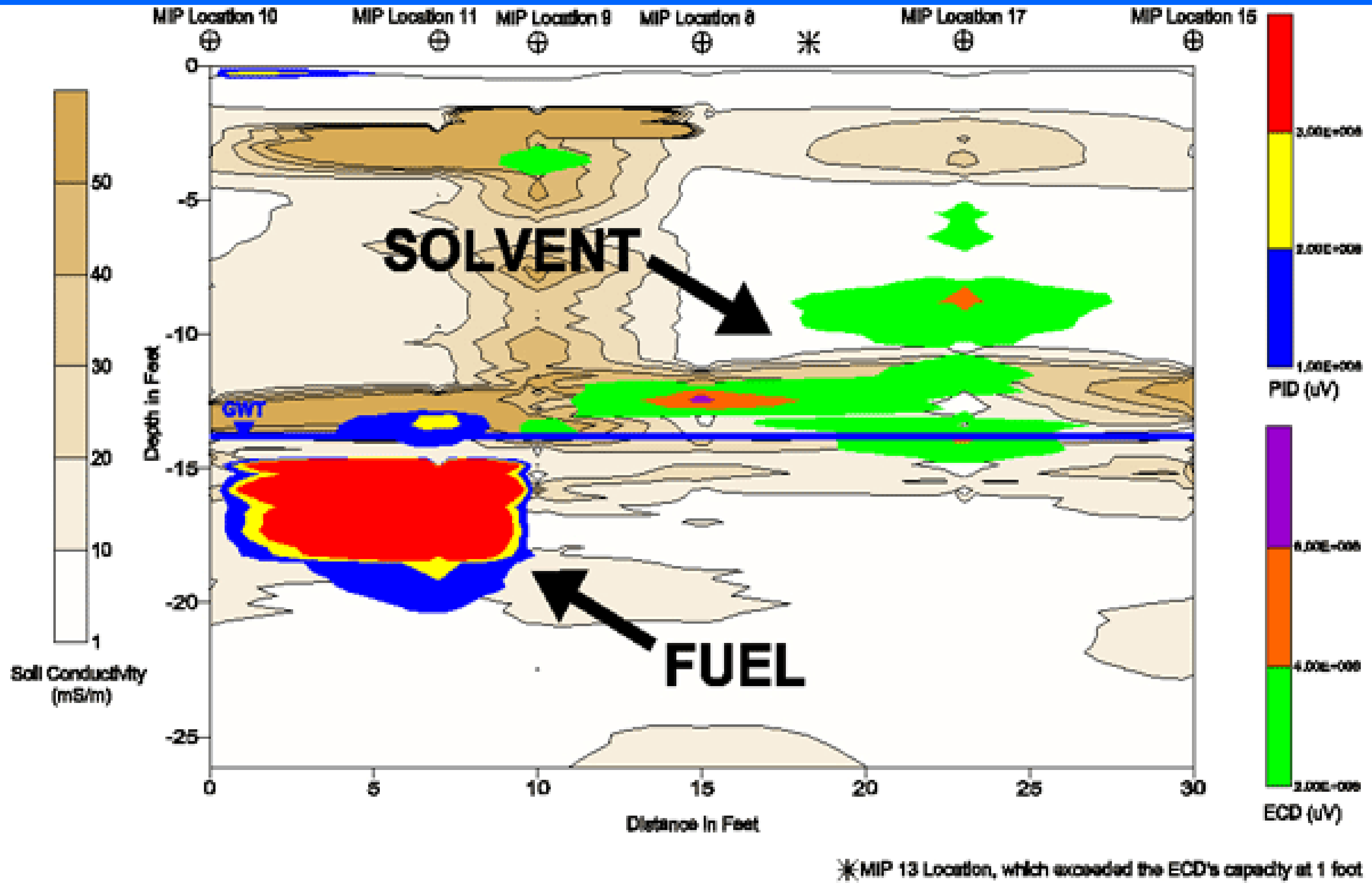
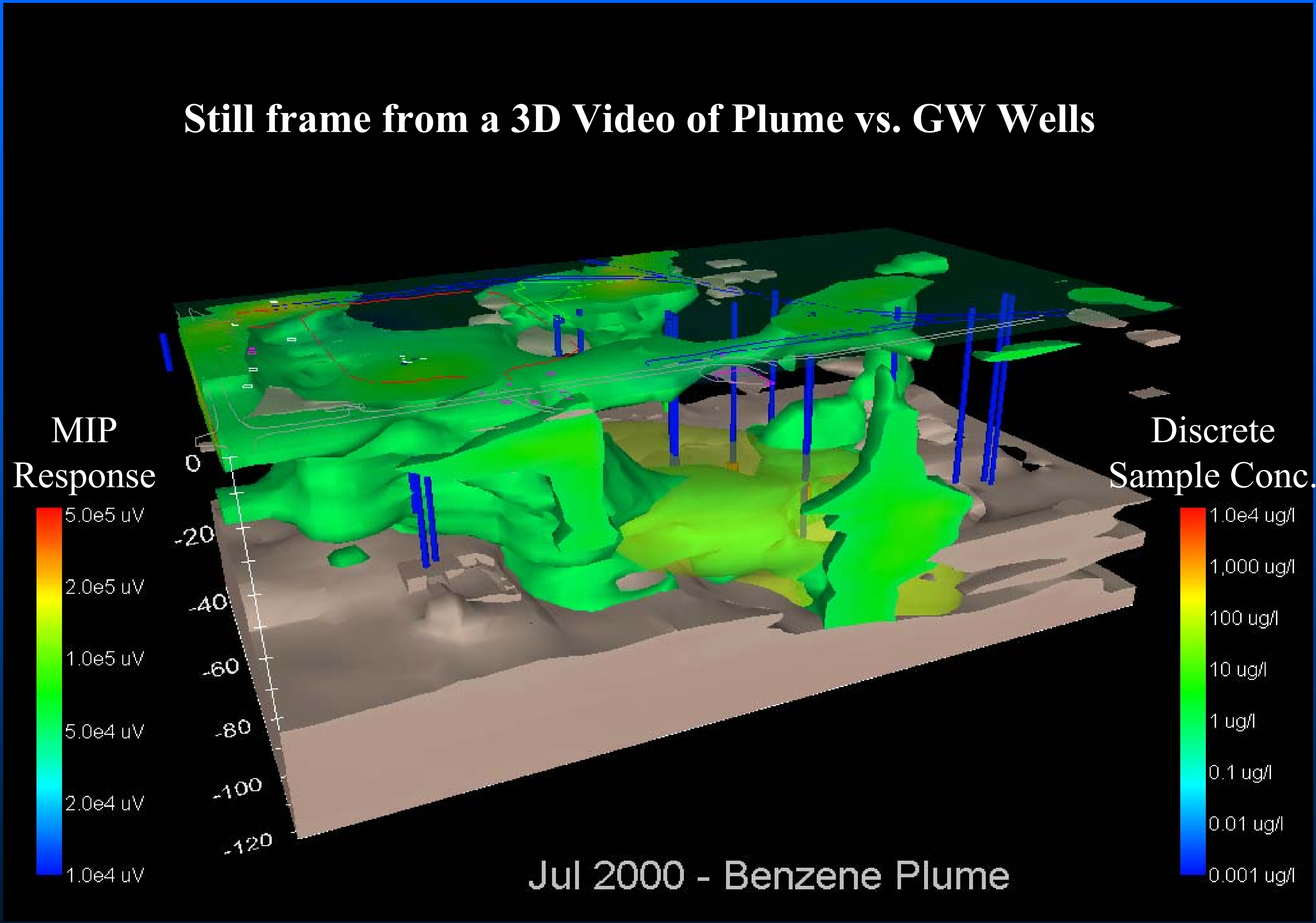


Figure 1
PID & ECD Response Transect
Dry Cleaner Site
January 30-31, 2001, February 1, 2001

COLUMBIA TECHNOLOGIES

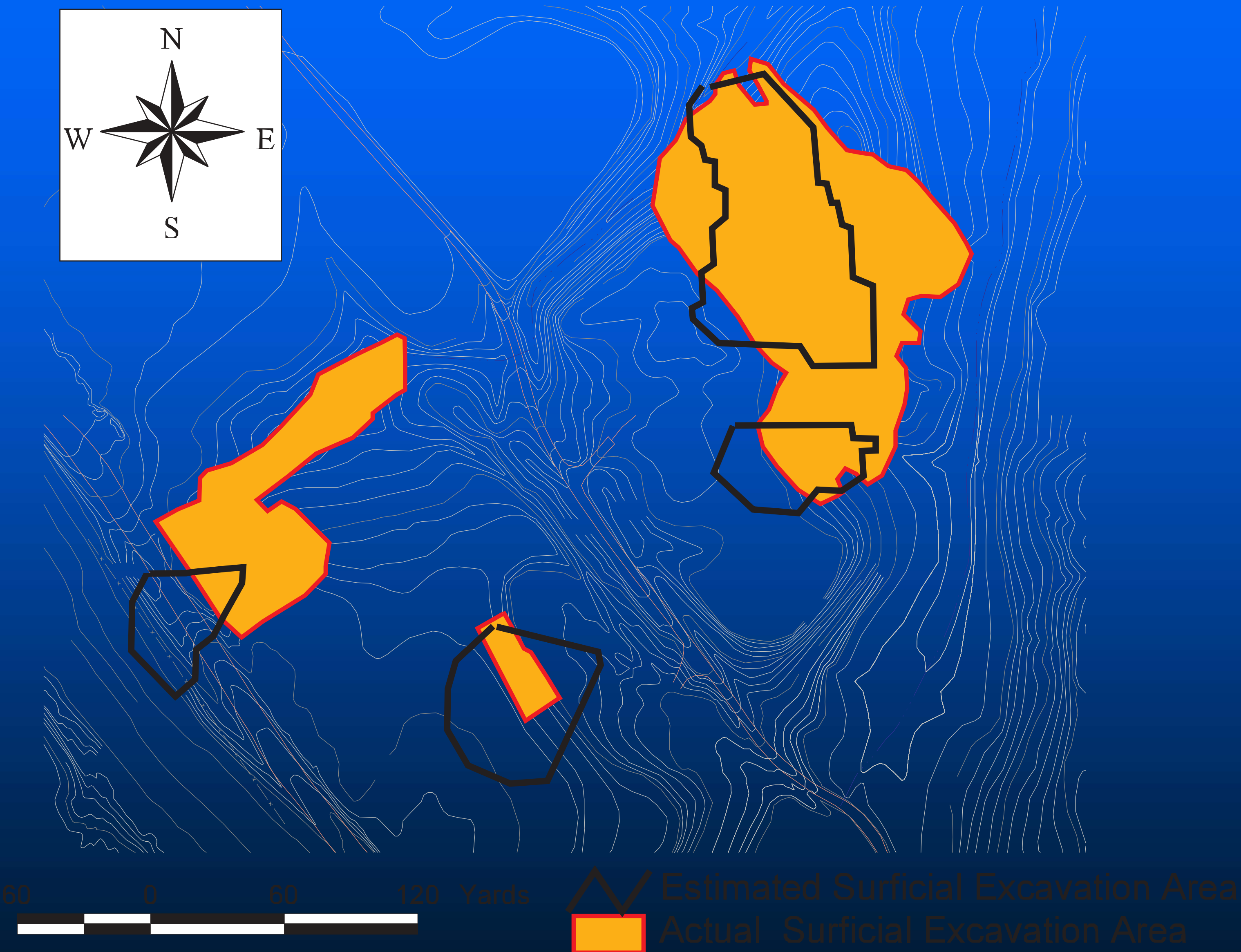
Slide adapted from Columbia Technologies, Inc., 2001

3-D CSM Built from Direct-Push Sensor Data



Slide adapted from Columbia Technologies, Inc., 2003

Inaccurate Soil CSM from Traditional RI Data (black) vs. CSM from Adaptive, High Density Sampling (orange)



Excavation based on RI data would have —

--removed ~4,000 c.y. compliant soil

-- missed ~8,000 c.y. non-compliant soil

Accurate CSM & precise excavation saved ~$10M.

Adapted from Argonne, 2002 http://cluin.org/download/char/ASAPs_ITSR_DOE-EM-0592.pdf

GW CSM from Traditional Sampling Effort (left) vs. CSM from High Density Sampling (right)

same well field…2 different sample collection techniques

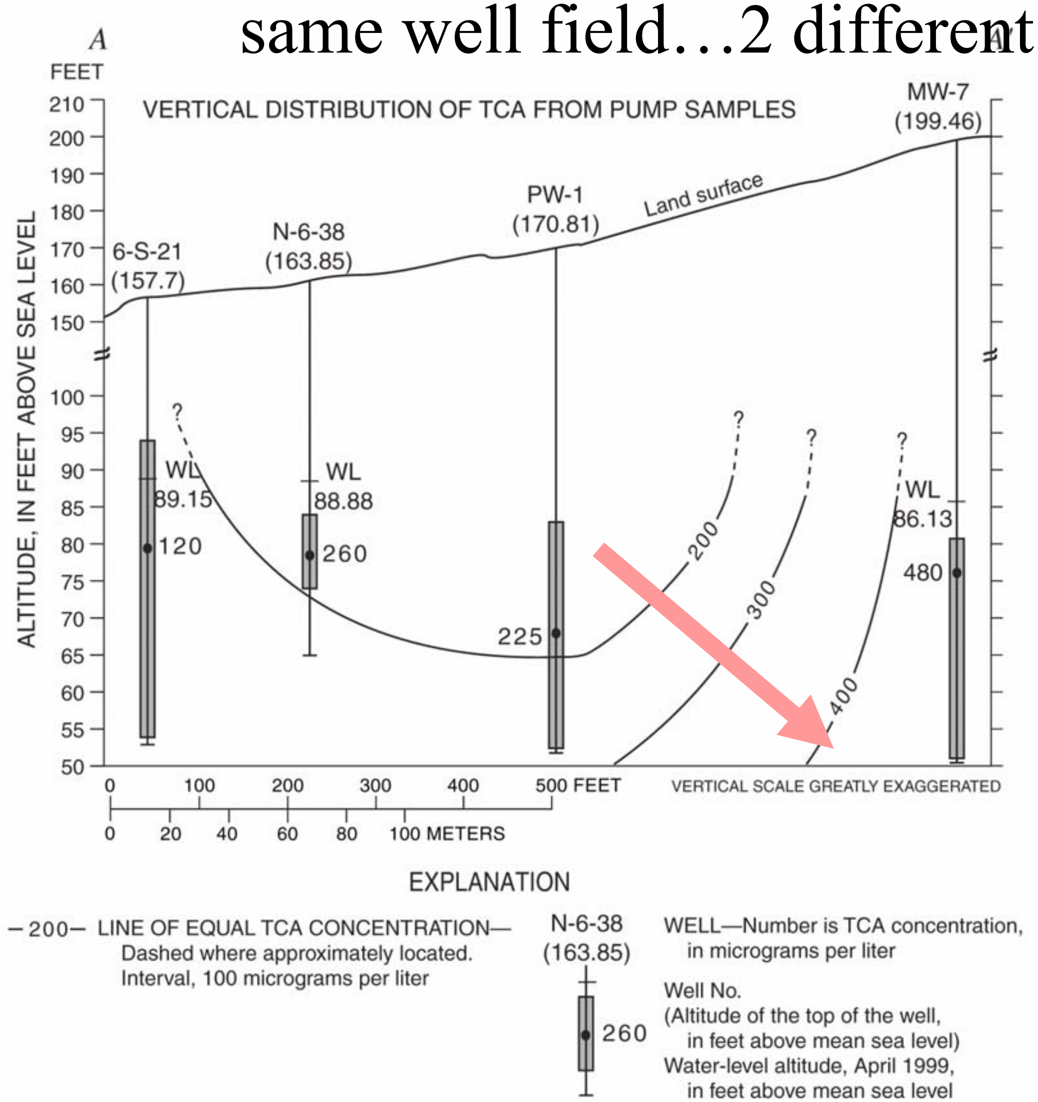


Figure 6. Vertical distribution of TCA concentrations in ground-water samples collected with the diffusion samplers and submersible pump.

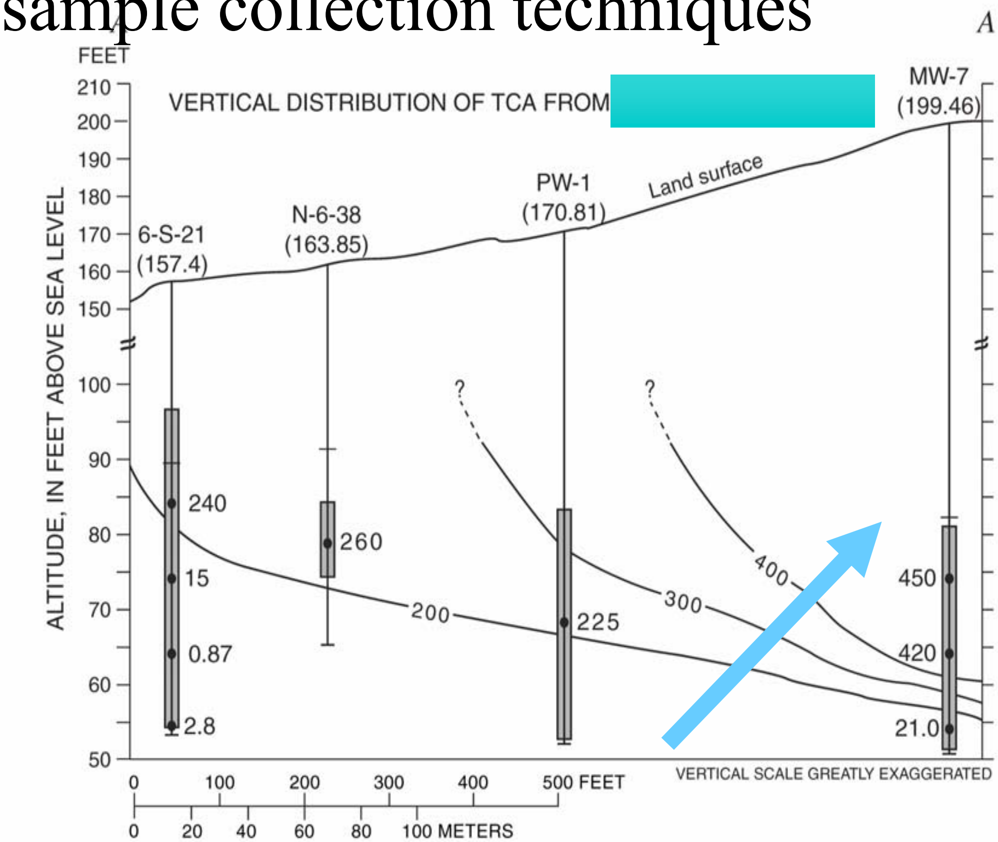


Figure 6.—*Continued.*

From USGS Report 02-4203 (2002)

http://water.usgs.gov/pubs/wri/wri024203/

Triad Uses A Next-Generation Environmental Data Quality Model to Manage Data Representativeness for Accurate CSMs

Oversimplified 1980's (First-Generation) Data Quality Model

Methods	=	Data	=	Decisions
Screening Methods	→	Screening Data	→	Uncertain Decisions
"Definitive" Methods	→	"Definitive" Data	→	Certain Decisions

This Model Fails to Distinguish:
Analytical Methods from Data from Decisions

Data Quality Involves Much, Much More than Just Chemical Analysis

Perfect Analytical Chemistry + **Non-Representative Sample(s)**

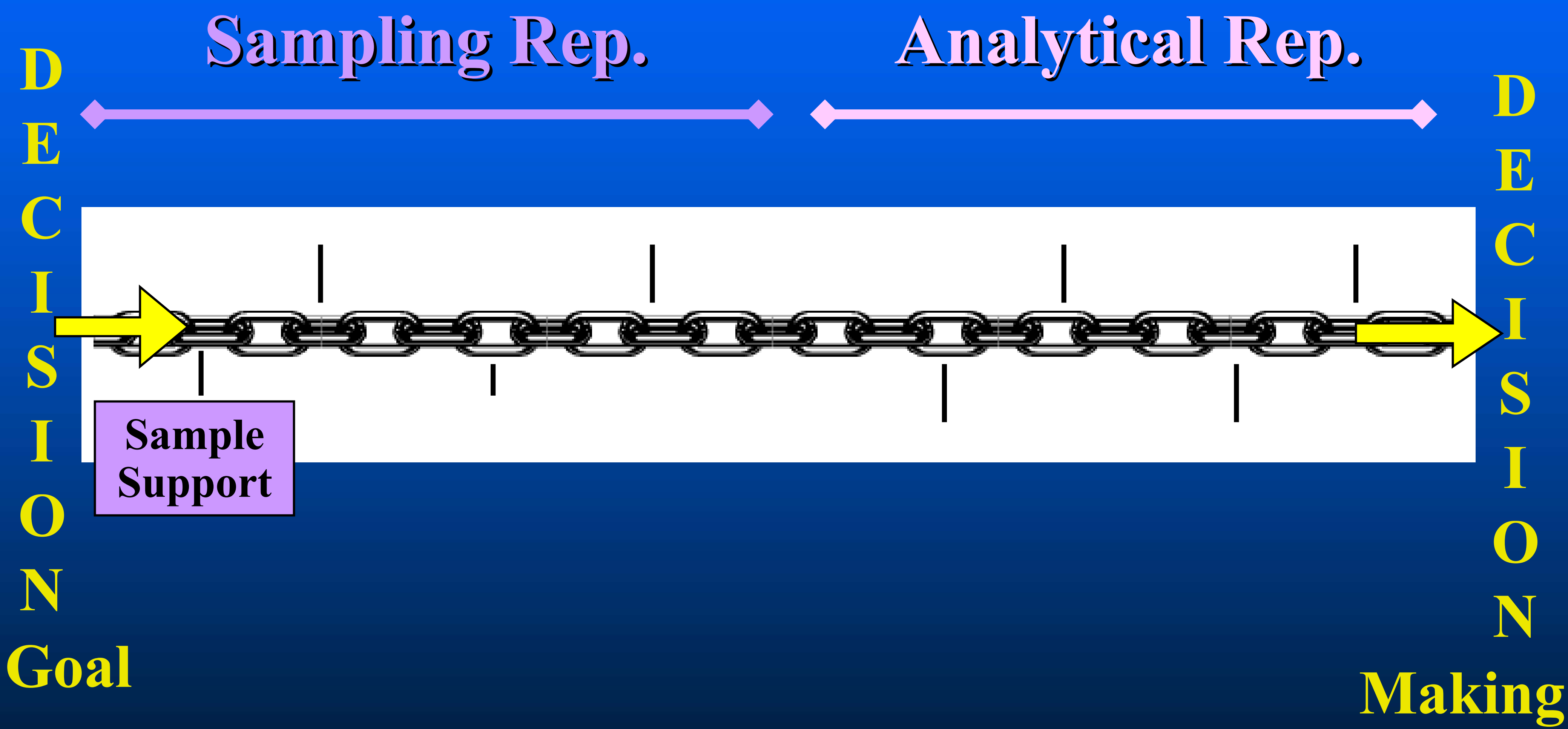
↓

"BAD" DATA

Distinguish:

Analytical Quality from Data Quality

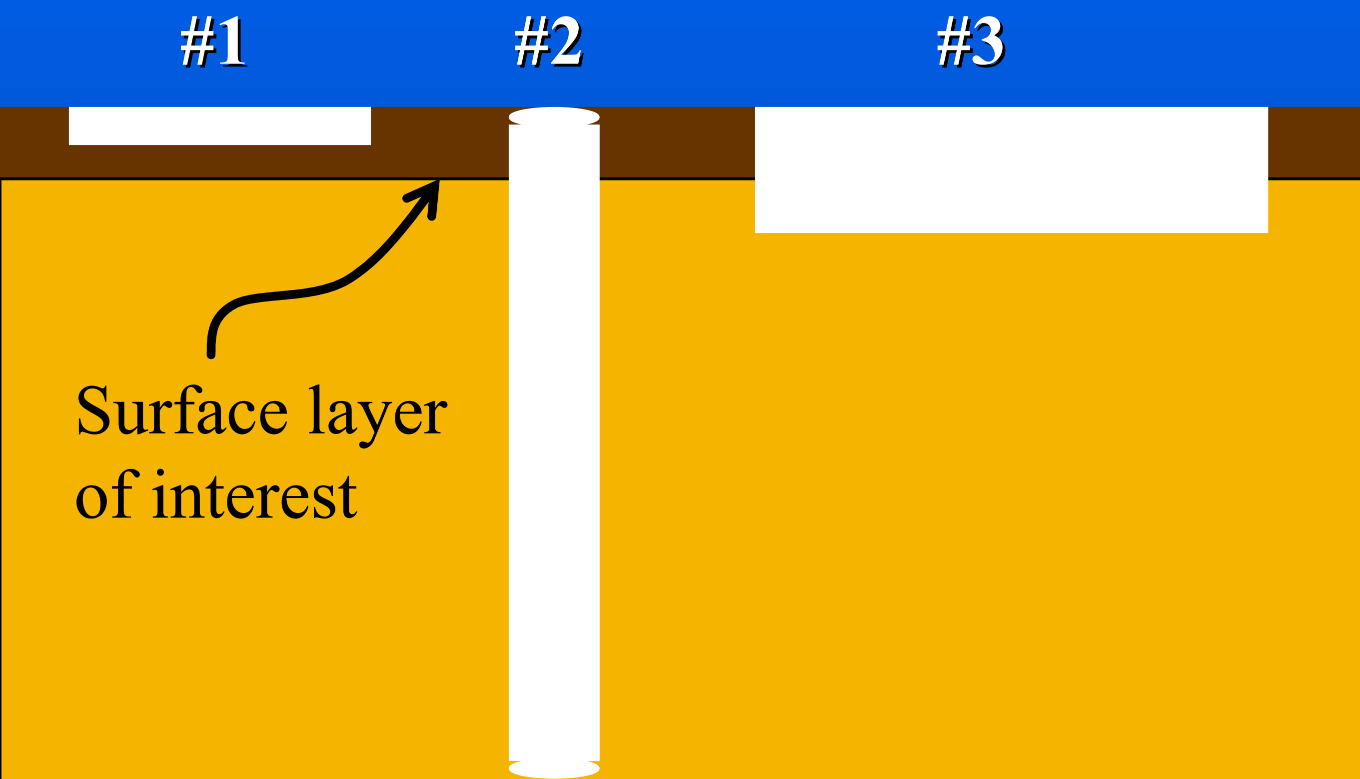
A Chain of Variables Impact “Representative Data”



All links in the Data Quality chain must be intact for data to be representative of the decision!

Sample Support: Includes Spatial Orientation

What sample support is representative of the decision?

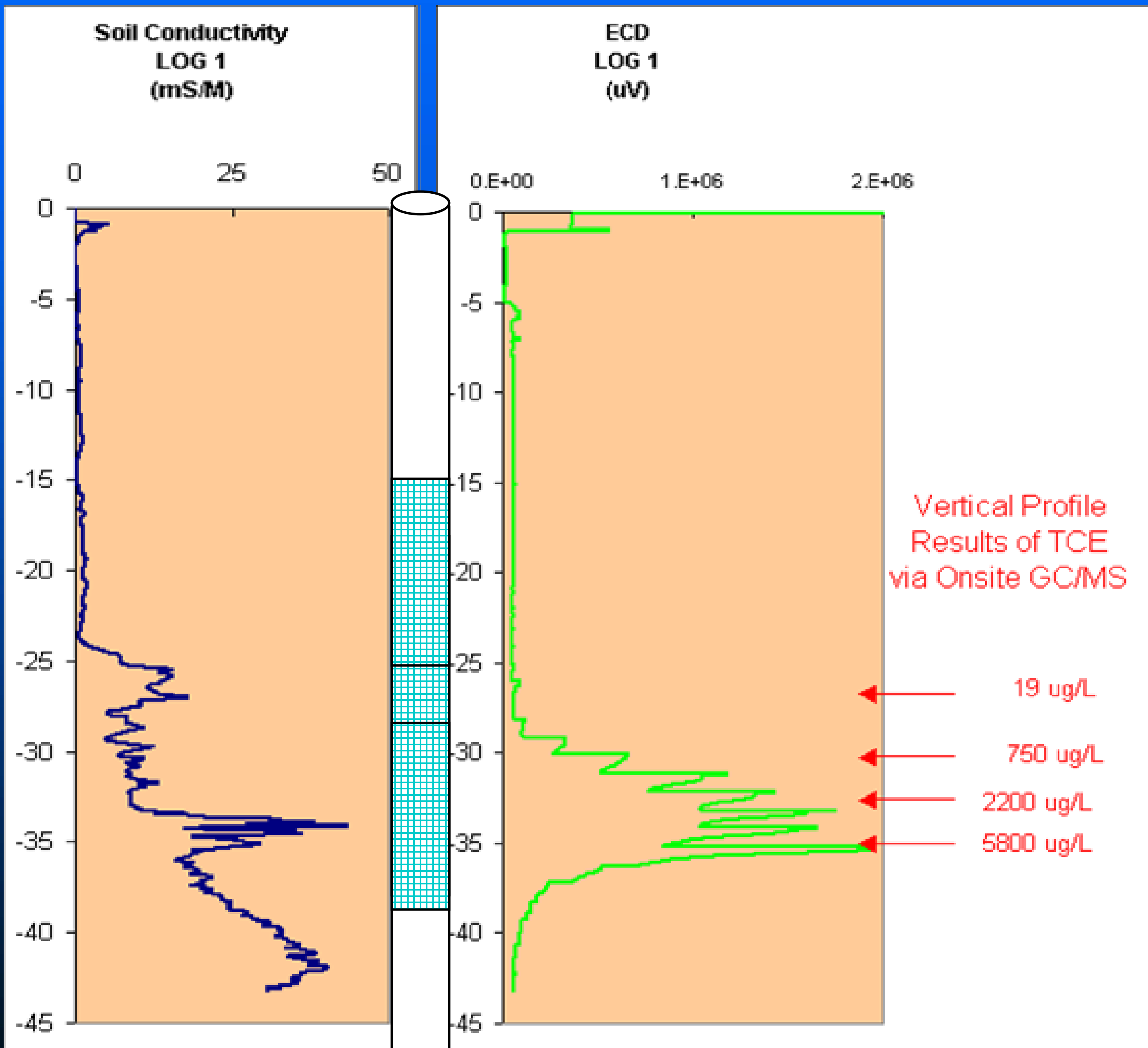


The decision driving sample collection:
Assess contamination resulting from atmospheric deposition

Given that the dark surface layer is the soil layer impacted by atmospheric deposition ("the population of interest") relevant to this project:

Which sample support (white areas #1, #2, or #3, each homogenized before analysis) provides a sample that is representative of atmospheric deposition for this site?

A Different Sample Support Changes the Measured Contaminant Concentrations



MIP = membrane-interface probe (w/ ECD detector)

Sample support for MIP on scale of mm to inches

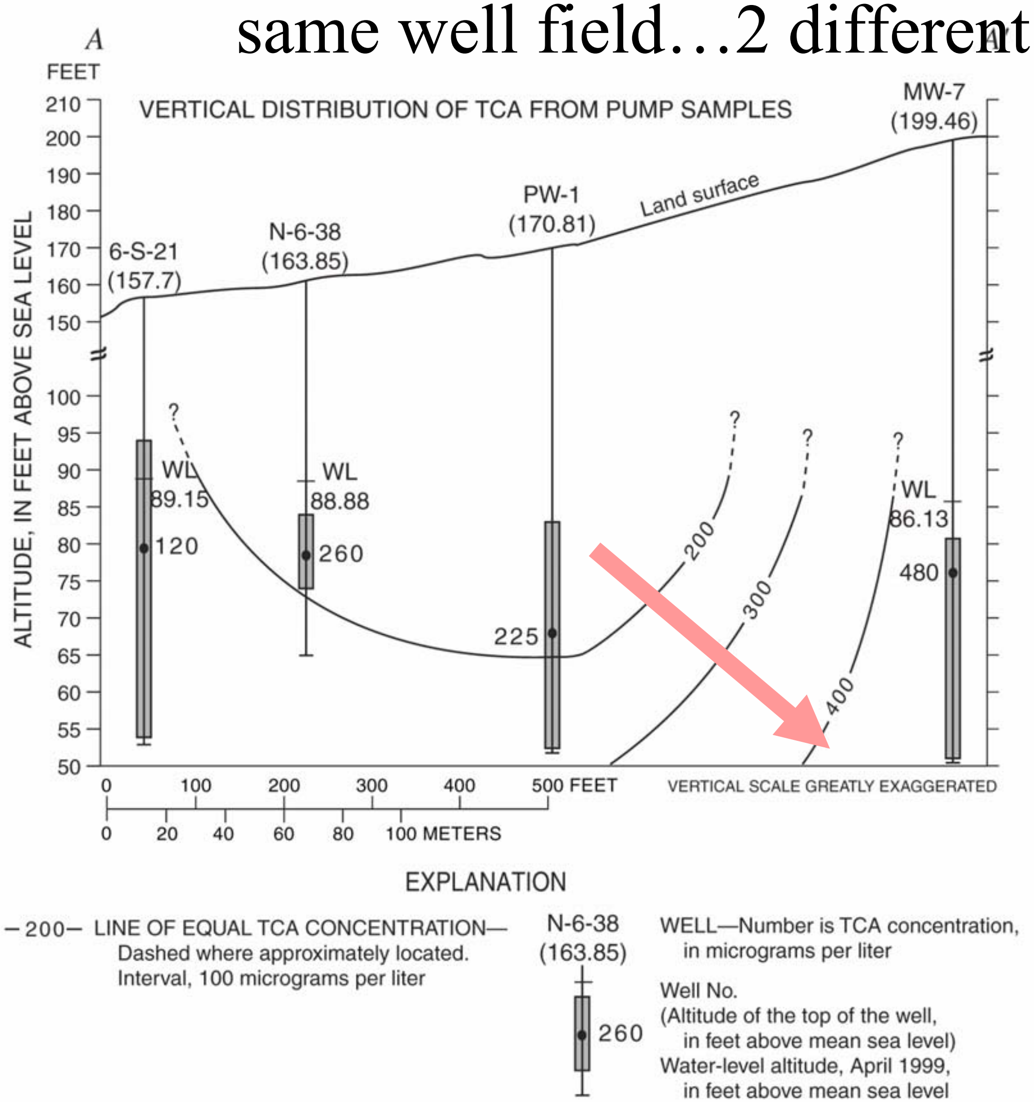
Sample support for discrete-depth GW samples on 6-in scale

Sample support for traditional well on sampling scale of feet

Graphic adapted from Columbia Technologies

Recall the Passive Diffusion Study…

same well field…2 different sample collection techniques



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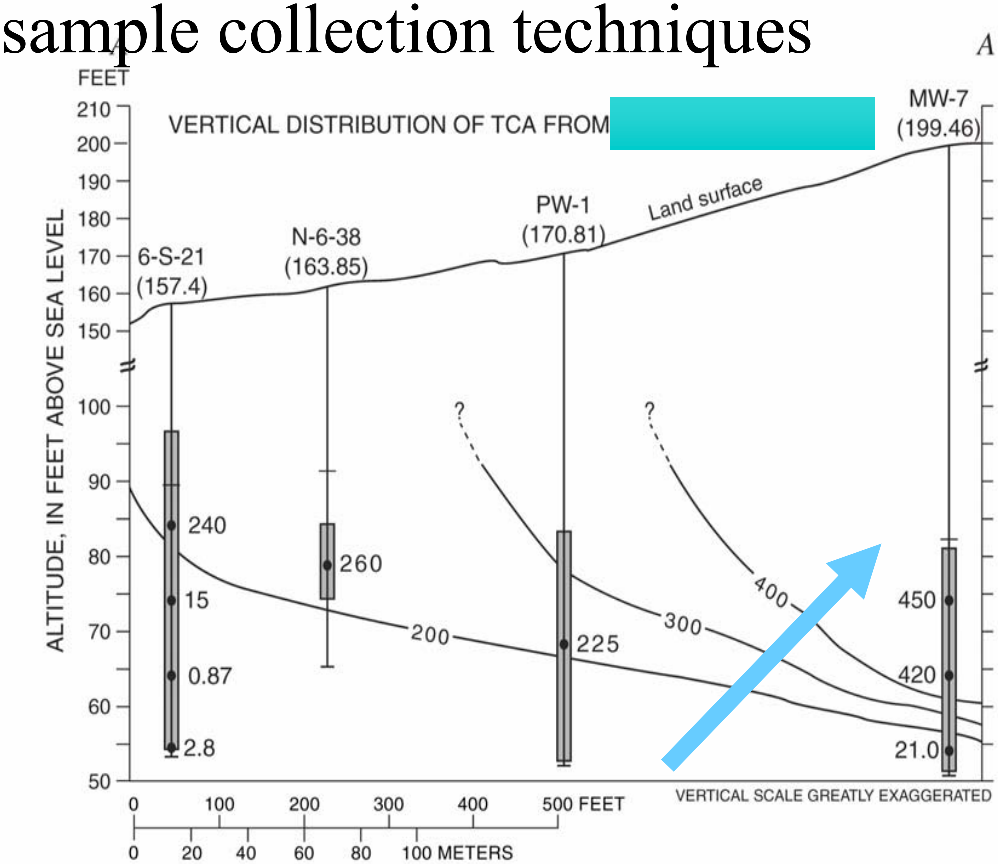


Figure 6.—*Continued.*

From USGS Report 02-4203 (2002)

http://water.usgs.gov/pubs/wri/wri024203/

Sample Support Can Spell the Difference Between Hits and NDs

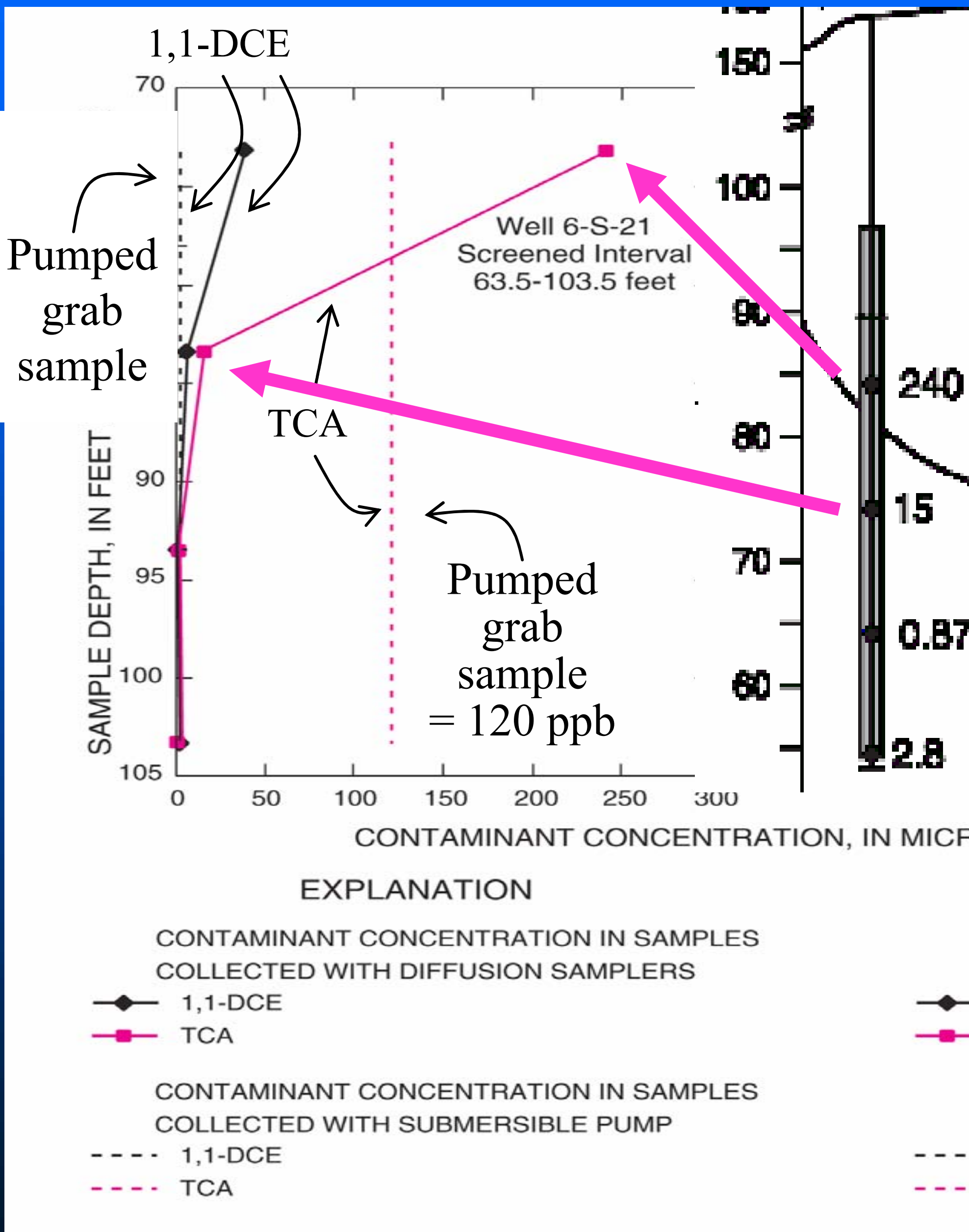


Figure 5. Comparison of selected volatile organic compound concentrations from and a submersible pump for wells with greater than 20-foot screened intervals in A

From USGS Report 02-4203 (2002); http://water.usgs.gov/pubs/wri/wri024203/

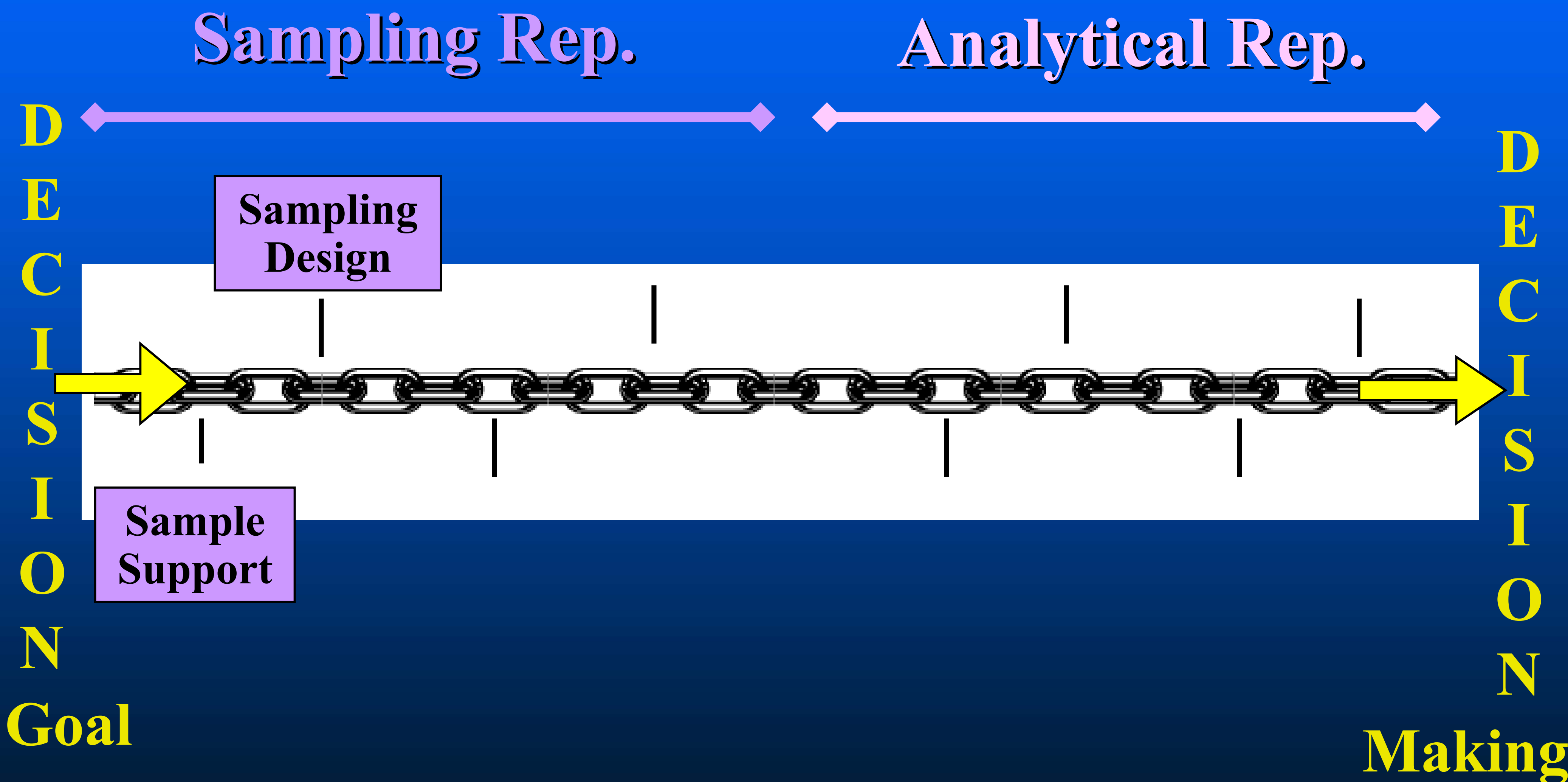
Particle Size: Another "Support" Variable
Different Particle Sizes Give Different Results

Soil Grain Size (Standard Sieve Mesh Size)	Soil Fraction-ization (%)	Pb Conc. in fraction by AA (mg/kg)	Lead Distribution (% of total lead)
Greater than 3/8" (0.375")	18.85	10	0.20
Between 4-mesh and 3/8"	4.53	50	0.24
Between 4- and 10-mesh	3.65	108	0.43
Between 10- and 50-mesh	11.25	165	2.00
Between 50- and 200-mesh	27.80	836	25.06
Less than 200-mesh	33.92	1,970	72.07
Totals	100%	927 (wt-averaged)	100%

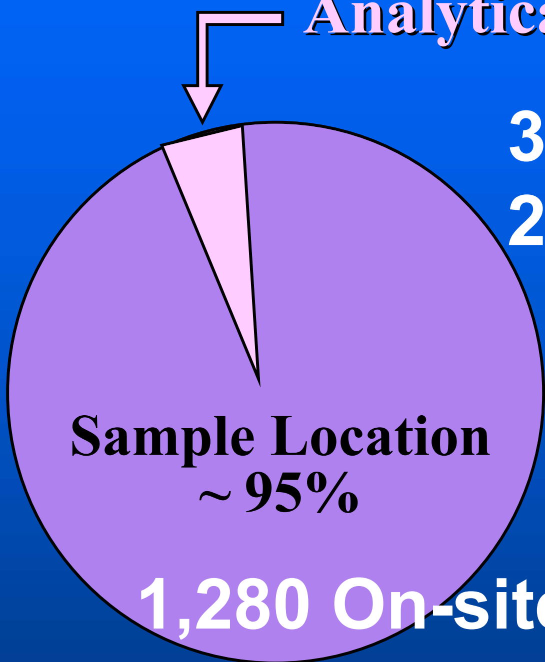
For this matrix, sampling/subsampling that captures larger particles will get lower results than procedures that get the smaller particles!! Cannot assume "average" is representative of decision!

Adapted from ITRC (2003); http://www.itrcweb.org/SMART-1.pdf

Sampling Design: Where & When Samples Are Collected



Can Your Sampling Design Avoid Decision Errors from Misleading Grab Sampling?



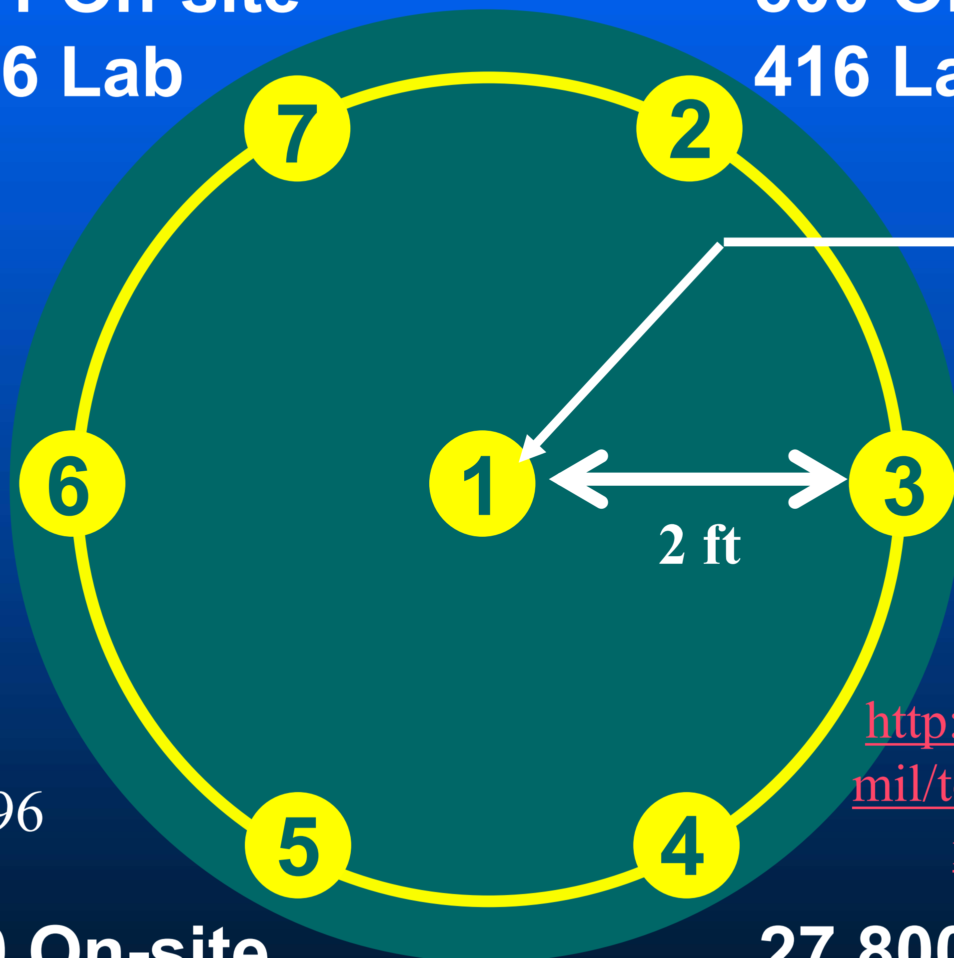
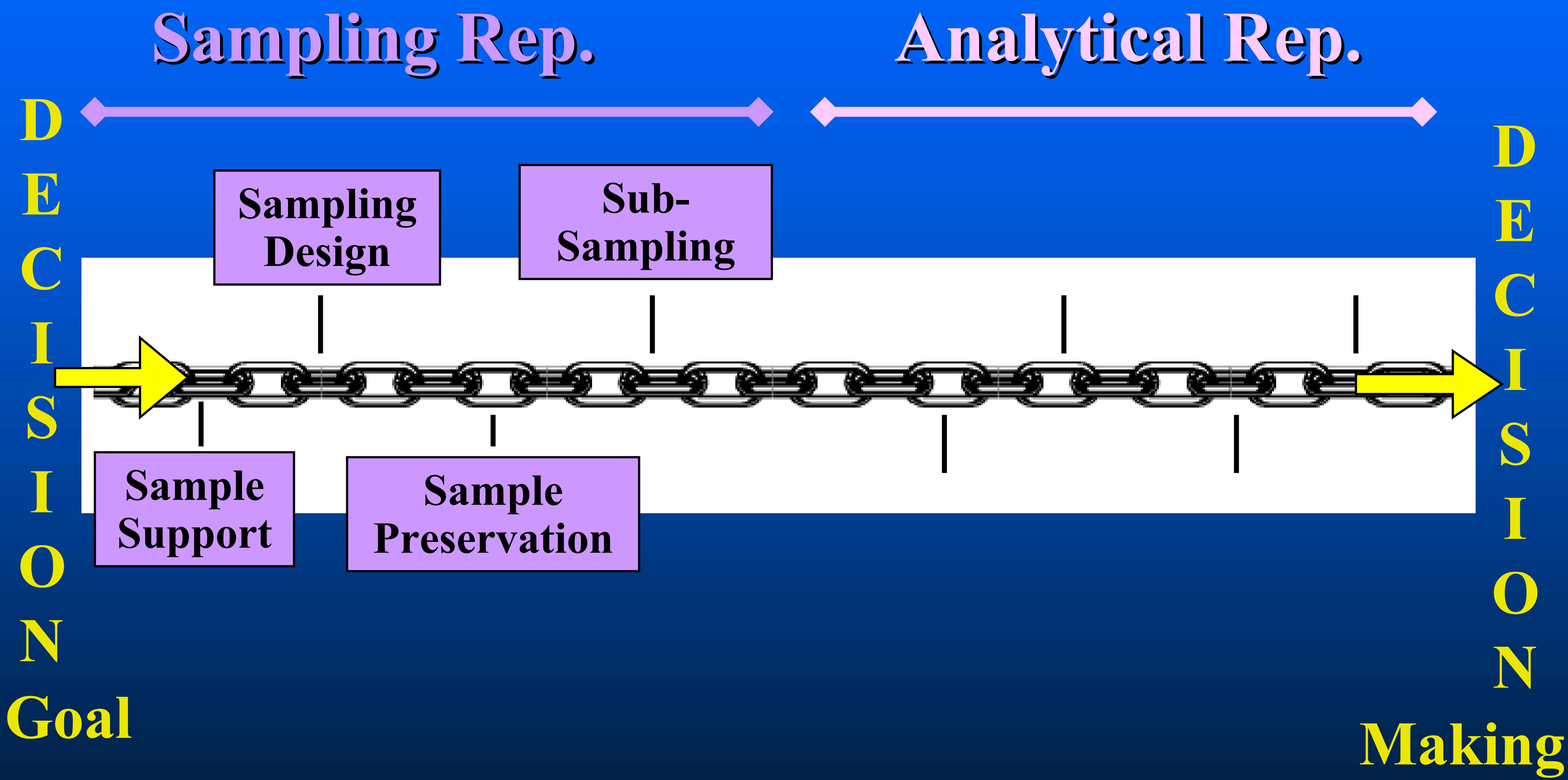


Figure adapted from Jenkins (CRREL), 1996

http://www.crrel.usace.army.mil/techpub/CRREL_Reports/reports/SR96_15.pdf

More Sampling Variables in the Data Quality "Chain"



All links in the Data Quality chain must be intact for data to be representative of the decision!

Is the Subsample Support Representative?

^{241}Am Concentration Varies w/ Subsample Support

Subsample Support (after sample was dried, ball-milled, sieved <10-mesh)	Coefficient of Variation	Number of subsamples required to estimate the sample true mean ± 25% *	Number of subsamples required to estimate the sample true mean ± 10% *
1 g	0.79	39	240
10 g	0.27	5	28
25 g	0.30	6	35
50 g	0.12	1	6
100 g	0.09	1	4

* Using classical parametric statistics at 95% confidence

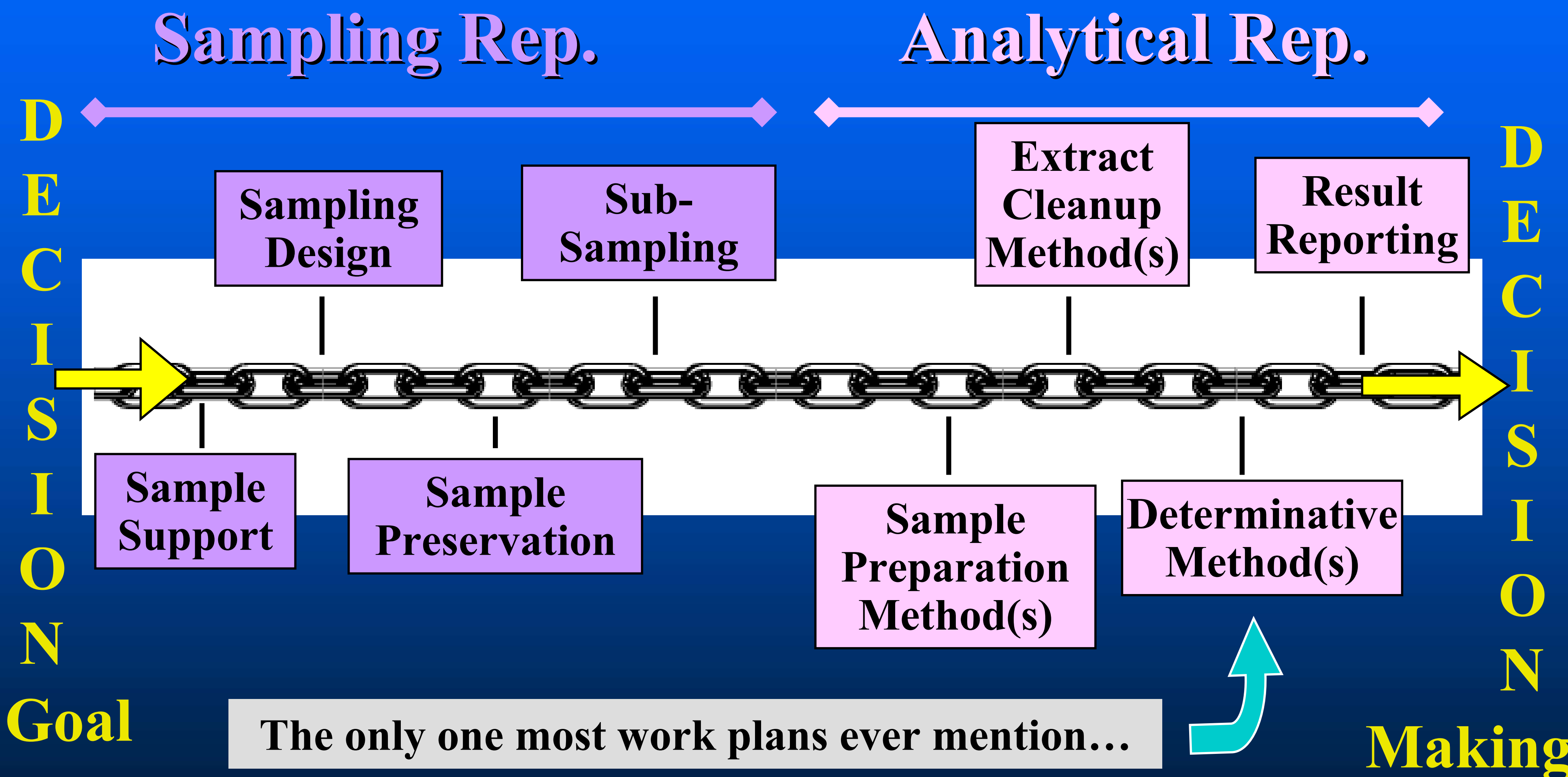
Adapted from DOE (1978)

Major problem!! Advancing analytical technologies use smaller and smaller subsample aliquots--undermine representativeness!

Generic Sampling Designs Cannot be Expected to Produce Representative Data for Heterogeneous Matrices

It is impossible to specify a one-size-fits-all data set that could be representative of all potential CSMs and site decisions!

Triad Data Quality Considers the Whole "Chain" of Sampling & Analytical Variables



All links in the Data Quality chain must be intact for data to be representative of the decision!

All this attention to detail becomes highly cost-effective when CSMs are built, and remediation activities are guided, in real-time

Mechanics of the
The Triad Approach

Systematic Project Planning

Dynamic Work Strategies

Real-time Measurement Technologies

Synthesizes practitioner experience, successes, and lessons-learned into an institutional framework

Unifying Concept for Triad: Managing Uncertainty

Systematic planning is used to proactively…

- **Manage uncertainty about project goals**
  - Identify decision goals with tolerable overall uncertainty
  - Identify major uncertainties (cause decision error)
  - Identify the strategies to manage each major uncertainty
- **Manage uncertainty in data**
  - **Sampling uncertainty:** manage sample representativeness
  - **Analytical uncertainty:** especially if field methods are used
- **Multidisciplinary expertise critical**
  - **A TEAM** is the best way to bring needed knowledge to bear

Dynamic Work Strategies

- Real-time decision-making "in the field" (often telecommunications assisted)
  - Implement pre-approved decision tree using senior staff
  - Contingency planning: most seamless activity flow possible to reach project goals in fewest mobilizations
- Real-time decisions need real-time data
  - Adaptive sampling design; in-field QC
  - Use off-site lab w/ short turnaround?
    - » Screening analytical methods in fixed lab?
  - Use on-site analysis?
    - » Mobile lab with conventional equipment?
    - » Portable kits & instruments?
    - » In situ detectors?

Mix And Match

In all cases, must generate data of <u>known</u> quality

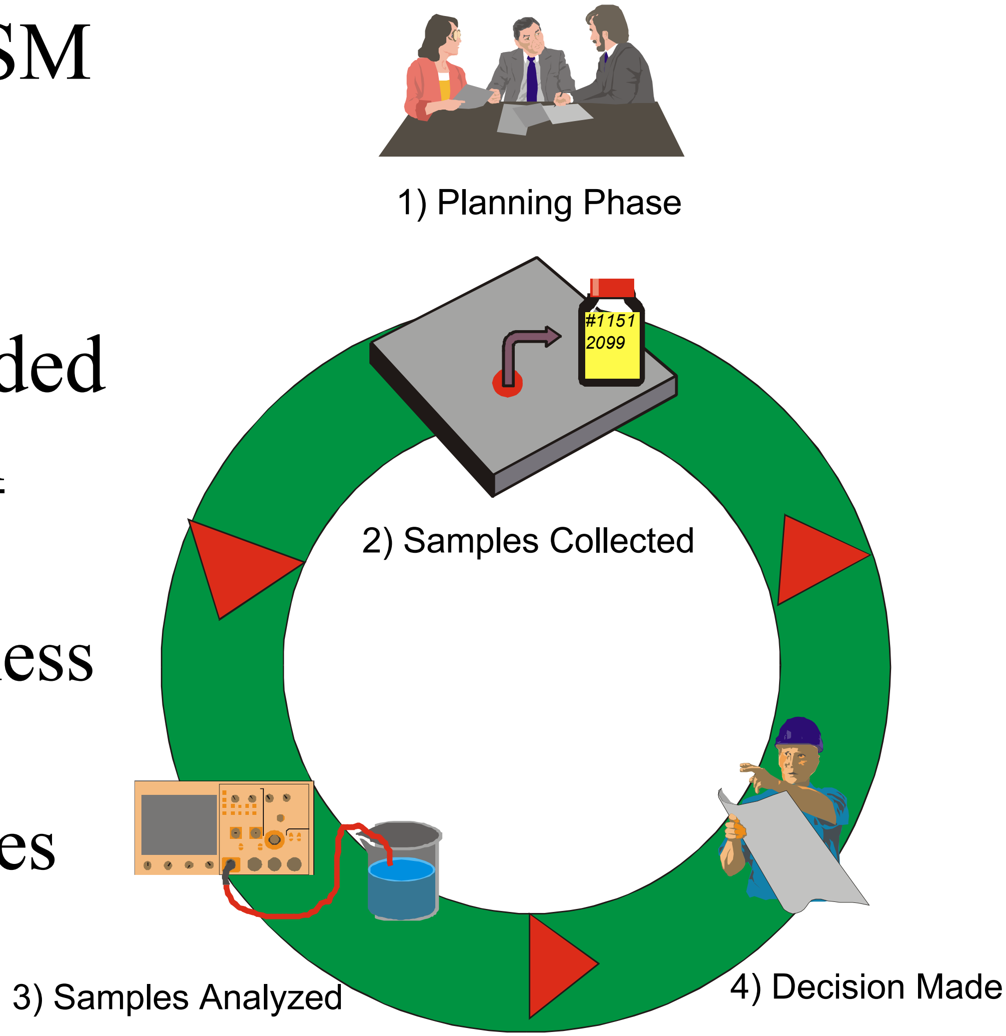
Triad's 3rd Element: "Real-time Measurement Technologies"

- Term was chosen carefully (takes more than just "field analytics")
- "Real-time Measurements"
  - Data turnaround that supports "real-time decision-making"
    - » Decisions made while the work crew remains in the field
    - » Includes rapid data turnaround from fixed lab
- "Measurement Technologies" more than just "test kits"
  - Rapid sampling platforms
  - Combination sampling-analysis capability of *in situ* technologies
  - Geophysical options
  - IMPORTANT: Software & IT tools to assist data management: data generation, data processing, data review, data interpretation, mapping/visualization, decision-support, & sharing

Summary

Despite the Up-Front Investment, Triad Planning Cuts Project Life-time Costs

- Achieve more confident characterization = accurate CSM
  - **Reduce # of mobilizations**
  - **More effective remedies**
- Fewer expensive samples needed to <u>achieve equivalent decision confidence</u>
  - Manage data representativeness using "cheaper" samples
  - Fewer un-informative samples using adaptive strategy



The Triad approach uses the concept of "managing uncertainty" as a compass that charts a clear course through the complexities of site cleanup science and policy.

Recognize Methods' Strengths & Limitations

Costly standard analytical methods

↓

Low DL + analyte specificity

↓

Manages analytical uncertainty
= analytical representativeness
= analytical quality

↙

"Definitive" analytical quality
Screening sampling quality →

Cheaper non-standard analytical methods

↓

High spatial density

↓

Manages sampling uncertainty
= sampling representativeness
= sampling quality

Builds CSM

↘

"Definitive" sampling quality
Maybe screening analytical qual. ←

Screening Quality Data

Triad's Data Quality Model for Heterogeneous Matrices

Cheaper (lab? field? standard? non-standard?) **analytical methods**

↓

High density sampling

↓

Manages CSM & sampling uncertainty

Costlier rigorous analytical methods

↓

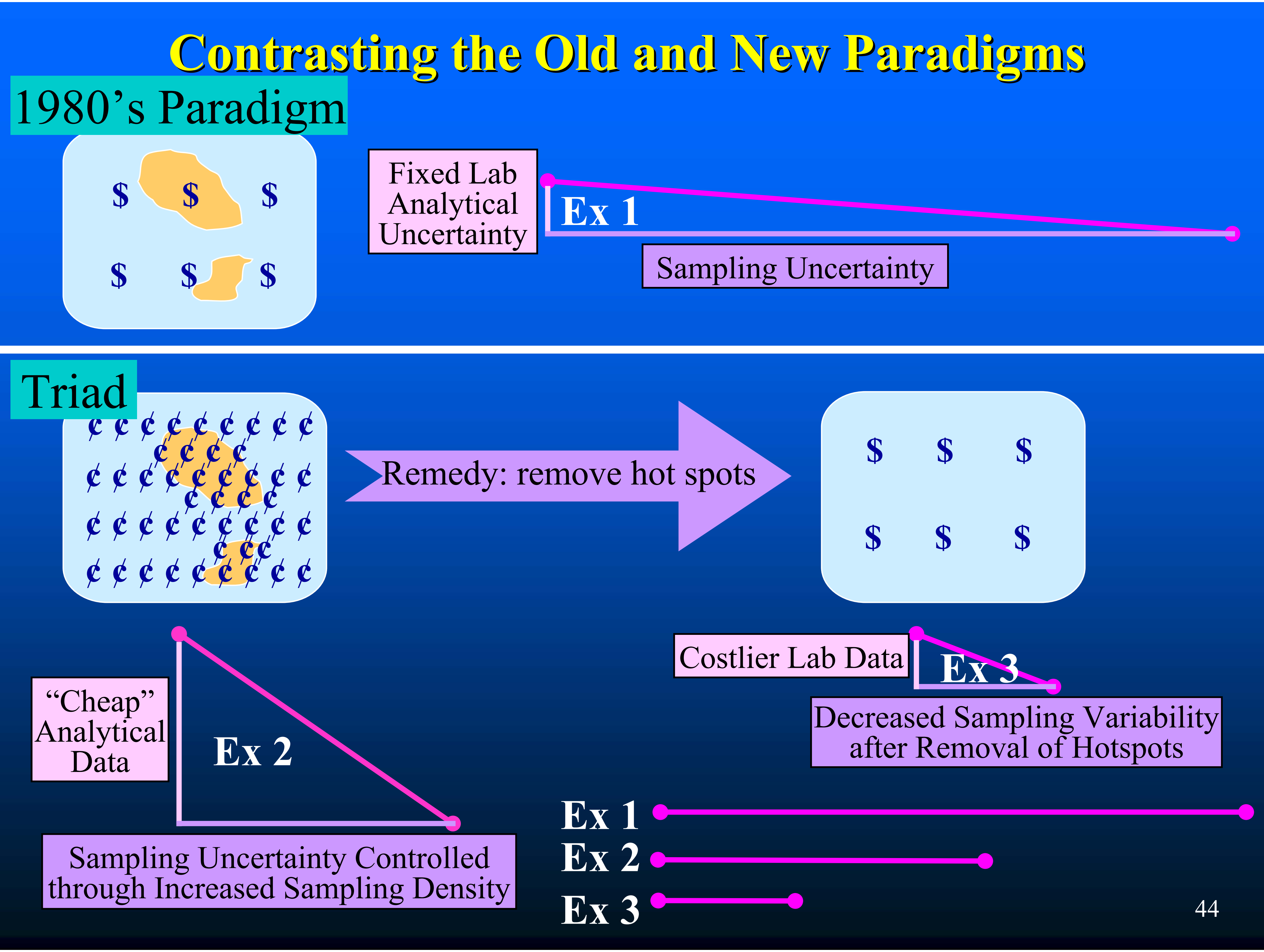
Low DL + analyte specificity

↓

Manages analytical uncertainty

Collaborative Data Sets

Collaborative data sets complement each other so that all sources of data uncertainty important to the decision are managed


Contrasting the Old and New Paradigms
1980's Paradigm
$ $ $
$ $ $
Fixed Lab Analytical Uncertainty
Ex 1
Sampling Uncertainty
Triad
Remedy: remove hot spots
$ $ $
$ $ $
"Cheap" Analytical Data
Ex 2
Sampling Uncertainty Controlled through Increased Sampling Density
Costlier Lab Data
Ex 3
Decreased Sampling Variability after Removal of Hotspots
Ex 1
Ex 2
Ex 3
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