Sampling Considerations for Characterization of DoD Training Ranges

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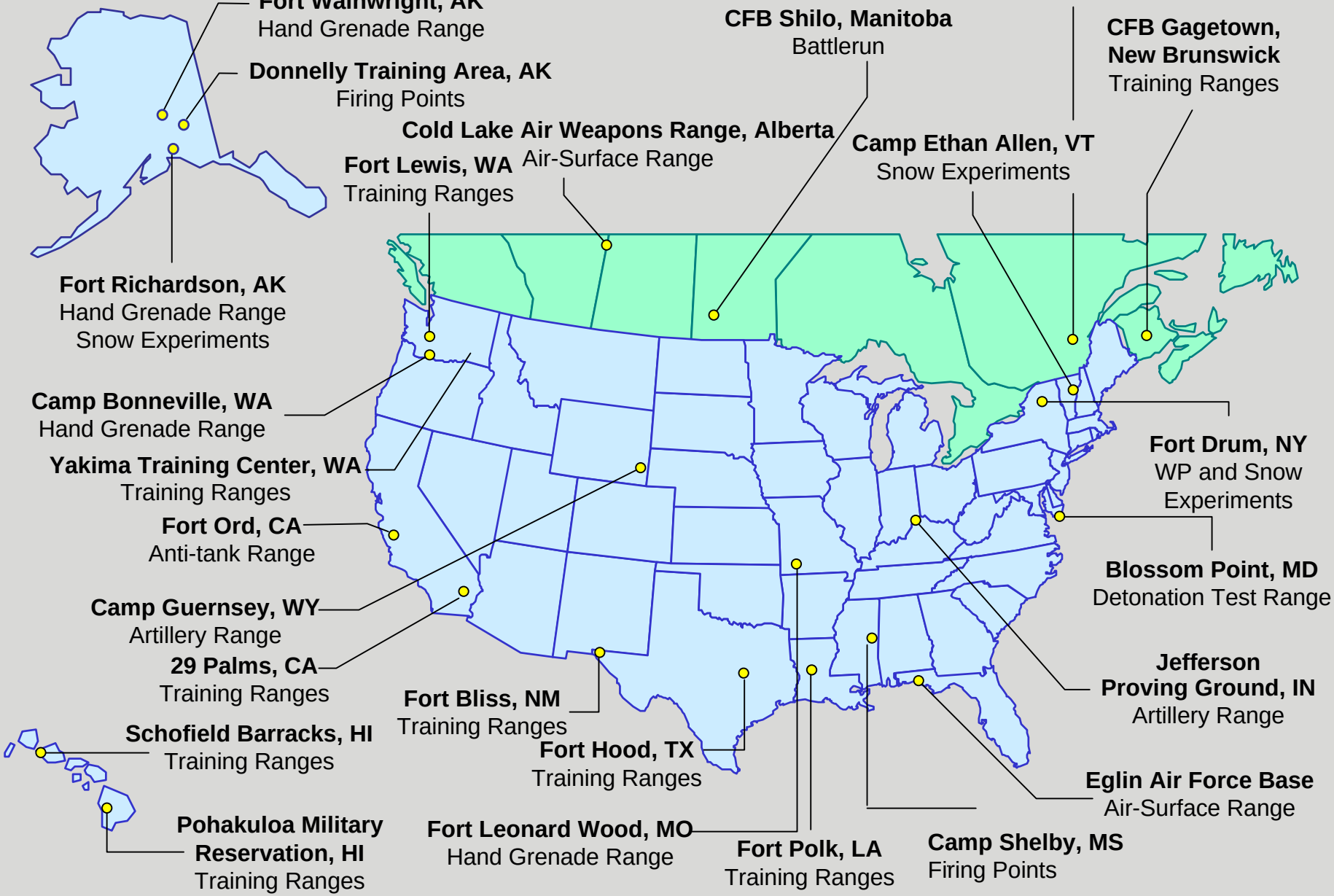
Ranges Studied



Data Quality Objective (DQO)

- Defines what data is needed for the decision
- Defines the inputs to the sampling design
- Defines how we make the decision

Data “Uncertainty”

- Field sampling error
- Sample processing error
- Laboratory subsampling error
- Analytical error

Total Error = $(FSE^2 + SPE^2 + LSE^2 + AE^2)^{1/2}$

Why be Concerned With Sampling Error ?

- “the major source of decision uncertainty (as much as 90% or more by some estimates) is due to sampling variability”
- “If evidence for representativeness is not presented, the data cannot be characterized as effective for project decision-making.”

  – *D.M. Crumbling EPA Technology Office*

Subsampling Error

- “Improper subsampling can lead to highly variable and biased analytical results that are not amenable to control through standard quality control measures. This can cause misleading results for decision makers relying on measurement results to support corrective actions.”
  - Guidance for Obtaining Representative Laboratory Analytical Subsamples from Particulate Laboratory Samples, EPA 600/R-03/027, 2003

DQOs in a Nutshell

- It is thinking about what you are going to do before you do it

- Three question the must be answered
  - What is the question to be answered?
  - What population is the question referring to?
  - How much and what type of confidence is desired in the answer?

Magic Formula

Number of Samples = budget / cost per sample

- Is this scientifically correct ?
- Is this defendable ?
- Is there a better way ?
- Is this what you do ?

Proper (Representative) Sampling is Controlling Heterogeneity

- Heterogeneity and resulting sampling errors must be completely understood
- Heterogeneity is measured in terms of sampling errors
- Different sampling strategies will yield different sampling errors
- Sampling error is then mitigated to an acceptable level, if necessary to meet the DQOs

How is Heterogeneity Controlled?

- Compositional heterogeneity leads to fundamental error which is controlled by sample mass.

- Distributional heterogeneity leads to grouping and segregation error which is controlled by required sample mass with many increments.

Most Difficult Step in DQOs "Determine the Population"

- Management unit
  - firing point / target / blow-in-place of UXO
- Exposure unit
  - habitat / maneuver area / chunk residue "hot spots"
- Treatment unit
  - (In all cases they could be called the "Decision Unit")

What do we want to know about the “decision unit”?

- Averages?
- Hot spots?
- Maximum value?
- Variability?
- Above background?

Average !

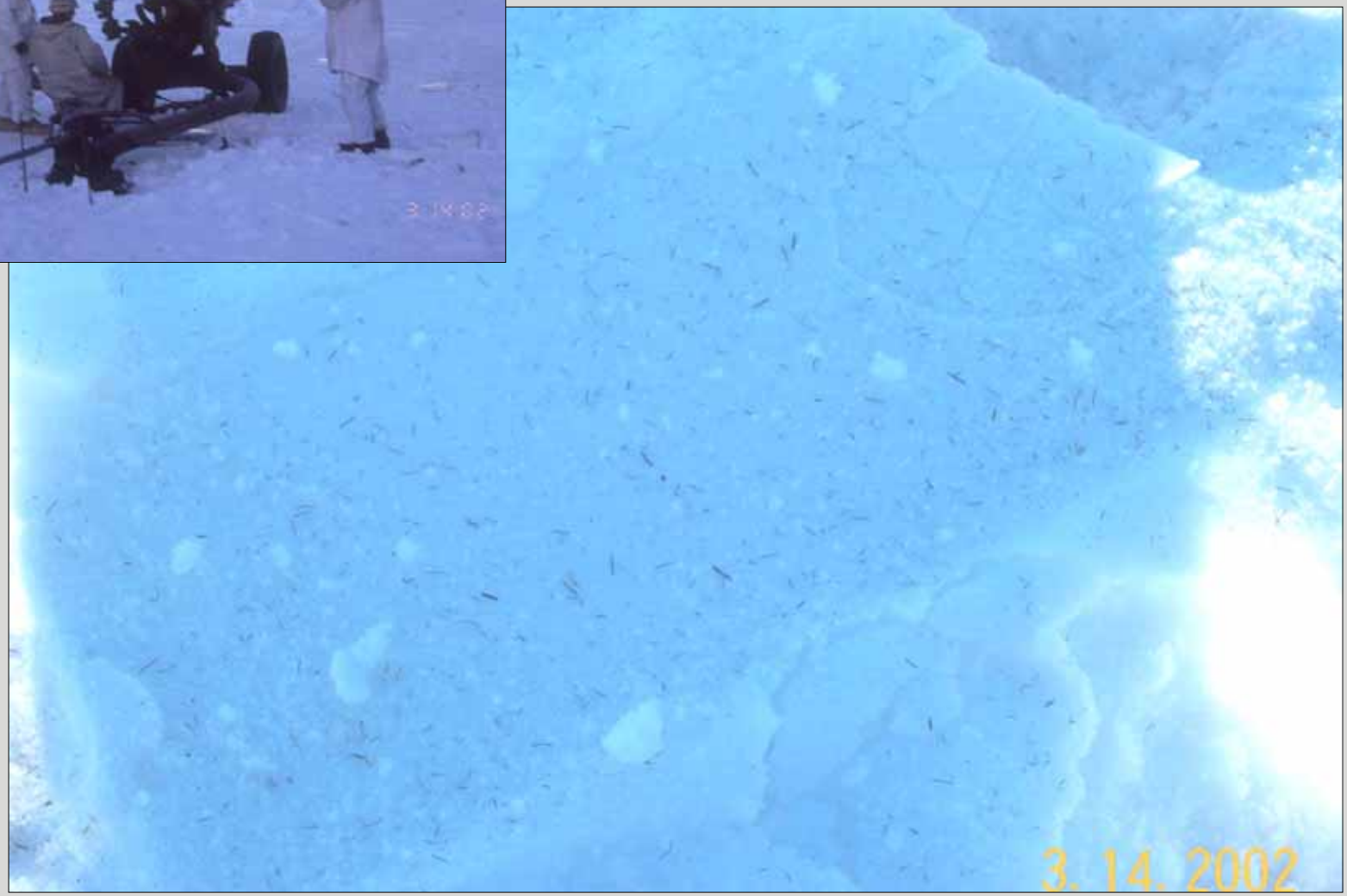
- “The overall goals of the sampling effort are to estimate an average soil lead concentration for risk assessment purpose”

- “Project managers should carefully choose the sampling points needed to estimate the average lead concentration in a cost-effective manner”

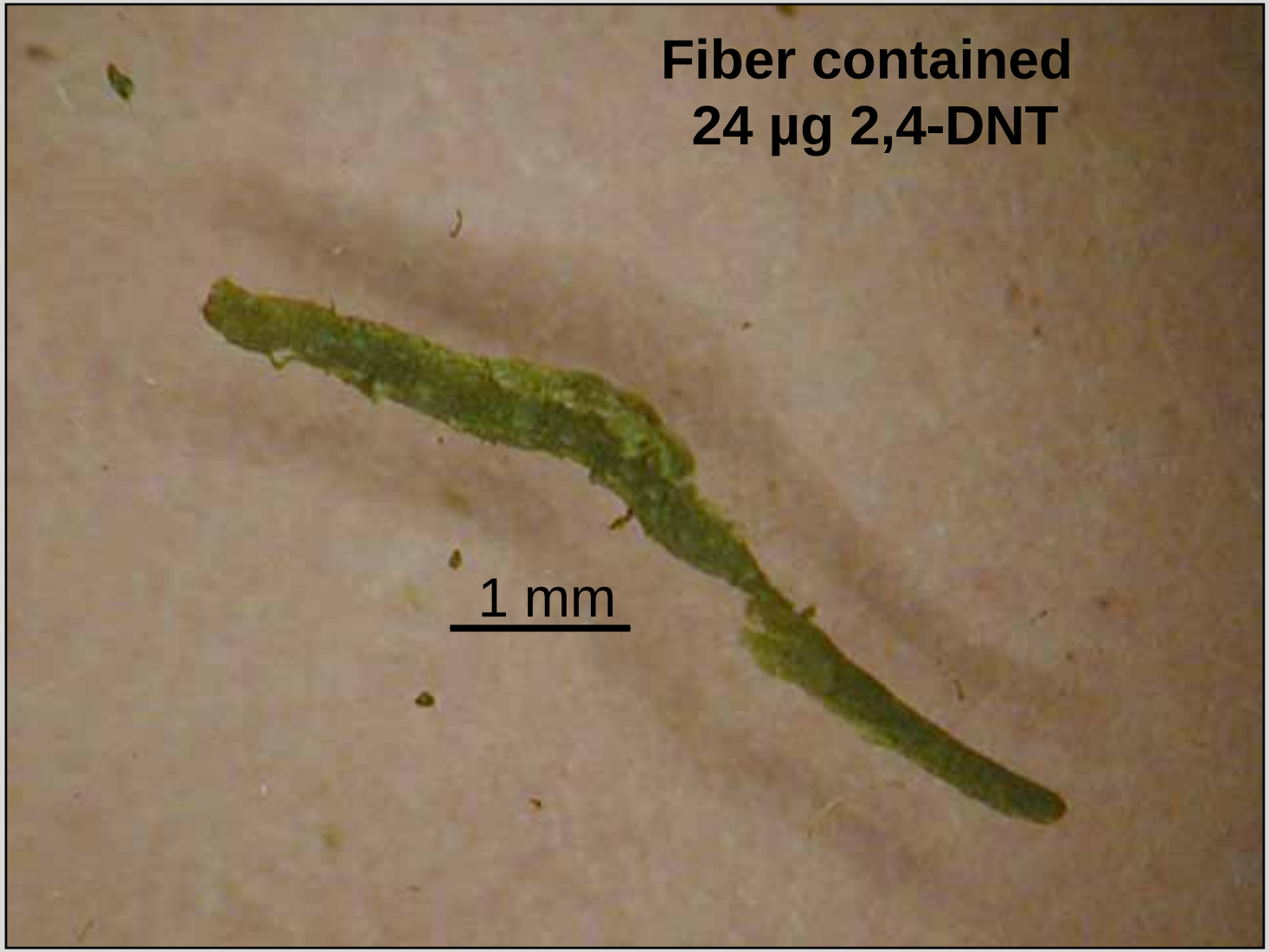
* Superfund Lead-Contaminated Residential Sites Handbook
  OSWER 9285.7-50.2003

105-mm Howitzer fired at Ft. Richardson, AK

Propellant Fibers



Propellant Fiber from 105-mm Projectile



Blow-in-place of a 155-mm Howitzer Round

81-mm Mortar Round BIP Plume
(≈850 m^2)

M67 Hand Grenade Plume

(20 to 100 m^2)

CFB-Valcartier Antitank Range

Energetic Residue Surface Concentrations around a Line of Site Target

CFB-Valcartier
Antitank Rocket Range

HMX Concentrations
(mg/kg)

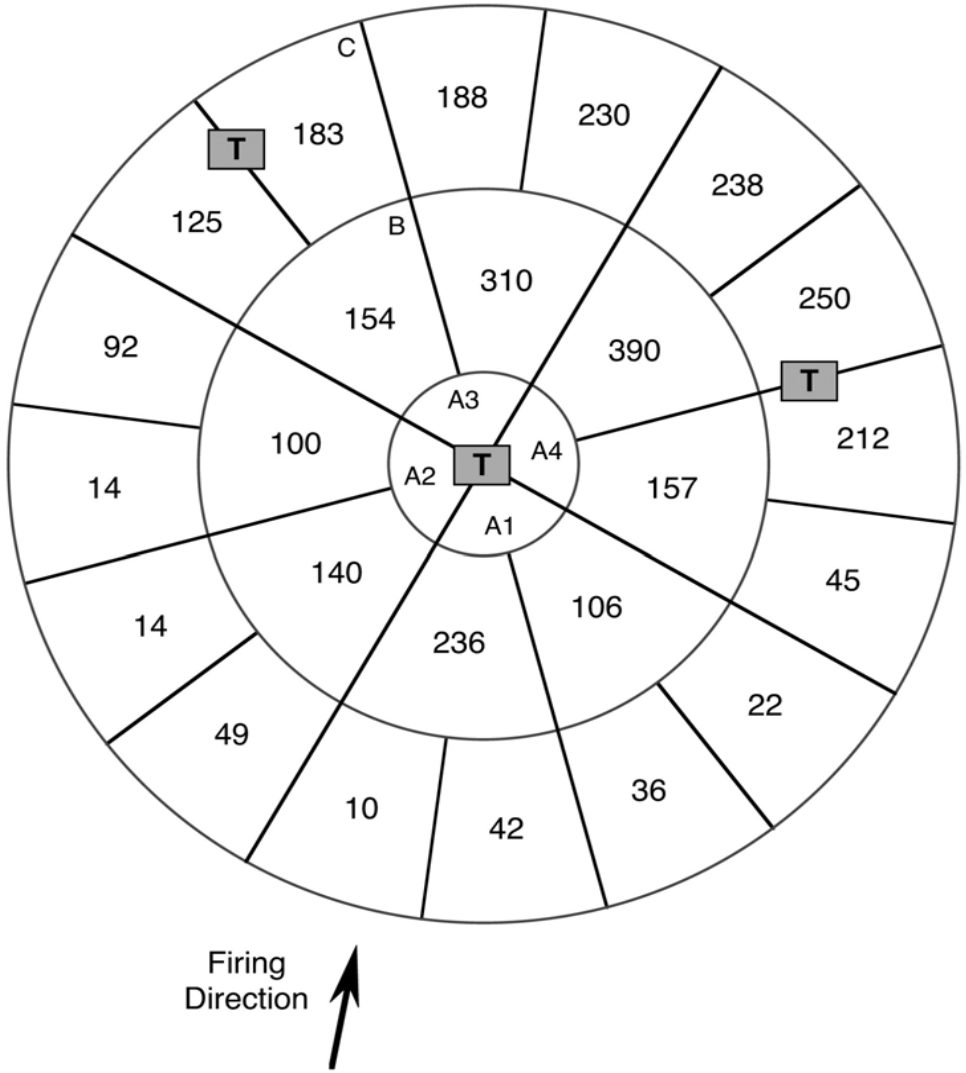
A1 – 1,230
A2 – 1,100
A3 – 924
A4 – 336

Halo Mean Values

A – 898
B – 199
C – 112

Halo Radius

A - 5 m
B - 15 m
C - 25 m



105-mm Howitzer Firing Point

Sampling Objective:

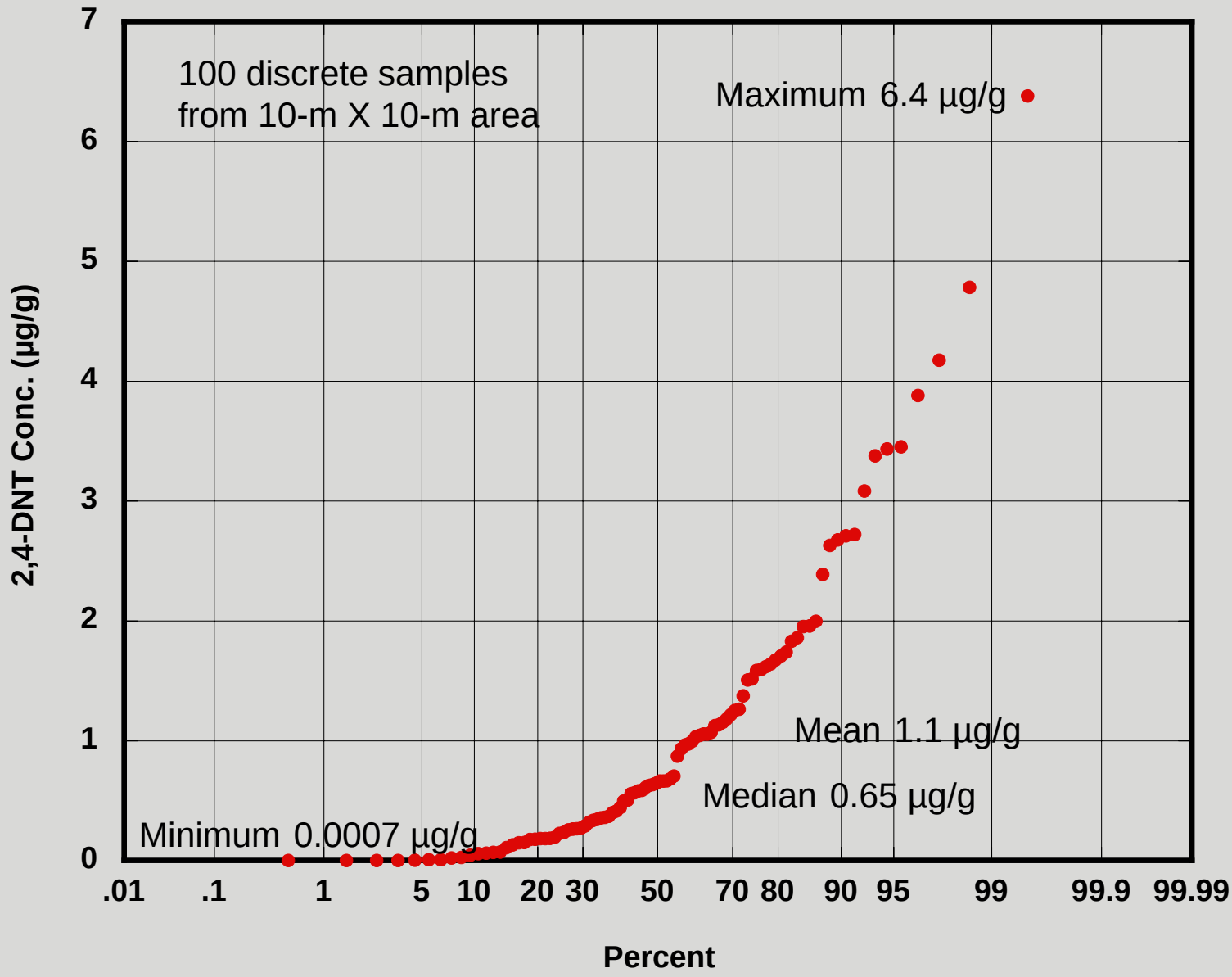
What is the mean concentration of 2,4-DNT in a 10-m X 10-m area at a 105-mm Howitzer Firing Point?

Method: 100 discrete samples collected in 1-m x 1-m cells within a 10-m X 10-m grid.

Results:

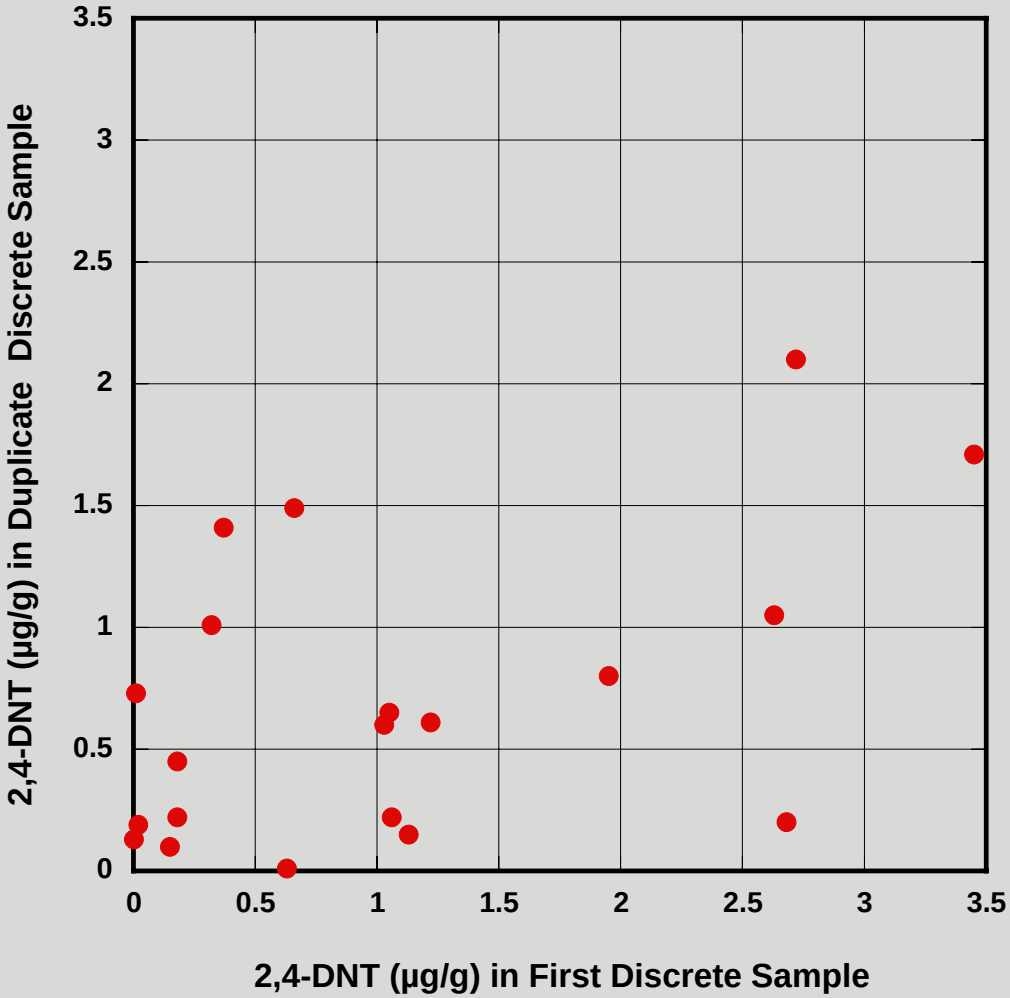
Number of Samples:	100
Minimum:	0.0007 µg/g
Maximum	6.4 µg/g
Mean:	1.1 µg/g
Standard Deviation:	1.2 µg/g
Median:	0.65 µg/g

Normal Probability Plot: 100 Discrete Samples



Sampling Objective:

What is the short range (within 1-m^2) spatial variability of 2,4-DNT (µg/g)?



Individual discrete samples are useless for representing 2,4-DNT concentrations in a 1-m^2 area.

Multi-increment Sampling

- Pooling of several individual subsamples
- Typically used to obtain an estimate of the mean concentration
- Reduces analytical costs
- Normalizes data

Why Fear “Composites”?

- Lack of understanding of regulations and models
- Historical meaning of what composites are
- Think grabs are more protective--but are not
- Been told and did not question

Sampling Objective:

What is the mean concentration of 2,4-DNT in a 10-m X 10-m area at FP Mark?

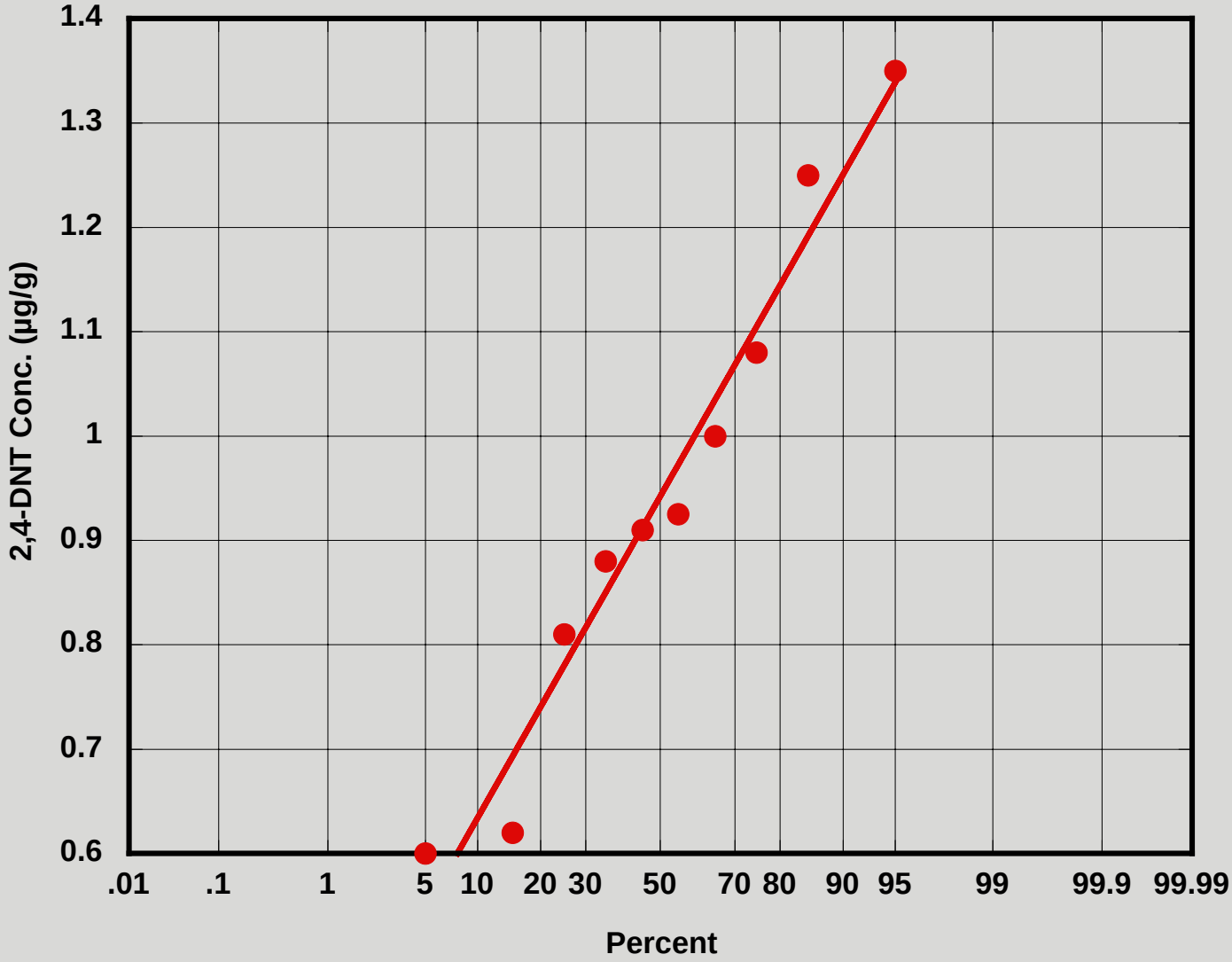
Method: Ten 30-increment samples from random locations within 10-m X 10-m area.

Results:

Number of Samples:	10
Minimum:	0.60 mg/kg
Max:	1.35 mg/kg
Mean:	0.94 mg/kg
Standard Deviation:	0.24 mg/kg
Median:	0.92 mg/kg

Normal Probability Plot:

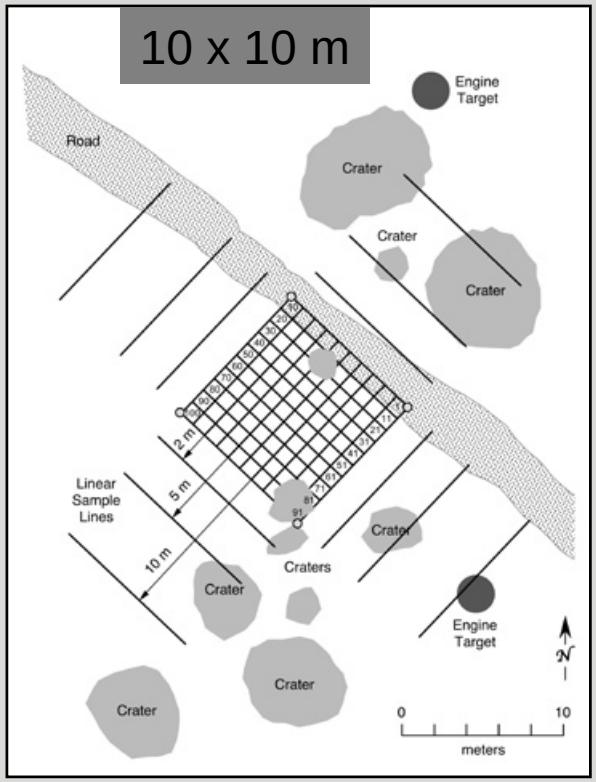
Ten 30-Increment Composite Samples



Artillery/Mortar Range

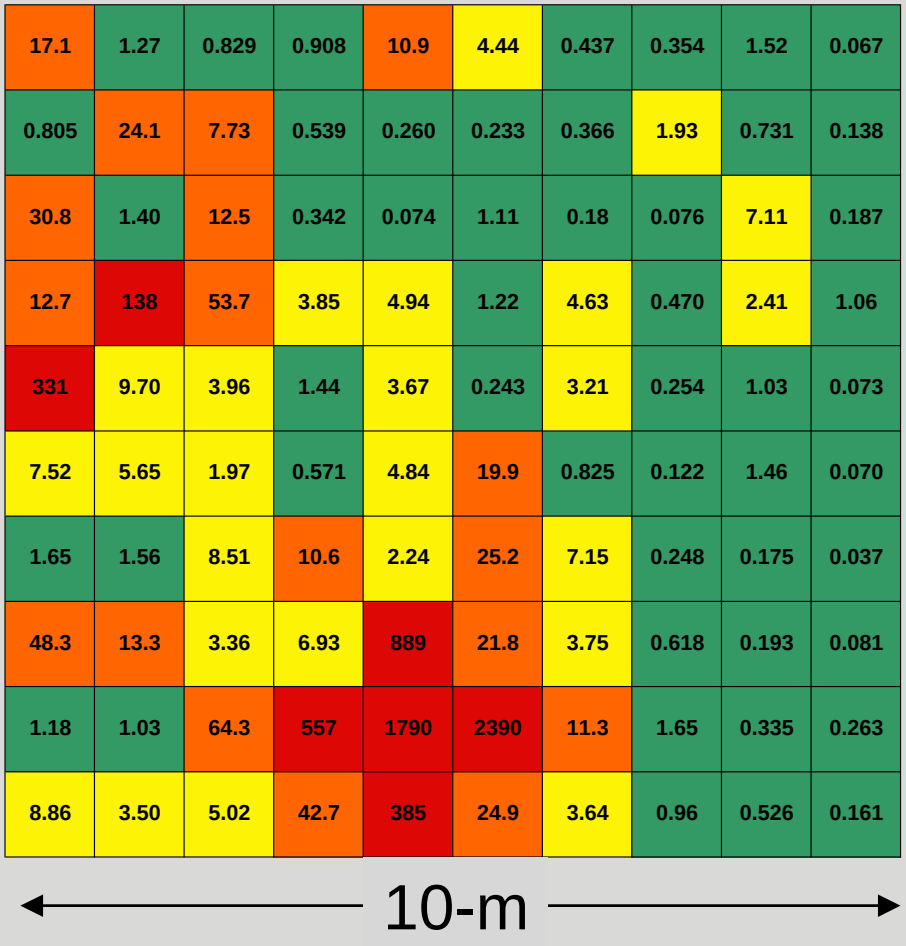
“Hot Spot”

10-m x 10-m Chunk Residue



Cobble-size Pieces of Composition B (60/40 RDX/TNT)

RDX Concentrations (mg/kg) in a 10- x 10-m chunk residue "Hot spot" area on artillery/mortar impact range



- Hotspots two to three meters in size
- Mean 71 mg/kg
- Loading: 300 g RDX
  100 g chunks
  200 g top 2.5 cm soil

Sampling Objective:

What is the mean concentration of RDX in a 10- x 10-m area at an artillery/mortar impact area?

Method: 100 discrete samples collected in 1-m x 1-m cells within a 10-m X 10-m grid.

Results:

Number of Samples:	100	
Minimum:	0.037	mg/kg
Maximum	2390	mg/kg
Mean:	71	mg/kg
Standard Deviation:	315	mg/kg
Median:	1.8	mg/kg

Sampling Objective:

What is the mean concentration of RDX in a 10- x 10-m area at an artillery/mortar impact area?

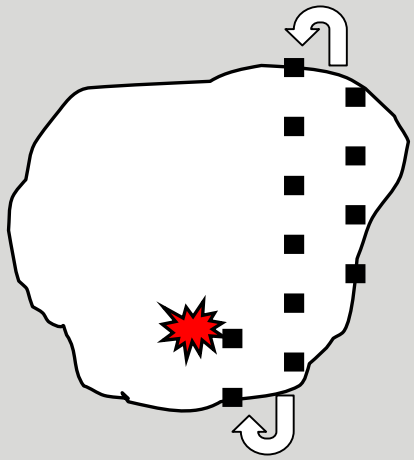
Method: Ten 25-increment samples from random locations within 10-m X 10-m area.

Results:

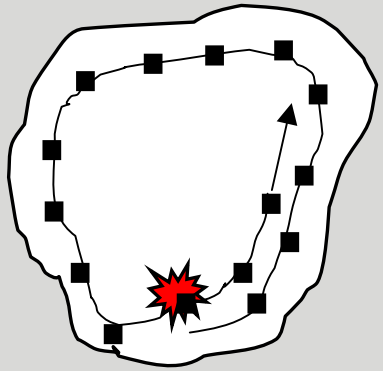
Number of Samples:	10	
Minimum:	4.6	mg/kg
Max:	290	mg/kg
Mean:	54	mg/kg
Standard Deviation:	86	mg/kg
Median:	25	mg/kg

Systematic Sampling Designs

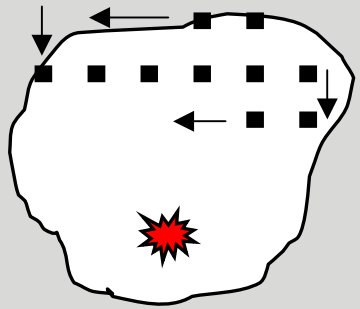
BIP- on snow



Laps



Spiral



Grid

* Sample the entire decision unit collected evenly spaced increments

Sampling Objective:

What is the mean concentration of RDX in a 10- x 10-m area at an artillery/mortar impact area?

Method: Four 25-increment samples using systematic sampling design within 10-m X 10-m area.

Results:

Number of Samples:	4
Minimum:	33 mg/kg
Max:	100 mg/kg
Mean:	71 mg/kg
Standard Deviation:	43 mg/kg
Median:	75 mg/kg

Surface Loading Estimates

Estimates of RDX residue surface loading at impact range targets.

Installation	Munitions	Size of Area (m^2)	Depth (cm)	Chunks present (yes/no)	Average conc. (mg/kg)	Mass (g) per area sampled	mg/m^2
A	Artil/Mrt/Rockets	10,000	2.5	Yes	1.2	510	51
A1	Artil/Mrt/Rockets	100	2.5	Yes	7.6	32	320
A2	Artil/Mrt/Rockets	100	2.5	No	0.029	0.12	1.2
B	Artillery/Bombs	10,000	1.5	Yes	2	510	51
B1	Artillery/Bombs	100	1.5	Yes	0.34	0.87	8.7
C	Artillery/Bombs	2,800	1.5	No	2.8	200	71
D1	Artillery/Bombs	10,000	1.5	Yes	5.6	1,400	140
D2	Artillery/Bombs	100	1.5	Yes	13	33	330
E	**Artillery/Mortars**	**100**	**2.5**	**Yes**	**55**	**230**	**2300**
F	Artillery/Mortars	10,000	2.5	No	<d	<d	<d
G	LAW Rockets	100	1.5	No	0.69	1.8	18

Discrete Samples

- **For 100 discrete samples from each of the 10-m x 10-m areas sampled:**

  - The median was always less than the mean.

  - Individual discrete samples underestimated the mean most of the time.

  - Standard deviations were equal or greater than the mean.

  - Statistical analyses based on normal distributions would be invalid.

Discrete Samples vs Multi-Increment Composite Samples

- Can a single discrete sample represent a 10-m x 10-m area? **NO**
- Can a single discrete sample represent a 1-m x 1-m area? **NO**
- Are the data from 100 discrete samples normally distributed? **NO**

Recommendation:

To determine mean concentration

- collect **multi-increment (composite) samples**.

To assess sampling uncertainty

- collect replicate **multi-increment (composite) samples**.

Recent Publications

www.crrel.usace.army.mil/techpub/

TR-04-7 TR-04-14 TR-05-5 TR-05-6

Jenkins et al. (2005) Representative Sampling for Energetic Compounds at Military Training Ranges. *Environmental Forensics*, 6:45-55.