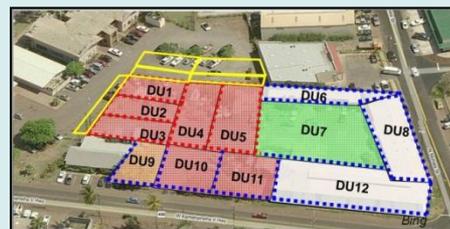
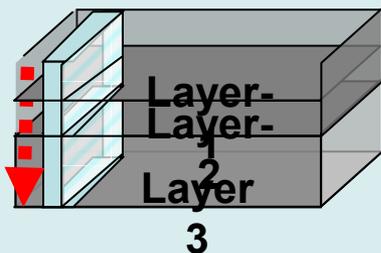


US EPA ARCHIVE DOCUMENT

# Evaluating and Improving Confidence in Site Investigations and Cleanup Decisions:

## Incremental Sampling Methodology



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**Tetra Tech, Inc.**

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**State of California, DTSC**

# Goals for Today:

- Introduce the concepts 5 min
- What is Incremental Sampling Methodology? 5 min
- What about traditional sampling? 5 min
- How does contamination exist in soil and how is it measured? 15 min
- Advantages of ISM 10 min
- ISM examples 10 min
- Questions/Discussion 10 min

# Why do we sample?

- ▶ To find the concentration of a constituent in a mass or volume of soil
- ▶ To make sound decisions

## What do we do with the results?

- ▶ To determine if a site is clean, needs further investigation, or cleanup
- ▶ To make important decisions! (= \$\$\$\$\$)

# What is Incremental Sampling Methodology?

- ▶ Highly structured composite sampling and processing protocol
- ▶ 30 – 50 “increments” collected to represent an average concentration over a defined area of interest (decision unit)
- ▶ Increments are grid-based or random
- ▶ Increments are not intended to characterize specific sub areas: they represent a population
- ▶ ISM attempts to control - or at least quantify - heterogeneity within a defined area of interest through collection of replicates

# Determine and Mark Increment Grid

**X** Primary ISM

**X** Replicate ISM



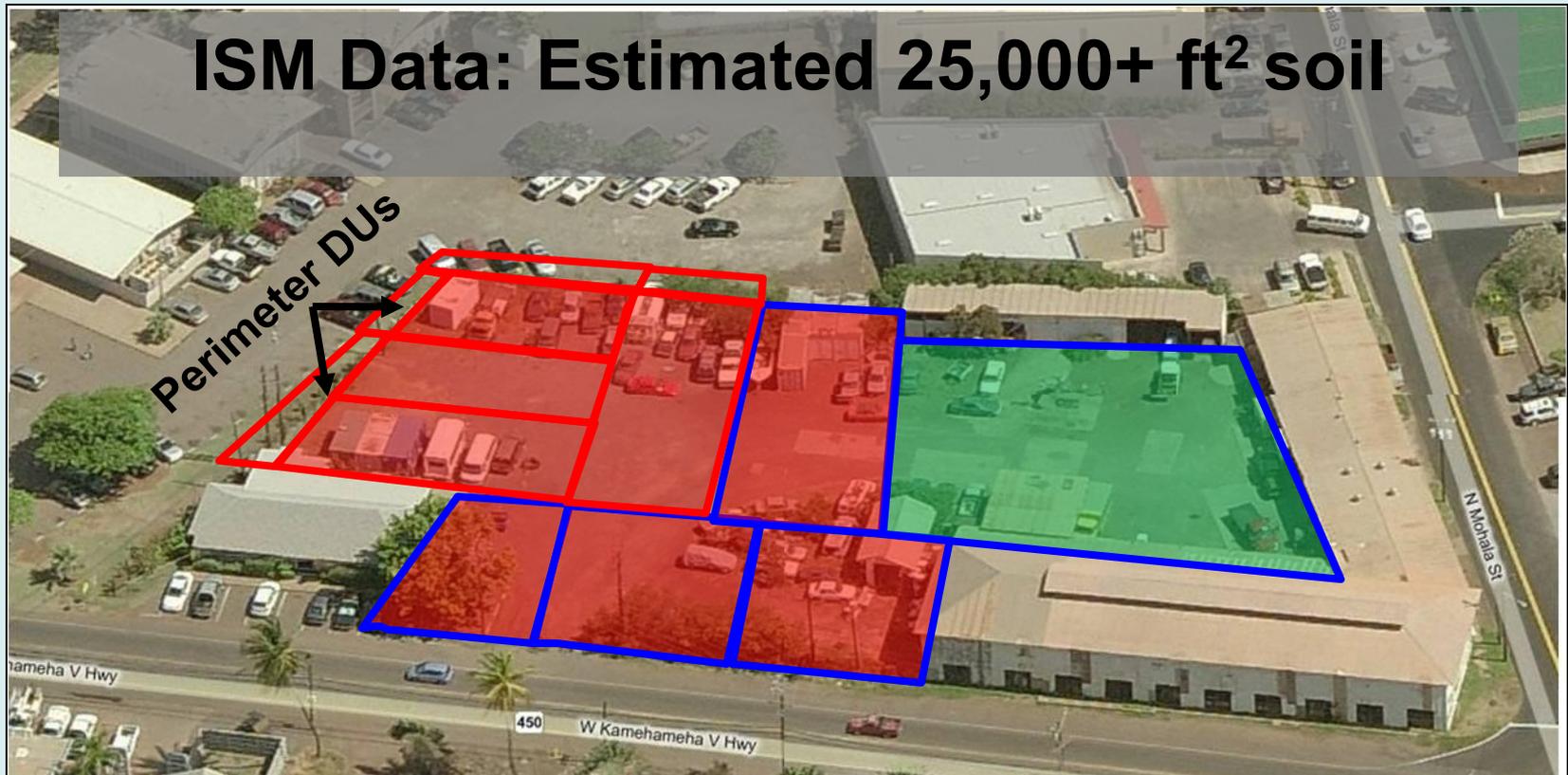
# Sample Decision Units



# Sample Decision Units

 > Action Levels

 ≤ Action Levels



# ISM Bulk Sample (typically 1-3kg)



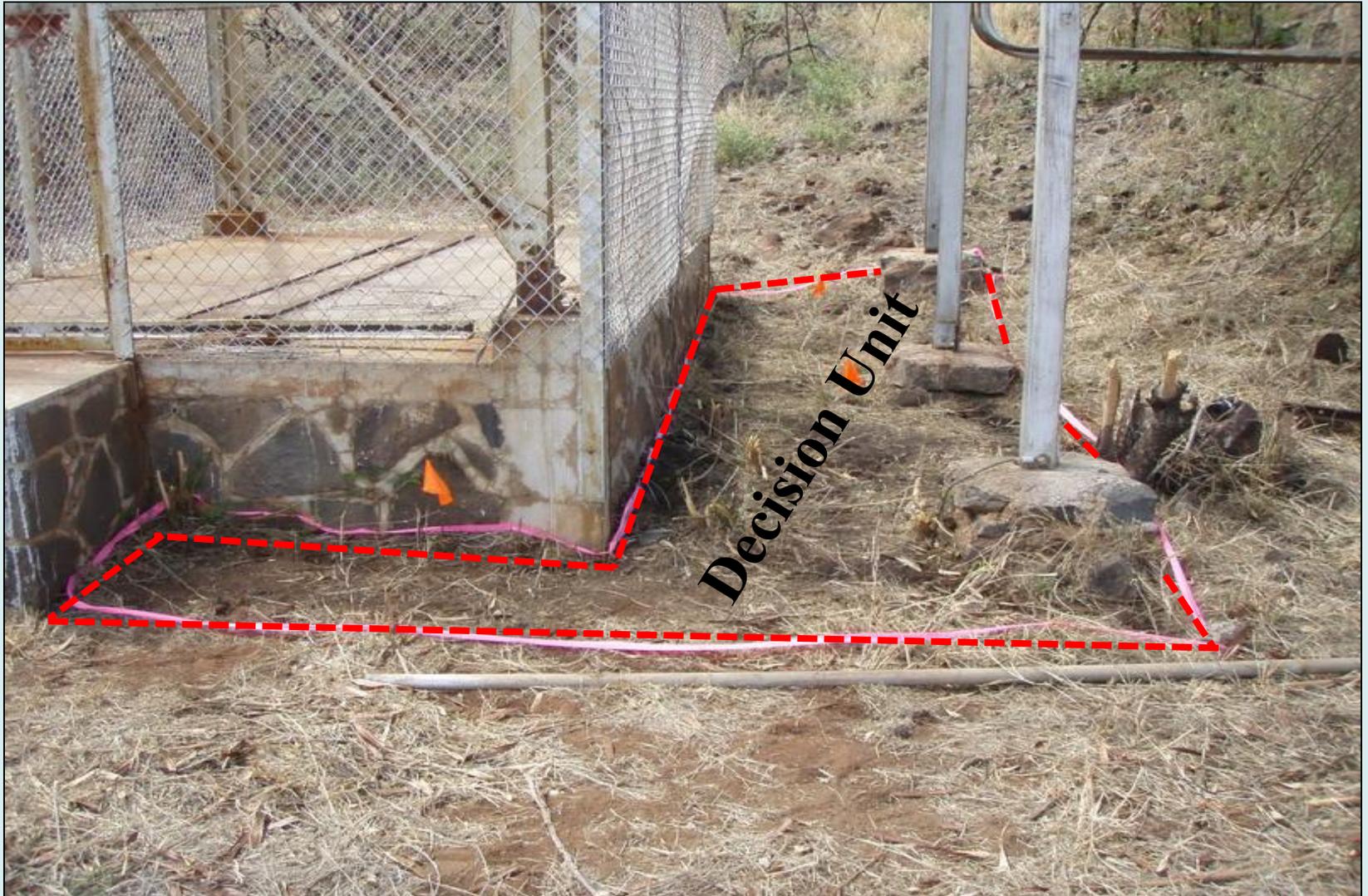
# What About Traditional Sampling?

- ▶ Sample points selected at area of concern – generally 50 to 200 feet apart
- ▶ Soil samples collected from 6-inch sleeves from each point, at varying depths
- ▶ 5 grams of soil from each sleeve is evaluated by the laboratory
- ▶ Duplicate samples not collected
- ▶ Common project: 10 sample points X 3 depths = 30 samples

# Traditional Example



# Traditional Example



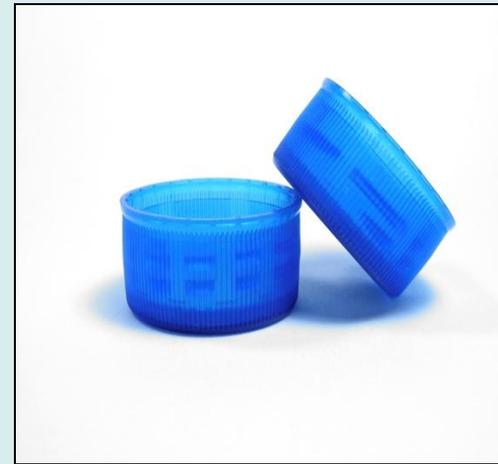
# How Big is Your Discrete Sample? (Standard Laboratory Sample Masses)



**Metals: One gram**



**TPH, Pesticides, PAHs: Thirty gram**



**VOCs: Five grams  
Dioxins: Ten grams**

# How Does Contamination Exist in Soil and How is it Measured?

- ▶ Soil contaminant data is collected to support site decision making
- ▶ Critical decisions based on sample data!
- ▶ How do we know if we can trust it?
- ▶ Answer: The Scientific Method\*

\* Oxford English Dictionary defines the scientific method as: "a method or procedure that has characterized natural science since the 17th century, consisting in systematic observation, measurement, and experiment, and the formulation, testing, and modification of hypotheses."

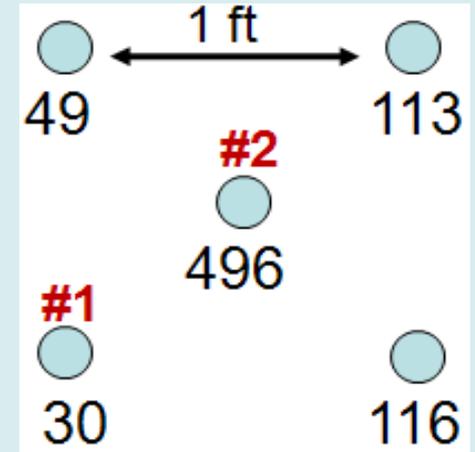
# Why is this a Concern?

- ▶ Site histories are rarely 100% known  
  
[Corollary: If we knew exactly where the contamination was, we would just sample there]
- ▶ Contaminant distribution is not homogeneous or predictable
- ▶ All soil is heterogeneous in composition, which has effects on how it is distributed and measured

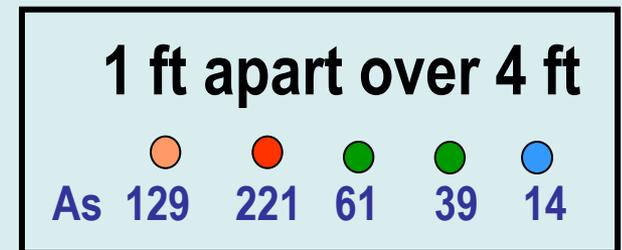
These factors make it extremely difficult to extrapolate data between traditional sample results

# Short-Scale Field Heterogeneity: Co-located Samples

- ▶ Shortest spatial scale in the field measured by “co-located samples” (inches to a few feet apart)
- ▶ Samples anticipated to be “equivalent,” but often give very different results
- ▶ Chance governs exact location where soil is scooped, and chance can determine the outcome



Set of co-located samples for uranium (mg/kg)



Arsenic in residential yard transect (mg/kg)

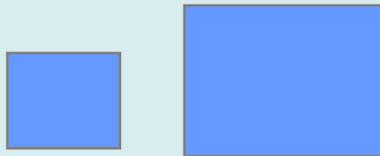
# Duplicate Discrete Samples

<b>Analyte</b>	<b>Primary Sample</b>	<b>Field Duplicate Sample</b>	<b>Difference Factor</b>	<b>Difference in Orders of Magnitude</b>
2-methylnaphthalene	9.5	4,700	495	2.7
Acenaphthene	21	20,000	952	3.0
Acenaphthylene	2.3	490	213	2.3
Anthracene	68	49,000	721	2.9
Benzo(a)anthracene	210	81,000	386	2.6
Benzo(a)pyrene	200	40,000	200	2.3
Benzo(b)fluoranthene	350	80,000	229	2.4
Benzo(ghi)perylene	110	16,000	145	2.2
Chrysene	190	73,000	384	2.6
Dibenzo(a,h)anthracene	38	6,500	171	2.2
Fluoranthene	480	260,000	542	2.7
Fluorene	33	28,000	848	2.9
Indeno(1,2,3-cd)pyrene	110	18,000	164	2.2
Naphthalene	40	12,000	300	2.5
Phenanthrene	280	220,000	786	2.9
Pyrene	370	190,000	514	2.7

# Concentration is a Function of Sample Support and Nugget Mass

## Common assumption

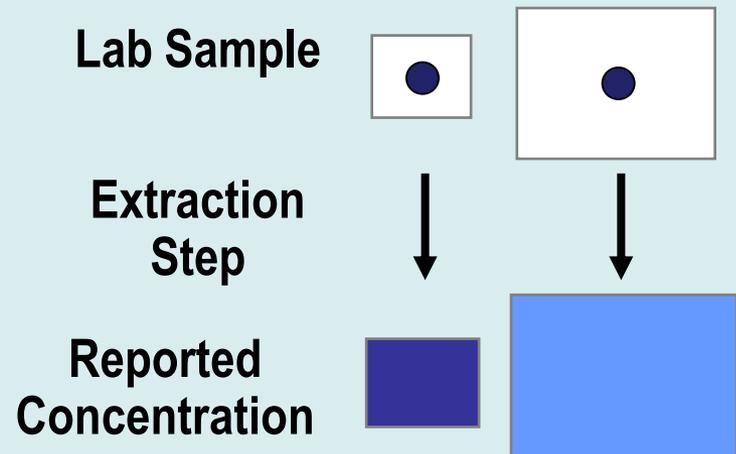
The amount of soil analyzed makes no difference to what results are obtained.



$$\text{Concentration} = \frac{\text{contaminant mass (mg)}}{\text{the soil mass (kg)}}$$

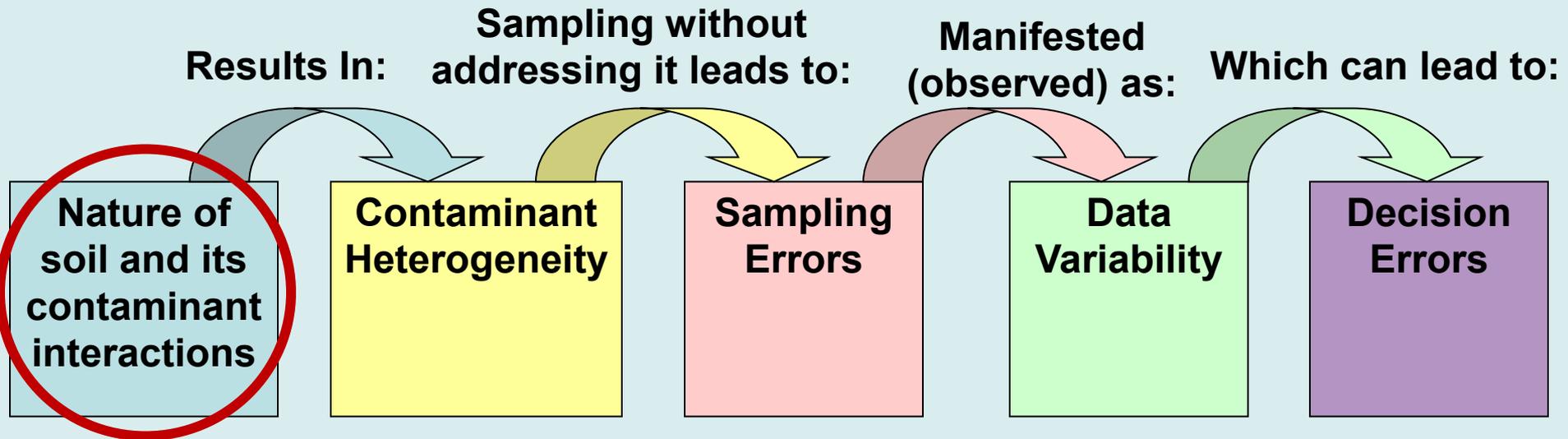
## Assumption wrong for solids

Can have the **same** contaminant nugget mass (blue), BUT in different **sample** masses (white)...



...get **different** concentration results

# And the result is:



Are you *sure* you have characterized the soil at your site?

# There are Established U.S. EPA Protocols

- ▶ Precision: How reproducible or repeatable is the data?
- ▶ Accuracy: How close is the data to actual concentrations?
- ▶ Representativeness: How well does the data represent the area of interest?
- ▶ Completeness: How good is the quality of data?
- ▶ Comparability: What is the relative confidence when comparing several data sets?

**Traditional sampling tends to ignores these**

# Advantages of ISM

- ▶ Increased use of replicate sample results to evaluate:
  - Precision
  - Accuracy
  - Representativeness
- ▶ More accurate, reproducible
- ▶ Produces data of known quality
- ▶ Enables decisionmakers to quantify the uncertainty
- ▶ Ties the scale of sampling to the scale of decision making

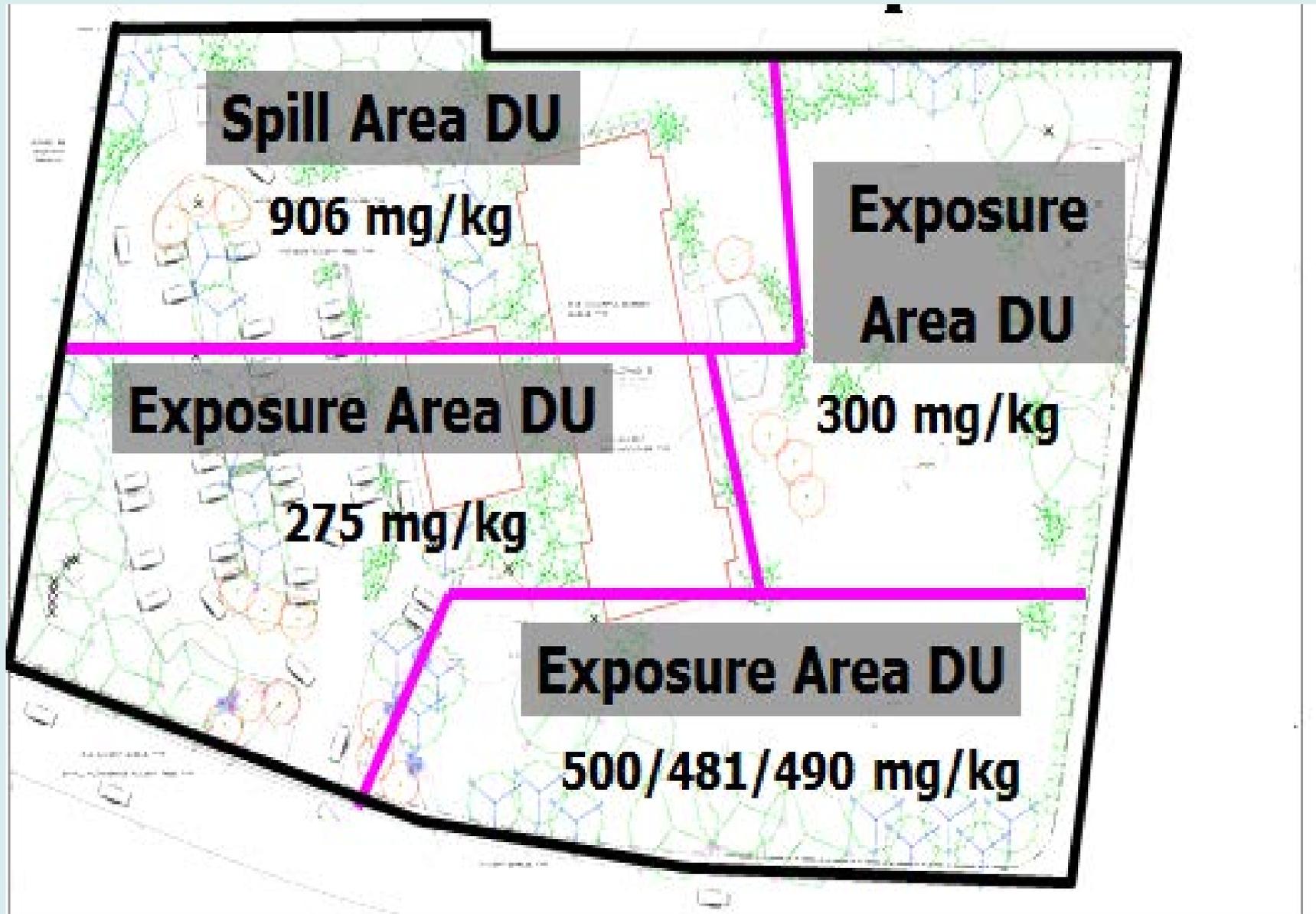
<b>DU24</b> <b>Area 4 - Surrounding Properties</b> Within the front, back and side yards for the Sansevere property.	<b>HDOH Tier I EAL</b> <b>(Unrestricted Use)</b>	<b>HDOH Tier I EAL</b> <b>(Commercial / Industrial Use)</b>	<b>PMAK-DU24-A-P</b>	<b>PMAK-DU24-A-T1</b>	<b>PMAK-DU24-A-T2</b>
Sample Date			8.10.11	8.10.11	8.10.11
Depth Intervals (' bgs)			0-0.5	0-0.5	0-0.5
<b>Soil Analyses (ng/kg)</b>					
TEQ DIOXINS	240	1500	92	92	98
<b>Soil Analyses (mg/kg)</b>					
TOTAL ARSENIC	24	24	<b>290</b>	<b>230</b>	<b>230</b>
BIOACCESSIBLE ARSENIC	23	95	16.8	16.1	17.1
PERCENT BIOACCESSIBLE ARSENIC	NE	NE	6.94	8.14	8.07
TOTAL ARSENIC (250 µm)	NE	NE	242	198	212
MERCURY	4.7	61	0.68	0.62	0.68
LEAD	200	800	180	130	130
PENTACHLOROPHENOL (8270CM)	3	5	ND [<0.317]	ND [<0.317]	ND [<0.319]
<b>TA Job No.</b>	HUH0072				

<b>DU18</b> <b>Area 2 - Core PMA</b> Within the West Drainage Outfall, adjacent to the intersection of Kilauea Road and Oka Street.	<b>HDOH Tier I EAL</b> <b>(Unrestricted Use)</b>	<b>HDOH Tier I EAL</b> <b>(Commercial / Industrial Use)</b>	<b>PMAK-DU18-A-P</b>	<b>PMAK-DU18-A-T1</b>	<b>PMAK-DU18-A-T2</b>
Sample Date			8.10.11	8.10.11	8.10.11
Depth Intervals (' bgs)			0-0.5	0-0.5	0-0.5
<b>Soil Analyses (ng/kg)</b>					
TEQ DIOXINS	240	1500	64	64	91
<b>Soil Analyses (mg/kg)</b>					
TOTAL ARSENIC	24	24	<b>50</b>	<b>47</b>	<b>49</b>
BIOACCESSIBLE ARSENIC	23	95	ND [<1.00]	ND [<1.00]	ND [<1.00]
PERCENT BIOACCESSIBLE ARSENIC	NE	NE	1.94	2.88	2.04
TOTAL ARSENIC (250 µm)	NE	NE	32.7	29.1	29.7
MERCURY	4.7	61	0.6	0.52	0.39
LEAD	200	800	55	55	56
PENTACHLOROPHENOL (8270CM)	3	5	ND [<1.58]	ND [<1.52]	ND [<1.59]
<b>TA Job No.</b>	HUH0072				

Sample Location	Metals																
	Antimony	Arsenic (I)	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead	Mercury	Molybdenum	Nickel	Selenium	Silver	Thallium	Vanadium	Zinc
CHSSL Residential CHSSL Commercial Background	30 380	16	5,200 63,000	150 1,700	1.7 7.5	100,000 100,000	660 3,200	3,000 38,000	150 3,500	18 180	380 4,800	1,600 16,000	380 4,800	380 4,800	5 63	530 6,700	23,000 100,000
Shade House	1.3	15	200	0.5	0.5	53	12	110	44	3.8	1.4	43	ND	ND	ND	46	170
Big Meadow DU 1	0.79	5.6	170	0.45	0.22	34	11	47	41	0.94	0.26	30	0.38	ND	ND	31	67
Big Meadow DU 1 Duplicate	0.71	5.8	160	0.47	0.21	37	11	41	35	0.89	0.15	35	ND	ND	ND	33	71
Big Meadow DU 2	0.49	6.3	140	0.48	ND	43	9.4	20	26	0.36	ND	25	ND	ND	ND	43	42
EPA Meadow	0.74	6.3	250	0.56	0.35	37	26	28	49	0.3	ND	39	0.69	ND	ND	39	84

## Field Duplicate Evaluation

Sample ID	Analyte	Original Sample (mg/kg)	Duplicate Sample (mg/kg)	Relative Percent Difference (%)
DU-04	Dioxin TEQ	137.74	114.31	18.6
DU-12	Dioxin TEQ	98.03	89.26	9.4
DU-18	Dioxin TEQ	57.27	62.06	8.0
DU-30	Dioxin TEQ	56.88	72.28	23.8
DU-50	Dioxin TEQ	129.55	130	0.3
DU-56	Dioxin TEQ	129.35	136.95	5.7
<i>Average Dioxin TEQ RPD</i>				<i>11.0%</i>
DU-04	Arsenic	17.2	11	44.0
DU-12	Arsenic	11.9	9.6	21.4
DU-18	Arsenic	6.1	8	27.0
DU-30	Arsenic	3.9	5	24.7
DU-50	Arsenic	12.2	11.3	7.7
DU-56	Arsenic	8.6	11.5	28.9
<i>Average Arsenic RPD</i>				<i>25.6%</i>



# Pros and Cons

- ▶ Pro: Increased confidence in precision, accuracy, representativeness (= Scientific Method)
- ▶ Pro: Increased confidence in remedial decisionmaking
- ▶ Con: Does not identify range of contaminant values with area of interest
- ▶ Con: Until accepted, is met with resistance regarding hot spot dilution, VOCs, ISM at depth, etc...
- ▶ Pro: Gets everyone thinking about representativeness
- ▶ Pro: Cheaper? YES

# Examples

# Determining the Decision Units

- ▶ What are your sampling objectives?
- ▶ Are there multiple sampling objectives that must be met?
- ▶ What receptors and pathways are being evaluated?
- ▶ What is the scale of decision making?
- ▶ What population parameter is of interest?

***The key is the volume over which the mean should be estimated.***

# Decision Units

The volume of soil where samples are to be collected and decisions made based on the resulting data.

## Source Areas

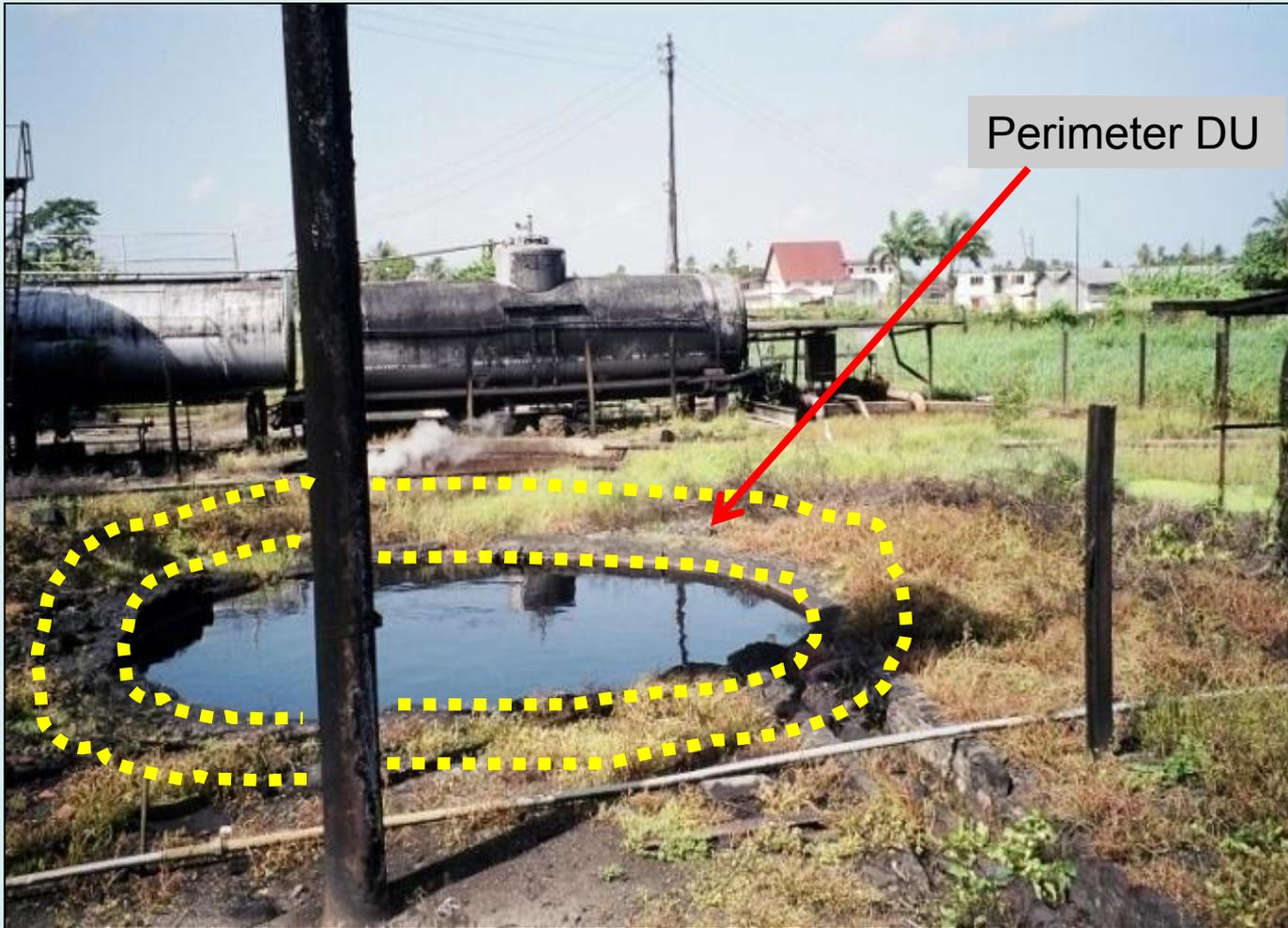


## Exposure Areas



Size, shape and type of DU are an outcome of systematic planning and depend on site specific data quality objectives.

# Source Area Delineation



- Define lateral & vertical extent of contamination
- Other DUs needed if first exceeds action level

Does TPH exceed action levels around the lagoon?

# Former Pesticide Mixing Area (0.5 acres)



**Suspected heavy contamination with arsenic,  
dioxins (from PCP) and leachable pesticides**

# Former Pesticide Mixing Area



Source Area DUs: Heavy contamination + leaching



Exposure Area DUs: Maximum 5,000 ft<sup>2</sup>

# Source Area and Exposure Area DU Designation

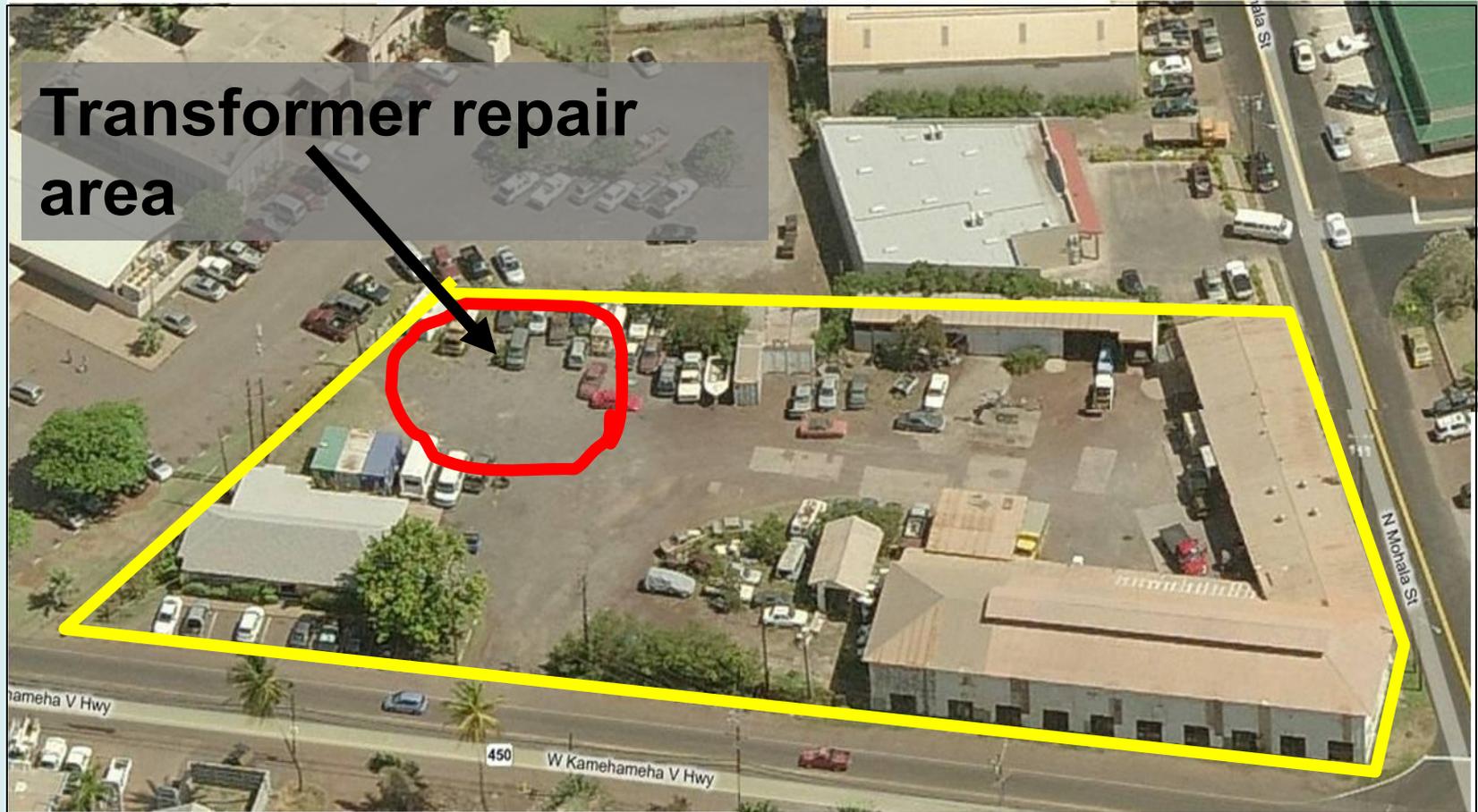
**Source Area DUs  
(Triazine Pesticides;  
leaching hazards)**

**Exposure Area DUs  
(Arsenic and Dioxins;  
direct exposure  
hazards)**



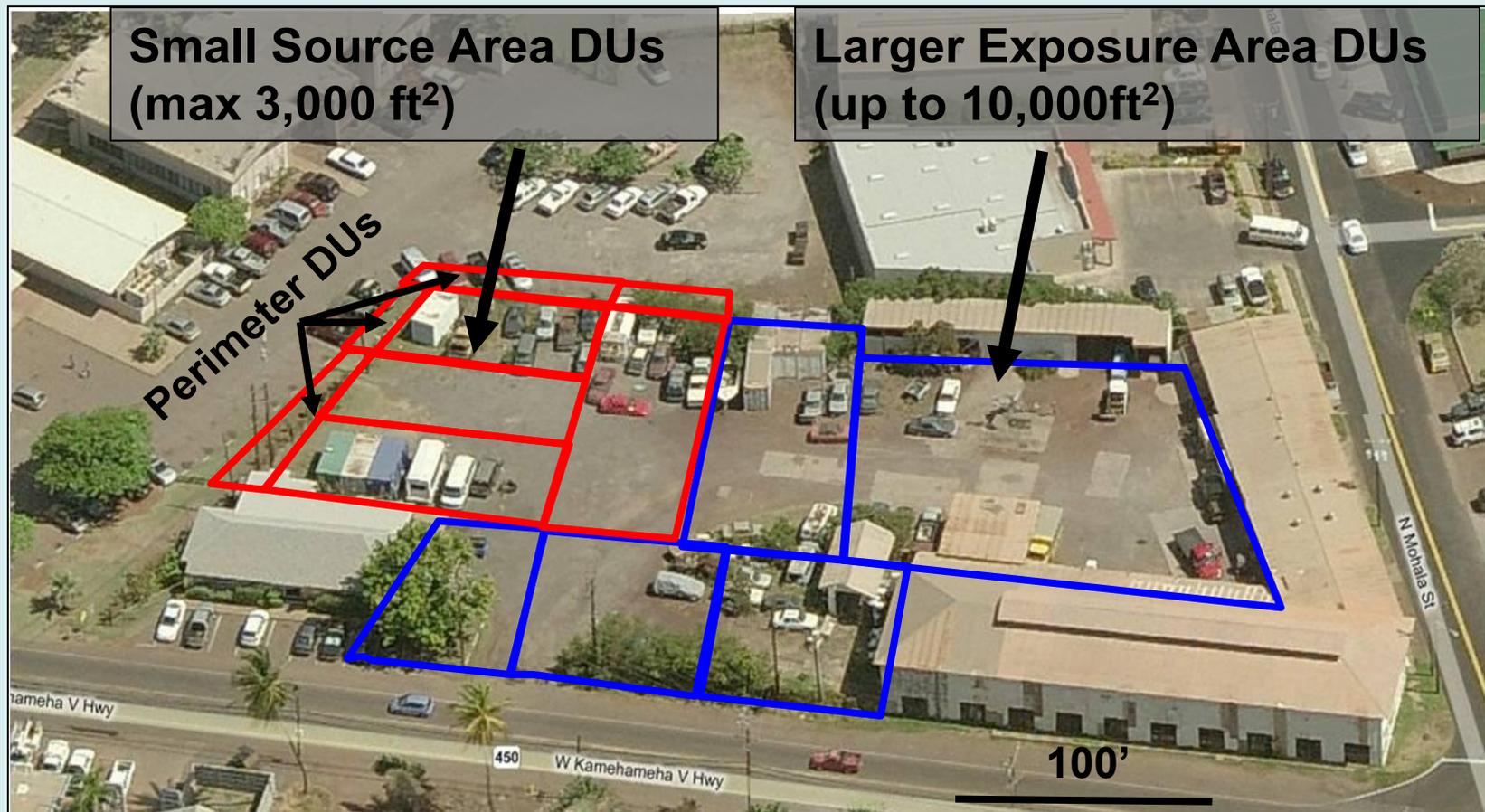
Primary Objective is to delineate the source area and the extent of contamination.

# Former Power Plant Proposed Community Center



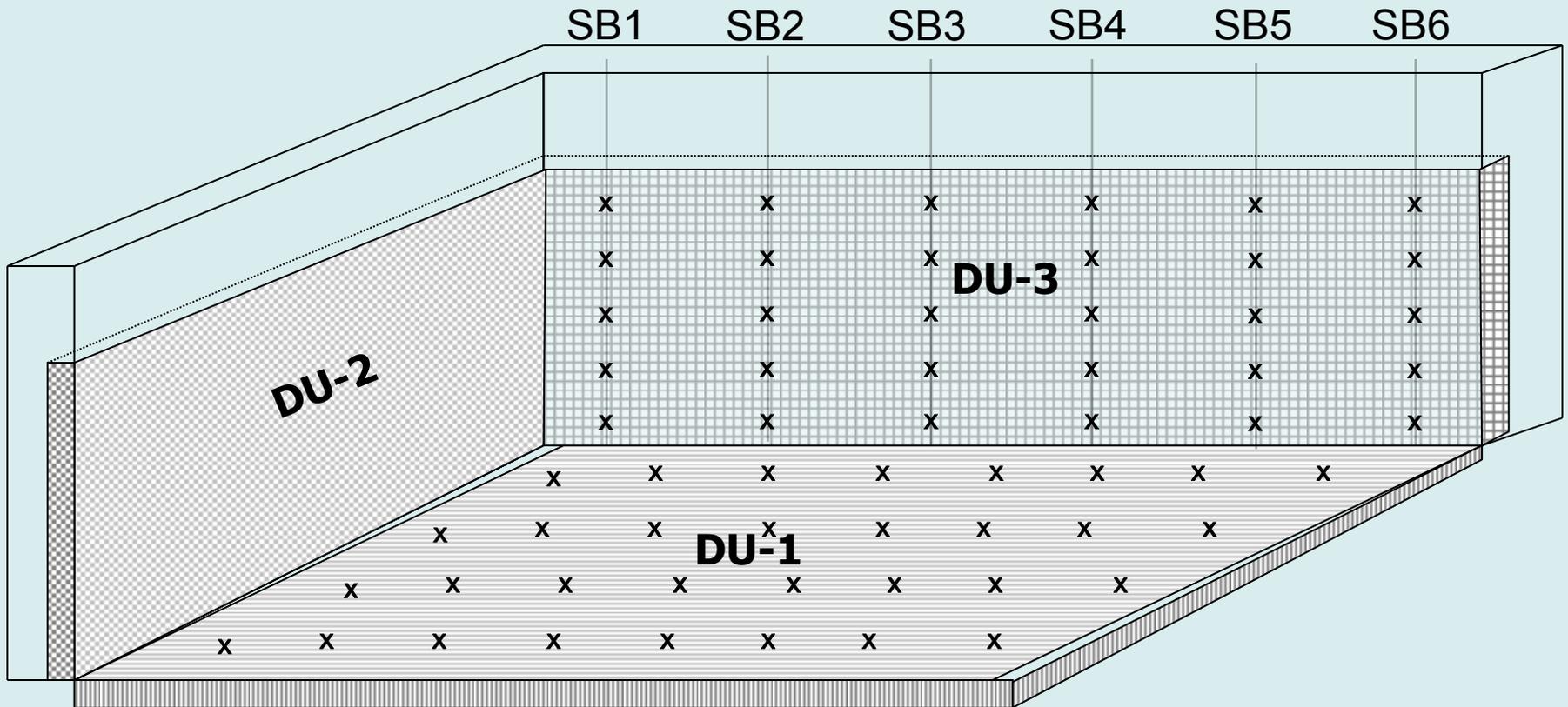
100'

# Former Power Plant Decision Unit Designation



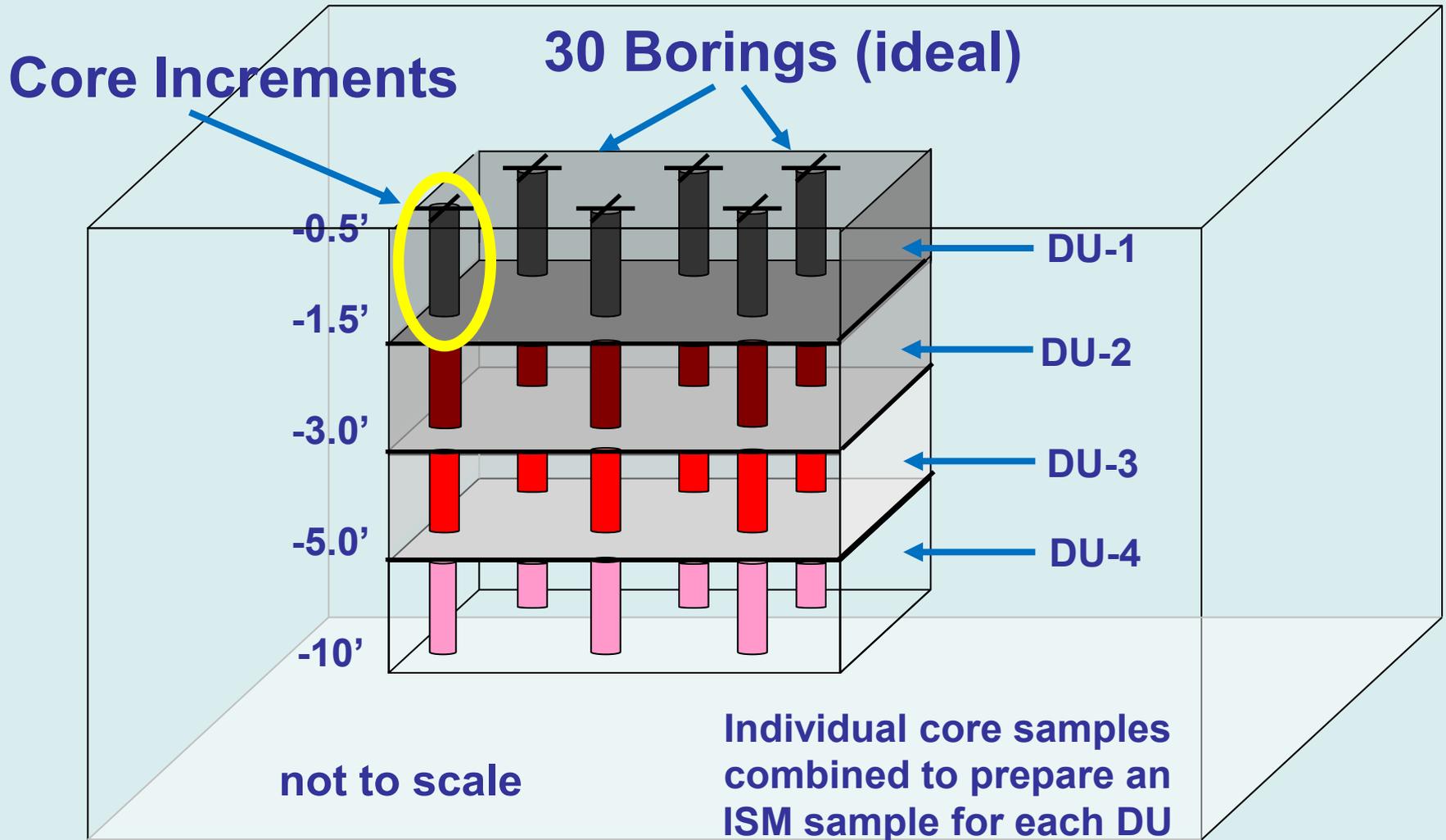
# Excavation Decision Units

Floor and sides tested as separate DUs

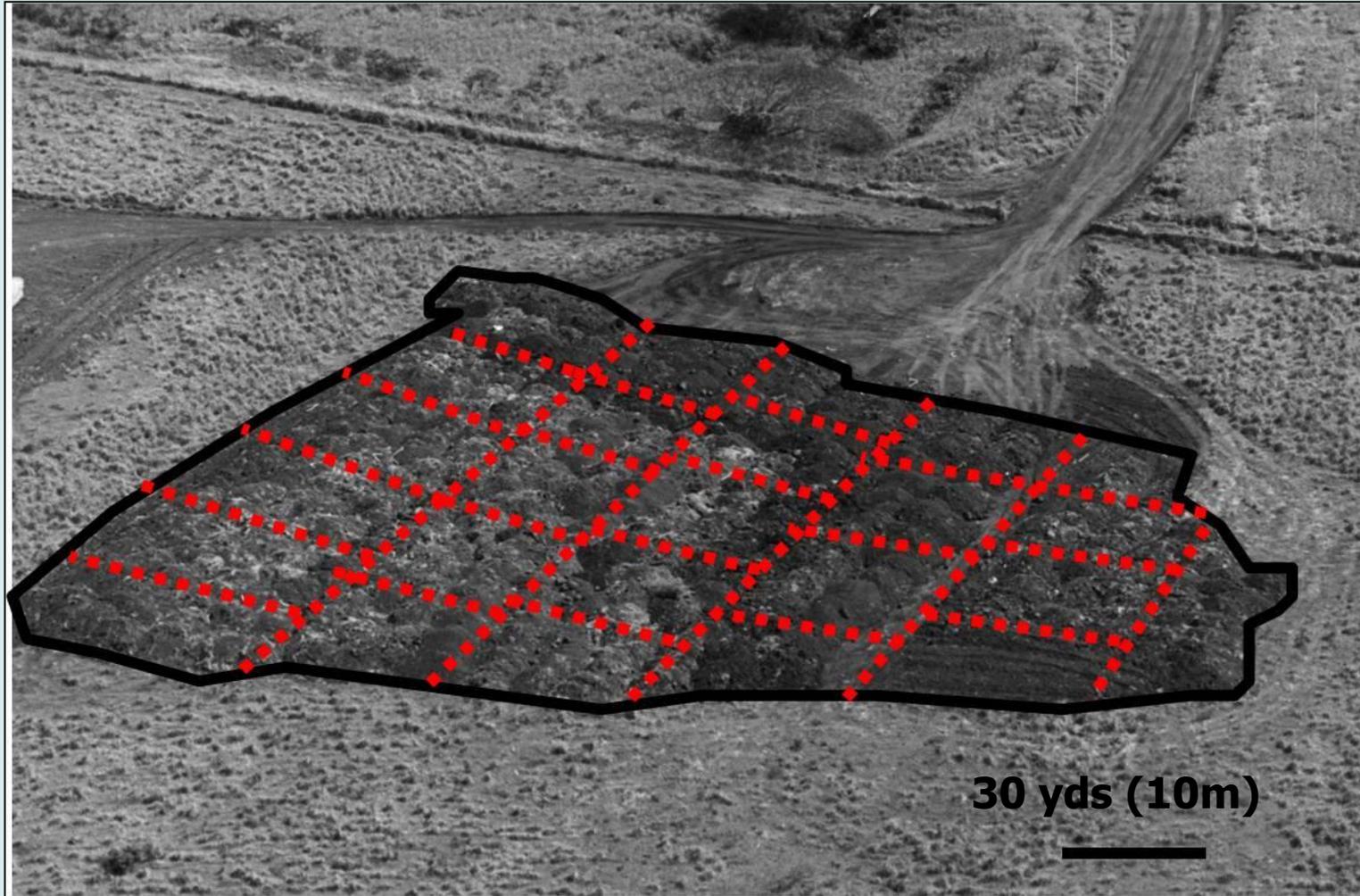


X - Increment Sampling Locations

# Subsurface Decision Units



# Stockpile Decision Units



# Former Maintenance Yard

**Planned Safeway-  
Target Store**



**Former Wood  
Treatment  
Facility  
(known arsenic  
& dioxin in  
soil)**

# Former Maintenance Yard -Decision Unit Designation-

Localized  
petroleum  
spill area



Small  
Remediation  
DUs in high-  
suspect areas  
(5,000ft<sup>2</sup> =  
200 yds<sup>3</sup>/ft)

Medium-Size,  
DUs in moderate-  
suspect areas  
(0.5 acres =  
1,000 yds<sup>3</sup>/ft)

Large Exposure  
area DUs in areas  
in low-suspect  
areas  
(1-2 acres =  
2-3,000 yds<sup>3</sup>/ft)

# Drainage Ditch Decision Units



**Upstream Background  
(dry boulder bed)**



**Inland Ditches  
(partially wet, gravelly mud)**



**Middle Ditches  
(locally ponded, gravelly mud)**

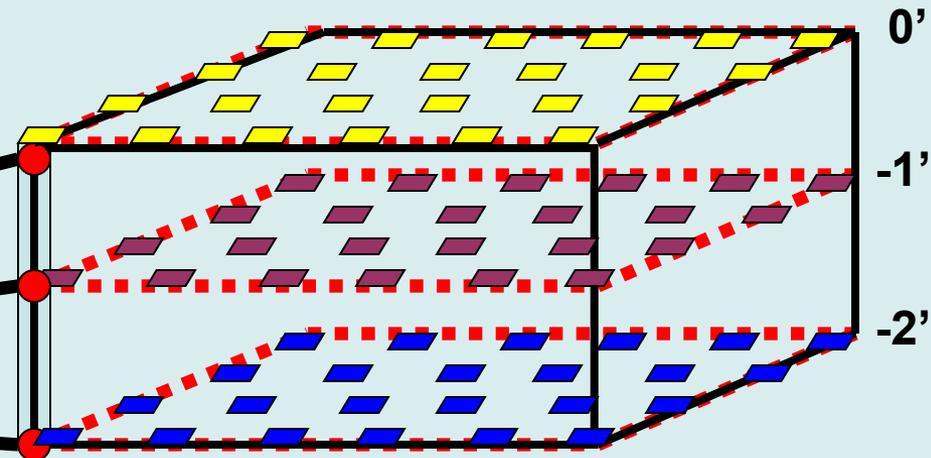
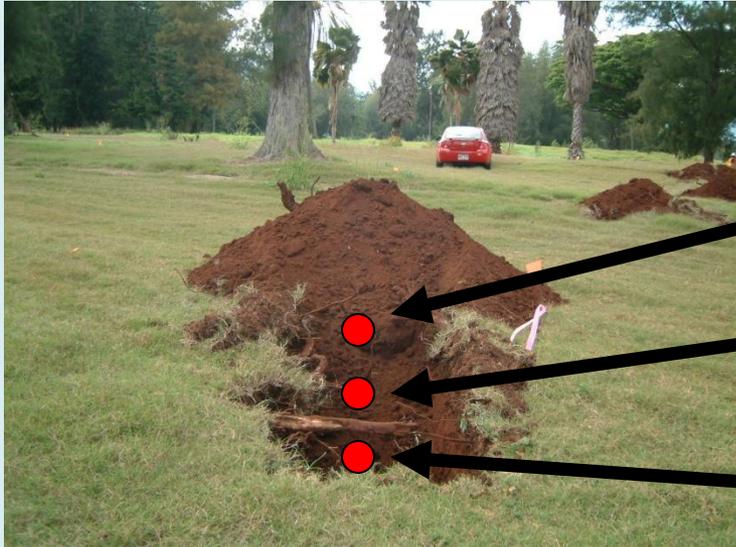


**Ocean Outlet  
(fine-grained sediment)**

# Targeted Depth MI Samples

Former golf course

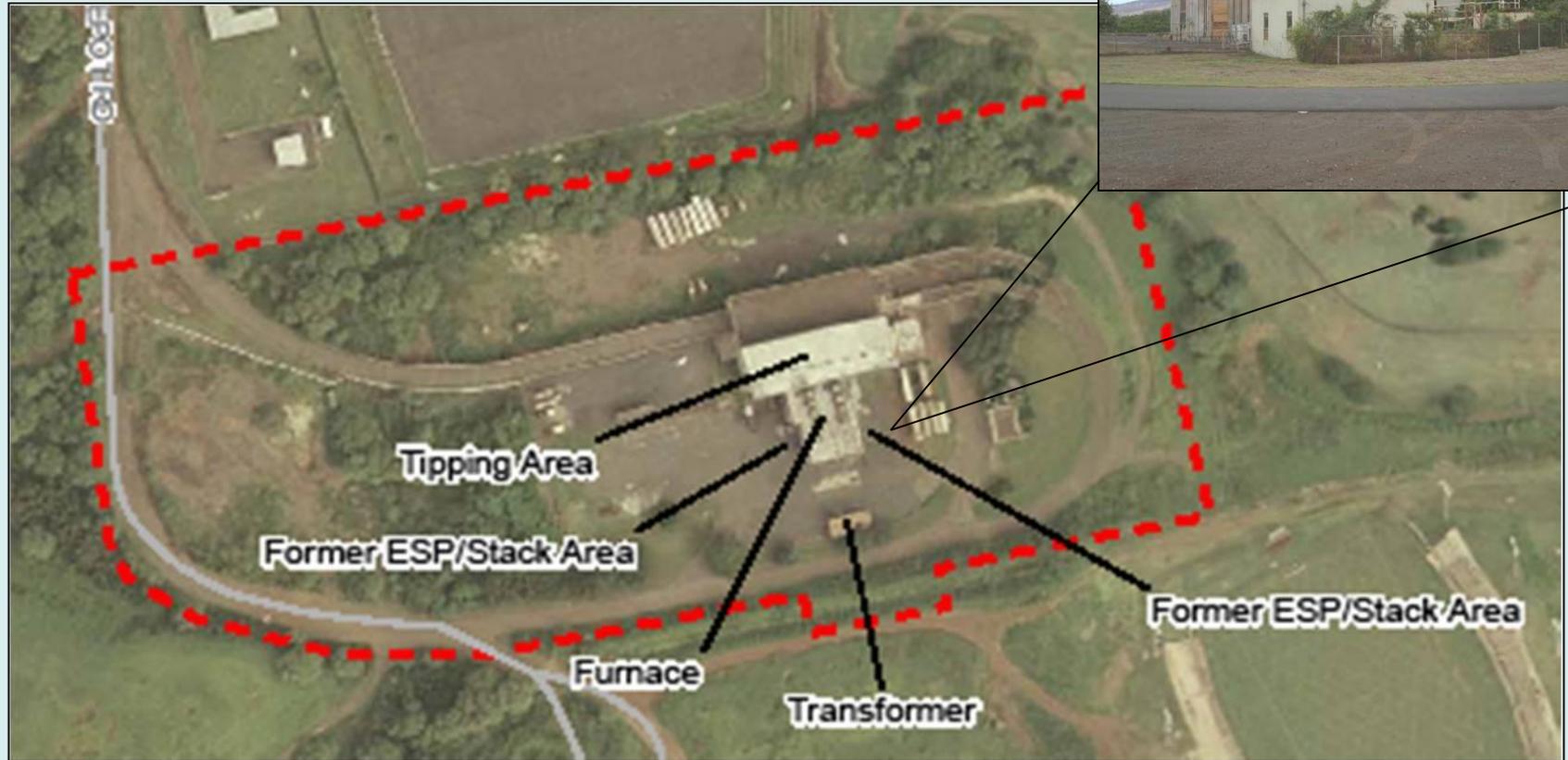
One-Acre Exposure Area DUs



- 200-acre site, to be redeveloped for town homes
- Thirty pits per one-acre DU
- Increments from targeted depths combined into depth-specific MI samples
- Soil above cleanup levels removed each DU

# Former Municipal Incinerator Plant (planned park development)

- Suspected lead and dioxin contamination around former stack area;
- Potential ash in other areas.



# Former Municipal Incinerator Plant -Decision Unit Designation-



**Exposure Area DUs  
(29) (<10,000 ft<sup>2</sup>)**



**\*Stack Area DUs  
(10) (<2,000 ft<sup>2</sup>)**



**\*Smaller DU in high-suspect areas to optimize potential soil disposal**

# Key References

**ITRC, 2012, Incremental Sampling Methodology (ISM-1): Interstate Technology & Regulatory Council, Incremental Sampling Methodology Team, Washington, D.C., (Good introduction) <http://www.itrcweb.org/ism-1/>**

**HDOH, 2009, *Technical Guidance Manual: Hawai‘i Department of Health, Office of Hazard Evaluation and Emergency Response, (Field implementation) <http://www.hawaiidoh.org>.***

**USACE, 2009, *Implementation of Incremental Sampling (IS) of Soil for the Military Munitions Response Program: U.S. Army Corps of Engineers, Environmental and Munitions Center of Expertise, Interim Guidance Document (IGD) 09-02, (Early ISM guidance), [www.hnd.usace.army.mil/oew/policy/IntGuidRegs/IGD%2009-02v2.pdf](http://www.hnd.usace.army.mil/oew/policy/IntGuidRegs/IGD%2009-02v2.pdf).***