**Characterization and Remediation of Contaminated Properties**
- **Lessons Learned in the United States –**
- 污染场地表征和修复——美国的经验教训

**Part 1: Risk Assessment and Environmental Screening Levels**
第**1**部分：风险评估和环境筛选值
**Part 2: Improving Site Investigation Reliability**
第**2**部分：提高场地调查的可靠性

**US Environmental Protection Agency Region 9** 美国环保署9区
**China Ministry of Environmental Protection** 中国环保部
**San Francisco, USA**
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# **Learning from Past Experience**
## 从过去的经验中学习

*There are three methods to gain knowledge:*

*The first, reflection, is the noblest;*

*The second, imitation, is the easiest;*

*And the third, experience, is the bitterest.*

*Confucius*

有三种获取知识的方法:
第一，反思，是最高尚的 ;
第二，模仿，是最简单的 ;
第三，经验，是最痛苦的 。

孔子

# References (draft translations in Chinese)
## (reflects compilation of United States and other guidance)
## 参考文献 (草稿翻译成中文 )
### （美国和其他国家导则汇编）

**1. Site Investigation:** *Technical  Guidance Manual* **(2016 and updates): Hawaiʻi Department of Health, HEER Office,http://www.hawaiidoh.org/**

*《技术指导手册》*（**2016**年以及更新）：夏威夷卫生署**HEER**办公室 **http://www.hawaiidoh.org/**

**2. Risk Assessment:** *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater – Tropical Pacific Edition* **(Fall 2017 and updates): Hawaiʻi Department of Health, http://eha-web.doh.hawaii.gov/eha-cma/Leaders/HEER/ehe-guidance---pacific-basin-edition**

*《土壤和地下水污染场地环境危害评估——热带太平洋版》*（**2017**年秋季版以及更新）：夏威夷卫生署 **http://eha-web.doh.hawaii.gov/eha-cma/Leaders/HEER/ehe-guidance---pacific-basin-edition**

# HDOH 2017 Technical Guidance Manual Training Webinar Series 技术导则系列网络培训
## (includes subtitles and transcripts in Chinese 包括中文字幕和文本)

**Part 1:** **Systematic Planning and Site Investigation Design**
系统的规划和场地调查设计

**Part 2:** **Decision Unit Designation**
确定决策单元

**Part 3:** **Sampling Theory, Discrete Sample Data Unreliability and Multi Increment Sampling Methods**
采样理论，离散样本数据不可靠，多点增量采样方法

**Part 4:** **Field Implementation of DU-MIS Investigation Methods**
多点增量采样方法的现场实施

**Part 5:** **Laboratory Processing of MI Samples**
多点增量样品的实验室处理

**Part 6:** **Expedited Environmental Hazard Evaluation Methods ("risk assessment")**
快速环境危害(风险)评估方法

# Roger Brewer's Background and Why I'm in Nanjing
罗杰的背景；我为什么在南京？

**1991:** **PhD Geology (minor in Chinese)**
地质学博士（辅修中文）

**1991-1993:** **Post-Doctorate Researcher, Nanjing University (Dept of Geology)**
南京大学地质系 博士后

**1993-2005:** **Environmental Scientist (Hawaii DOH, California EPA, international consulting)**
环境科学家（夏威夷卫生署，加州环境局，国际咨询）

**2005-2017:** **Environmental Scientist (Hawaii DOH)**
环境科学家（夏威夷卫生署）

**2017-2018:** **Visiting Scholar, Nanjing Institute of Soil Science**
南京土壤研究所访问学者

**Expertise: Expedited investigation, risk assessment and remediation of contamination lands**
专长：快速调查，风险评估和污染土地**修复**

# Why Don't I Work for the USEPA?
## 为什么我不为美国环保署工作？

**1970-1980s:** **USEPA initiates environment regulation and publishes initial guidance. States lack experience.**
USEPA 发起环境监管并发布初步导则，各国缺乏经验

**1990-2000s:** **USEPA begins to transfer responsibility of contaminated land oversight to states but continues to provide important technical support and funding.**
**USEPA**开始将污染土地监督责任转交给各州，但继续提供重要的技术支持和资金

**1990-2017:** **Close collaboration with USEPA Region 9 to develop more efficient and expedited methods for site characterization and environmental risk assessment.**
与美国环保署9区紧密合作，开发更有效和快速的场地表征和环境风险评估方法

# Why is the Hawaii Guidance so Advanced?
## 为什么夏威夷的导则更先进？

- **Strong sense of environmental awareness;**
  强烈的环保意识

- **Urgent need for new housing;**
  迫切需要新的住房

- **Land is very limited and cannot be abandoned;**
  土地非常有限，不能遗弃

- **Much of the land is owned or leased by the government;**
  大部分土地由政府拥有或租赁

- **Provides motivation to improve efficiency of government guidance (government's land, time and money)**
  为提高政府指导效率提供动力（政府的土地，时间和金钱）

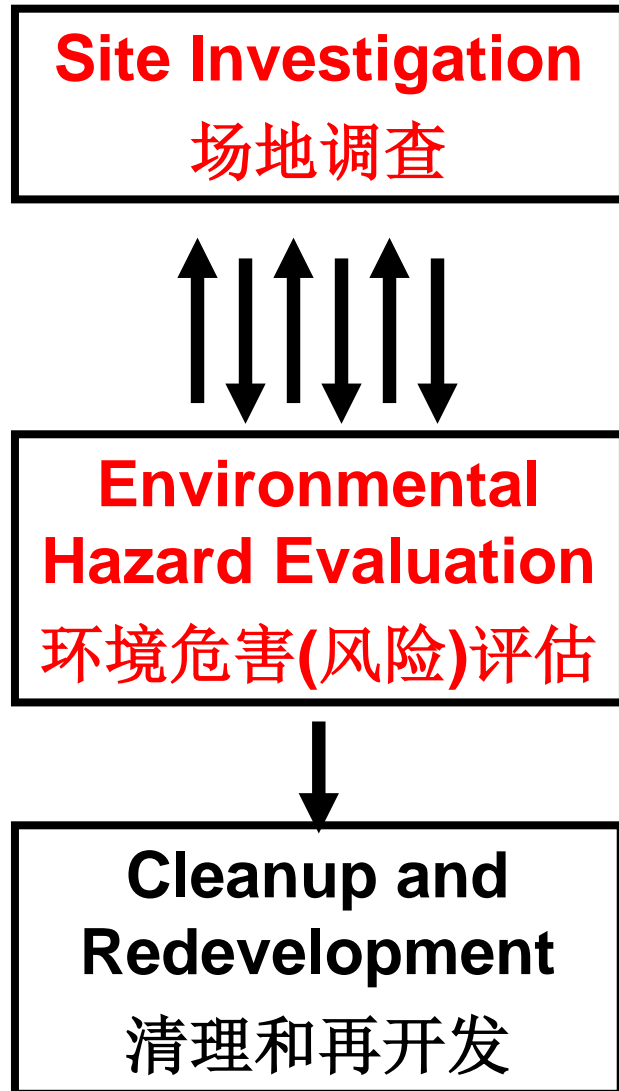- **Strong technical and financial support from the USEPA.**
  美国环保局提供强大的技术和财政支持

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*"Evolution takes place at the fringes of the environment, where the stresses are greatest and the need for change most urgent."*
**Carl Sagan (American scientist)**

*"进化通常发生在环境条件异常的区域，因为那里胁迫最大，最迫切需要改变。"* **Carl Sagan**（美国科学家）

# Common Problems in Contaminated Soil and Groundwater Investigations
## 污染土壤和地下水调查的常见问题

**Site Investigation**
**场地调查**

↑↓↑↓↑↓↑↓

**Environmental Hazard Evaluation**
**环境危害(风险)评估**

↓

**Cleanup and Redevelopment**
**清理和再开发**

- **Need for repeated site investigations**
  需要重复开展场地调查
- **Debates over risks and cleanup levels ("risk assessment")**
  争论风险和清理程度 (风险评估)
- **Investigation and cleanup can be delayed for years**
  调查和清理会延误很多年
- **Abandoned Property = "Brownfield"**
  废弃土地 = "棕地"

# Two Tools to Expedite Investigation and Remediation
# 加快调查和修复的两个工具

**1. Decision Unit (DU) and Multi-Increment Sample (MIS) site characterization approaches.**

决策单元（**DU**） 和多点增量样品（**MIS**） 场地表征方法

**2. "Balanced" Environmental Screening Levels and Risk-Based Corrective Action ;**

"均衡的" 环境筛选值和风险纠正措施；

# Science Challenges for Environmental Investigations
环境调查的科学挑战

- **Multiple disciplines (geology, chemistry, physics, biology, toxicology);**
  多学科（地质、化学、物理学、生物学、毒理学）；
- **Many sources of information;**
  许多信息来源；
- **Limited local expertise (government and private);**
  当地专家有限（政府和私人）；
- **Limited Resources (time and money);**
  资源有限（时间和资金）；
- **Uncertainty in data and decisions;**
  数据和决策的不确定性；
- **Guidance must be scientifically defensible but quick, cheap and easy-to-use.**
  导则必须有理有据，且快速、廉价、简单。

Potential Environmental Concerns Associated with Contaminated Soil and Groundwater

污染土壤和地下水相关的潜在环境问题
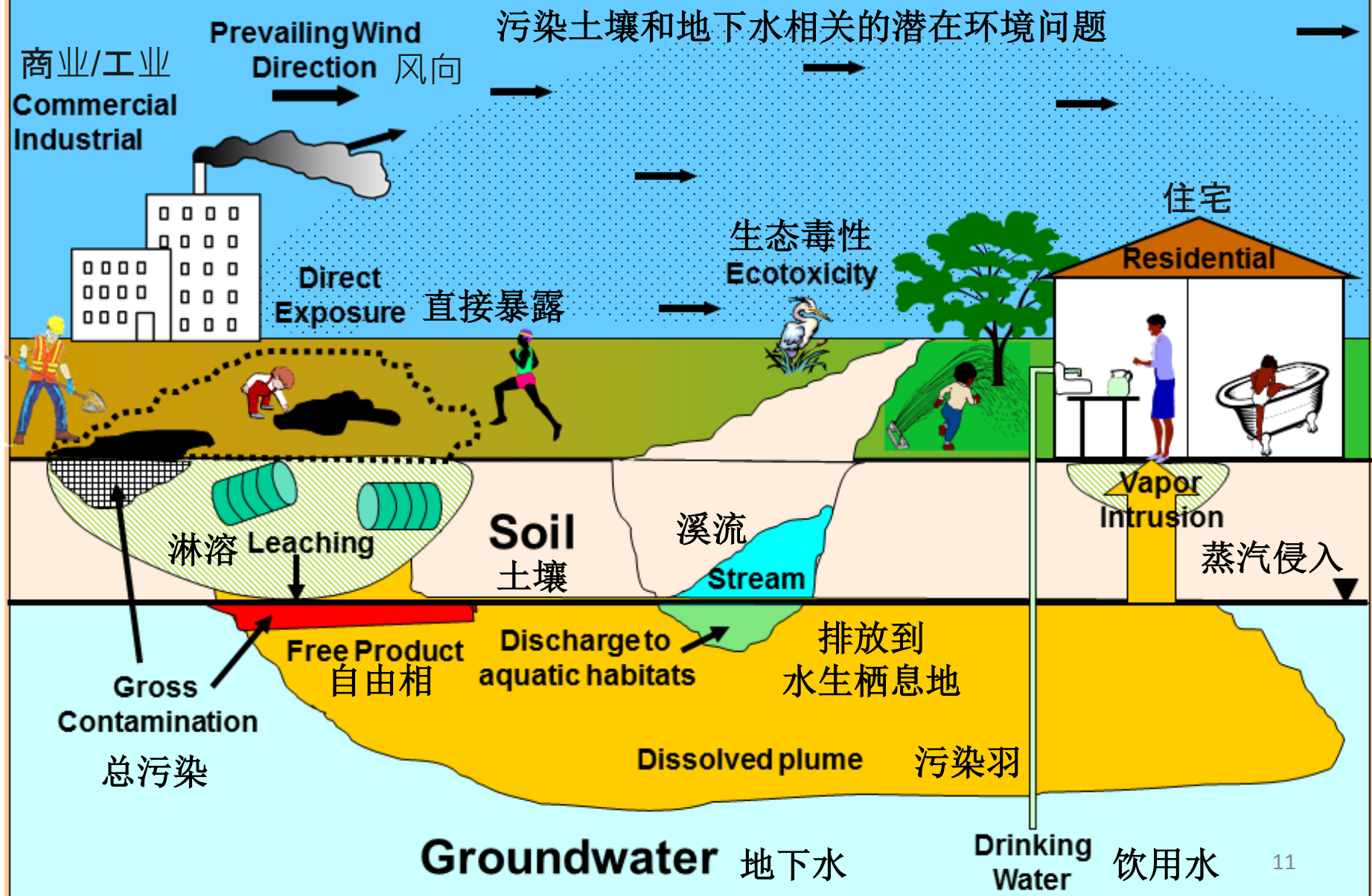
# Gross Contamination Hazards
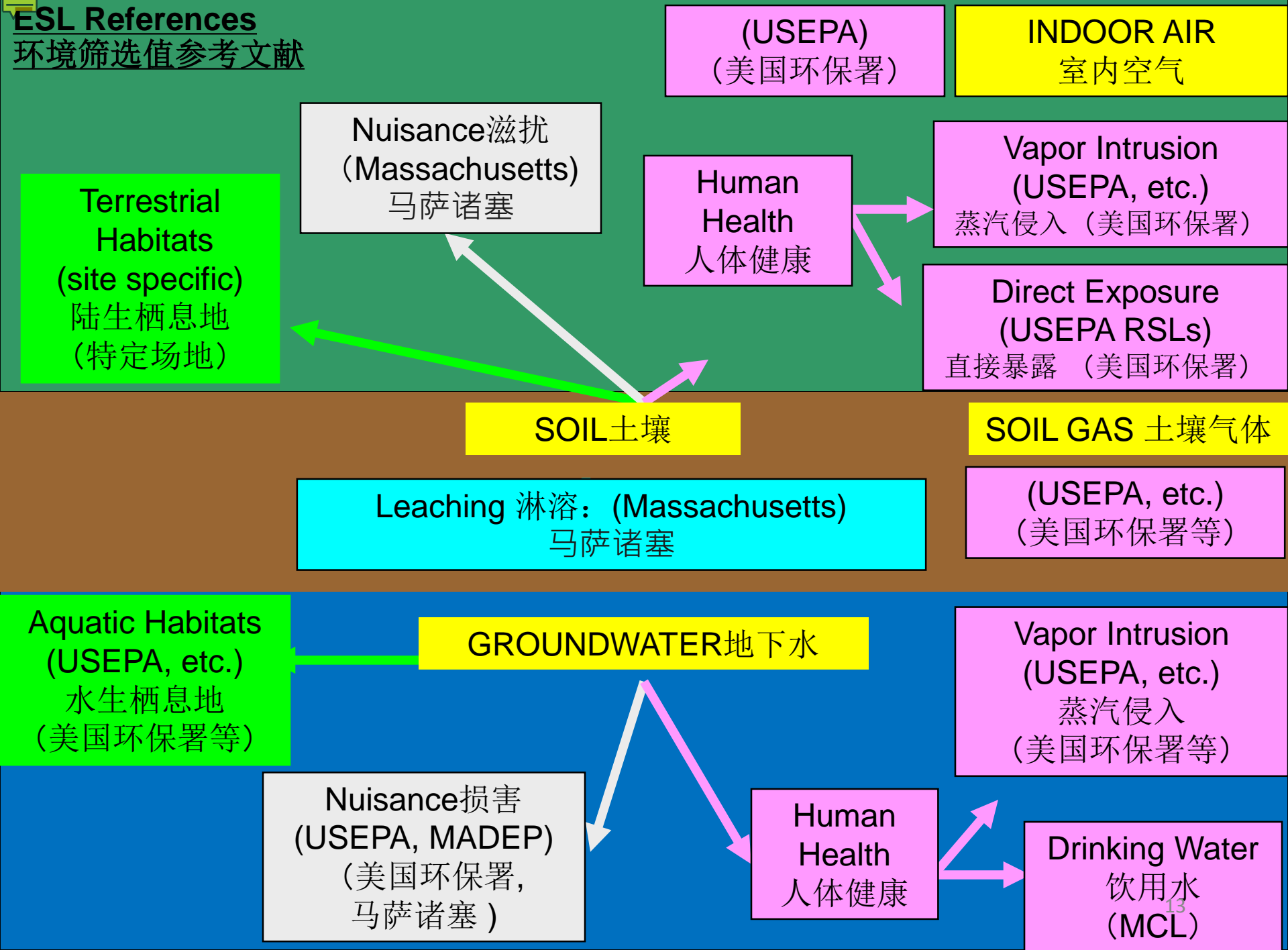# (especially important for petroleum)

总污染危害( 对石油尤其重要 )

- **Odors & nuisance**
- **Explosive vapors**
- **Potentially mobile free product**
- **Interference with future development**
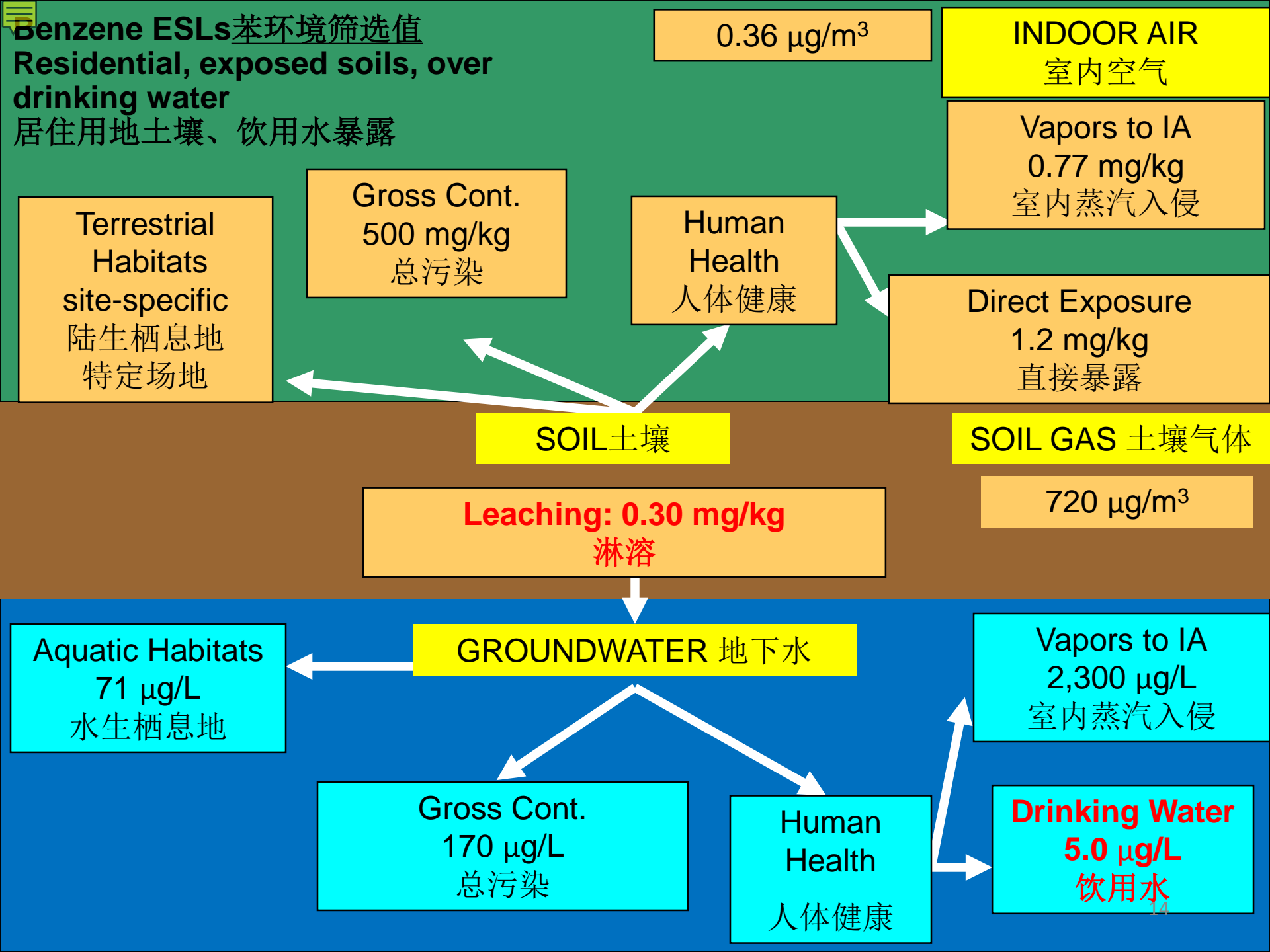- **General resource degradation**

- 气味与滋扰
- 爆炸性气体
- 可迁移的自由相
- 干扰未来开发
- 一般资源退化

(USEPA)
（美国环保署）

INDOOR AIR
室内空气

Nuisance滋扰
（Massachusetts)
马萨诸塞

Terrestrial
Habitats
(site specific)
陆生栖息地
（特定场地）

Human
Health
人体健康

Vapor Intrusion
(USEPA, etc.)
蒸汽侵入（美国环保署）

Direct Exposure
(USEPA RSLs)
直接暴露 （美国环保署）

SOIL土壤

SOIL GAS 土壤气体

Leaching 淋溶：(Massachusetts)
马萨诸塞

(USEPA, etc.)
（美国环保署等）

Aquatic Habitats
(USEPA, etc.)
水生栖息地
（美国环保署等）

GROUNDWATER地下水

Vapor Intrusion
(USEPA, etc.)
蒸汽侵入
（美国环保署等）

Nuisance损害
(USEPA, MADEP)
（美国环保署,
马萨诸塞 ）

Human
Health
人体健康

Drinking Water
饮用水
(MCL)

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**Benzene ESLs苯环境筛选值**
**Residential, exposed soils, over**
**drinking water**
居住用地土壤、饮用水暴露

| | |
|---|---|
| 0.36 μg/m³ | **INDOOR AIR**<br>室内空气 |

Vapors to IA
0.77 mg/kg
室内蒸汽入侵

Terrestrial
Habitats
site-specific
陆生栖息地
特定场地

Gross Cont.
500 mg/kg
总污染

Human
Health
人体健康

Direct Exposure
1.2 mg/kg
直接暴露

**SOIL土壤**

**SOIL GAS 土壤气体**

**Leaching: 0.30 mg/kg**
淋溶

720 μg/m³

**GROUNDWATER 地下水**

Aquatic Habitats
71 μg/L
水生栖息地

Vapors to IA
2,300 μg/L
室内蒸汽入侵

Gross Cont.
170 μg/L
总污染

Human
Health

人体健康

**Drinking Water
5.0 μg/L**
饮用水

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# Example "Environmental Hazard Map"

示例"环境危害图
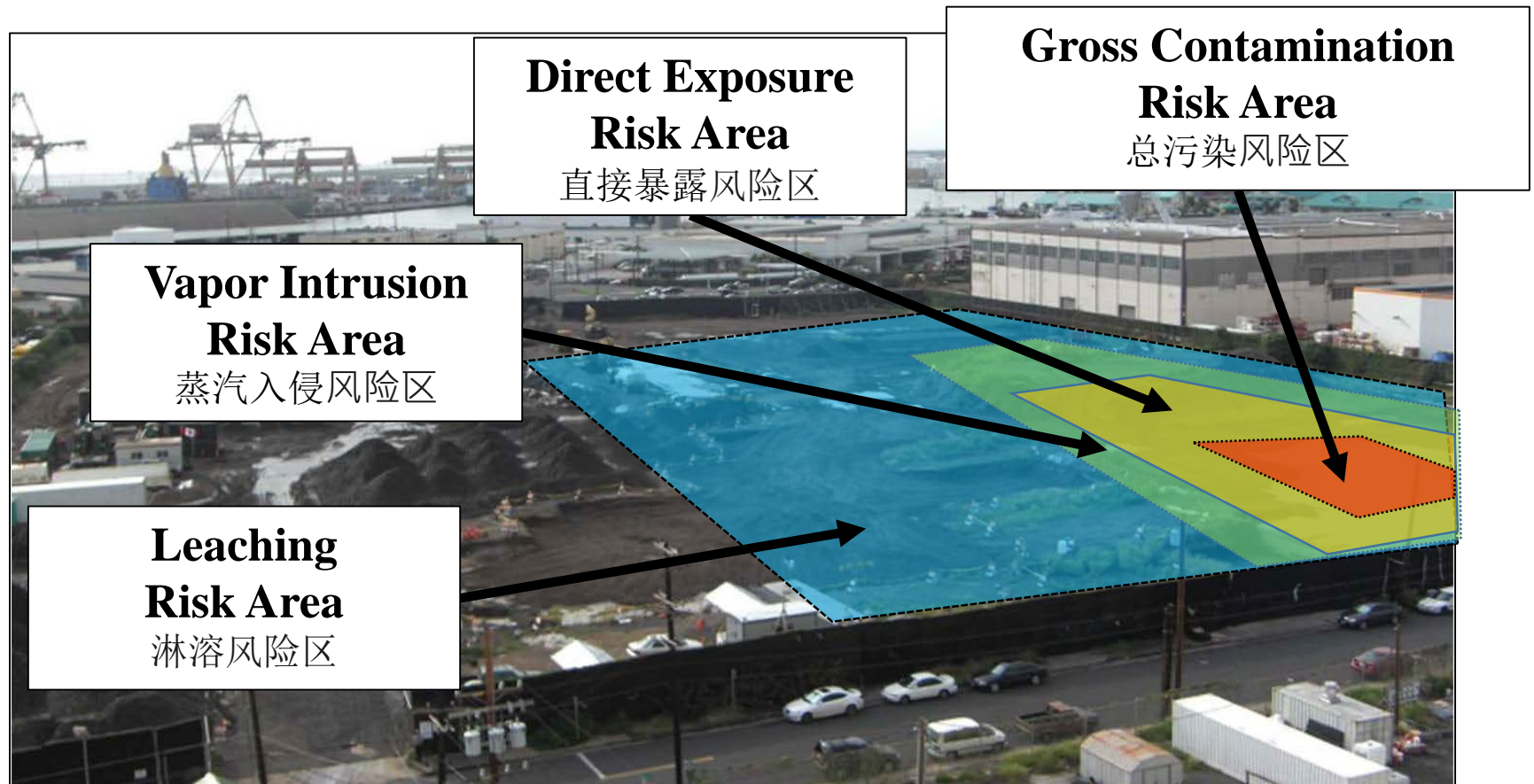


**Direct Exposure Risk Area**
直接暴露风险区

**Gross Contamination Risk Area**
总污染风险区

**Vapor Intrusion Risk Area**
蒸汽入侵风险区

**Leaching Risk Area**
淋溶风险区

**Example Remediation and Redevelopment Design:**修复和再开发设计示例
- **Active remediation of Gross Contamination and Direct Exposure, Vapor Intrusion areas;** 积极修复总污染以及直接暴露、蒸汽入侵高风险区
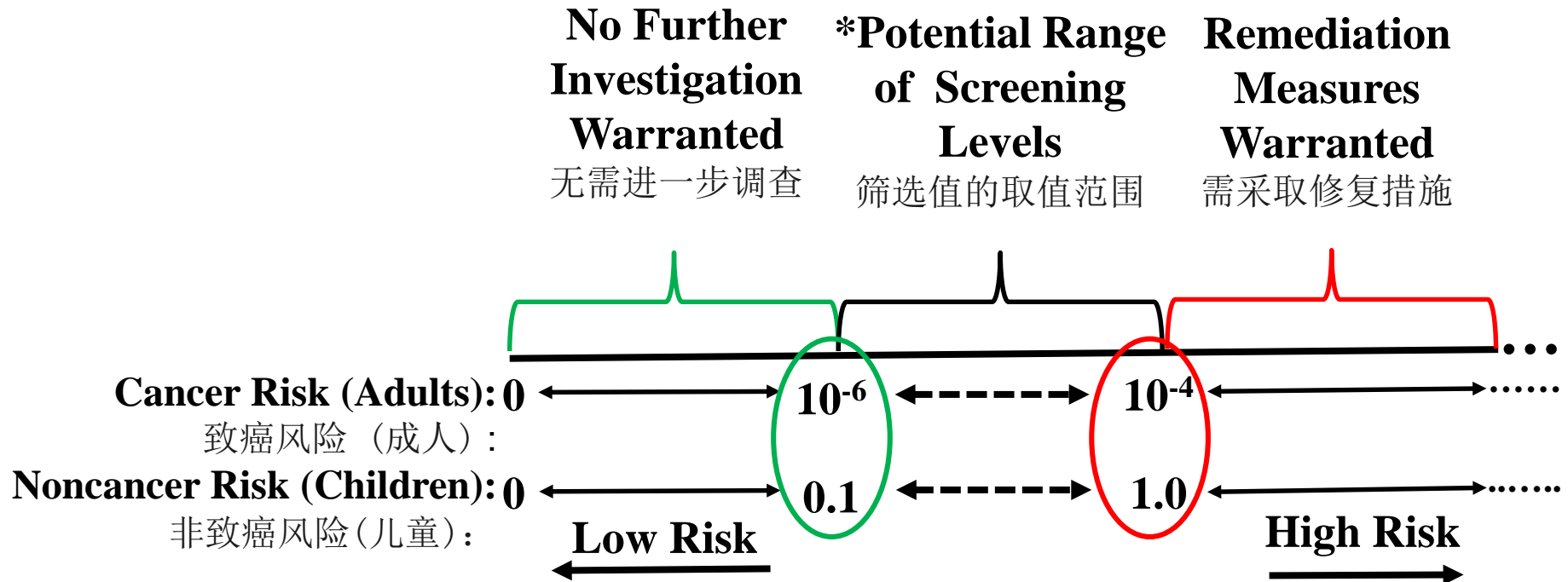- **Groundwater monitoring of leaching risk area.** 地下水监测存在淋溶风险的区域

# Full or Partial Remediation and Long-Term Management
## 全部或部分补救和长期管理
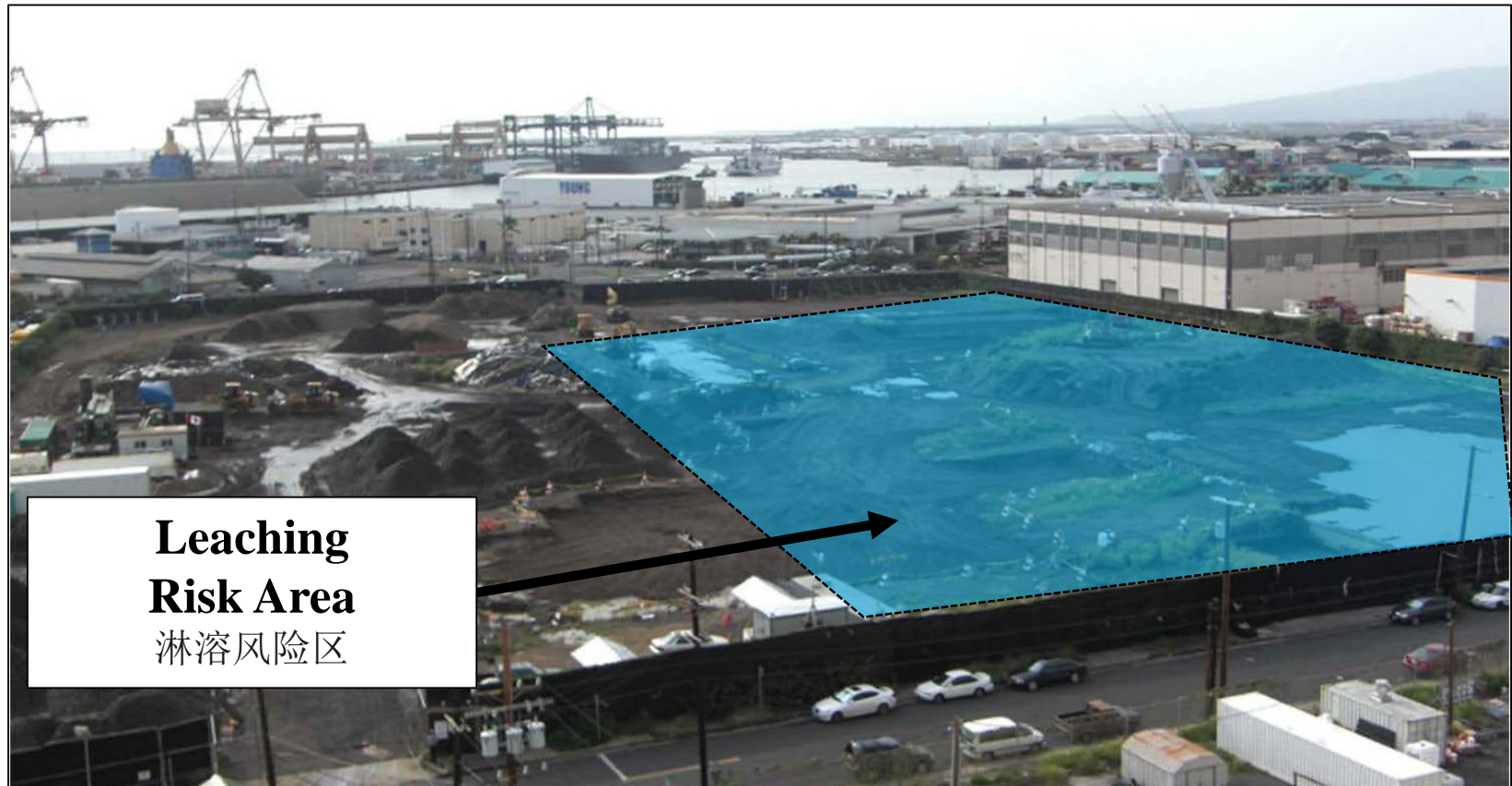


**Leaching Risk Area**
淋溶风险区

**Example Remediation and Redevelopment Design:**修复和再开发设计示例
- **Active remediation of Gross Contamination and Direct Exposure, Vapor Intrusion areas;** 积极修复总污染以及直接暴露、蒸汽入侵高风险区
- **Groundwater monitoring of leaching risk area.** 地下水监测存在淋溶风险的区域

# Target Health Risk versus Remediation Requirements

目标健康风险与修复要求

**USEPA EPA 2017 (Removal Management Levels):**

**"Where the *cumulative carcinogenic site risk*… is less than $10^{-4}$ and the *(cumulative) non-carcinogenic (index)* is less than 1.0, action generally is not warranted."**

"场地累计致癌风险…小于$10^{-4}$，（累计）非致癌（指数）小于1.0时，通常不需要采取行动。"



**No Further Investigation Warranted**
无需进一步调查

**\*Potential Range of Screening Levels**
筛选值的取值范围

**Remediation Measures Warranted**
需采取修复措施

**Cancer Risk (Adults):** 0    $10^{-6}$    $10^{-4}$ ……
致癌风险（成人）：

**Noncancer Risk (Children):** 0    0.1    1.0 ……
非致癌风险（儿童）：

**Low Risk**      **High Risk**

**\*USEPA RSLs reflect most conservative target risk necessary
(most conservative of potential range of acceptable screening levels)**
美国环保署区域筛选值采用的目标风险水平最为保守

# Remediation Measures *Always* Required if Excess Cancer Risk >$10^{-4}$ and Noncancer Hazard >1.0

如果致癌风险> $10^{-4}$，非致癌危害商> 1.0，需要，就需要采取修复措施

**USEPA 1991 (OSWER DIRECTIVE 9355.0-30):**

**"For sites where the *cumulative site risk* to an individual based on reasonable maximum exposure… is below $10^{-4}$ (i.e., low excess cancer risk), action generally is not warranted."**
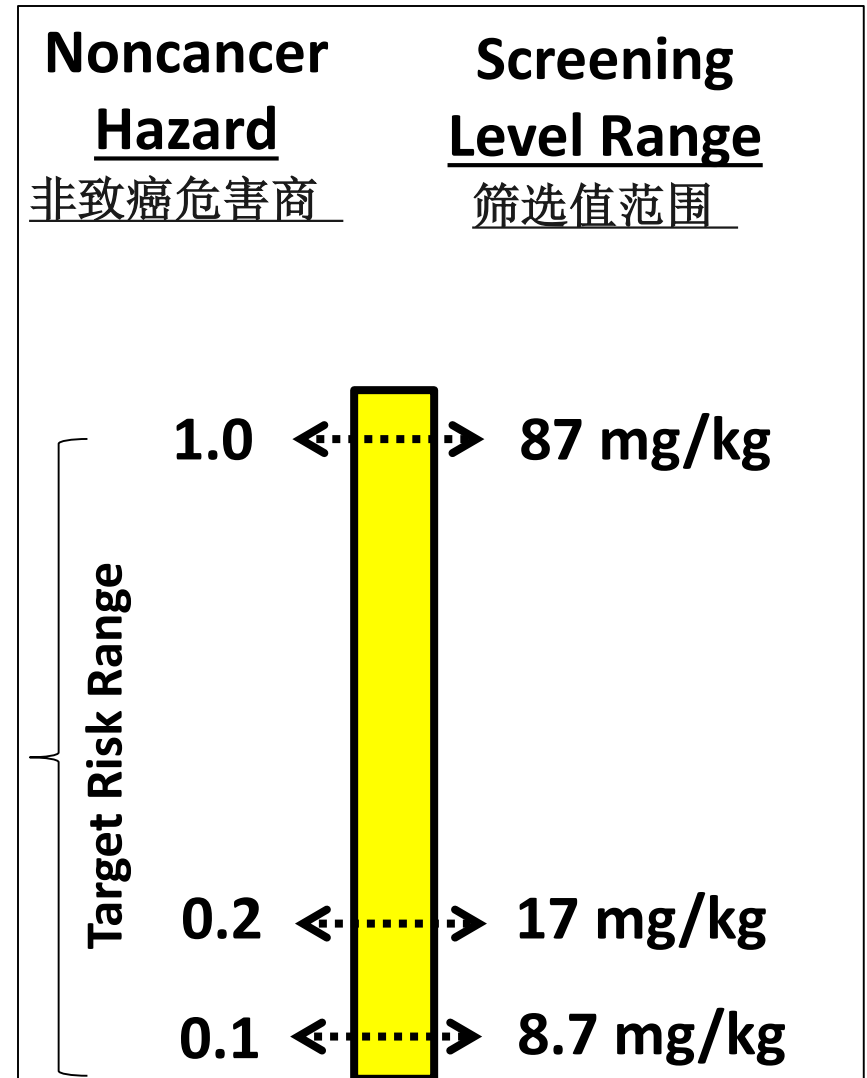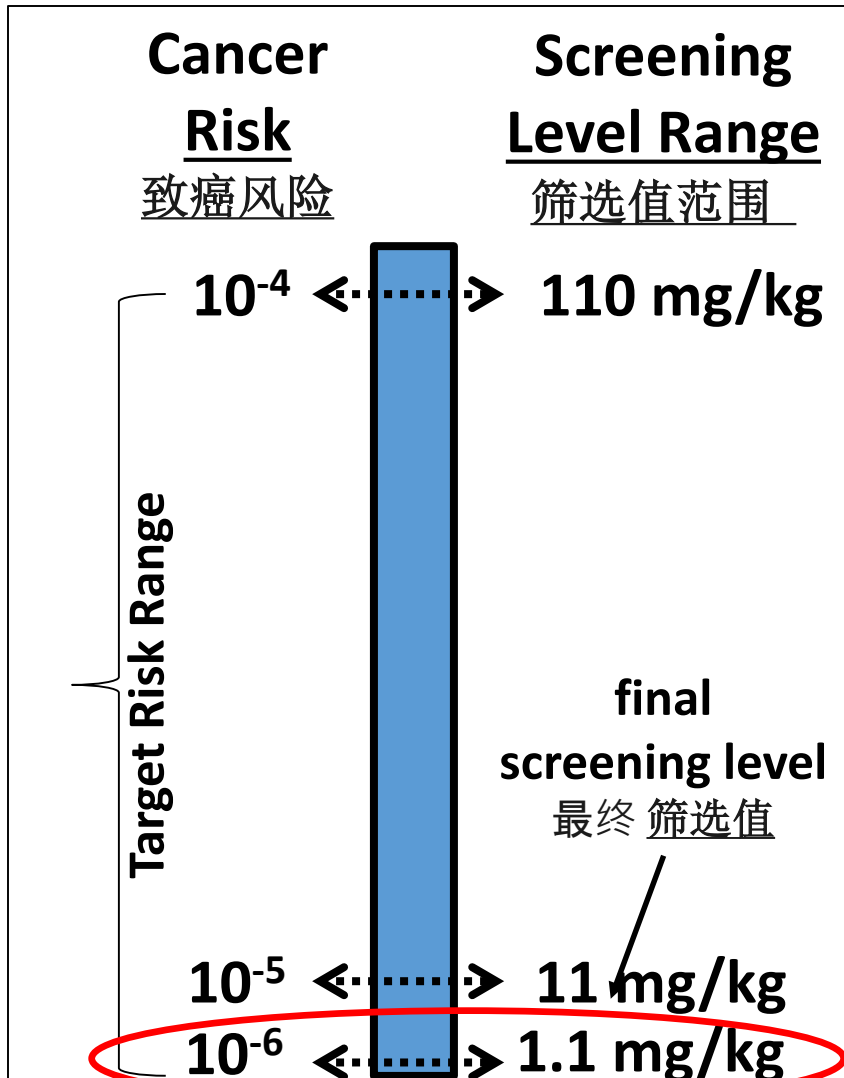
"如果基于合理的最大暴露量，对个体的累计风险...低于$10^{-4}$（即致癌风险低）的场地，通常不需要采取行动。"

**USEPA 1994 (National Contingency Plan):**

**"In cases (which) result in a *cumulative risk* in excess of $10^{-4}$ (i.e., high excess cancer risk), (site-specific factors) may be considered when determining … (remedial actions and final) cleanup level(s)."**

"在累计风险超过$10^{-4}$（即高致癌风险）的情况下，在确定...（修复行动和最终）清理目标时，可考虑（场地特征因素）。"

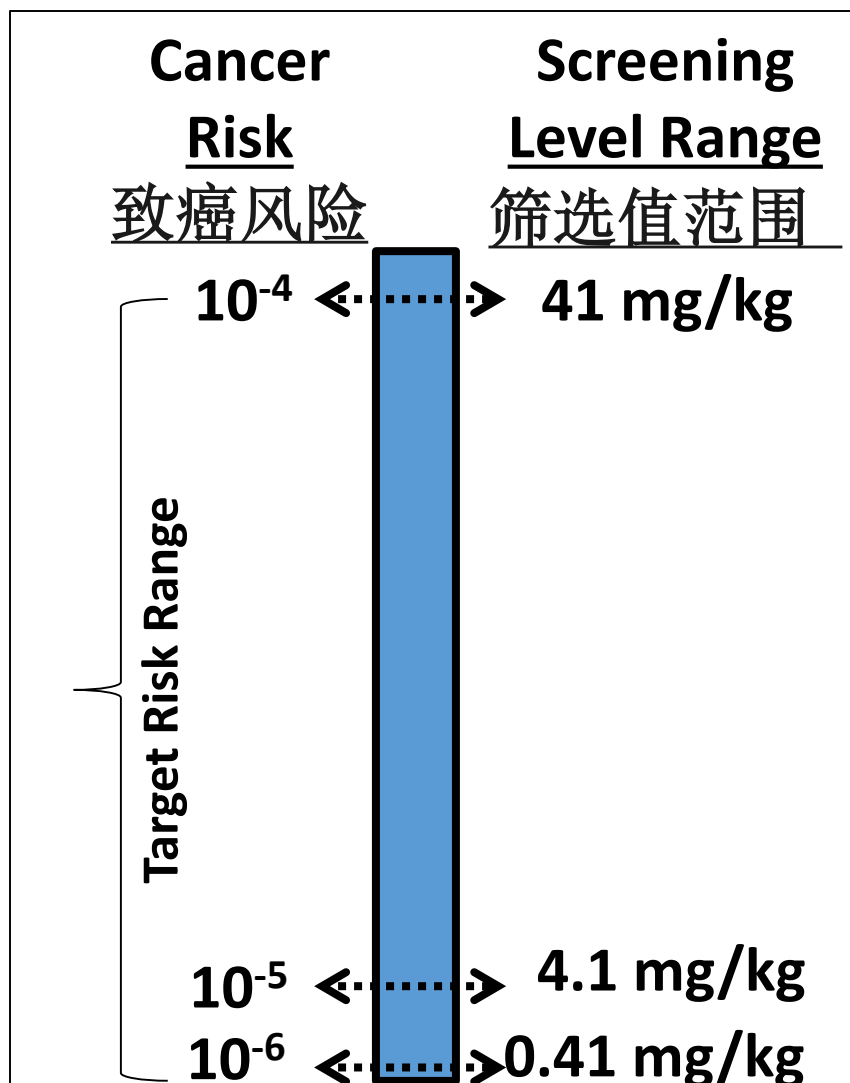# PCE Target Risk vs Soil Direct Exposure Screening Level
## 四氯乙烯的目标风险与土壤直接暴露筛选值

**Cancer Risk**
致癌风险

**Screening Level Range**
筛选值范围

$10^{-4}$ <·····> 110 mg/kg

**Target Risk Range**

**final screening level**
最终 筛选值

$10^{-5}$ <·····> 11 mg/kg

$10^{-6}$ <·····> 1.1 mg/kg

**Noncancer Hazard**
非致癌危害商

**Screening Level Range**
筛选值范围

1.0 <·····> 87 mg/kg

**Target Risk Range**

0.2 <·····> 17 mg/kg

0.1 <·····> 8.7 mg/kg

**Considerations: Volatile chemical, inhalation risk, high confidence in cancer studies, often present with other carcinogenic VOCs.** 注意事项：挥发性化学物质，吸入风险，致癌效应研究可信度高，往往与其他致癌性VOCs一起出现.

# Arsenic Target Risk vs Soil Direct Exposure Screening Level
## 砷的目标风险与土壤直接暴露筛选值

| Cancer Risk 致癌风险 | Screening Level Range 筛选值范围 |
|---|---|
| $10^{-4}$ ◄┈┈► | 41 mg/kg |
| $10^{-5}$ ◄┈┈► | 4.1 mg/kg |
| $10^{-6}$ ◄┈┈► | 0.41 mg/kg |

Target Risk Range

| Noncancer Hazard 非致癌危害商 | *Screening Level Range 筛选值范围 |
|---|---|
| | final screening level 最终 筛选值 |
| 1.0 ◄┈┈► | 23 mg/kg |
| 0.2 ◄┈┈► | 4.6 mg/kg |
| 0.1 ◄┈┈► | 2.3 mg/kg |

Target Risk Range
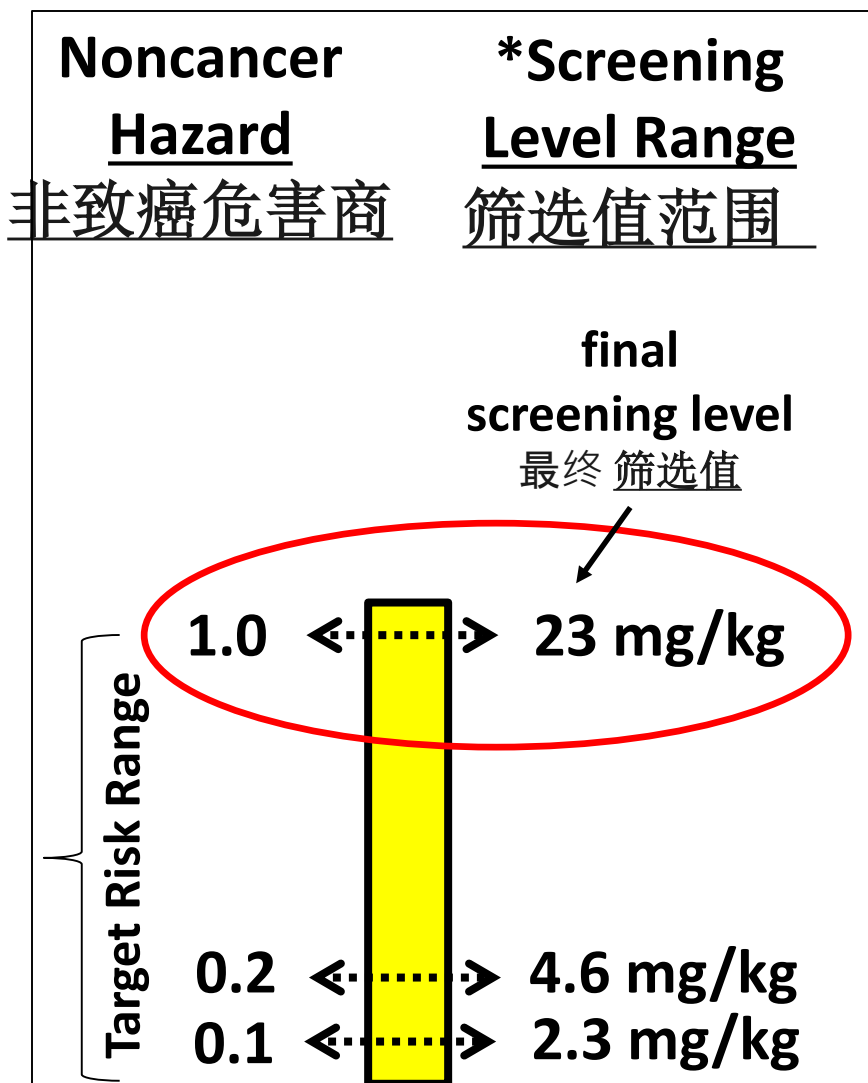
**Considerations: Natural background, higher confidence in noncancer studies, primary risk driver if present, *bioaccessible arsenic.** 注意事项：自然背景，非致癌效应研究可信度更高，主要风险驱动因素，生物有效态砷。

# Example Adjustments to USEPA
# Soil Direct Exposure Screening Levels (residential)
### 对 USEPA 的示例调整 直接暴露土壤筛选值（住宅）

| Chemical<br>化学品 | Initial Level (mg/kg) | [1]Adjusted Level (mg/kg) | Rationale<br>依据 |
|---|---|---|---|
| Arsenic<br>砷 | 0.68 | 23 | HQ =1.0; *Natural* background; *Higher confidence* in noncancer toxicity factors, risk driver 自然背景; 非致癌毒性因子可信度高, 风险驱动 |
| Benzo(a)pyrene<br>苯并(a)芘 | 0.11 | 3.6 | HQ = 0.2; Higher confidence in noncancer toxicity factors 非致癌毒性因子可信度高 |
| Total Petroleum Hydrocarbon<br>总石油烃 | Carbon Ranges<br>碳范围 | Weighted TPH Fuels<br>碳范围加权 TPH燃料 | Expedited decision making; Reduced laboratory cost 加快决策; 降低实验室成本 |

1. Must fall within USEPA $10^{-4}$ to $10^{-6}$ range; calculation of cumulative risk required if multiple chemicals approach screening levels.

必须在USEPA $10^{-4}$至$10^{-6}$范围内;如果多个化学品接近筛选水平，则需要计算累积风险

# Chemical-Specific Target Risks
# and "Balanced" Screening Levels

具体化学品的目标风险和"均衡"环境筛选值

| Chemical<br>化学品 | Target Risk<br>目标风险 | Rationale<br>依据 |
|---|---|---|
| *Default (most VOCs)<br>默认（大多数挥发性化合物) | ECR = $10^{-6}$<br>HQ = 0.2 | *Most stringent screening levels necessary* (starting point)<br>最严格的筛选值（起点） |
| Arsenic, Aldrin, Chlordane, Hexavalent Chromium, Dieldrin, Dioxins, Ethylbenzene, Heptachlor, Heptachlor Epoxide, Naphthalene, PAHs, PCBs, Total Petroleum Hydrocarbons<br>砷，艾氏剂，氯丹，六价铬，狄氏剂，二恶英，乙苯，七氯，七氯环氧化物，萘，多环芳烃，多氯联苯，总石油烃 | *ECR = $10^{-4}$ to $10^{-5}$*<br>HQ = 0.2 *to* 1.0<br><br>致癌风险<br>=$10^{-4}$到$10^{-5}$<br><br>危害商<br>=0.2到 1.0 | • *Natural* Background;<br>• *Anthropogenic* background;<br>• *Higher confidence* in noncancer toxicity factors;<br>• Often *primary risk drivers;*<br>• Evaluate *cumulative risk* as needed.<br><br>• 自然背景；<br>• 人为背景；<br>• 非致癌毒性因子可信度高；<br>• 常常是风险主导因子;<br>• 需要时评估累计风险。 |

# EHE Summary 环境危害评估总结

- **EHE approach with ESLs expedites screening of site data and identification of potential environmental hazards;**
  采用环境筛选值进行环境危害评估可快速筛选场地数据，识别潜在的环境危害；
- **ESLs "balanced" to consider background, confidence in toxicity factors, target risk, etc., to make more useful for quickly determining remedial actions;**
  综合考虑背景 、毒性因子的可信度 、目标风险等因素，可用于快速确定修复措施；
- **Minimizes needs for time consuming, expensive, detailed risk assessment that would result in the same decision;**
  最大限度地减少耗时，昂贵，详细的风险评估的需求这将导致相同的决定
- **Site-specific "forward" risk assessment allowed but must address ALL potential environmental concerns and explain deviations from default assumptions used in ESLs.**
  允许开展特定场地风险评估，但必须考虑所有潜在的环境问题，并说明与环境筛选值中默认假设的偏差。

# Common Problems in Contaminated Soil and Groundwater Investigations
## 污染土壤和地下水调查的常见问题
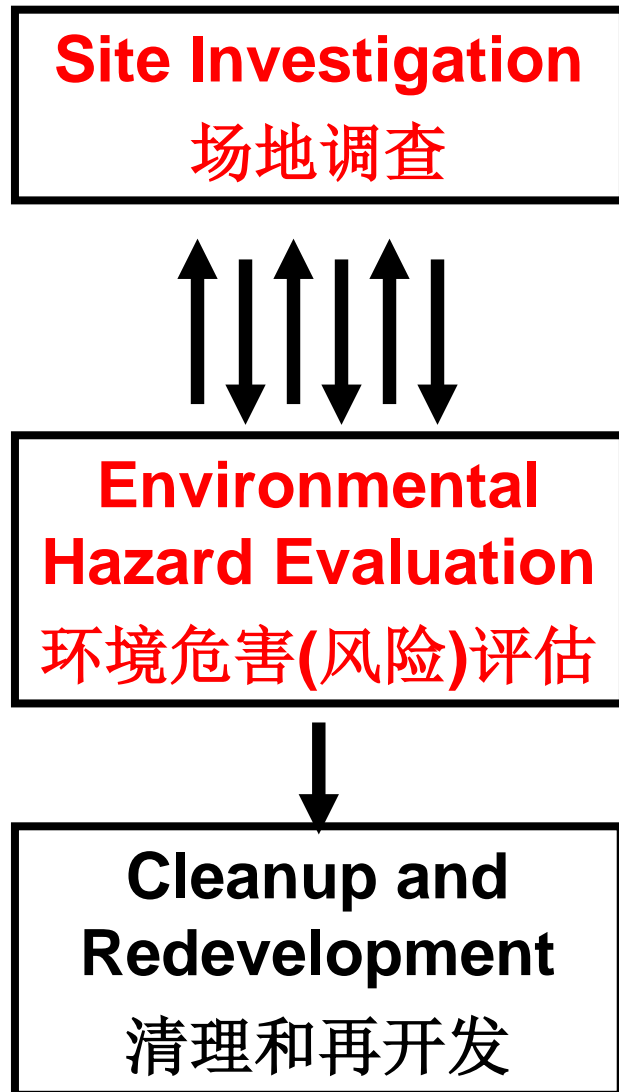
**Site Investigation**
**场地调查**

↑↓↑↓↑↑↓↓

**Environmental Hazard Evaluation**
**环境危害(风险)评估**

↓

**Cleanup and Redevelopment**
**清理和再开发**

- **Need for repeated site investigations**
  需要重复开展场地调查
- **Debates over risks and cleanup levels ("risk assessment")**
  争论风险和清理程度 (风险评估)
- **Investigation and cleanup can be delayed for years**
  调查和清理会延误很多年
- **Abandoned Property = "Brownfield"**
  废弃土地 = "棕地"

# References (draft translations in Chinese)
## (reflects compilation of United States and other guidance)
# 参考文献 (草稿翻译成中文 )
## （美国和其他国家导则汇编）

**1. Site Investigation:** *Technical  Guidance Manual* **(2016 and updates): Hawaiʻi Department of Health, HEER Office,http://www.hawaiidoh.org/**

 *《技术指导手册》* （**2016**年以及更新）：夏威夷卫生署**HEER**办公室 **http://www.hawaiidoh.org/**

**2. Risk Assessment:** *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater – Tropical Pacific Edition* **(Fall 2017 and updates): Hawaiʻi Department of Health, http://eha-web.doh.hawaii.gov/eha-cma/Leaders/HEER/ehe-guidance---pacific-basin-edition**
 *《土壤和地下水污染场地环境危害评估—— 热带太平洋版 》* （ **2017**年秋季版以及更新）：夏威夷卫生署
**http://eha-web.doh.hawaii.gov/eha-cma/Leaders/HEER/ehe-guidance---pacific-basin-edition**

# Why Collect Soil Samples?
## 为什么采集土壤样品?

1. ***Estimate the extent of contamination* that might pose an environmental concern (direct exposure, eco risk, leaching and groundwater impacts, gross contamination, etc.).**

   估计可能导致环境问题（直接接触、生态风险、淋溶与地下水的影响、总污染等）的*污染程度*。

2. ***Estimate the true or "average" concentration* of contaminant for targeted area and volume of soil (e.g., a "source" or "exposure" area).**

   估计目标区域和土体中污染物的真或"平均"浓度 （例如，"源"或"暴露"区域）。

> **All data for particulate matter like soil represent an "average."**
> 像土壤这样的颗粒态物质的所有数据都是"平均值"

# 1980s USEPA Soil Sampling Guidance
## Based on 1970s Guidance for Industrial Waste

### 20世纪80年代美国环保署土壤采样指导
### 基于20世纪70年代工业废物导则

**English 英语** ✓

**French 法语** ✗

**Industrial Waste (liquid)**
工业废物
（液体）

↓

**Consistent Process Yields "Uniform" Waste**
连续过程产生 "均质" 废物

↓

**Sample Collection Method and Sample Mass Not Important**
采样方法与
样本量不重要

↓

**"Discrete" Sampling Methods (any mass from target area representative)**
"离散" 采样方法
（目标区域任意质量都有代表性）

**Mining Industry**
采矿业

**Agricultural Industry** 农业

↓

**Large- & Small-Scale Spatial Heterogeneity Important**
大尺度和小尺度空间异质性很重要

↓

**Sample Collection Method and Sample Mass Very Important**
采样方法与样本量很重要

↓

**Decision Unit & "Multi Increment" Sampling Methods Required**
需要决策单元与 "多点增量" 采样方法

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# 1980s Origin of "Discrete" Sampling Methods (based on testing of industrial chemicals and waste)
## 20世纪80年代开始使用"离散"采样方法
### （基于工业化学品与废物的测试）

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*"The PCB level is assumed to be uniform within (a contamination zone/spill area) and zero outside it."*

**USEPA 1985: Verification of PCB Spill Cleanup (basis of TSCA regulations and guidance)**

*"假定（污染区域/泄漏区域）内PCB水平是均匀的，区域外为零。"*

美国环保署 **1985**年：多氯联苯泄漏清理的核查（**TSCA** 条例和导则的基础）

---

*"When there is little distance between points it is expected that there will be little variability between points."*

**USEPA 1989: Methods for Evaluating the Attainment of Cleanup Standards**

*"当采样点之间的距离很小时，点和点之间几乎没有变异。"*

美国环保署 **1989**年：清理达标的评估方法

---

- **Implications:** *Location* of sample within targeted area and *mass/volume* of sample collected *NOT important*;
  含义：目标区域内样品的位置以及样本的质量/体积不重要;
- **Greatly simplified environmental investigations.**
  大大简化了环境调查。

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# Common Problems with Discrete Soil Sample Data
离散土壤样品数据的常见问题

## Need for multiple remobilizations and "step-out" investigations
需要多次进出场调查
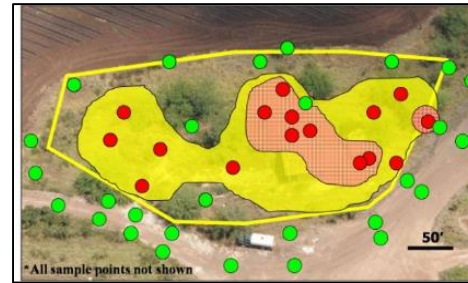


## Failed confirmation samples and multiple over excavations
确认样品不合格和多次超挖



## Accidental Import or Export of Contaminated Soil
意外运进或运出污染土壤

# Example Excavation Plan Based on Discrete Data
## 基于离散数据的开挖计划

- **25 discrete soil samples collected**；
  采集了25份离散土壤样品；
- **# Samples based in part on budget;**
  # 样品数部分基于预算；
- **Soil excavation plan prepared.**
  编写土壤开挖计划。

**Initial Sample Results**
初始采样结果
**X：Not detected** 未检出
**X：Detected but below 1ppm screening level**
检出，但低于1ppm的筛选值
**X：Detected above 1ppm screening level**
检出，且高于1ppm的筛选值

**Apparent Isolated Hot Spot**
明显独立的热点区

**Apparent Isolated Cold Spot**
明显独立的非污染区
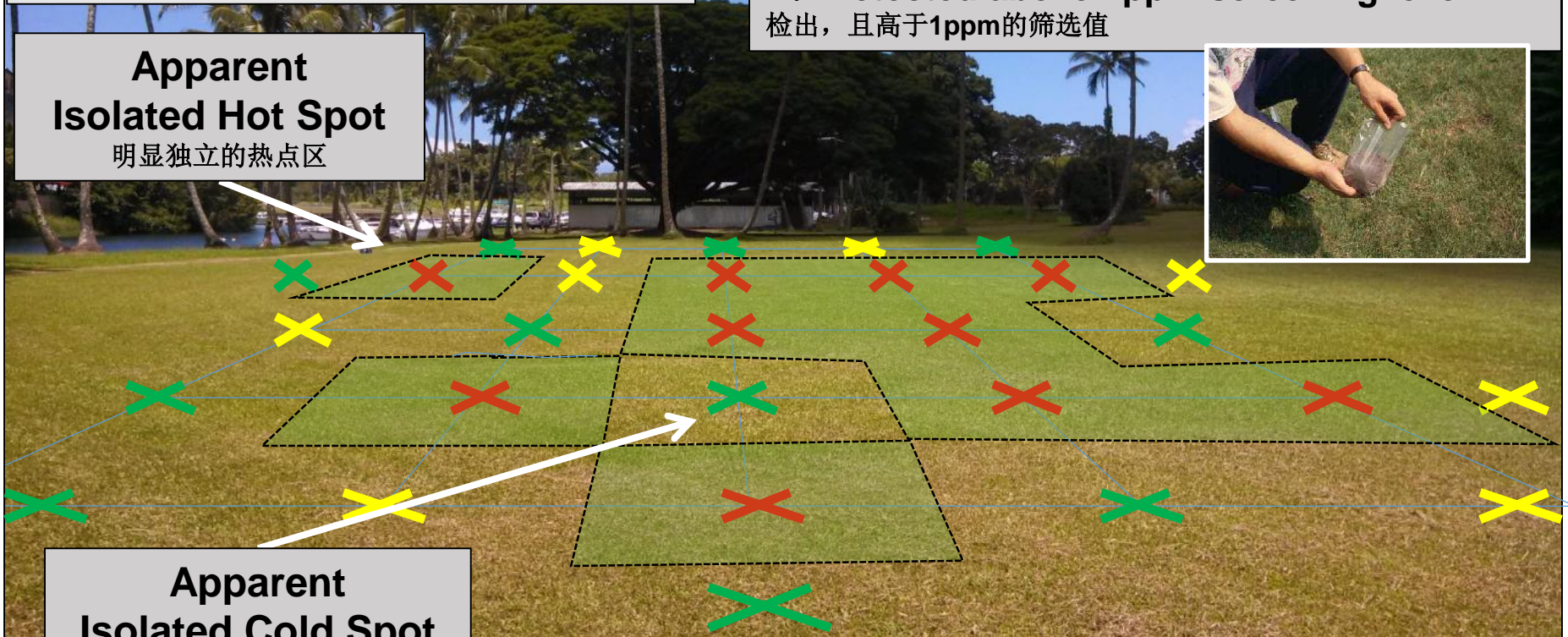
# Failed Excavation Confirmation Samples??

## 开挖确认样品不合格??

- **Multiple failed confirmation samples**；
  多个确认样品不合格；
- **Additional excavation and resampling required**；
  需要再次开挖和重新采样；
- **No clear end point**；
  没有明确的终点；
- **Significant added time and cost to project.**
  显著增加项目的时间和成本。

**Confirmation Sample Results**确认采样结果

- 🟢：**Not detected** 未检出
- 🟡：**Detected but below 1ppm screening level** 检出，但低于1ppm的筛选值
- 🔴：**Detected above 1ppm screening level** 检出，且高于1ppm的筛选值
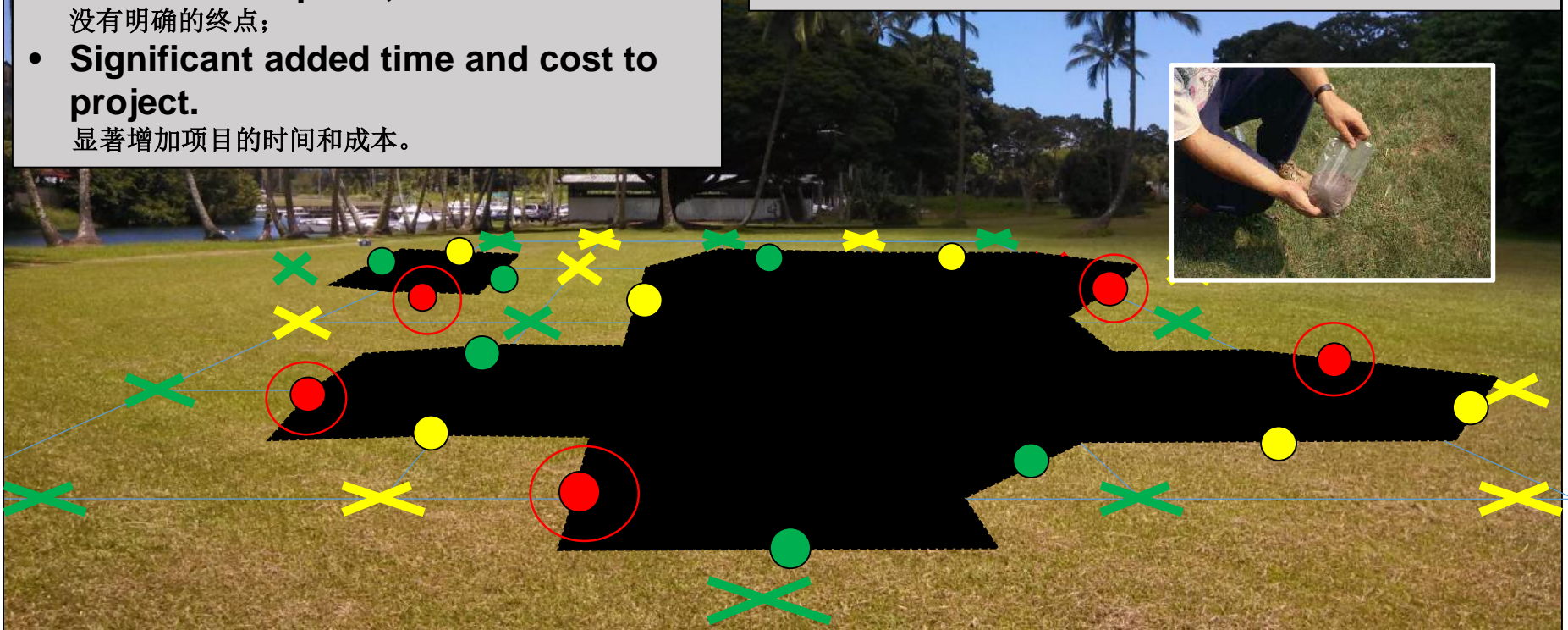
# Every wonder...每一个惊愕...

## "What if I moved my sample point over a few feet?"
如果我把采样点偏移了几英尺，会怎么样？
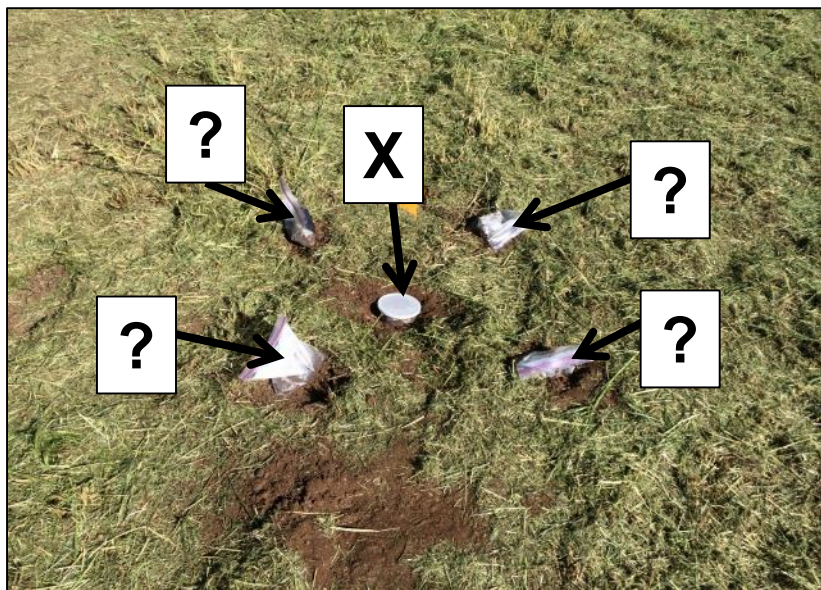


## "What if the lab tested a different aliquot of soil?"
"如果实验室测试的是另一份土壤分样，会是怎么结果？"



**Metals:**
**0.5-1.0 grams**
金属：
**0.5-1.0 克**



**VOCs:**
**5 grams**
挥发性有机化合物：
**5 克**



**PCBs, Pesticides, Dioxins, TPH, PAHs:**
**10-30 grams**
**PCB、杀虫剂、二恶英、TPH、PAH：**
**10-30 克**

# So did we… Discrete Soil Sample Variability Field Study
## 那我们……离散土壤样品变异性现场研究

- **24 grid points designated at each of 3 sites;**
  3 个场地都指定了24 个网格；
- **Hundreds of discrete samples collected;**
  采集了数百个离散样品；
- **Multi Increment triplicate samples collected from same areas.**
  从同一片区域采集三个多点增量重复样。
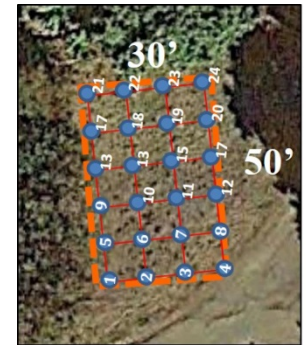


### Study Site A
### (arsenic in wastewater)
研究场地 A
（废水中的砷）



**13,500 ft2 area**
面积13,500 平方英尺

### Study Site B
### (lead in incinerator ash)
研究场地 B
（垃圾焚烧灰中的铅）



**1,500 ft2 area**
面积1,500 平方英尺

### Study Site C
### (PCBs transformer oil)
研究场地 C
（变压器油中的PCB）



**6,000 ft2 area**
面积6,000 平方英尺

*Small-Scale Variability of Discrete Soil Sample Data (HDOH 2015)*
*离散土壤样品数据的小尺度变异性* （HDOH 2015）
**http://eha-web.doh.hawaii.gov/eha-cma/Org/HEER/**

# Published Study Results

发表的研究结果

**Roger Brewer, John Peard & Marvin Heskett (2017)**

*A critical review of discrete soil sample reliability:*

- *Part 1 – Field study results*
- *Part 2—Implications*

**Journal of Soil and Sediment Contamination.**

**Part 1: DOI: 10.1080/15320383.2017.1244172**

**http://dx.doi.org/10.1080/15320383.2017.1244171**

**Part 2: DOI: 10.1080/15320383.2017.1244172**
**http://dx.doi.org/10.1080/15320383.2017.1244172**

> **Field report and recorded webinars posted to HEER webpage**
> **http://eha-web.doh.hawaii.gov/eha-cma/Leaders/HEER/Webinar**

# "Low" Variability at Arsenic Study Site
## (arsenic-contaminated wastewater, fine-grained soils)
### 砷研究场地 "低" 变异性
### （砷污染废水、细粒土壤）



**Grid Pt #2**
网格点#2

**Inter-Sample Variability**
样品间变异性

**230 mg/kg**

**140 mg/kg**

**120 mg/kg**

**120 mg/kg**

**260 mg/kg**

**Variability between co-located samples**
相邻样品之间的变异性

**Average Variability = 2X**
平均变异性 = 2X
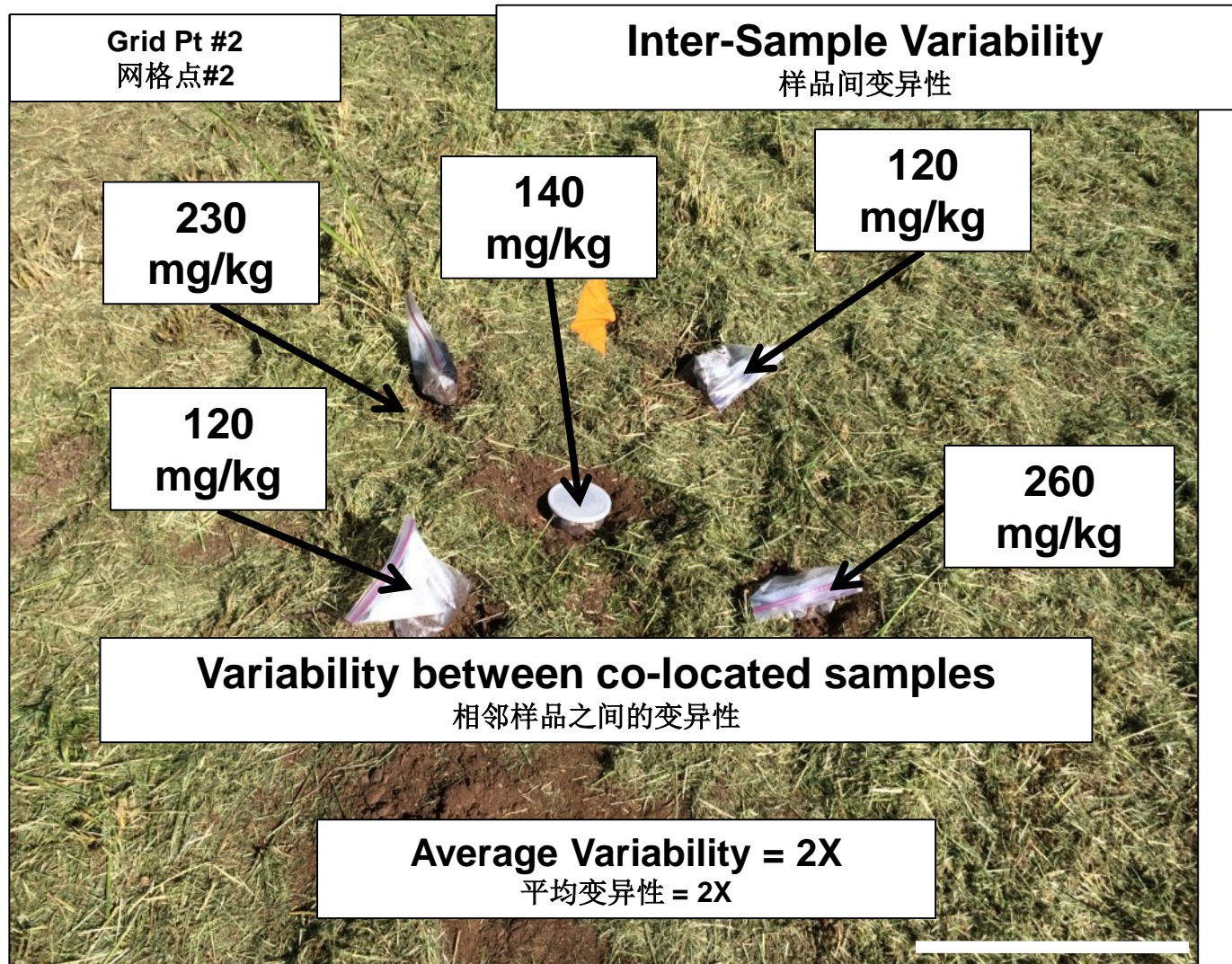
# "Moderate" Variability at Lead Study Site (lead-contaminated ash mixed with soil)
铅研究场地*"中等"变异性*（铅污染的灰-土混合物）



**Grid Pt #7**
网格点#7

**Inter-Sample Variability**
样品间可变性

**240 mg/kg**

**240 mg/kg**

**120 mg/kg**

**Hawai'i Lead**
夏威夷铅
**ESL = 200 mg/kg**

**800 mg/kg**

**260 mg/kg**

**Variability between samples is random and not indicative of larger-scale trends**
样品之间的变异性是随机的，不代表更大尺度的趋势

**Average Variability = 7X**
平均变异性 = 7X

**3 feet**英尺
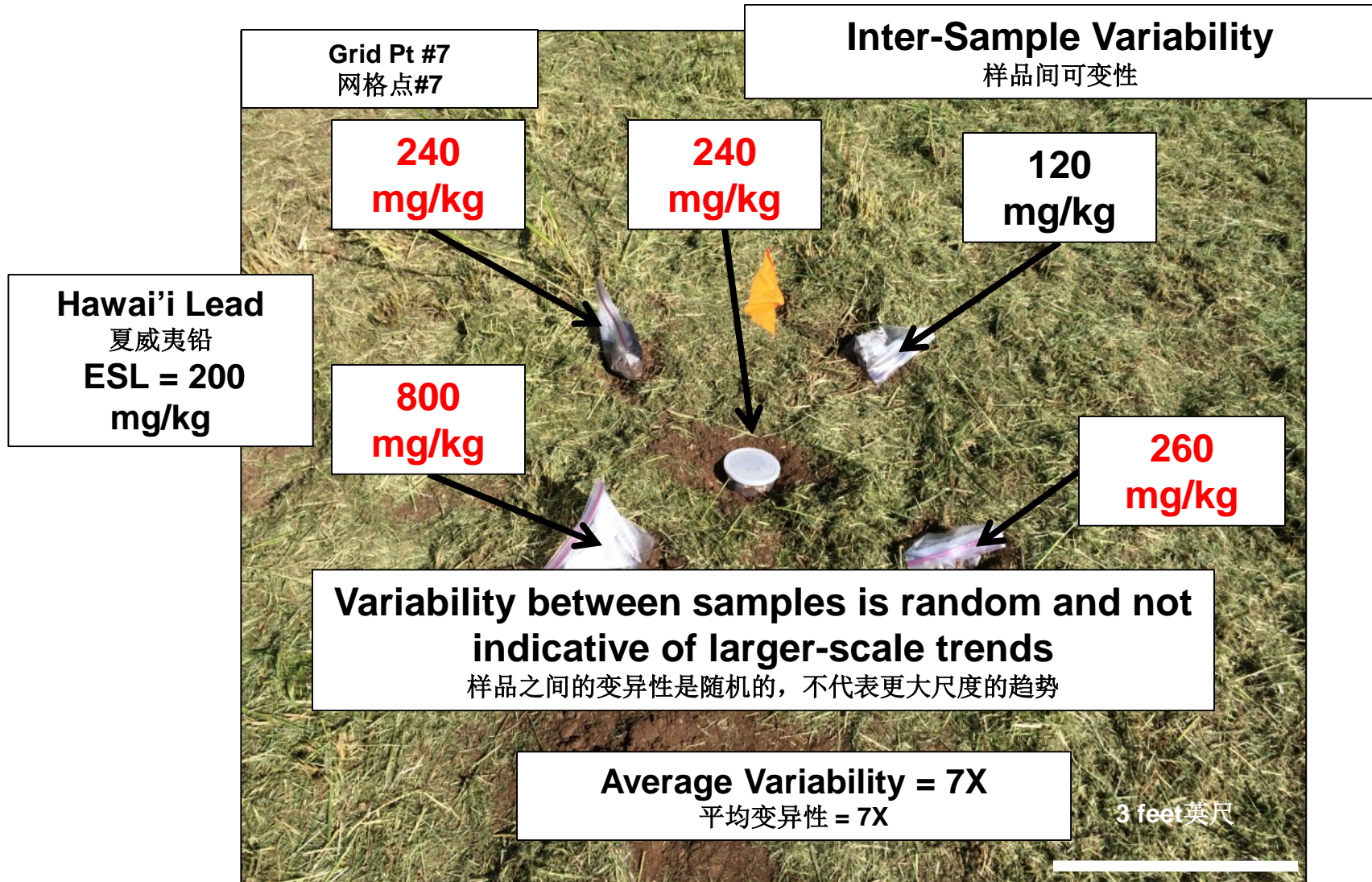
# High Variability at PCB Study Site
## (Waste transformer oil poured on bare soil)
### PCB研究场地"高"可变性
### （倾倒在裸露土壤上的废变压器油）



Grid Pt #24
网格点#24

Inter-Sample Variability
样品间可变性

Average Variability = 39X
平均变异性 = 39X

2,400 mg/kg !

4.9 mg/kg

6.0 mg/kg

14 mg/kg

7.7 mg/kg

91 mg/kg

3 feet英尺
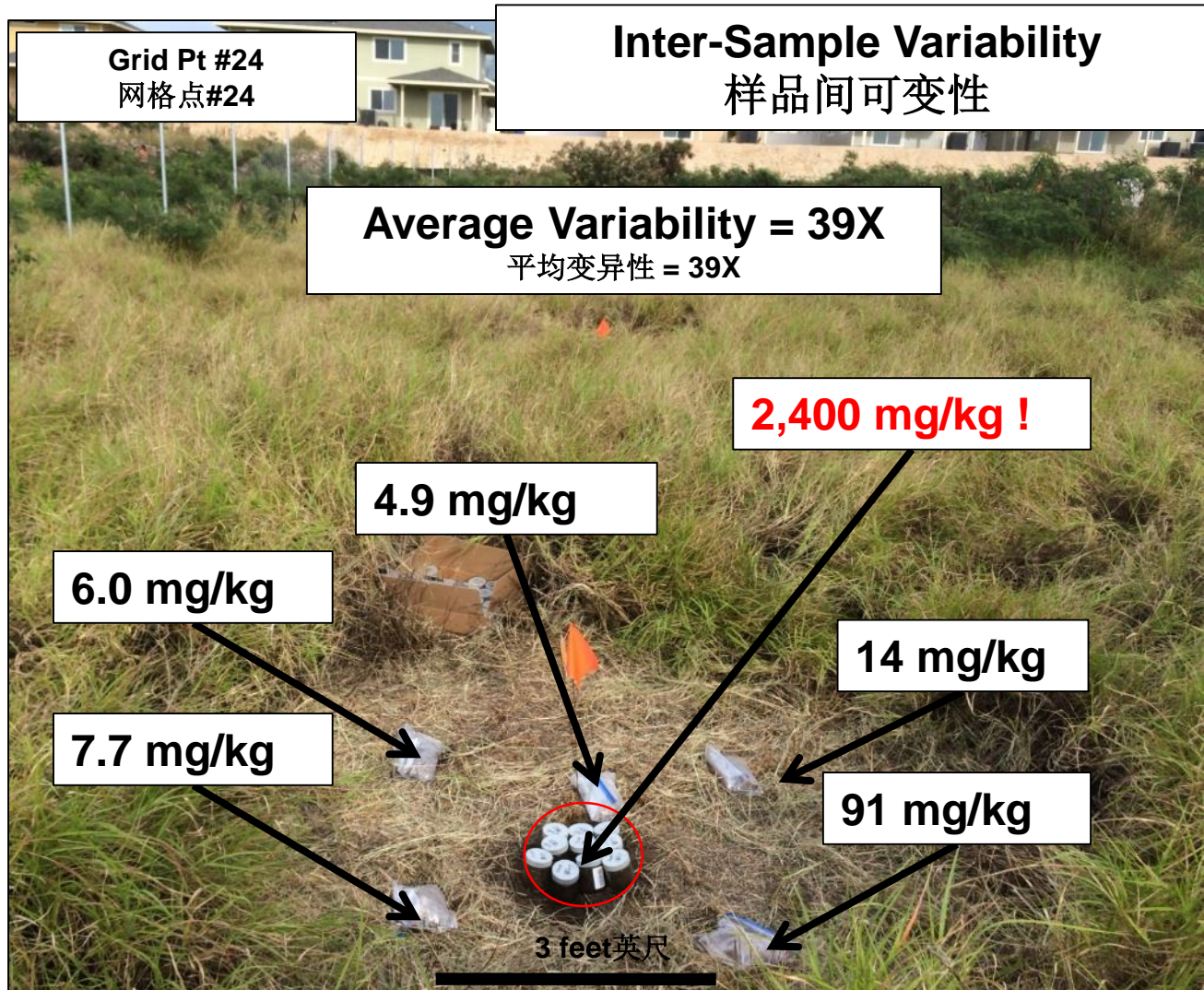
如;

# Suspect PCB-Infused Tar Balls (Nuggets)
## 疑似**PCB**浸渍过的焦油球（小块）

1mm

2mm

1cm
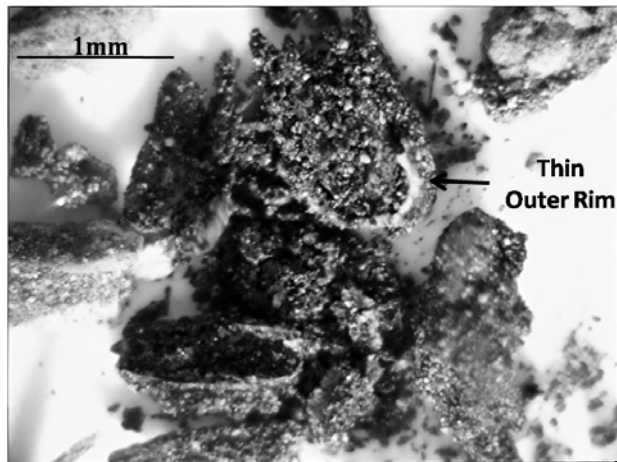
**Photomicrograph**
**(different nugget)**
显微照片
（*不同小块）
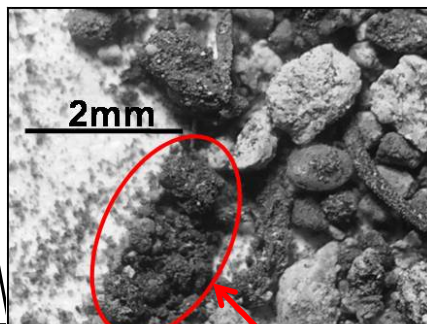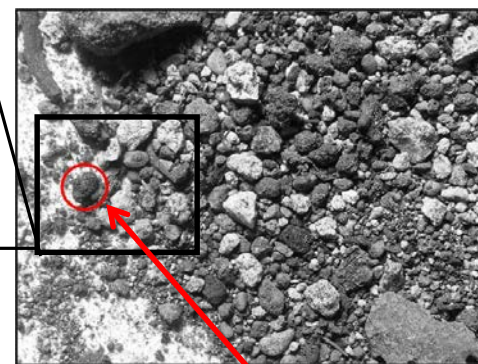
**Suspect PCB-Rich**
**Nugget in Soil**
土壤中疑似富含**PCB**的小块

**Implications**:启示：

- *Very low concentration* **if no nuggets included in 10-gram laboratory aliquot;** 果10克实验室等分试样中没有金块，则浓度非常低
- *Very high concentration* **if no nuggets included in 10-gram laboratory aliquot;** 如果10克实验室等分试样中没有金块，则浓度非常高;
- *Reported concentration is random* **and not reliably representative of sample provided.** 报告的浓度是随机的，不能可靠地代表所提供的样品.

# Discrete Soil Sample Data is Random within an Unknown Range of Concentrations

## 离散土壤样本的检测数据是一个未知浓度范围内的随机数

- **Small-scale, random variability of contaminant concentrations over a few inches or feet;**
  几英寸或几英尺内污染物浓度的小尺度*随机*变异性；
- **Concentration reported for any given discrete sample is largely random;**
  任何给定的离散样本的报告浓度很大程度上是随机的；
- **Statistics can't fix bad data.**
  统计无法修复坏数据。

**Concentrations highly variable around any given grid point**
任何网格点周围的浓度都是高度变异的
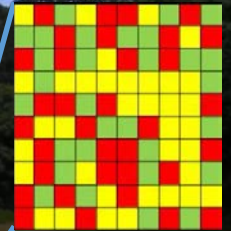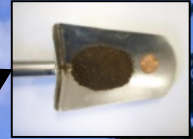
**Problem *can't be fixed* by collected more discrete samples**

无法通过采集更多的离散样品来解决问题

# The Problem is Simple:
# Discrete Soil Samples are <u>too small</u> to Overcome and Capture Random, Small-Scale Contaminant Variability

问题很简单：
离散土壤样本<u>太小</u>，无法克服和捕获随机性的小尺度污染物变异性
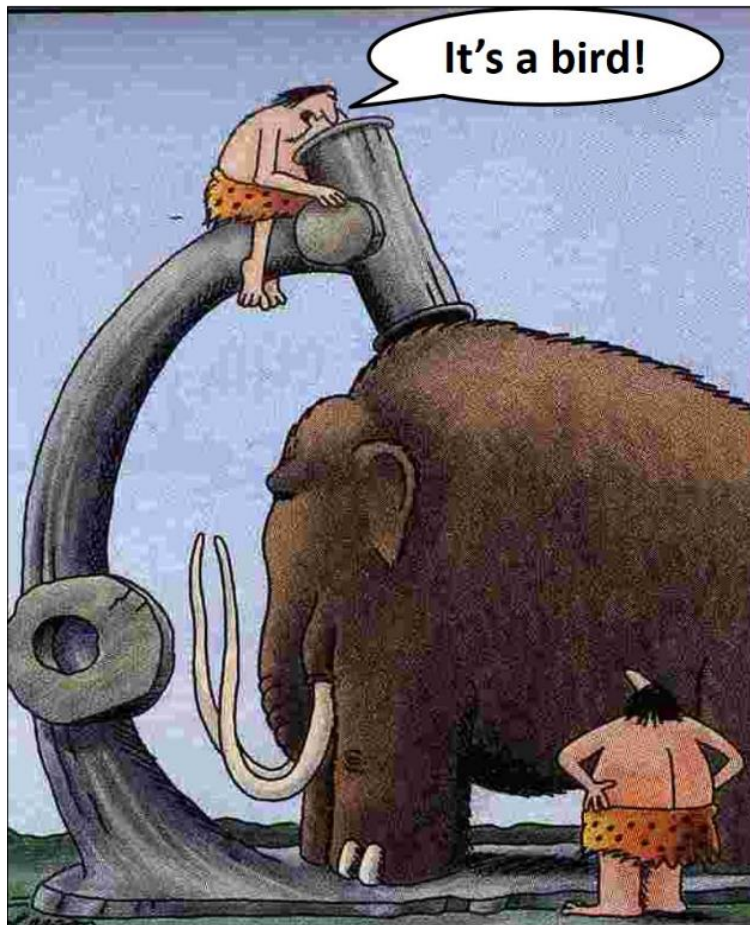




## Result:
结果：

- **Lab data not reliably representative of discrete sample submitted;**
  实验室数据*无法可靠地代表*所提交的离散样本；
- **Discrete sample not reliably representative of immediate area where it was collected.**
  离散样本*无法可靠地代表*采样点附近的区域。

# 21ˢᵗ Century Enlightenment
## 21世纪启蒙运动

## What we thought in the 1980s:
### 1980年代，我们是这样想的：
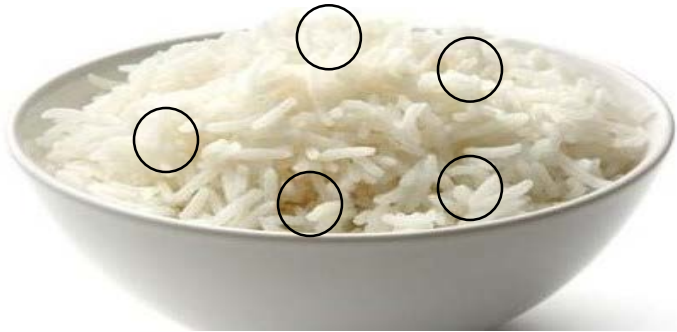


### Contaminated Soil is like a Bowl of Steamed Rice
污染土壤就像一碗白米饭

- **Contaminant concentrations identical regardless of sample location and mass of soil tested sample;**
  无论采样位置在哪里，测试土壤样本的质量有多大，污染物浓度都相同；
- **Testing of any given, small mass will be representative of area as a whole.**
- 任何给定小质量样本的测试都能代表整个区域。

## What we know in the 2010s:
### 2010年代，我们才知道



### Contaminated Soil is like a Bowl of Fried Rice
污染土壤就像一碗炒饭

- **Contaminant concentrations can vary significantly between discrete-size masses of soil;**
- 不同离散及样本量的土壤中污染物浓度差异很大；
- **Collection of a large sample made of many "increments" is required to obtain representative data.**
- 为了获取具有代表性的数据，需要收集由很多"增量"组成的大样本。

# Think About the Implications…
考虑一下意义......

**Need for multiple remobilizations and "step-out" investigations**
调查需要多次进出场
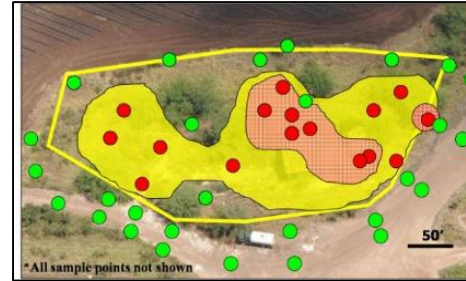


**Failed confirmation samples and multiple over excavations**
确认样品不合格和多次超挖



**Accidental Import or Export of Contaminated Soil**
意外运进或运出污染土壤

# Site Characterization Error (Discrete Sample Data)
误判场地污染特征 （离散样本数据）

**>Action Level**
**>行动值**

**<Action Level**
**≤行动值**

**Former Power Plant (PCBs)** 原发电厂（多氯联苯）

**Discrete data: Estimated 10,000 ft$^2$ soil**
离散数据：预计**10,000** 平方英尺的土壤

**Premature termination of investigation**
调查提前终止

**"False Negatives" Unavoidable**
**"假阴性" 无法避免**

**1.5 Acres**
**1.5英亩**

100'

**PCB sample aliquot = 30 grams (one spoonful of soil)**
**PCB 分样= 30 克 （一匙土壤）**

# Decision Unit and Multi Increment Sample Investigation Results
决策单元与多点增量样本调查结果

🟥 **> Action Levels**
**>行动值**

🟩 **< Action Levels**
**≤行动值**

**Former Power Plant (PCBs)** 原发电厂（多氯联苯）

**MIS Data: Estimated 25,000+ ft² soil**
**MIS 数据：预计25,000+ 平方英尺 土壤**

**Discrete data *significantly underestimated* extent of contamination**
离散数据*显著低估了污染程度*

Perimeter Dus
周长决策单元

100'
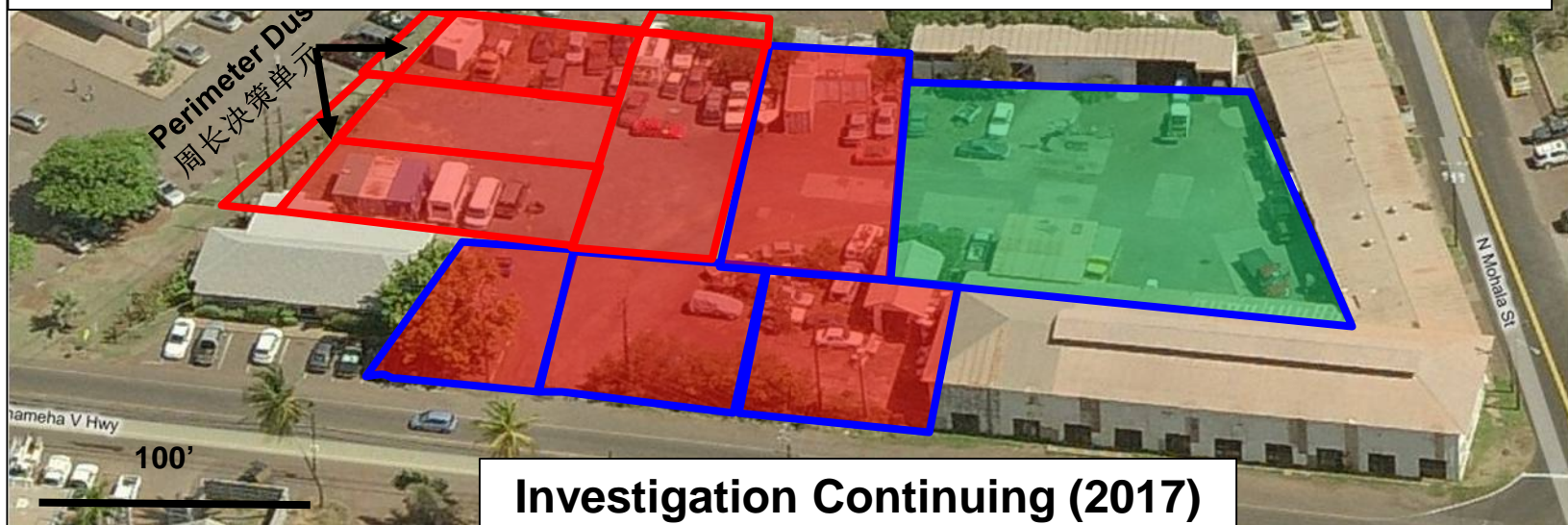
**Investigation Continuing (2017)**
调查继续（2017）

# Discrete Sample Data *Risk Assessment Error #1*
## Representativeness of Single Data Set Unknown
离散土壤样本数据风险评估错误 #1; 单个数据集的代表性未知

### Study Site B (Lead): Calculated 95% UCL based on different combinations of grid point data
研究场地B （铅）：根据网格点数据的不同组合计算出95%置信上限（UCL）



| Parameter参数 | *Lead (mg/kg) *铅 | | |
| --- | --- | --- | --- |
| | Lowest Data Pts 最小值 | Median Data Pts 中值 | Highest Data Pts 最大值 |
| Mean 平均值： | 131 mg/kg | 262 mg/kg | 452 mg/kg |
| RSD： | 58% | 53% | 64% |
| 95% UCL ： | 157 mg/kg | 325 mg/kg | 559 mg/kg |

- **Statistical tests only evaluate the precision of the test method used to estimate a mean for the data set provided**; 统计测试只能用于估计所提供数据集平均值的测试方法的精度；
- **Field representativeness of single discrete sample data set unknown;**
- 单个离散样本数据集的现场代表性是未知的；
- **RSD can provide some clues (e.g., high = lower certainty) but *sample collection method* is most important part of quality control.**
- **RSD**可提供某些线索 （如，高= 更低的确定性）， 但是*样品采集方法*是质量控制最重要的部分。

# Discrete Sample Data *Risk Assessment Error #2*
## Inappropriate Deletion of "Outlier" Data
离散土壤样本数据风险评估错误 *#2*; 不恰当地删除 "异常值" 数据

- **Statisticians often receive un-interpretable soil sample data;**
  统计学家经常收到*无法解释的*土壤样品数据；
- **Exclusion of "outliers" from data set *distorts estimation of mean* in a risk assessment;**
  从数据集中去掉"异常值" 会使风险评估中平均值的估算失真；
- **The sample data are no longer representative;**
  样本数据*不再具有代表性*；
- **Geologists would never delete (or over interpret) data for "discrete" gold veins in an ore body.**
  地质学家绝不会删除（或过度解释） 矿体中"离散" 金矿脉数据。

**All data not known to be in error *should be considered valid… High concentrations are of particular concern* for their potential health and environmental impact.**
所有确认不是错误的数据都应视为*有效......*高浓度是潜在健康与环境影响特别要关注的问题。

**USEPA 1989. *Methods for Evaluating the Attainment of Cleanup Standards***
美国环保署*1989*年。*清理标准达标的评估方法*


Outliers Are Important
异常值很重要
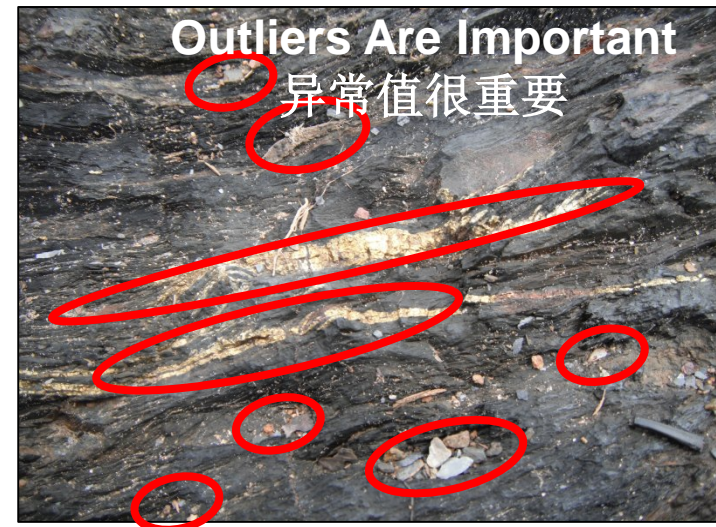
# Discrete Sample Data *Risk Assessment Error #3*
## Erroneous Search for "Maximum" Concentration
### 离散土壤样本数据风险评估错误 **#3**; 错误地寻找"最大"浓度

**1mm**

**100,000s ppm**

1mm

Thin
Outer Rim

**2mm**

**1,000s ppm**

2mm

**1cm**

**低ppm**

**Concentration #3**
浓度 #3
**(PCB matrix)**
（PCB基质）

**Concentration #2**
**(single nugget)**
浓度 #2
（单个小块）

**Concentration #1**
**(whole sample)**
浓度 #1
（整个样品）
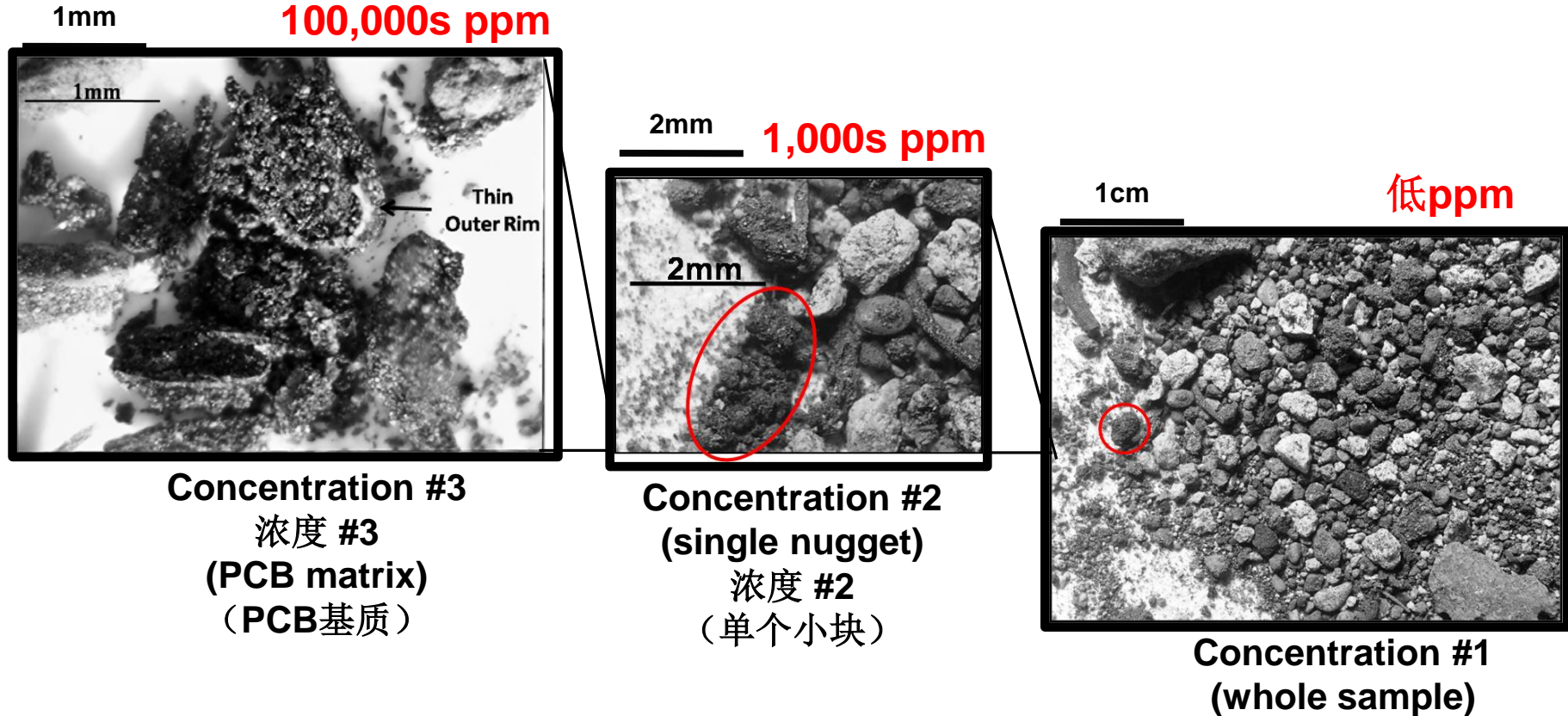
- **Soil screening levels based on chronic, long-term random exposure;**
  土壤筛选值基于慢性、长期的随机接触;
- **Concentration varies with mass of soil tested;**
  *浓度因测试土壤的质量而异;*
- **Maximum concentration always 0 % (absent) or 100% (present).**
  最大浓度*总是* **0 %** （不存在）或**100%** （存在）**.**

# Solution: <u>Sampling Theory</u>
## 解决方案：采样理论

**Step 1: Decision Unit (DU) Area Designation**
步骤1：决策单元面积指定

**Step 2: Multi Increment Sample (MIS) Collection and Testing**
步骤2：多点增量样本采集和测试

<u>**Sampling Theory Training采样理论培训**</u>
<u>**1. Envirostat, Inc.：**</u>
**Chuck Ramsey (*www.envirostat.org*）**
**Four-day, detailed introduction to sampling theory and Multi-Increment Sample® (MIS) site investigations.**
**四天，详细介绍采样理论和多点增量样品® （MIS） 场地调查。**

<u>**2. Hawai'i DOH *Technical Guidance Manual***</u>
**Implementation of DU-MIS investigations in the field (August 2016)**
<u>***夏威夷卫生署*** *《技术指导手册》*</u>
**现场实施DU-MIS调查（2016年8月）**

**http://eha-web.doh.hawaii.gov/eha-cma/Org/HEER/**

**DU-MIS Step 1: Designate "Decision Units" for Characterization**
步骤 1：设定场地调查的"决策单元"
**DU-MIS Step 2: Collect a Representative Sample From each "DU"**
步骤 2：在每个"决策单元"中采集代表性样品

**Decision Units Types**
决策单元类型

**Source Areas**
源区

**Exposure Areas**
暴露区域



**Decision Unit Basics:**
决策单元基本要素：

- *Area/volume of soil* about which a decision will be made;
  需要做出决策的*土壤面积/体积*；
- Designated based on suspect *spill areas*, risk-based *exposure areas*, *boundaries of contamination*, *remedial action design*, etc.;
  基于疑似*泄漏区域*、风险暴露区域、*污染的边界*、修复行动*设计*等因素设定；
- <u>One</u> sample collected for each DU;
  从每个决策单元中采集<u>一个</u>样品；
- Replicate samples collected in some DUs to test data reproducibility.
  复制在一些**DU**中收集的样品以测试数据重现性

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- DU = Volume of soil you would send to lab *as a single sample* if possible;
  决策单元 = *作为单个样品*送到实验室的土壤体积（如有可能）；
- Used in the mining and agriculture industries for decades;
  已经在采矿业和农业使用了几十年；
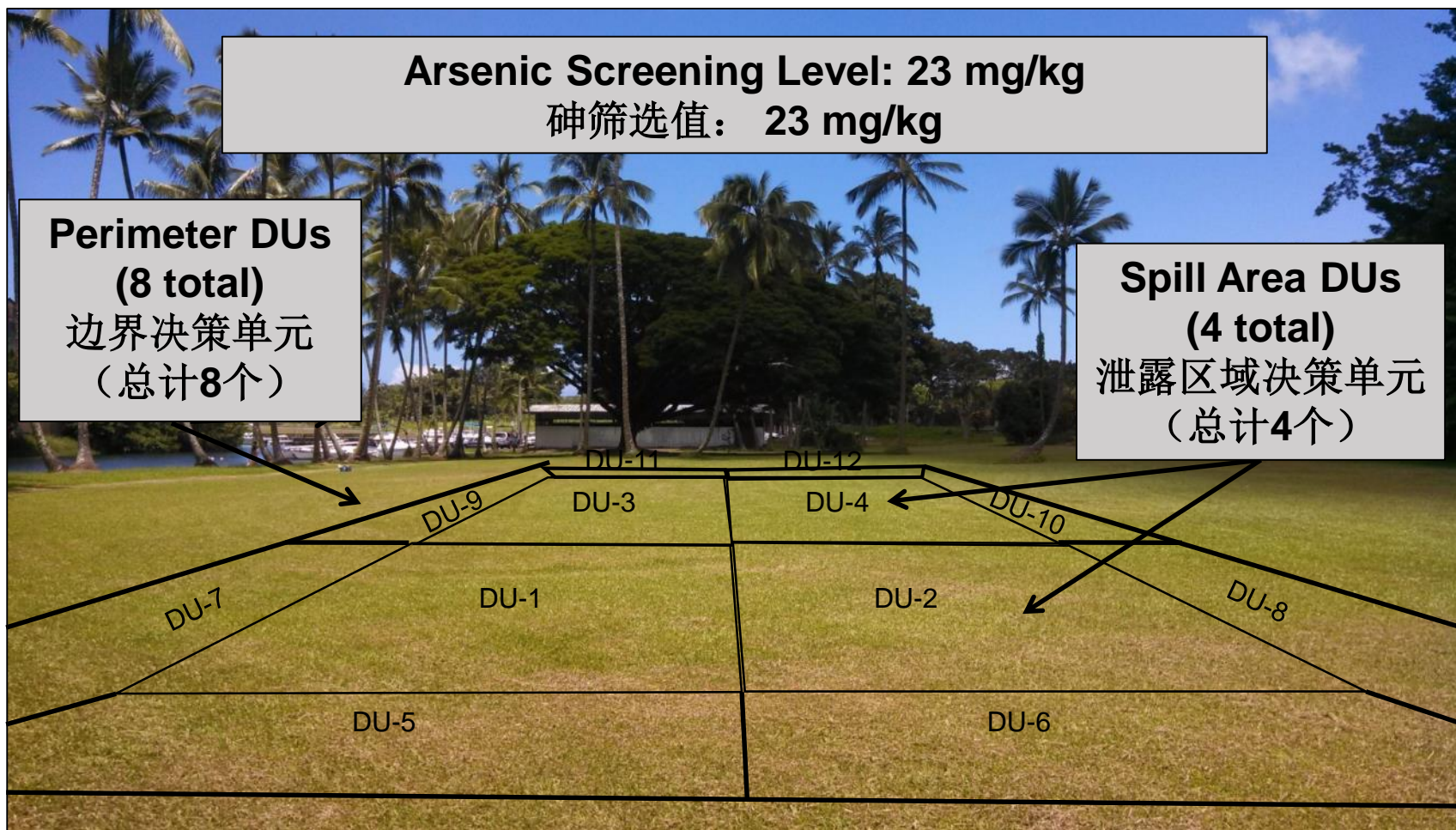
- **Example suspect arsenic spill area;**
  疑似砷泄露区域的示例；

- **Estimate extent of contamination;**
  估计污染程度；

- **Determine if mean arsenic concentration exceeds soil screening level**
  确定砷的浓度是否超出基于土壤筛选值。

- **Single, large (1-2kg) MI sample collected from each DU;**
  从每个决策单元中采集由多点增量组成的单个大样本（**1-2kg**）；
- **Minimum 30 to 75+ "increments" per DU;**
  每个决策单元至少有 **30到75+** "增量"；
- **Triplicate MI samples collected from 1 DU to test field precision of sampling method (e.g., suspect most contaminated, highest risk, etc.);**
  从每个决策单元中采集三个多点增量样本，测试采样方法的现场精度（如，疑似污染最严重、最高风险等）；
- **Samples processed and subsampled at lab using same MI methods.**
  实验室运用同样的多点增量方法进行样品前处理和二次抽样。

**X: Increments collected from systematic, random grid**

**X: 从系统、随机网格中采集增量**

DU-11  DU-12
DU-9  DU-3  DU-4  DU-10
DU-1  DU-2  DU-8
DU-5  DU-6
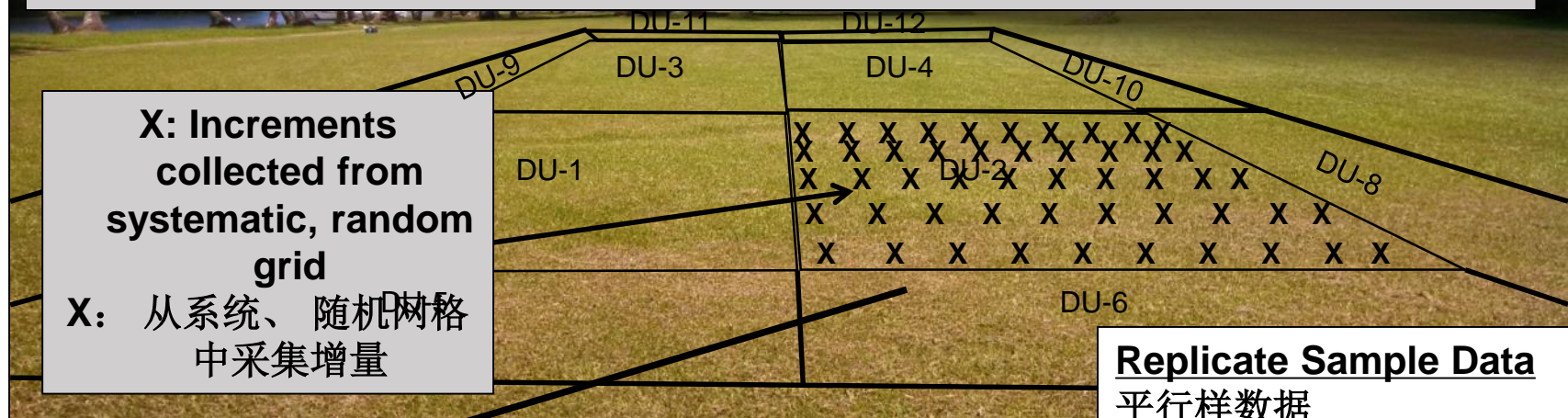
**Replicate Sample Data**
平行样数据
**Sample 样品 A：  140 mg/kg**
**Sample 样品 B：  179 mg/kg**
**Sample 样品 C：  135 mg/kg**
**RSD = 16%** （good 好!）
**95% UCL：  192 mg/kg**

# Multi Increment Sample Collection

多点增量样本采集

# Multi Increment Sample Collection

多点增量样本采集

# Multi Increment Sample (typically 1-3kg)

多点增量样本采集 (通常1-3公斤）

# Laboratory Processing and Subsampling

实验室处理和二次分样







- **Sample *air dried and sieved* (preserved in methanol for VOCs);**

  样品风干，过筛（测VOC需保存在甲醇中）

- ***30-50+ increment subsample* collected for analysis;**

  **采集30-50 增量子**样本用于分析

- **Minimum *10 grams* must be tested;**

  **至少要**测试10克

- ***Preserves field representativeness* of original bulk sample;**

  **保留了原始大**样本的现场代表性

- **Test replicate subsamples to check *precision.***

  测试重复子样本来检查精度

# Example DU-MIS Results
## DU-MIS 结果示例

- **Additional testing required in one area;**
- 一个区域需要额外的测试；
- **Confirm depth of contamination *prior to excavation* (subsurface IS).**
- *在挖掘前确认污染深度（地表下**IS**）。*

**Confirmation Sample Results确认样品结果**
- 🟩：**Not detected** 未检出
- 🟨：**Detected but <screening level** 检出但低于筛选值
- 🟥： **Detected and >screening level** 检出并大于筛选值

**Additional Step Out Testing Required**
**需要再次退场进行测试**



DU-11  DU-12
DU-9  DU-3  DU-4  DU-10
DU-7  DU-1  DU-2  DU-8
DU-5  DU-6
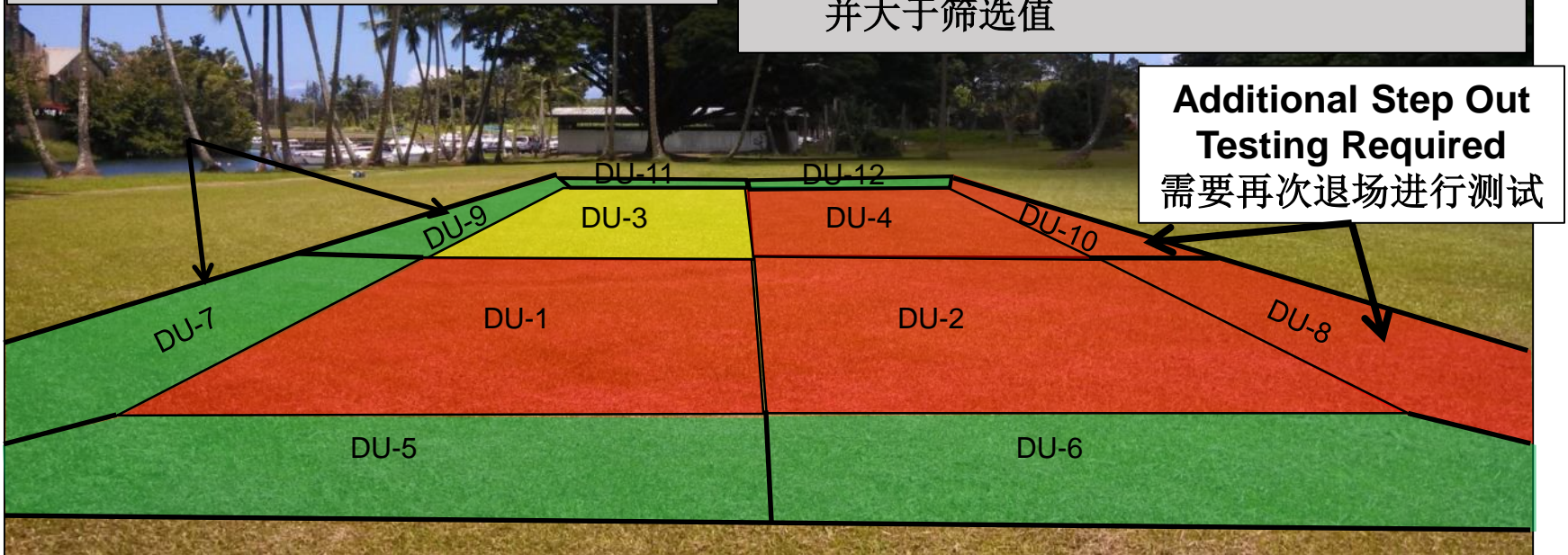
# "New" Old Ideas and Simple Solutions
## "新"旧理念和简单的解决方案

- **Collect a LARGE sample (Sampling Theory);**

  采集大样品 （采样理论）；

- **From multiple points ("increments");**

  来自多点（"增量"）；

- **Within a well-thought-out, targeted area ("Decision Unit");**

  在精心策划目标区域（"决策单元"）中；

- **With clearly defined characterization, risk and/or remediation objects .**

  有明确定义的特征描述、风险和/或修复对象。

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**Particulate sampling theory is new to most environmental investigators even though the techniques used to apply the theory to soil sampling are familiar.**

对于大部分环境调查者而言，颗粒采样理论是一种新理论，尽管将理论应用到土壤采样所采用的技术都是熟知的。

**USEPA 1992, *Preparation of Soil Sampling Protocols***

美国环保署 **1992**年，*土壤采样方案的编制*

# Dividing the Property into Decision Units for Testing is the Most Important Step (many examples presented)
将地块划成不同决策单元进行测试是最重要的步骤（提出了许多例子）

## Former Industrial Properties
原工业地块
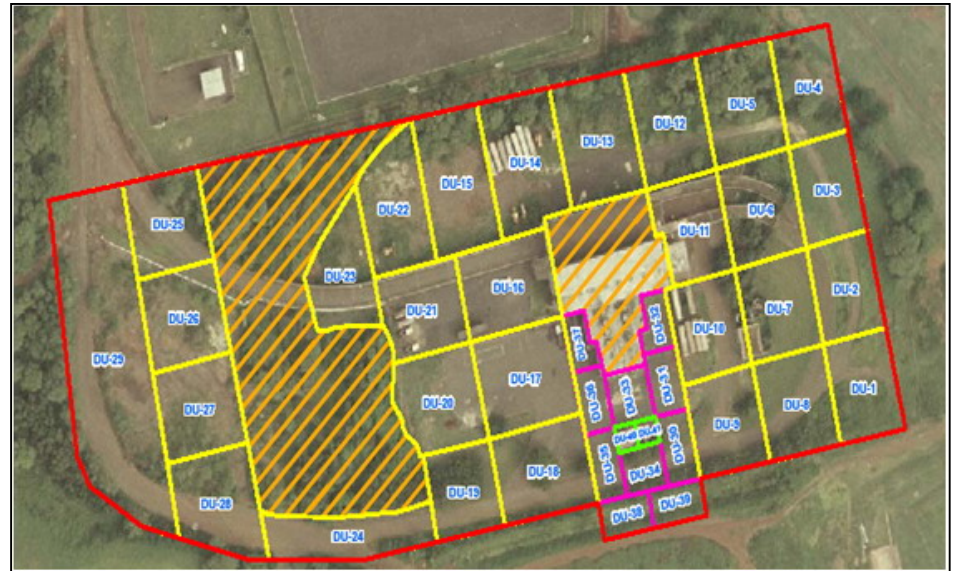


## Test the Entire Property
测试整个地块

在DU-MIS调查中辅助使用离散样本数据

**9 acres** ● **Discrete samples**离散样本

9 英亩
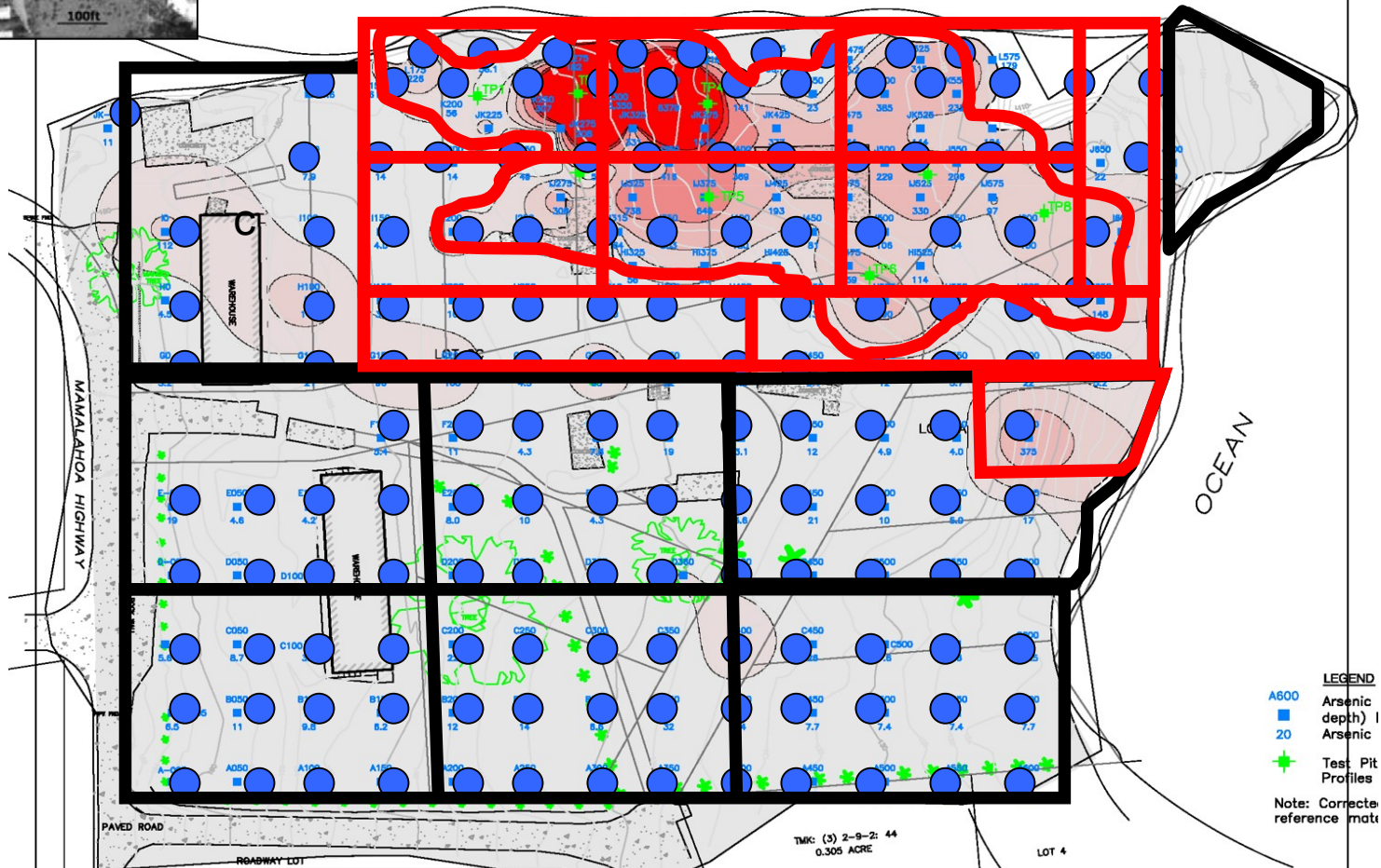
# Large Agricultural Fields

大农田
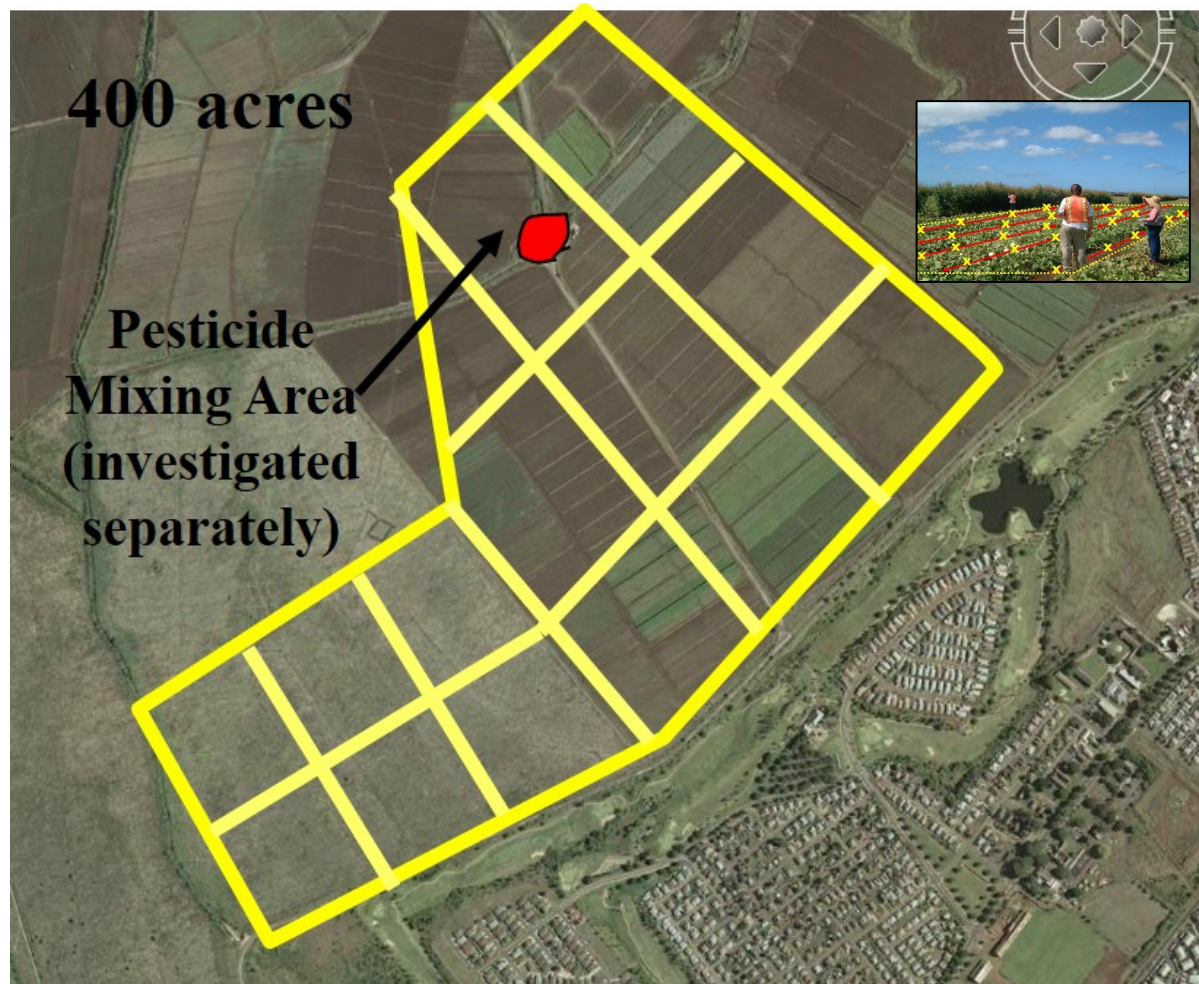
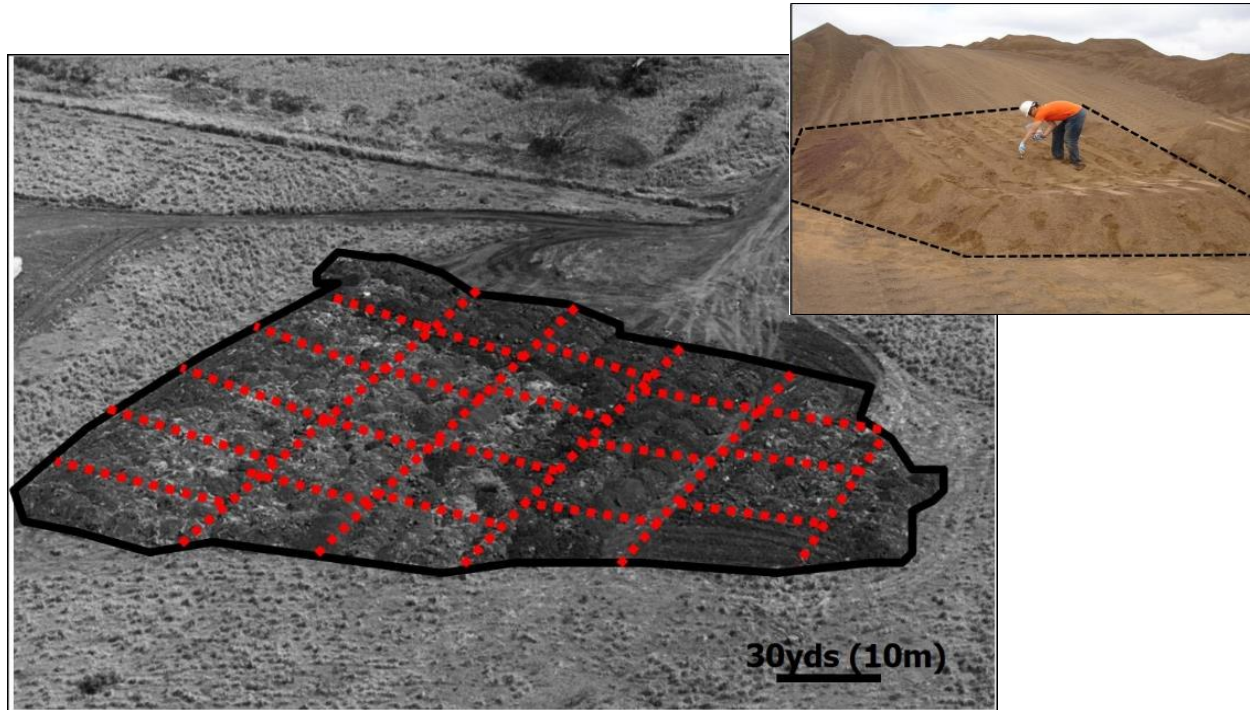# Very Small Spill Areas

非常小的泄露区

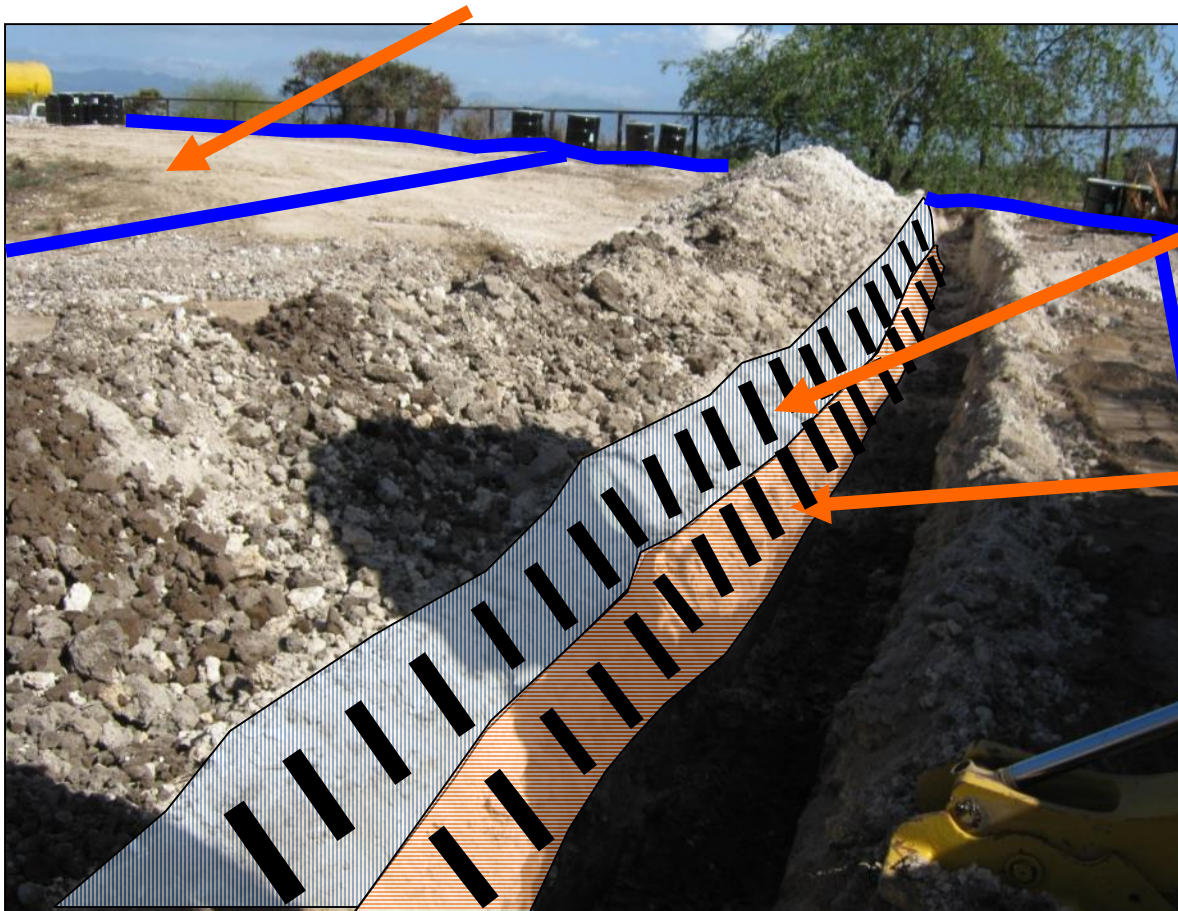# Drainage Ditches and Canals
排水沟和运河

# Excavations 挖掘



DU-2

DU-3

DU-1
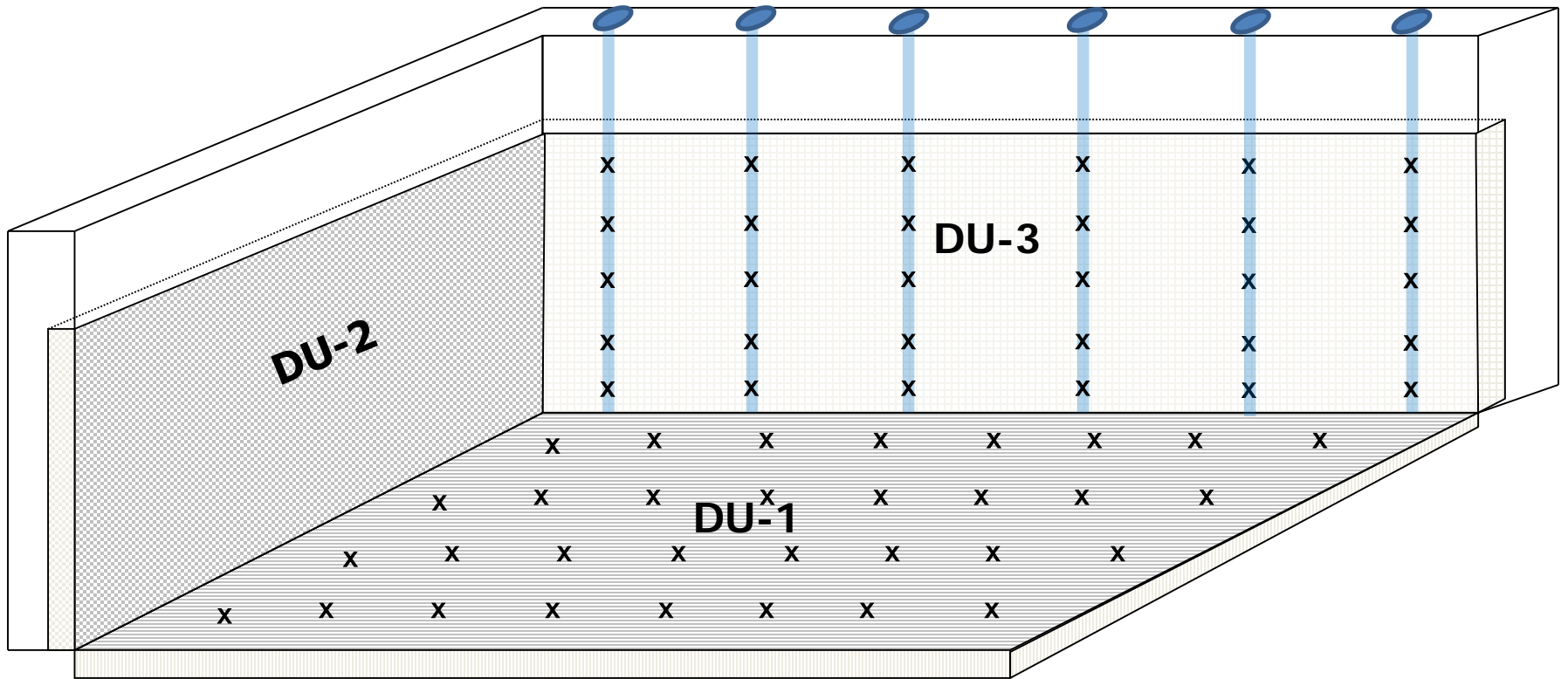
# Stockpiles 库存

# Ecological Habitats 生态栖息地
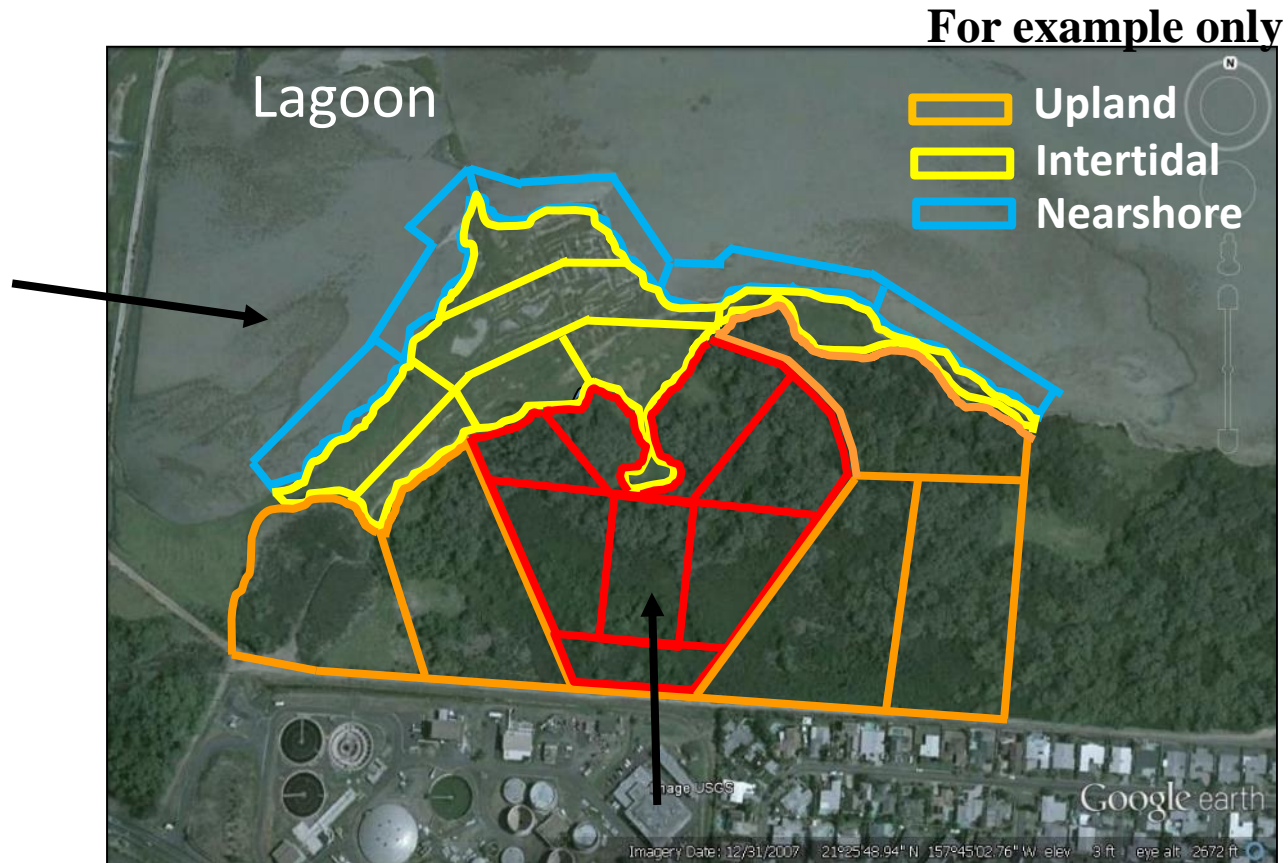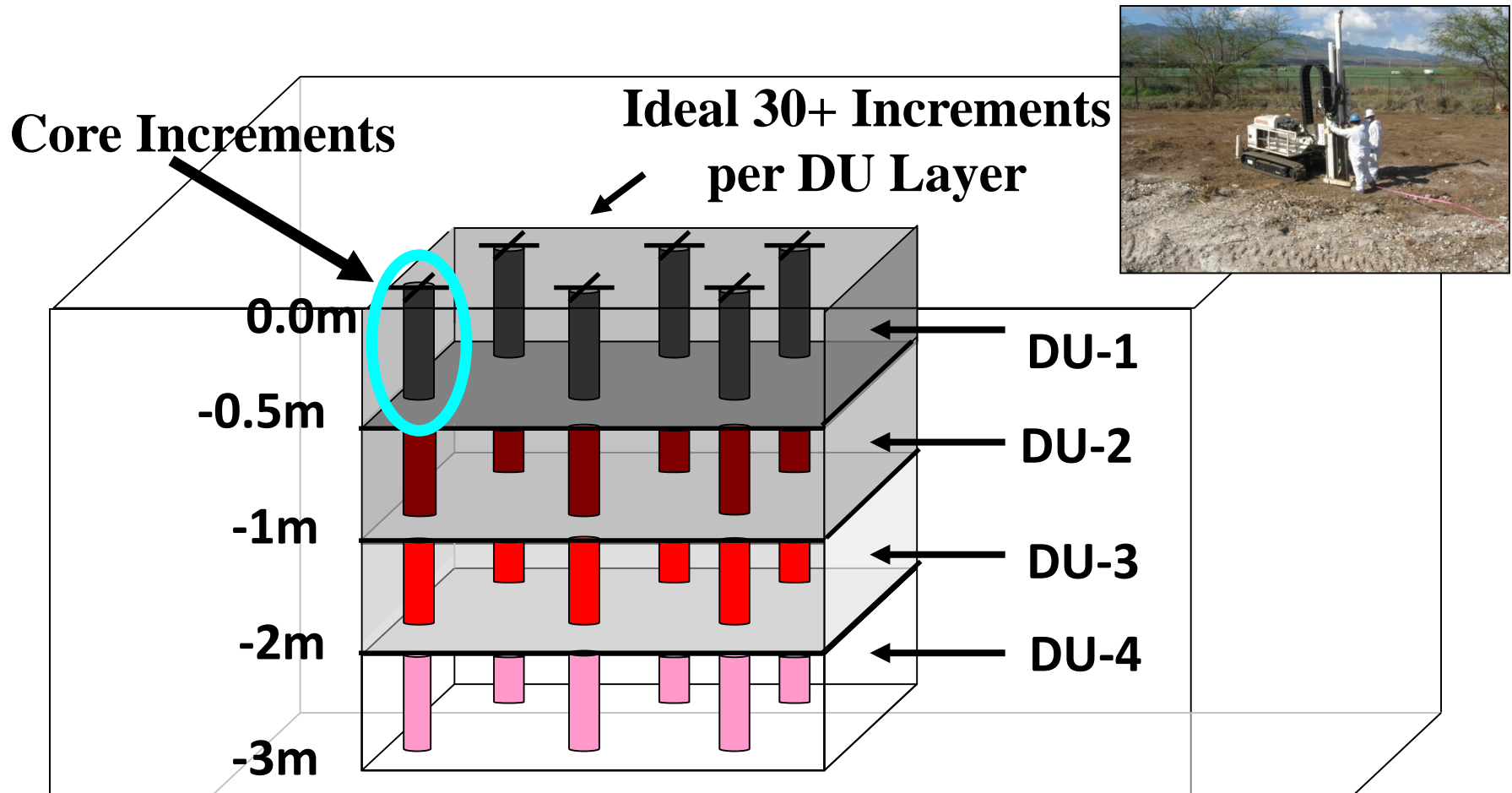
# Trenches and Pits 沟槽和坑



**Surface DU (0-6")** 表层土壤 DU

**Subsurface DU Layer (6"- 1 ft)** 亚表层土壤 Du层

**Subsurface DU Layer (1 ft – 3 ft)** 亚表层土壤 Du层

# Subsurface Investigations 地下调查



**Core Increments**

**Ideal 30+ Increments per DU Layer**

0.0m — DU-1

-0.5m — DU-2

-1m — DU-3

-2m — DU-4

-3m

- **DU Layers designated based on spill/release characteristics;**
- **Each core through layer represents an increments;**
- **Subsampled and combined to prepare a bulk MI sample for DU layer;**
- **Smaller number or cores or even single borehole ('Borehole DU') to determine presence or absence may be useful but use with caution.**

# Single Boreholes Subsurface DUs

单个钻孔地下DUs
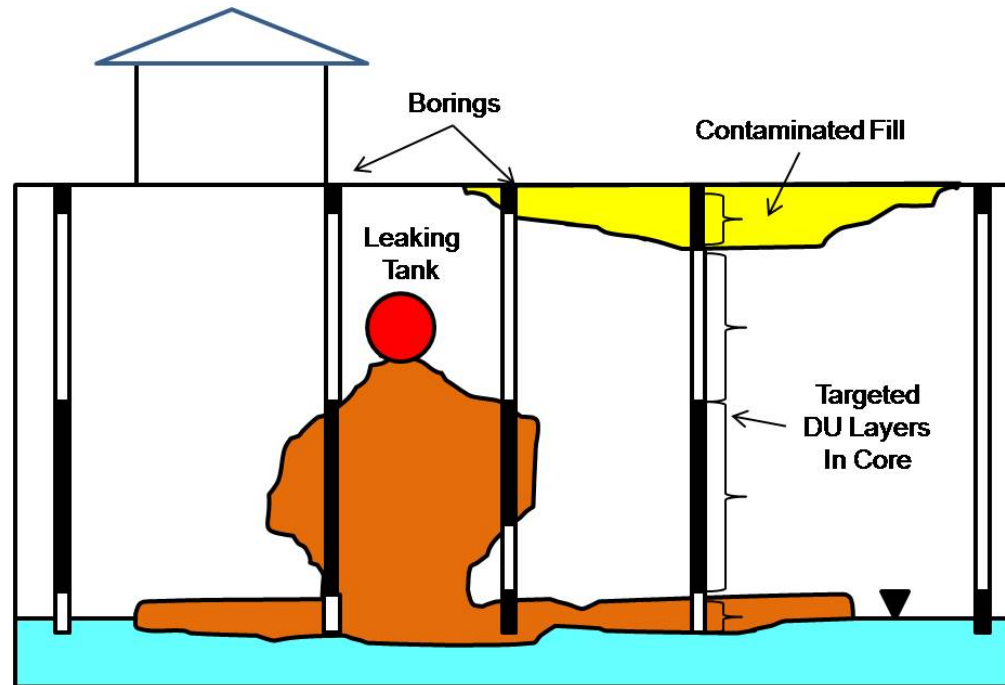


- **Estimate lateral or vertical extent of contamination;估计污染的横向或垂向范围**
- **Boring divided into <u>targeted DU layers</u> for sample collection (staining, soil type, etc.; *no discrete samples*);土孔分成不同的目标DU层进行采样（染色、土壤类型等；无离散样本）**
- **Entire core interval sent to lab for processing (or subsample with replicates to test subsampling precision; 整个土芯段送到实验室进行处理（或设置重复样检验分样的精度）**
- **Presence or absence only; 只有存在或不存在**
- **Risk of false negatives. 假阴性风险**
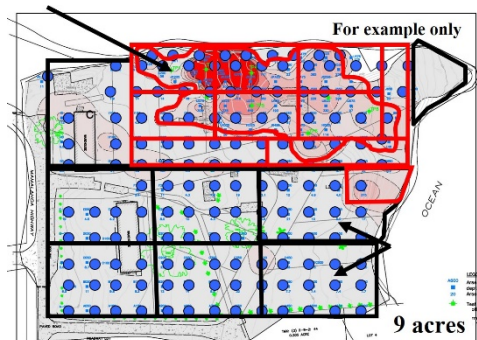
# Volatile Chemicals 挥发性化学品

# Sediment 沉积物
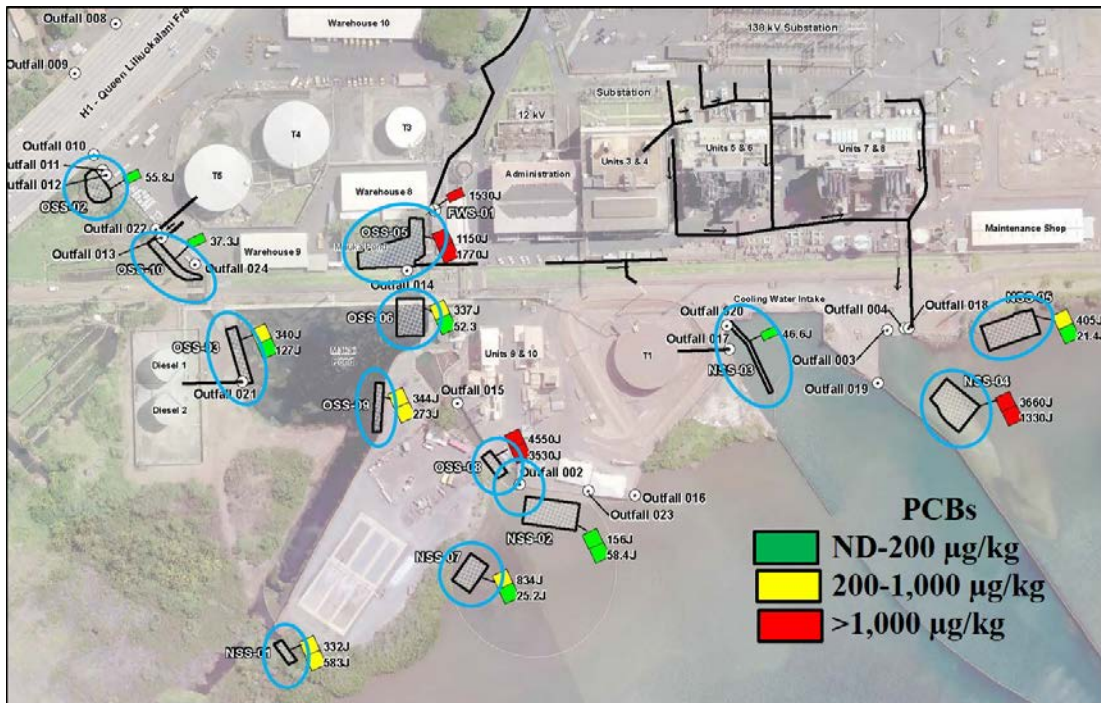
# DU-MIS Webinars #1 & #2: Systematic Planning and Decision Unit Designation (TGM Section 3)

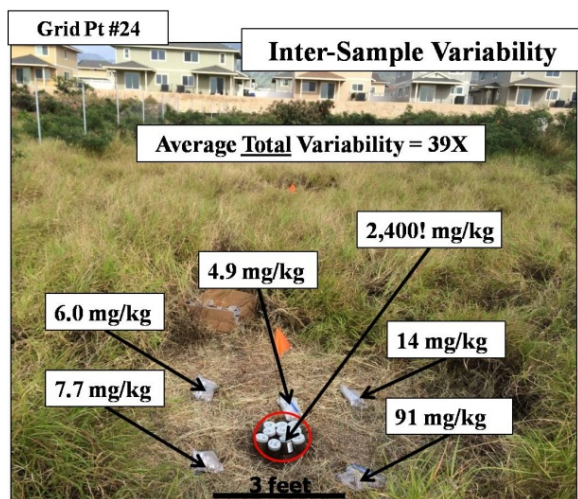DU-MIS 网络研讨会＃1和＃2：系统规划和决策单元设定



**Surface Exposure DU Soil**

**Trench Worker DU Soil**

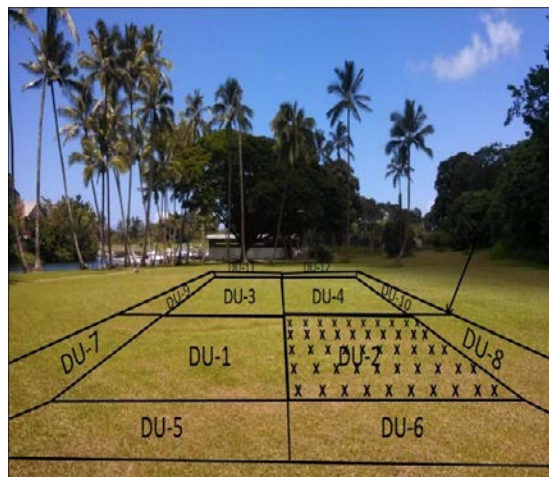DU-MIS 网络研讨会＃3和#5：DU表征和多点增量采样方法

## Discrete Problems

离散样本问题



## DU-MIS Solutions

DU-MIS解决方案



**Brewer, R., Peard, J. and M. Heskett (2017).**
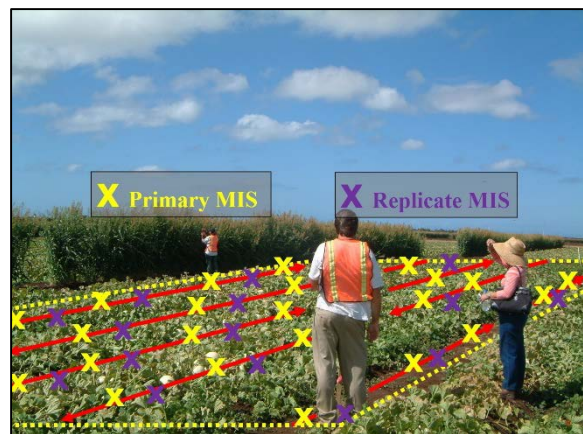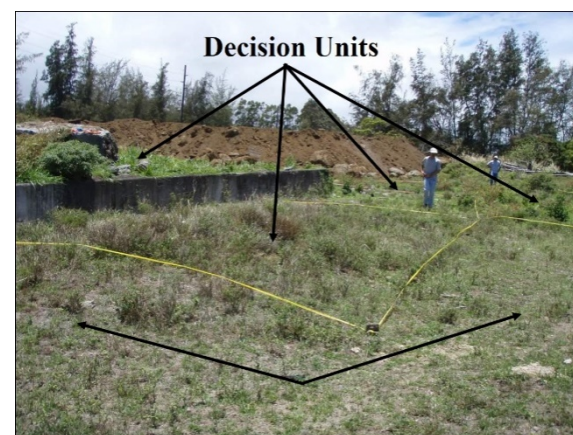*A critical review of discrete soil sample reliability:*
- *Part 1 – Field study results*
- *Part 2—Implications*

**Journal of Soil and Sediment Contamination.**

# DU-MIS WEBINAR #4: FIELD IMPLEMENTATION OF DU-MIS INVESTIGATION METHODS (TGM SECTION 5)

DU-MIS 网络研讨会＃4： DU-MIS调查方法的现场实施

# DU-MIS Methods for Agricultural Fields and Contaminant Uptake into Crops

DU-MIS法用于农地和农作物污染的调查



**Possible DU Designation Factors:** 可能的DU设定因素

- **Current and past crop types;** 当前和过去的作物类型
- **Soil type;** 土壤类型
- **Drainage;** 排水系统
- **Separate paddies;** 独立的稻田
- **Separate slopes;** 独立的斜坡
- **Irrigation water source;** 灌溉水源
- **Other desired research factors;** 其他所需的研究因素
- **One MI sample collect in each DU;** 在每个DU中采集1个MI样本
- **Triplicate MI samples in 10% of DUs.** 在10%的DU中采集一式三份MI样本

# China Will Make Important Advances
# 中国将取得重要进展

- **Investigation and cleanup of contaminated properties in the U.S. can take many years;**

  在美国，调查和清理污染地块可能需要很多年；

- **Rapid growth of urban areas requires that China significantly improve and expedite this process;**

  由于城区快速增长，中国需要大大改善和加快这一过程

- **Hawaii has faced similar problems and worked with the USEPA for the past 25 years to develop improved methods.**

  夏威夷面临类似的问题并与美国环保署合作了**25年**开发改进的方法

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*"Evolution takes place at the fringes of the environment, where the stresses are greatest and the need for change most urgent."*
**Carl Sagan (American scientist)**

*"进化通常发生在环境条件异常的区域，因为那里胁迫最大，最迫切需要改变。"* **Carl Sagan**（美国科学家）

# Questions? 问题?

**NOT Just Another Tool in the Tool Box…**
不仅仅是工具箱中的另一种工具**……**

**Discrete Sampling**
离散采样
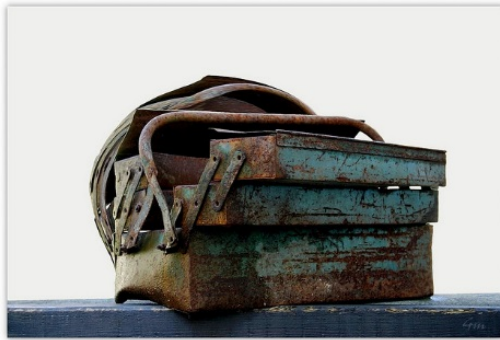
**DU-MIS Investigation Methods**
决策单元 - 多点增量调查方法





**It's an entirely NEW and IMPROVED set of tools.**
这是一套改进的全新工具集。

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**Wrong Question:** 错误的问题：

"**DU-MIS**方法什么时候适用？"

"**When are DU-MIS methods applicable?**"

**Right Question:** 正确的问题：

"**Knowing what we now know, when are discrete sampling methods still acceptable?**"

"基于我们现在的理解，离散点采样方法什么时候依然适用**?**"

# Extra Slides 额外的幻灯片

# Summary of Potential Environmental Hazards
## 潜在环境危害总结

**INDOOR AIR**
室内空气

**Gross Contamination**
总污染

**Human Health**
人体健康

**Vapors Intrusion**
蒸汽入侵

**Direct Exposure**
直接暴露

**Terrestrial Habitats**
陆生栖息地

**SOIL**
土壤

**SOIL GAS**
土壤气体

**Leaching 淋溶**

**Aquatic Habitats**
水生栖息地

**GROUNDWATER**
地下水

**Vapors Intrusion**
蒸汽入侵

**Gross Contamination**
总污染

**Human Health**
人体健康

**Drinking Water (toxicity)**
饮用水
（毒性）

78
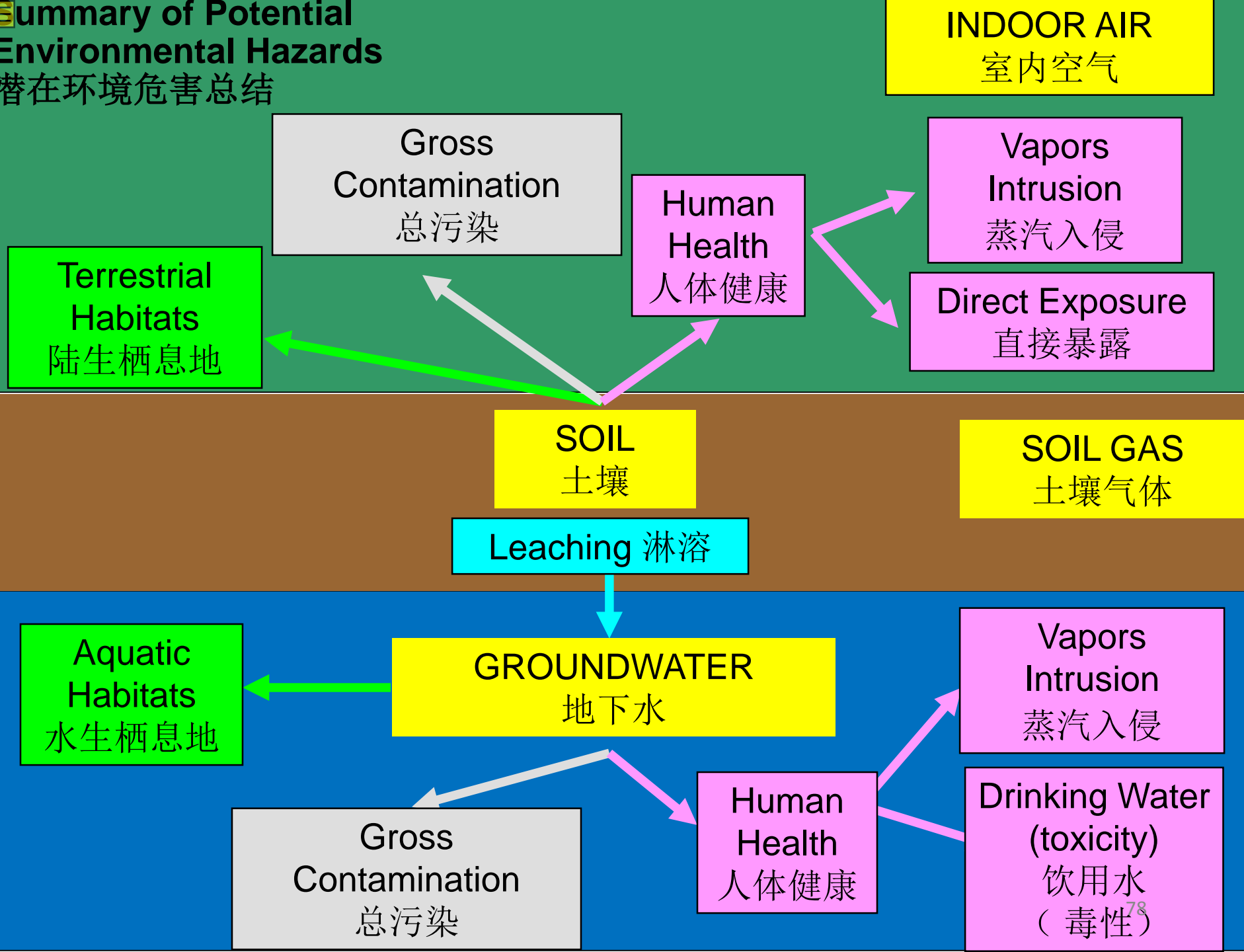
# Initial Comparison to Single "Tier 1" ESLs

与单个"第一层次" 环境筛选值的初布比较

**Benzene (residential, surface soil, drinking water)**
苯（住宅，表土，饮用水 )

| **Final Tier 1 ESLs** 最终第一层次环境筛选值 |
|:---:|
| **Soil** 土壤: **0.30 mg/kg** |
| **Groundwater** 地下水: **5.0 μg/L** |
| **Soil Vapors** 土壤气体: **720 μg/m$^3$** |

- *Lowest screening level* **selected as final "Tier 1" ESL;**
  选择最低的筛选值作为最终第一层次环境筛选值
- **ESLs for 150+ chemicals presented in easy-to-use** *Excel lookup tables***;**
  以Excel表的形式方便地查找150多种化学品的环境筛选值
- *No environmental concerns* **if screening levels not exceeded;**
  如果未超过筛选值，则无环境问题
- *Further site-specific evaluation* **of individual, <u>potential</u> concerns required;**
  需针对具体场地开展单个、潜在问题的评估
- **Traditional, site-specific risk assessment allowed but rarely needed.**
  可进行传统的具体场地风险评估，但很少需要

# Comparison to USEPA Regional Screening Levels
## 与美国环保署区域筛选值比较

- **Considers default bioavailability for dioxins;**
  考虑了二恶英默认的生物可利用度；
- **Bioaccessibility test data considered for arsenic in soil;**
  考虑了土壤砷生物有效性测试数据；
- **Considers natural concentration of background dioxins and metals in soils (Hawaii data);**
  考虑了土壤二恶英和金属的自然背景浓度（夏威夷数据）；
- **Anthropogenic background for lead and PAHs considered;**
  考虑了铅和多环芳烃的人为背景；
- **Alternative target cancer risk used for: 对于下列污染物使用了替代目标致癌风险：**
  - **Arsenic, dioxins, PAHs, organochlorine pesticides, carcinogenic polyaromatic hydrocarbons, PCBs, 砷、二恶英、多环芳烃 、有机氯农药、致癌多环芳烃、多氯联苯**
- **Final screening level based on noncancer risk (protects children) for many common chemicals Arsenic, dioxins, PCBs, BaP, etc.; 对于许多常见的化学品如，砷、二恶英、多氯联苯等，最终筛选值基于非致癌风险（保护儿童）**

# HDOH EALs versus USEPA RSLs

| | Environment Hazard | HDOH EALs | [1]USEPA RSLs |
|---|---|---|---|
| **Soil** | Direct Exposure | X | X |
| | Vapor Intrusion | X | - |
| | Leaching | X | - |
| | Gross Contamination | X | - |
| **GW** | DW Toxicity | X | X |
| | Vapor Intrusion | X | - |
| | Aquatic Habitats | X | - |
| | Gross Contamination | X | - |

1. Additional screening levels or risk assessment required to address other potential environmental concerns.

# Example Chemical-Specific Target Risks

| Chemical | Target Risk | Rationale |
|---|---|---|
| *Default (most VOCs) | ECR = $10^{-6}$ <br> HQ = 0.2 | *Conservative* consideration of cumulative risk |
| Ethylbenzene, Naphthalene, Heptachlor, Heptachlor Epoxide | *ECR = $10^{-5}$* <br> HQ = 0.2 | Higher confidence in *noncancer toxicity factors* |
| PAHs | ECR = $10^{-5}$ <br> *HQ = 0.2* | *Anthropogenic background*, (BaP ECR = $5 \times 10^{-5}$, focus on nc) |
| Chlordane, PCBs | ECR = $10^{-5}$ <br> *HQ = 1.0* | Focus on noncancer hazard, *primary risk driver* |
| Aldrin, Dieldrin, | *ECR = $10^{-4}$* <br> *HQ = 0.5* | Focus on noncancer hazard, *co-occur*, primary risk drivers |
| Arsenic, TEQ Dioxins, CrVI | ECR = $10^{-4}$ <br> HQ = 1.0 | Focus on nc hazard, primary risk drivers, *nat background* |
| TPH | HQ = 1.0 | Primary *noncancer risk driver* |
| Lead | separate model | *Reduced target blood level,* anthropogenic background. |

*Tapwater default ECR = $10^{-6}$ HQ = 1.0 (see Appendix 1 for variances).

# Summary 总结

- **Discrete sampling methods can identify the *core of heavy contamination* (e.g., any small mass of soil exceeds screening level);**

  离散采样方法可以识别严重污染的核心区（如，任何小质量的土壤样本都超过筛选值）；

- **"False negatives" and *premature termination of initial investigation* unavoidable in outer areas (small masses both above and below screening level);**

  *在外围地域*不可避免地*出现*"假阴性"和*初步调查*提前终止（在筛选值上下）；

- **Confusion over *artificial "hot spots"* common;**

  *假"热点区"常常*混淆；

- ***Representativeness* of discrete sample data set for use in risk assessment not directly testable;**

  用于风险评估的离散样本数据集的代表性无法直接测试；

- **Deletion of "*outliers*" in risk assessments *distorts* estimation of mean;**

  删除风险评估中的"*异常值*"会使平均值的估算失真；

- **Use of discrete sampling methods *highly inefficient* at best and *highly misleading* at worst.**

  采用离散采样方法，在最好的情况下效率十分低下，在最坏的情况下会产生很大程度的误导。