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A Defensible and Unbiased Approach for Confirming Effective Removal of Contaminated Soil for Remedial Excavations

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Background…1

- To confirm effective cleanup for a remedial excavation a confirmatory sampling plan is necessary.
- However, not all Provinces have provided guidance on confirmatory sampling plans…

Environmental Sampling Plans

- **Usually based either on:**
  - **Professional judgement and "expert" opinion**
- **Or**
  - **Statistically defensible decisions**

Judgemental Sampling

- **Strengths:**
  - Focussed – can avoid areas of no apparent interest
  - Greater control over sampling costs
- **Weaknesses:**
  - Depends on quality of judgement
  - Variability in quality and reliability
  - Difficult to defend statistically – how many samples should be taken?

Sometimes it is obvious where to sample.


Sometimes it is not.
50

Statistical Sampling Plans…1

- **Strengths**
  - Statistics based – valid inference to population parameters, e.g. mean and variance
  - Can quantify performance – probability of detection or confidence limit
  - Can optimize design – balance between uncertainty and cost

Statistical Sampling Plans…2

- **Weaknesses**
  - More complicated process – more difficult to explain
  - Usually more samples – higher costs
  - Cannot be used for point sources, e.g. PHC-impacted groundwater plume
  - Limited to populations where values are not spatially or temporally correlated

A Short History of SSP

- 1948 Freeman et al. Sampling Inspection
- 1972 Singer. ELIPGRID – a FORTRAN program to locate elliptical hot-spots
- 1977 – 1982 PNL TRAN-STAT Bulletins
- 1984 Zirschky & Gilbert. Detecting hot spots at hazardous-waste sites
- 1987 Gilbert. Statistical Methods for Environmental Pollution Monitoring – The BOOK!
- 1990s USEPA / DOE DQO Process

Statistically Defensible Decisions - Procedure

1. Develop a conceptual site model
2. Formulate null hypothesis, H_0: e.g. “Site is dirty” (Regulators view)
3. Arrive at decision by testing H_0 statistically
4. Bound decision errors
5. Obtain an adequate number of samples and sample locations

VSP

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A tool for developing statistical sampling plans:

Visual Sampling Plan (VSP)

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VSP – Visual Sampling Plan

- Tool to develop systematic statistics-based sampling plans
- Developed by PNNL in 2001
- Currently Version 4.6b
- For soil, sediment, surface sampling – not groundwater (yet)
- Web site: http://dqo.pnl.gov/index.htm
- VSP training courses held a few times per year

VSP 4.6

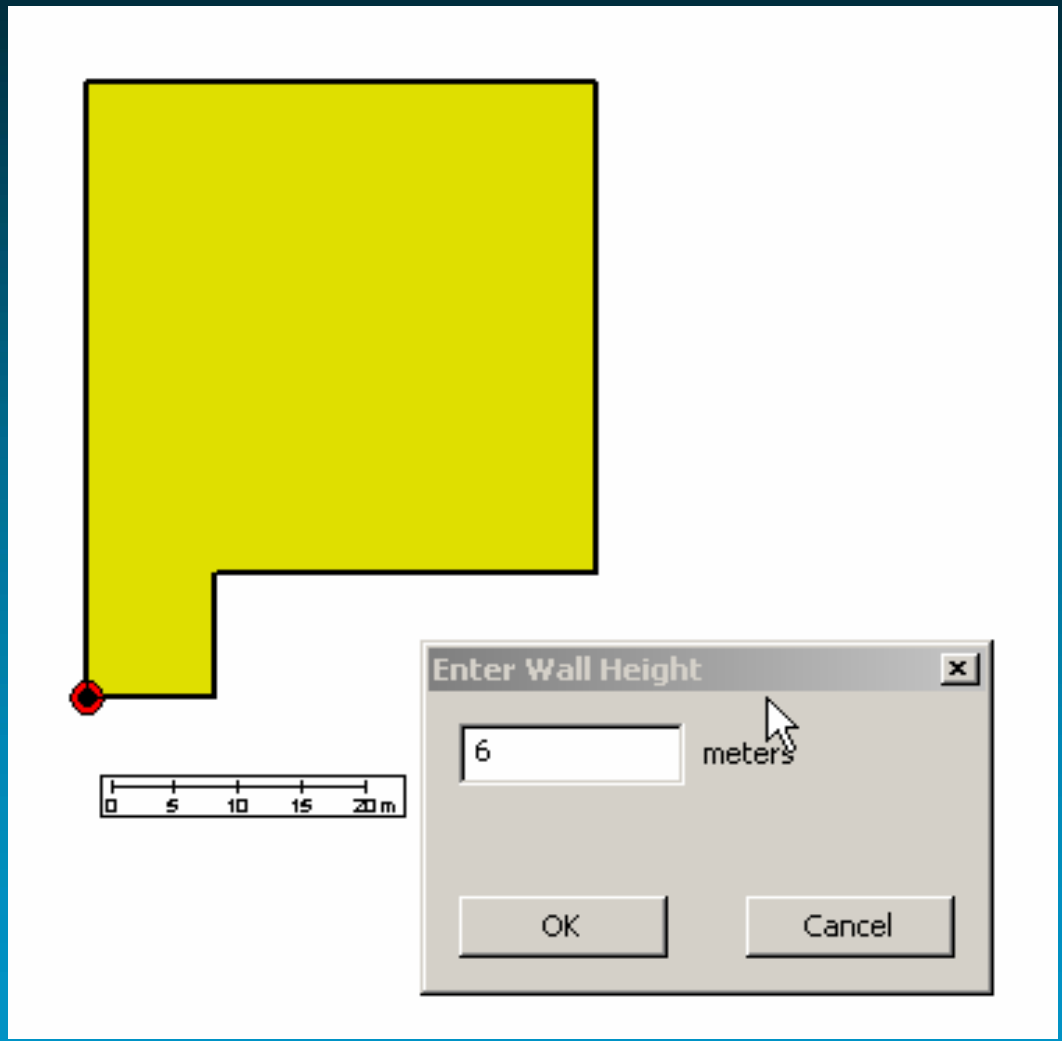
- Addresses part of the 7-step EPA DQO process:
  - Specifies limits on decision errors
  - Optimizes design of sampling plan
- Determines:
  - How many samples are needed?
  - Where should the samples be taken?
- Performs some statistical evaluations

How to Use VSP?

- **Examples to illustrate developing a sampling plan:**
  1. **Sampling remedial excavation walls to determine probable “hot spot” size**
  2. **Determining grid size for given “hot spot” size & probability of detection**
  3. **Sampling a study area for remedial excavation requirements**

Example 1 – Excavation Wall for UST Removal

- **Plan View:**
  - Approximately 40 m x 40 m
- **Wall height:**
  - 6 m



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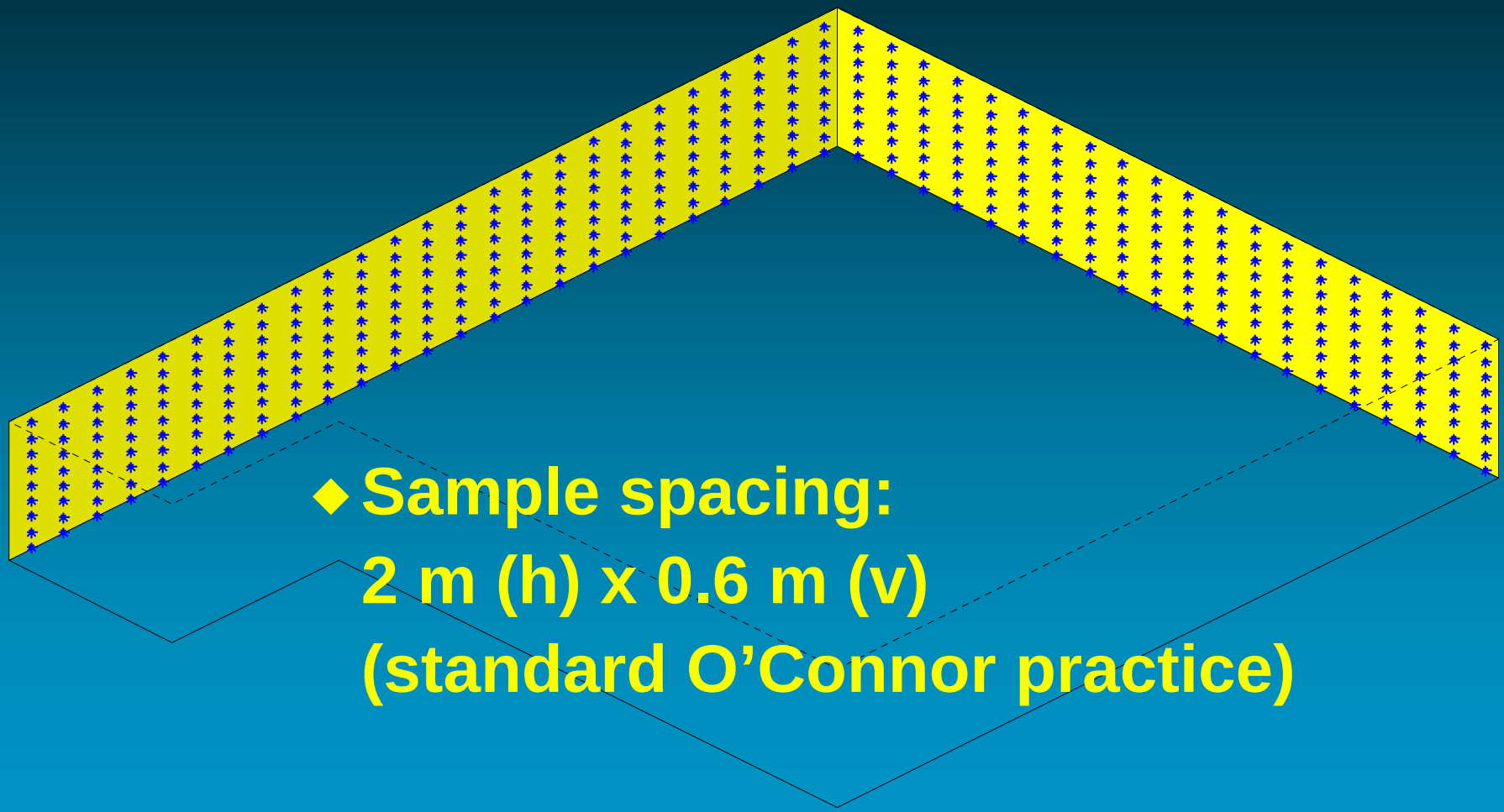
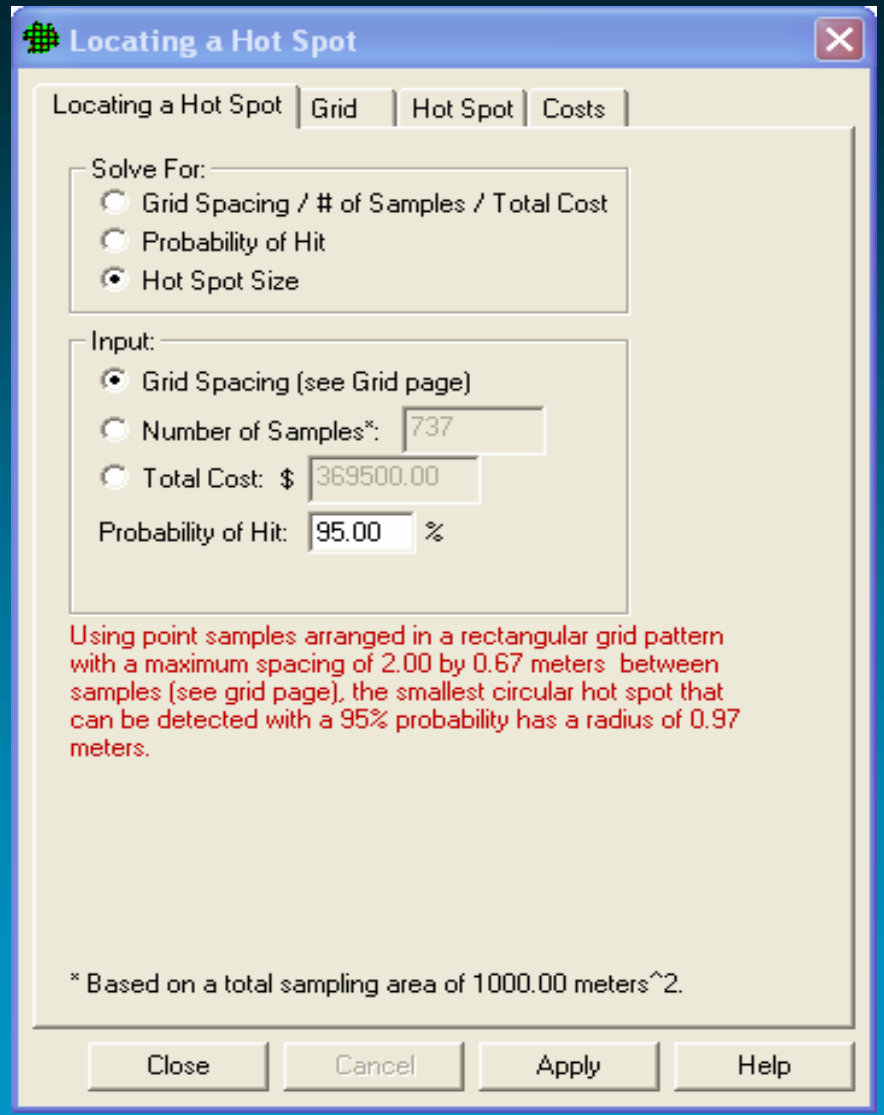
Ex.1 - Grid Sampling on Walls



- **Sample spacing:**
  2 m (h) x 0.6 m (v)
  (standard O'Connor practice)

Ex.1 - Performance of Grid

- Using a 2 m x 0.67 m grid, we can detect circular hot spots 0.97 m radius (min.) with a probability of 95%
- Area of hot spot = 2.95 m^2



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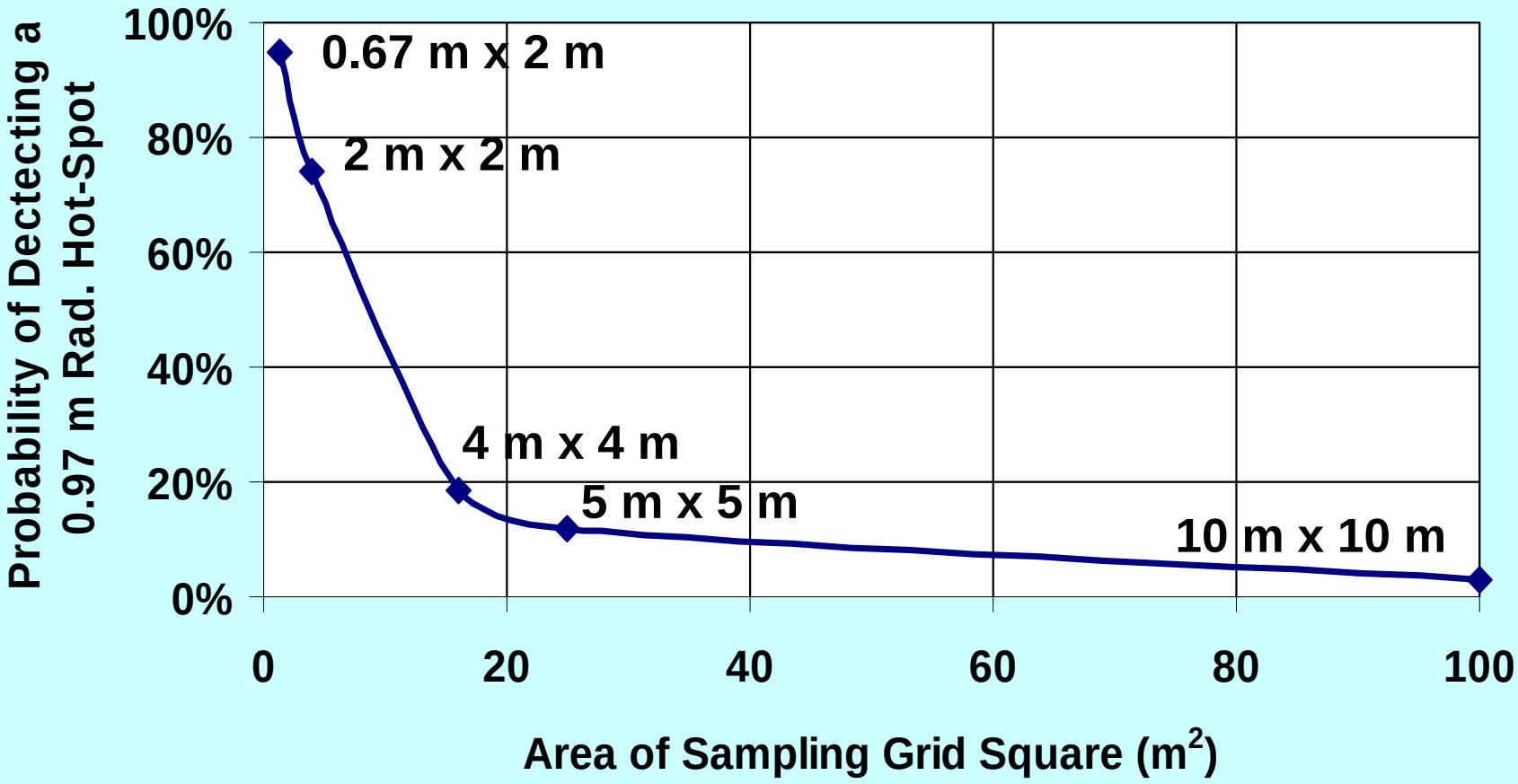
Grid Size vs. Probability of Detection



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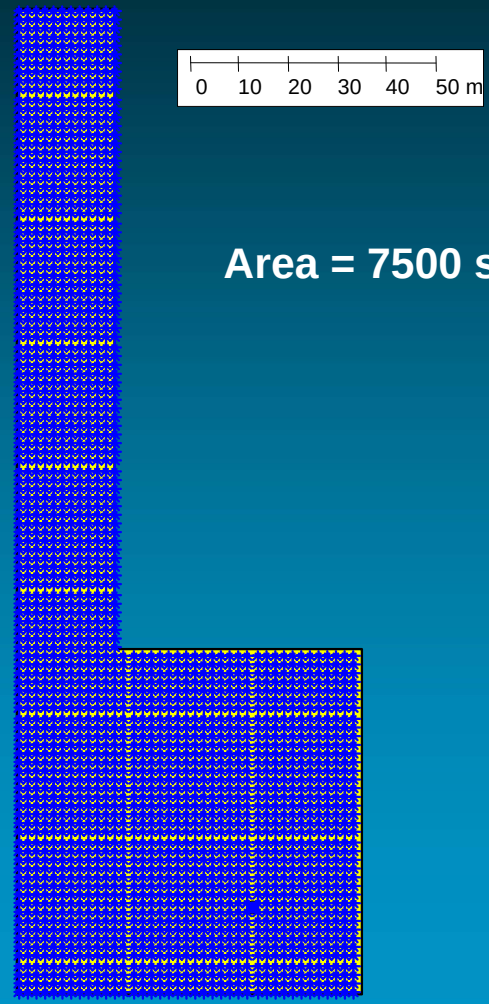
Example 2 – Grid to Locate Hot Spots

- To locate hot-spots ≥ 1.0 m radius at 90% probability
- Requires a square grid of 1.8 m spacing
- And 2,332 samples



Area = 7500 sq.m.

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Ex. 2 - Refinement to the Sampling Grid

- If *p(A)* : (probability of encountering a sample > criterion) can be determined *a priori*
- Grid spacing can be modified based on conditional probability (Gilbert, 1987, p. 127)

Use of *a priori* probability, *p(A)*

- To locate 1.0 m radius hot spots in area of 7500 m^2 with 90% probability:

p(A)	≥50%	20%	15%	10%
Grid Spacing (m)	1.8	2.4	3.0	10.5
No. Samples	2,332	1,302	835	73

Example 3 – Surficial Excavation for Metal Impacts

- **Purpose:**
  - To determine the extent of a surficial excavation to remove metal impacts from top 0.3 m
- **Performance criteria:**
  - Hot-spots to a maximum size of 1 m radius will be removed with a 90% certainty

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Example 3 - Procedure

- Sample site to determine *a priori* probability *p(A)*
- Determine actual sampling grid size
- Establish step-out sampling methodology
- Complete sampling and analyses
- Check to ensure frequency of exceedance is not > *p(A)*
- Lay out area to be excavated

A Priori Probability

- **Procedure**
  - Carried out pilot test using a 10 m square grid
  - Obtained samples in the top 0.3 m using a Geo-probe rig and sampler
- **Results from laboratory analyses indicated *p(A)* = 15%**
  - Therefore a 3 m grid would be sufficient

p(A)	≥50%	20%	15%	10%
Grid Spacing (m)	1.8	2.4	3.0	10.5

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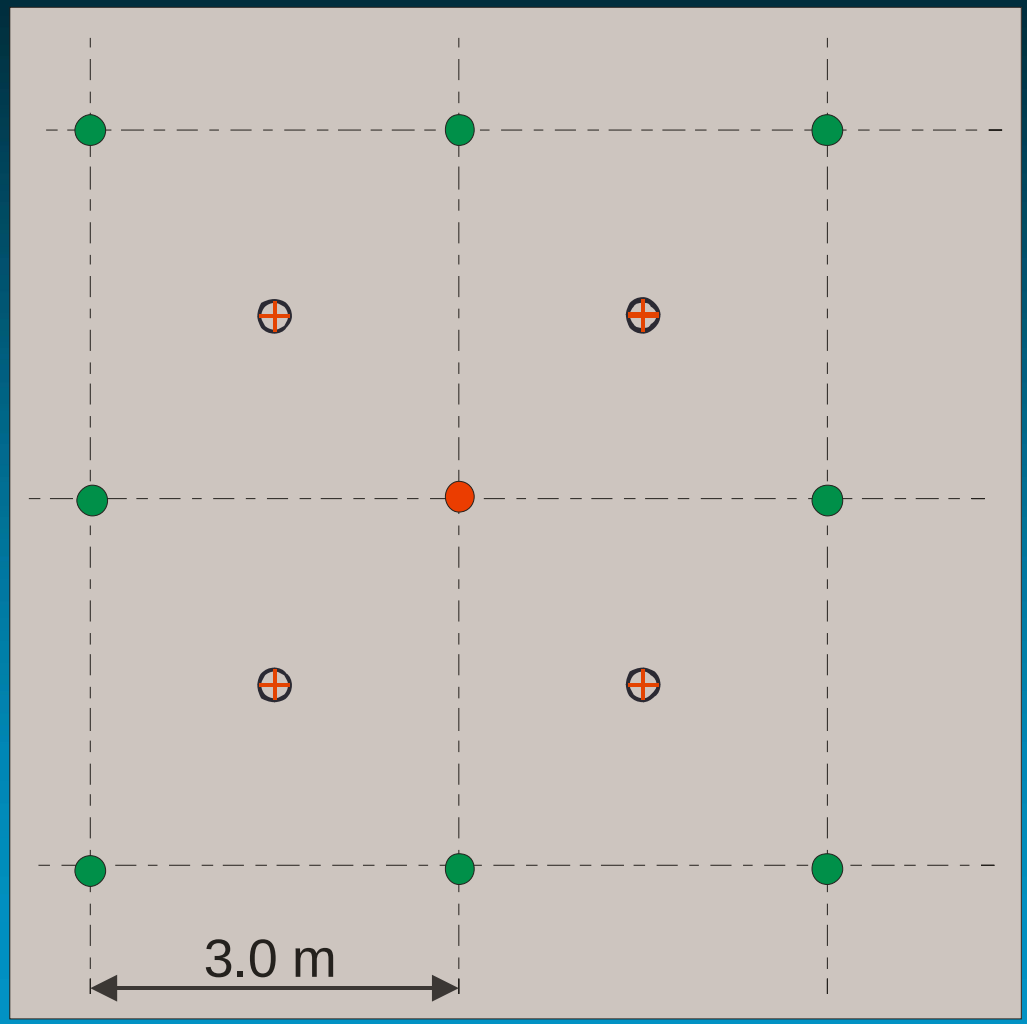
Step-Out Sampling Procedure



- Initial Sampling Grid Point without Chemical Exceedance
- Initial Sampling Grid Point with Chemical Exceedance
- Additional Step-Out Sampling Point

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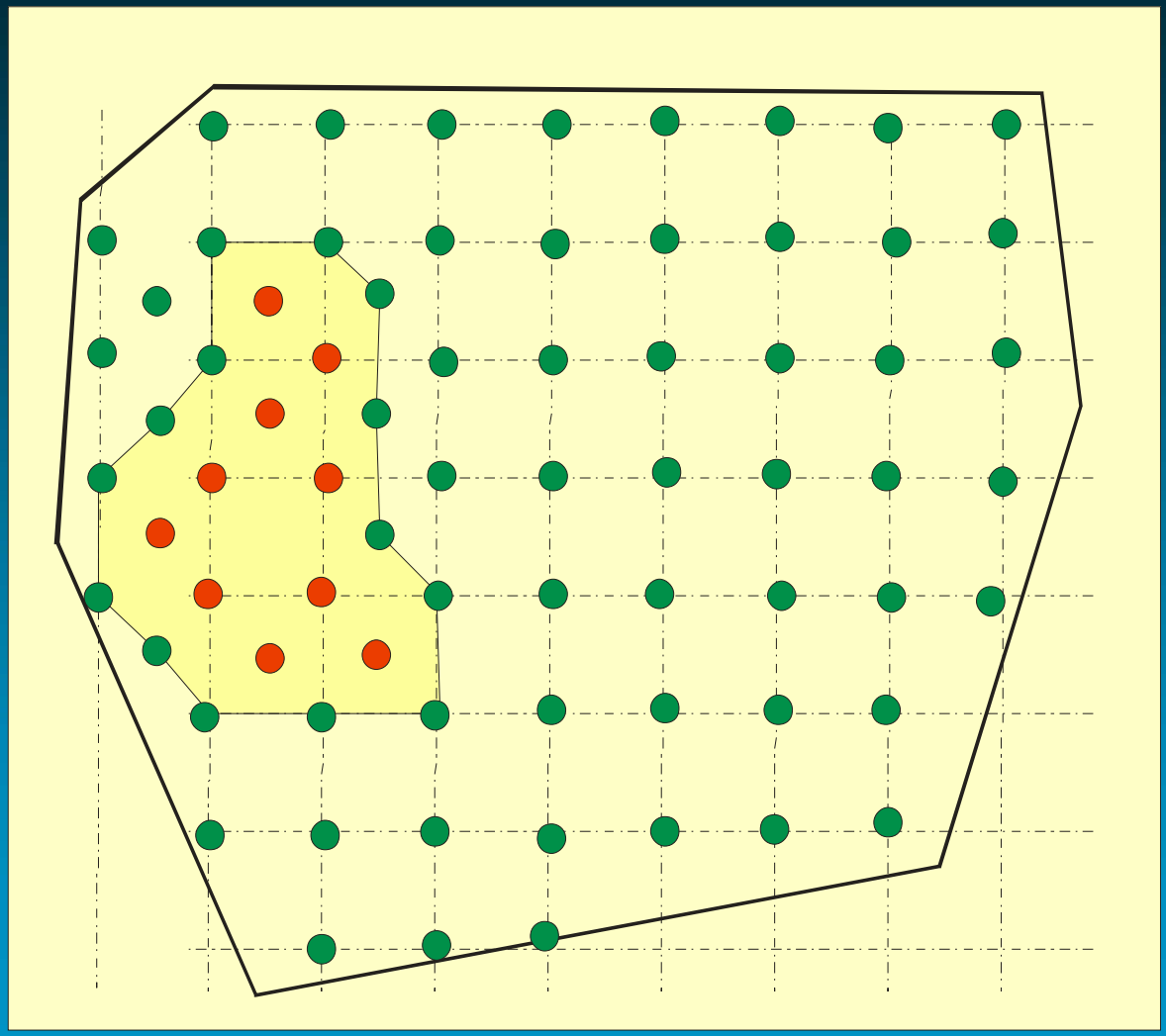
Establish Extent of Excavation



- Sampling Grid Point without Chemical Exceedance
- Sampling Grid Point with Chemical Exceedance
- Region to be Excavated

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Concluding Remarks….1

- Statistical sampling plans can be used to assist in reaching excavation goals
- VSP is a useful tool for developing statistically defensible sampling plans
- Current limitations include:
  - Only applicable for areal impacts

Concluding Remarks…2

- Need to be used with appropriate judgement and knowledge – don't accept results blindly
- REMEMBER - GIGO

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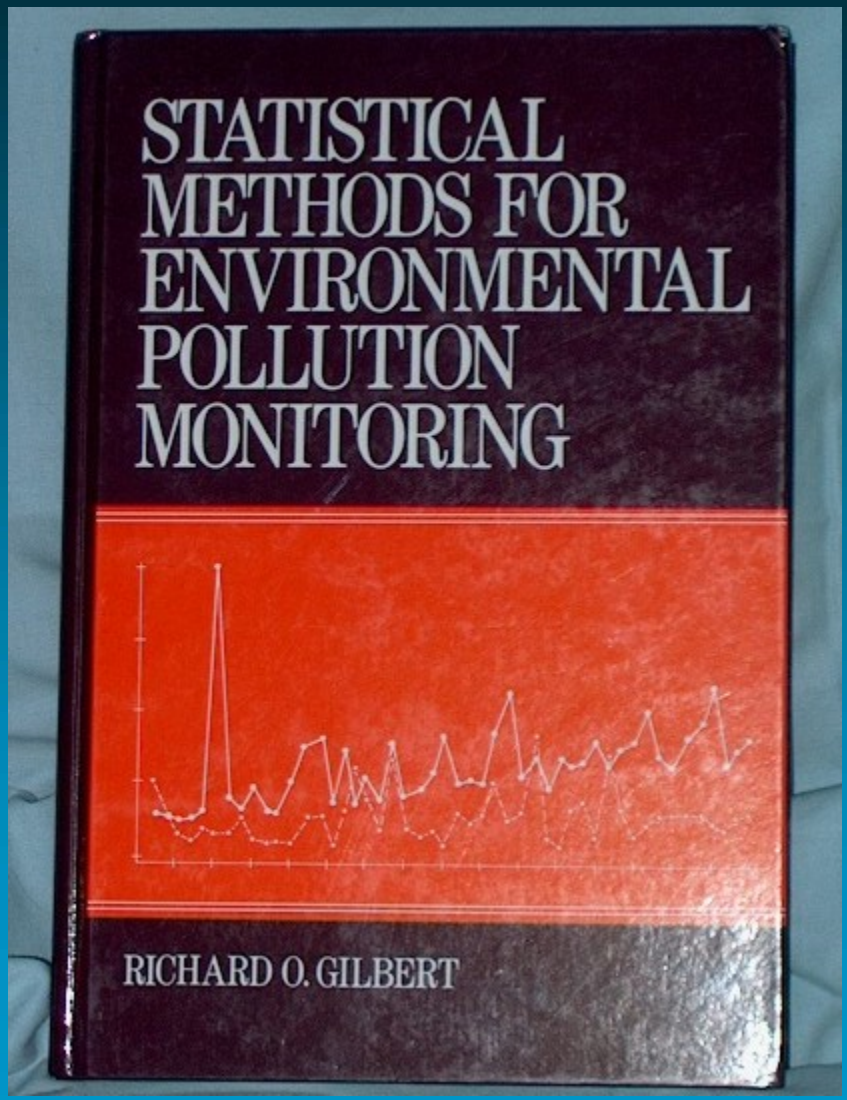
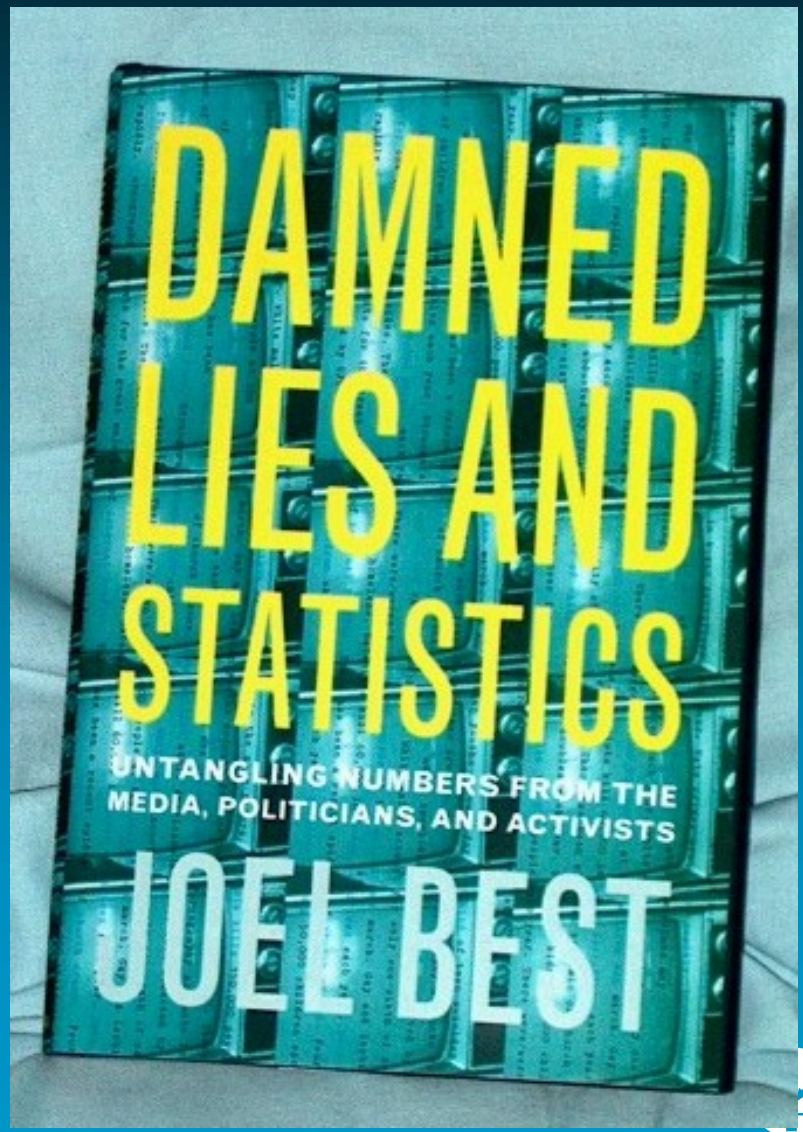
References…


STATISTICAL METHODS FOR ENVIRONMENTAL POLLUTION MONITORING
RICHARD O. GILBERT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UNTANGLING NUMBERS FROM THE MEDIA, POLITICIANS, AND ACTIVISTS
JOEL BEST

“It is easy to lie with statistics, but easier to lie without them.”

- Frederick Mosteller,
founding chairman of Harvard University's statistics department

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Thank you!

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