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Radiological Surveys in Support of Decommissioning

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Radiological Surveys in Support of Decommissioning

- Decommissioning Survey Guidance
- Radiation Survey and Site Investigation Process
- Classification of Survey Units
- Data Quality Objective Process
- Statistical Survey Design
- Survey Methods and Techniques
- Survey Lessons Learned

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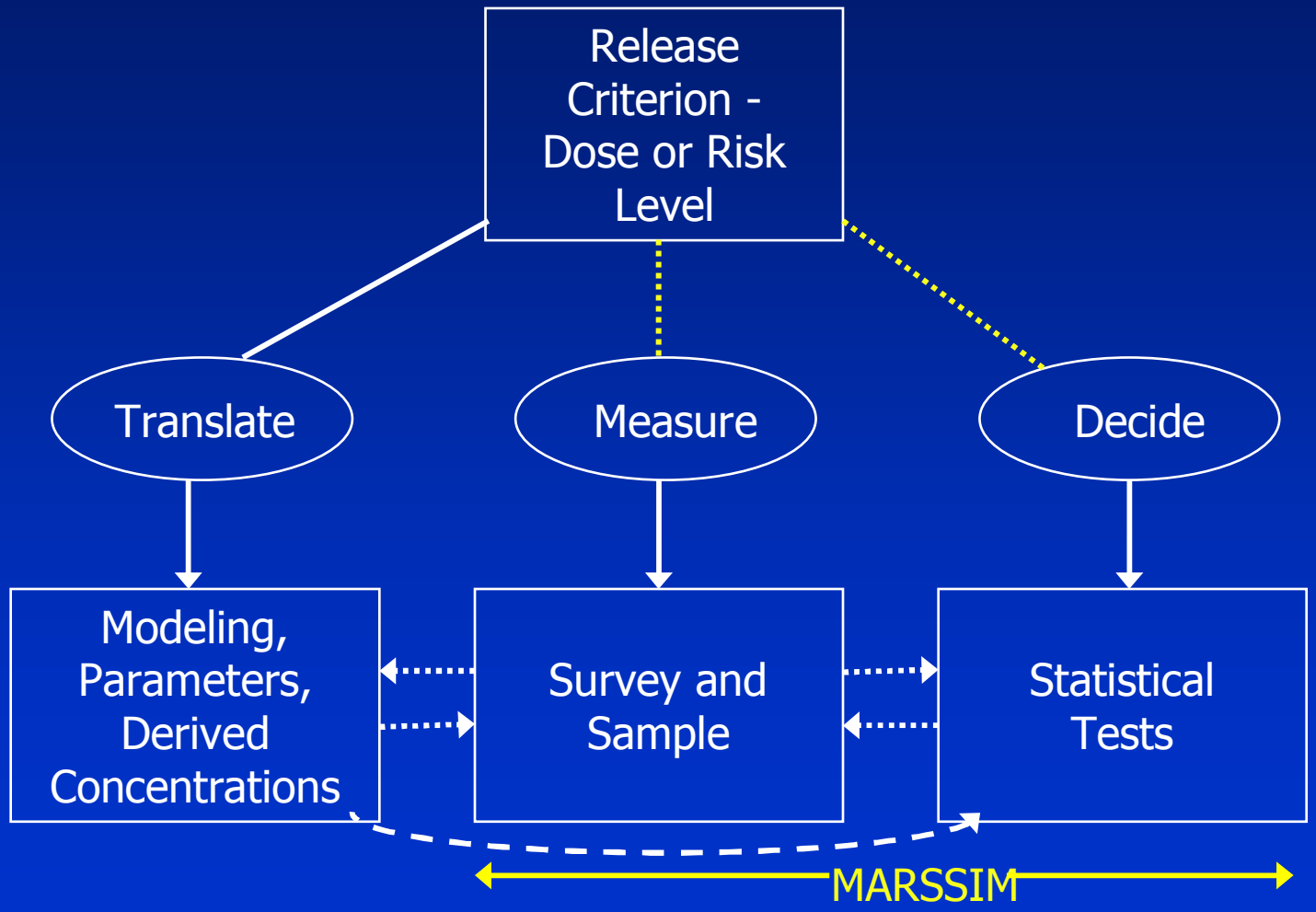
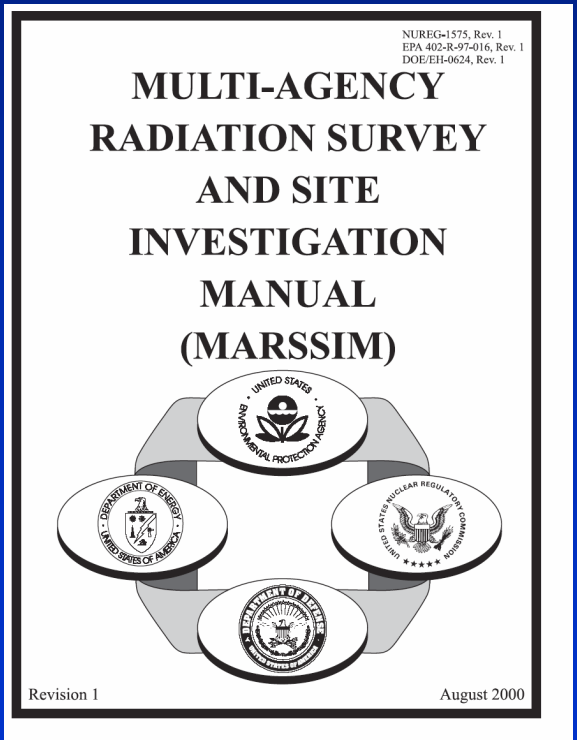


Need for Decommissioning Guidance

- **Regulations do not address topics like:**
  - **How many physical samples should be taken and analyzed or direct measurement methods to use**
  - **How to determine the physical sampling, analysis, or measurement methods to use**
  - **How to evaluate sample analysis and measurement data sets to determine if the regulatory criteria are met**

MARSSIM

- Multi-Agency Radiation Survey and Site Investigation Manual
- Nationally consistent approach
  - Design Final Status Surveys
  - Evaluation of Collected Data
- Surface Contamination
  - Soil
  - Building Surface



What's Old	What's New
• **Release Criterion** – ***Concentration/Activity Based***	➡ ***Dose Based***
• **Survey Unit Classification** – ***Affected vs Unaffected***	➡ ***Based on Contamination Potential***
• **Survey Design** – ***Fixed Sampling Density***	➡ ***Flexible, Integrated Scanning and Sampling***
• **Statistical Methodology** – ***Parametric "Student's t" Confidence Interval***	➡ ***Nonparametric Hypothesis Test***

MARSSIM Process

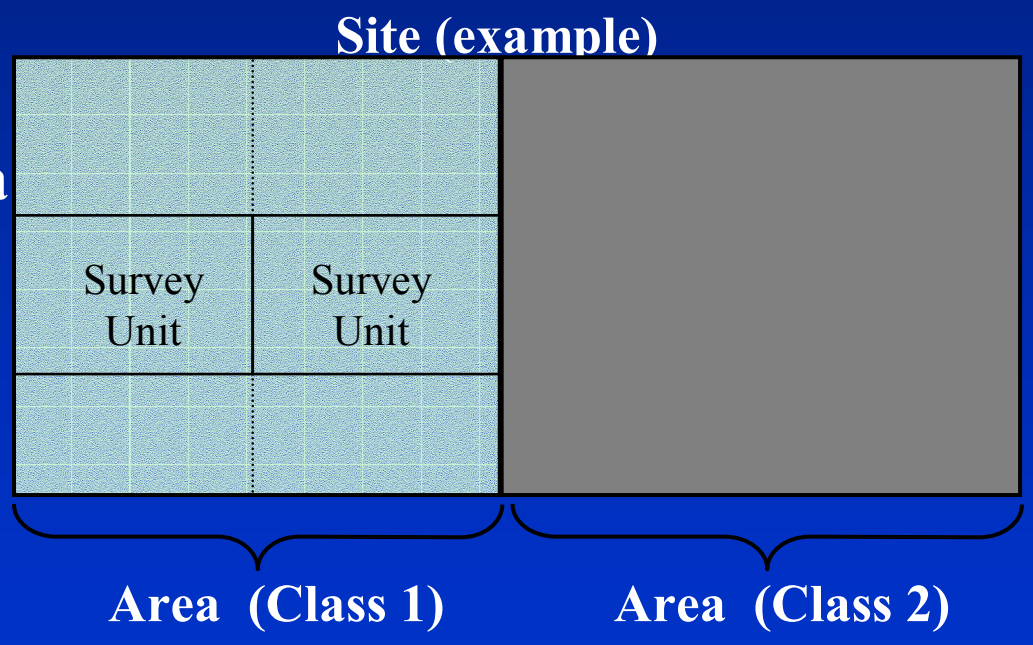
- Plan
- Implement
- Access
- Decide

MARSSIM (continued)

- MARSSIM survey may not be necessary
  - Appendix B of MARSSIM
  - Appendix B of NUREG-1757
- Computer-Based Data Acquisition Systems
  - Scans
  - Complete characterization of the property

MARSSIM Terminology

- DCGL
- Measurement
- Survey Unit Area
- Site
- Hypothesis
  testing and
  null hypothesis



Statistical Testing

- **Statistical tests are used to plan and evaluate Final Status Survey data.**
  - **Wilcoxon Rank Sum (contaminants in background)**
  - **Sign Test (contaminants not in background)**
- **Null Hypothesis: Residual radioactivity exceeds the release criteria**
- **Survey design relies on DQOs to set acceptable decision errors.**

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Radiation Survey and Site Investigation Process

- Historical Site Assessment
- Preliminary Surveys
  - scoping
  - characterization
- Remedial Action Support Surveys
- Final Status Survey
- Confirmatory Survey

Historical Site Assessment

- **Objectives**
  - **Identify potential sources of contamination**
  - **Differentiate areas of different contamination potential (impacted or non-impacted)**
  - **Provide input to scoping and characterization survey designs**

Evaluation of Historical Site Assessment Data

- **Decisions following assessment of HSA data:**
  - **site is <u>impacted</u> - further investigation needed; scoping and characterization surveys required for area classifications**
  - **site is <u>non-impacted</u> - extremely low probability of residual radioactivity; site release possible**

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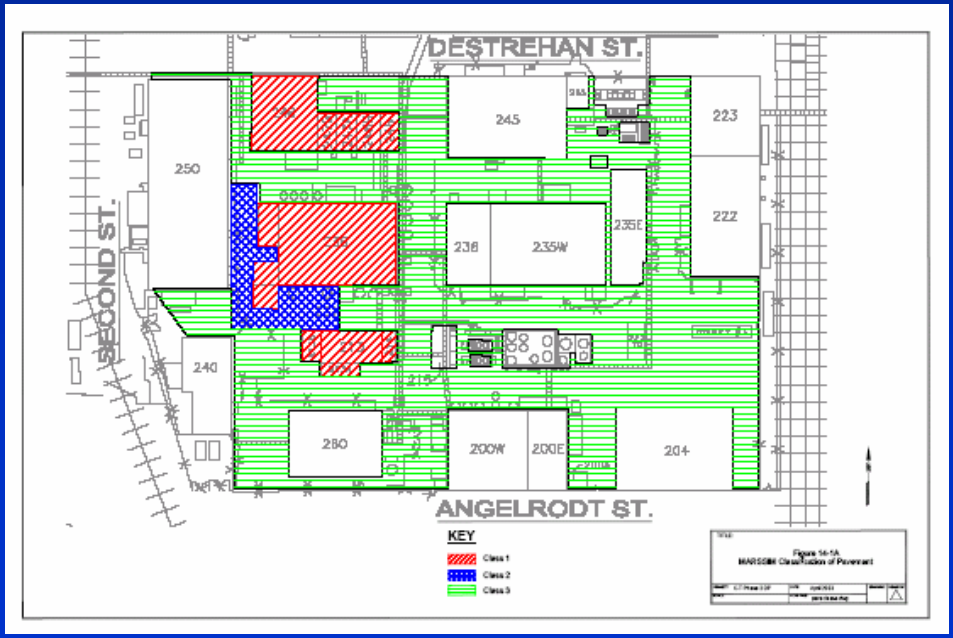
Evaluation of Historical Site Assessment Data

Evaluation of HSA Data (continued)

- Surface Soil
- Subsurface Soil
- Buildings/Structures
- Groundwater

Evaluation of HSA Data (continued)

- **HSA Summary**
  - **Site diagram showing <u>preliminary</u> classification of areas: impacted (Class 1, 2, or 3) and non-impacted**



Scoping Survey

- Collect judgmental samples in potential areas of concern
- Objectives
  - Provides input to characterization survey design
  - Supports classification of site areas
  - Identifies site contaminants and their variability

Characterization Survey

- **Primary objective: Determine the nature and extent of contamination**
- **Other objectives:**
  - **Evaluating remediation alternatives**
  - **Pathway modeling input for site-specific DCGLs**
  - **Input to final status survey**

Remedial Action Support Survey

Final Status Survey

- Statistical tests are used to plan and evaluate Final Status Survey
- Survey design relies on DQOs to set acceptable decision errors.
- Needed to demonstrate compliance

Confirmatory Survey

Decommissioning Project Phases

• Assessment	Scoping/Characterization
• Planning and Development	Remediation Plan
• Operation	Remedial Actions Remedial Action Survey
• Closeout	Final Status Survey Confirmatory Survey

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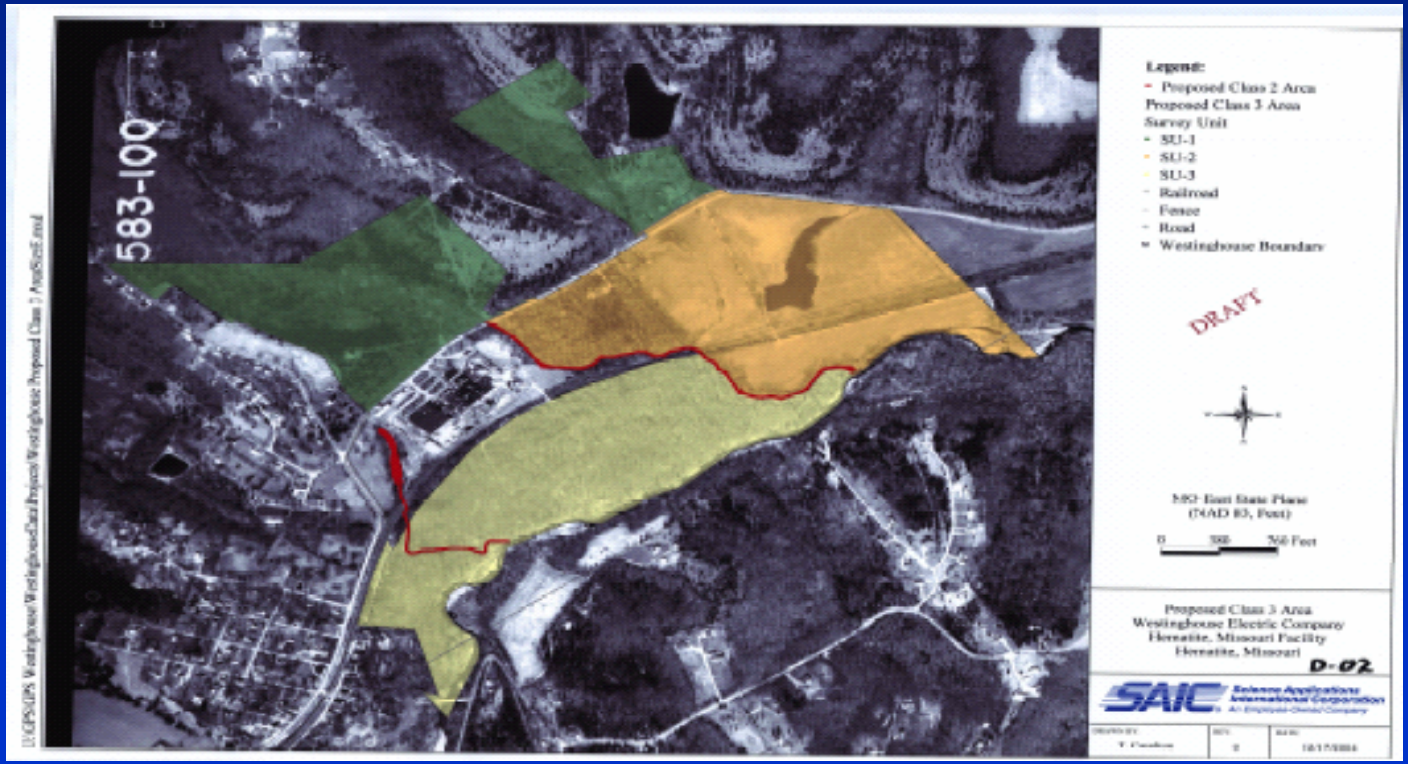
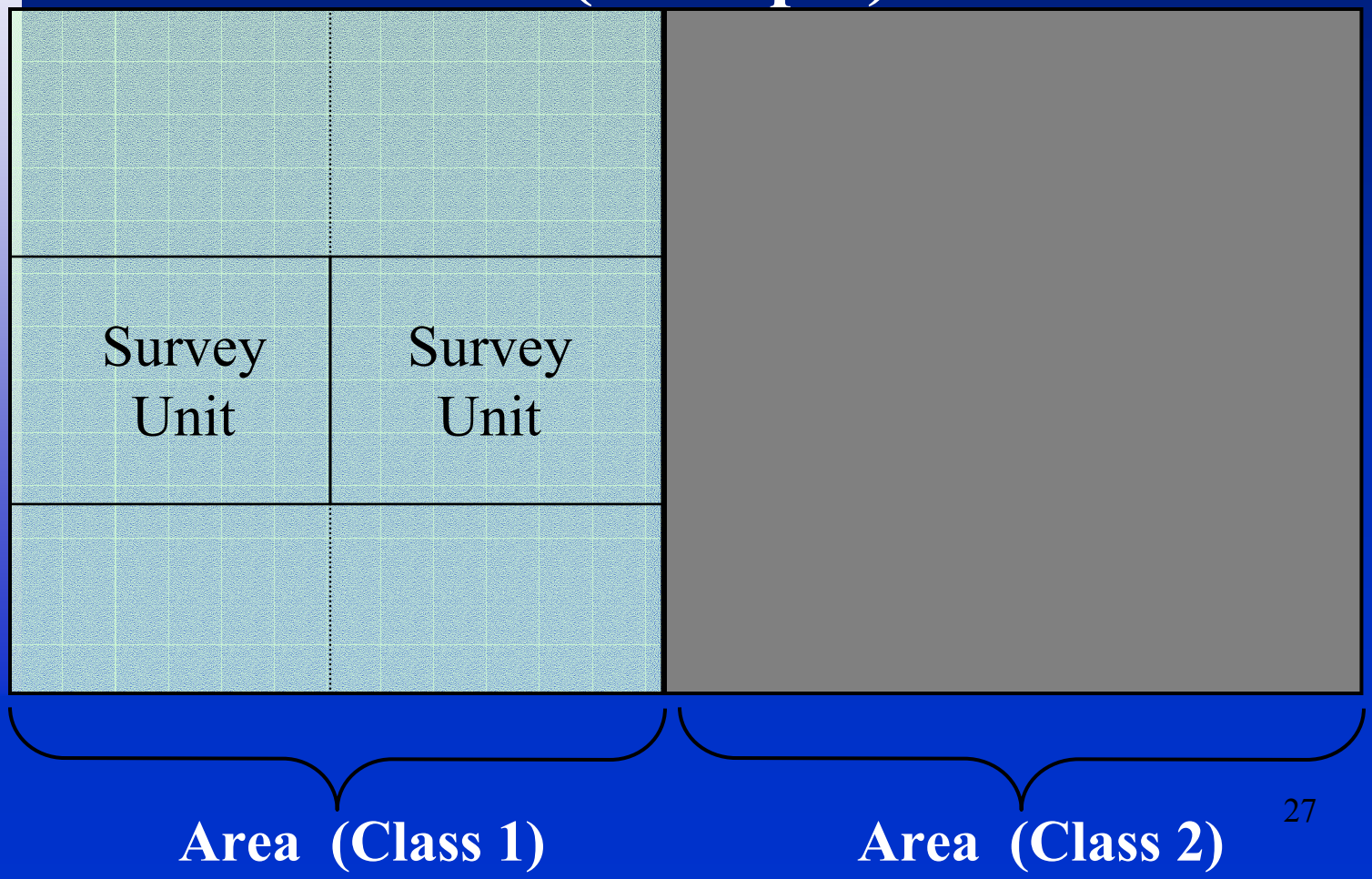
Classify Areas

- Areas with higher potential for contamination receive higher degree of survey effort
  - Class 1
  - Class 2
  - Class 3
- Site is divided into Class 1, 2 and 3 areas

Classifying the Site

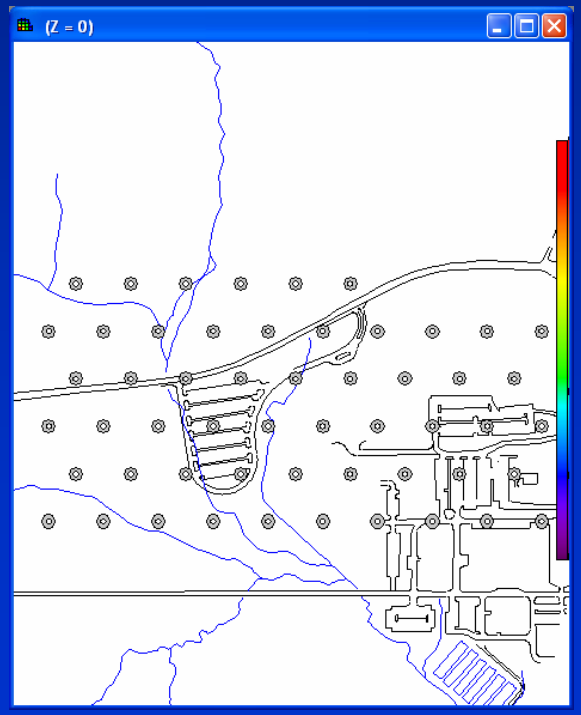


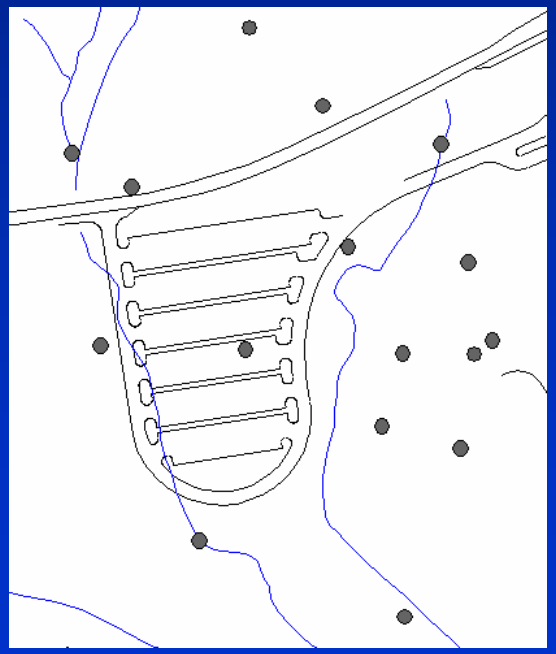
Site (example)



Classify Areas

- **Class 1** **Class 2** **Class 3**





Identify Survey Units

- Class 1, 2 and 3 areas divided into survey units prior to final status survey
  - areas of similar contamination potential or common history
  - areas naturally distinguishable from other portions of site
- A survey unit may <u>not</u> include areas that have different classifications

Suggested Survey Unit Sizes

	Typical Maximum
• Class 1	
– Structures	100 m^2 floor area
– Land areas	2,000 m^2
• Class 2	
– Structures	100 to 1,000 m^2 floor
– Land areas	2,000 to 10,000 m^2
• Class 3	
– Structures	no limit
– Land areas	no limit

Examples of Survey Units

- Individual rooms within a building or multiple rooms along a hallway
- Floor and lower walls in a room may be Class 1 survey unit, while upper walls and ceiling a Class 3 survey unit
- Former "burn pit" area may be Class 1, while land subject to effluent depositions include several Class 2 survey units

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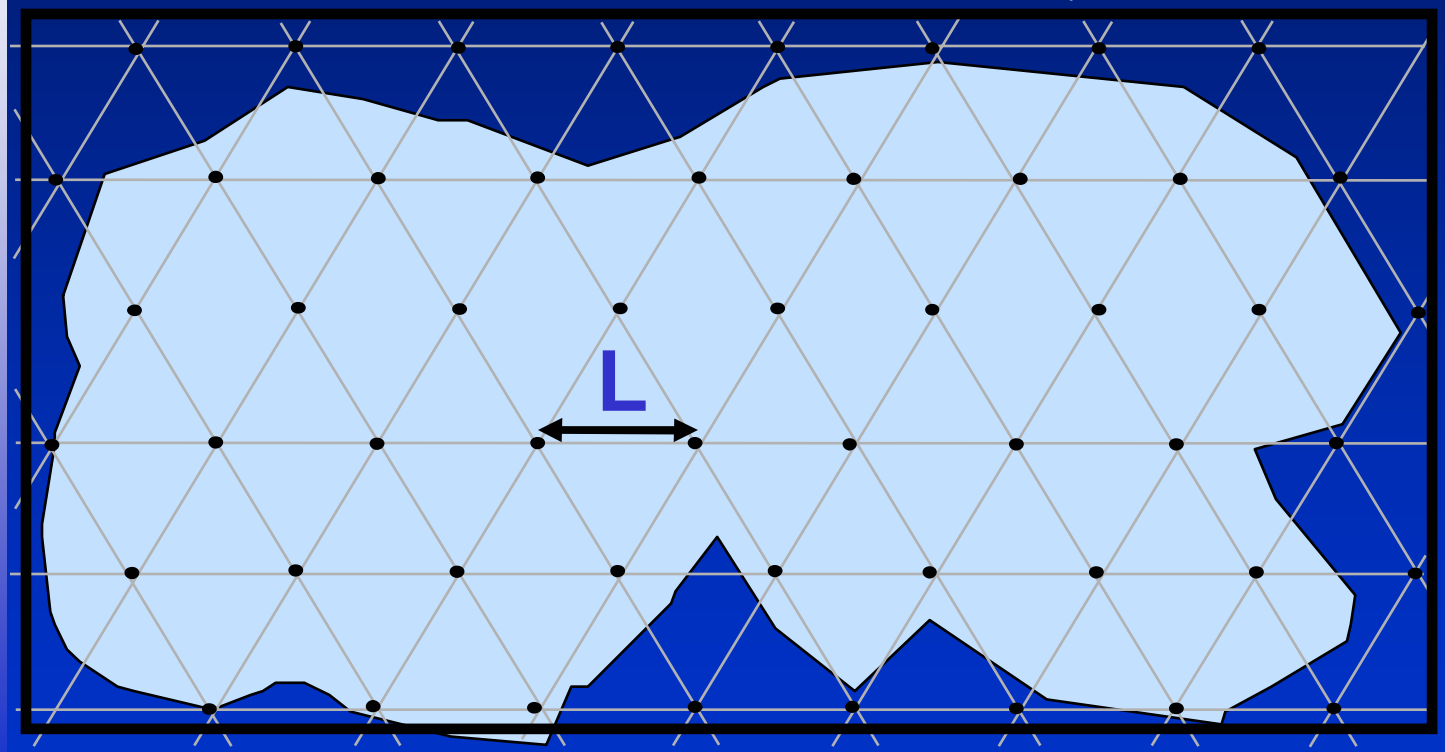
Statistics test over the entire survey unit...



…using data taken on a random start grid.

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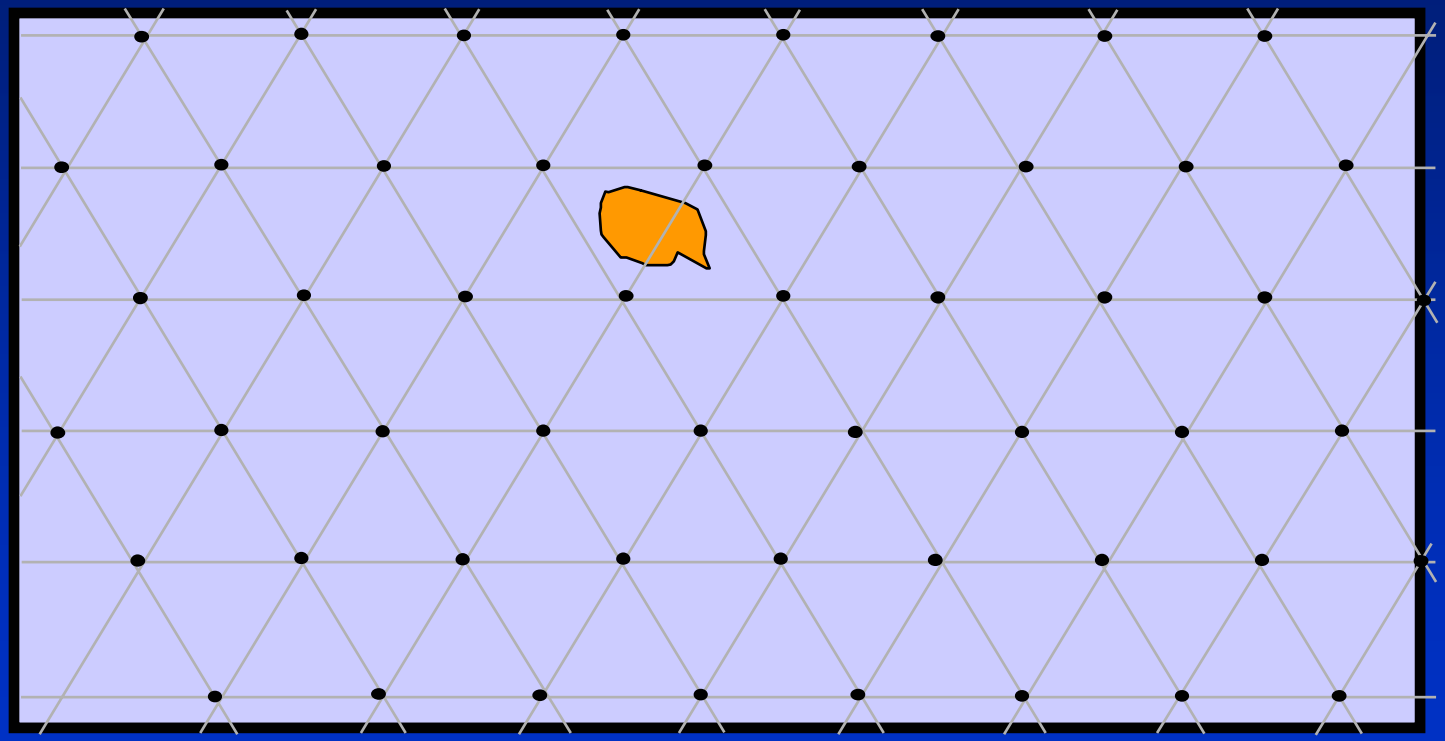
EMC is used to detect small areas...



primarily by *scanning* methods.

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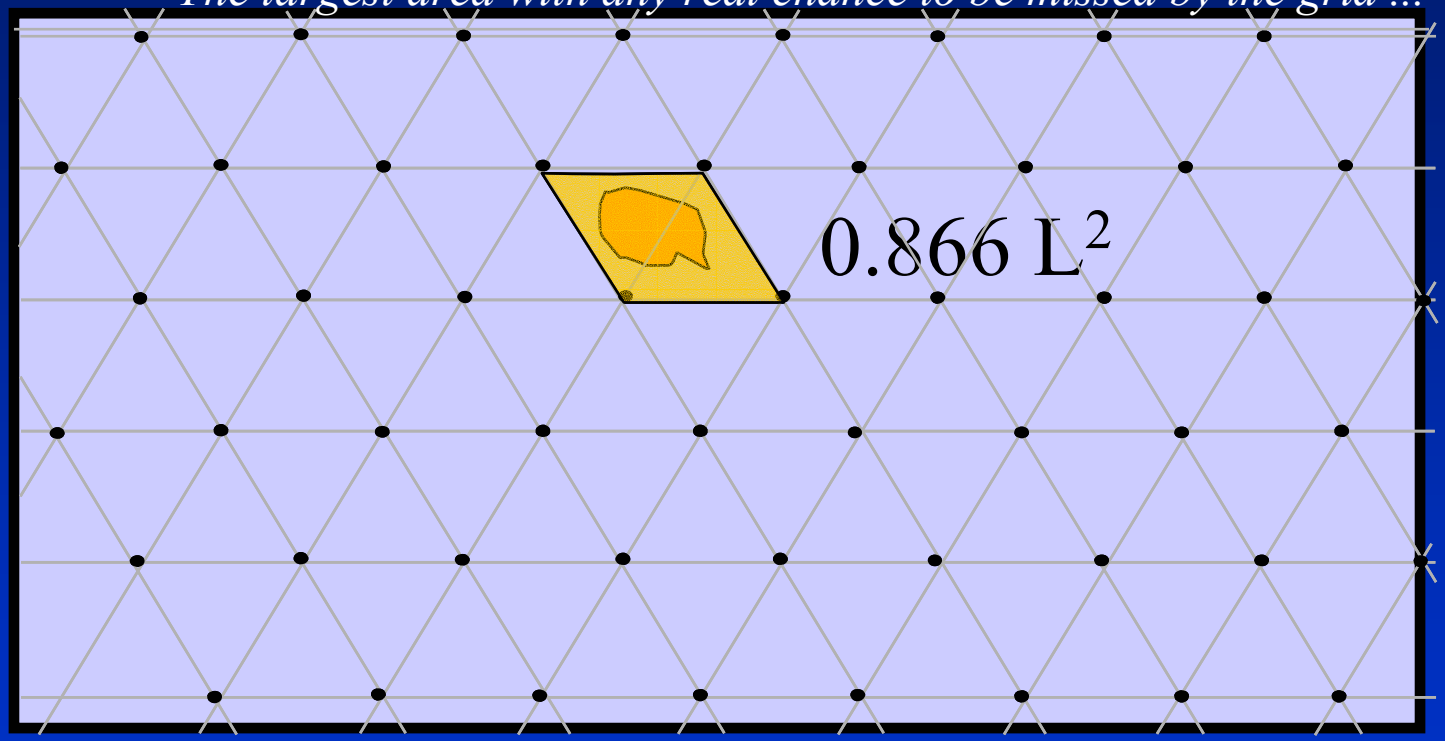
The largest area with any real chance to be missed by the grid ...



is the grid area defined by neighboring sample points.

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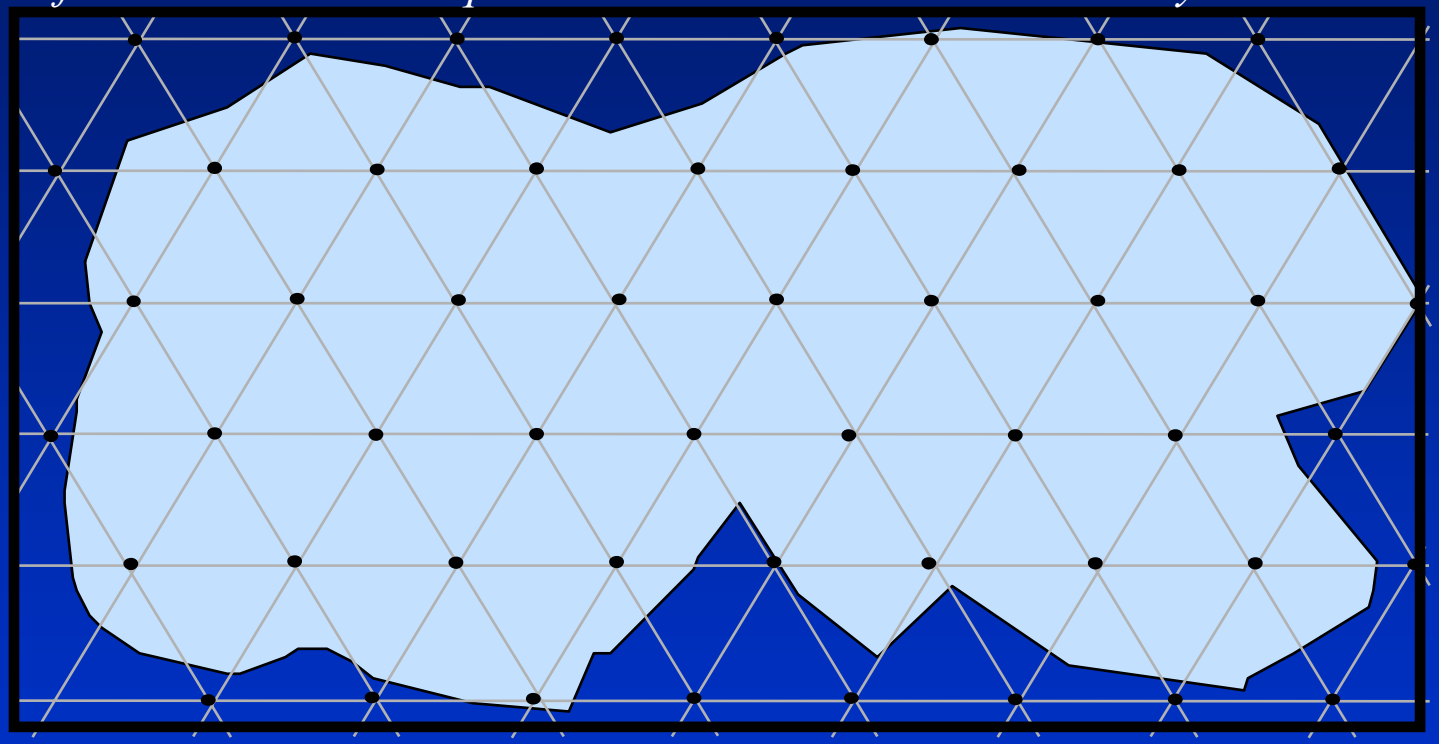
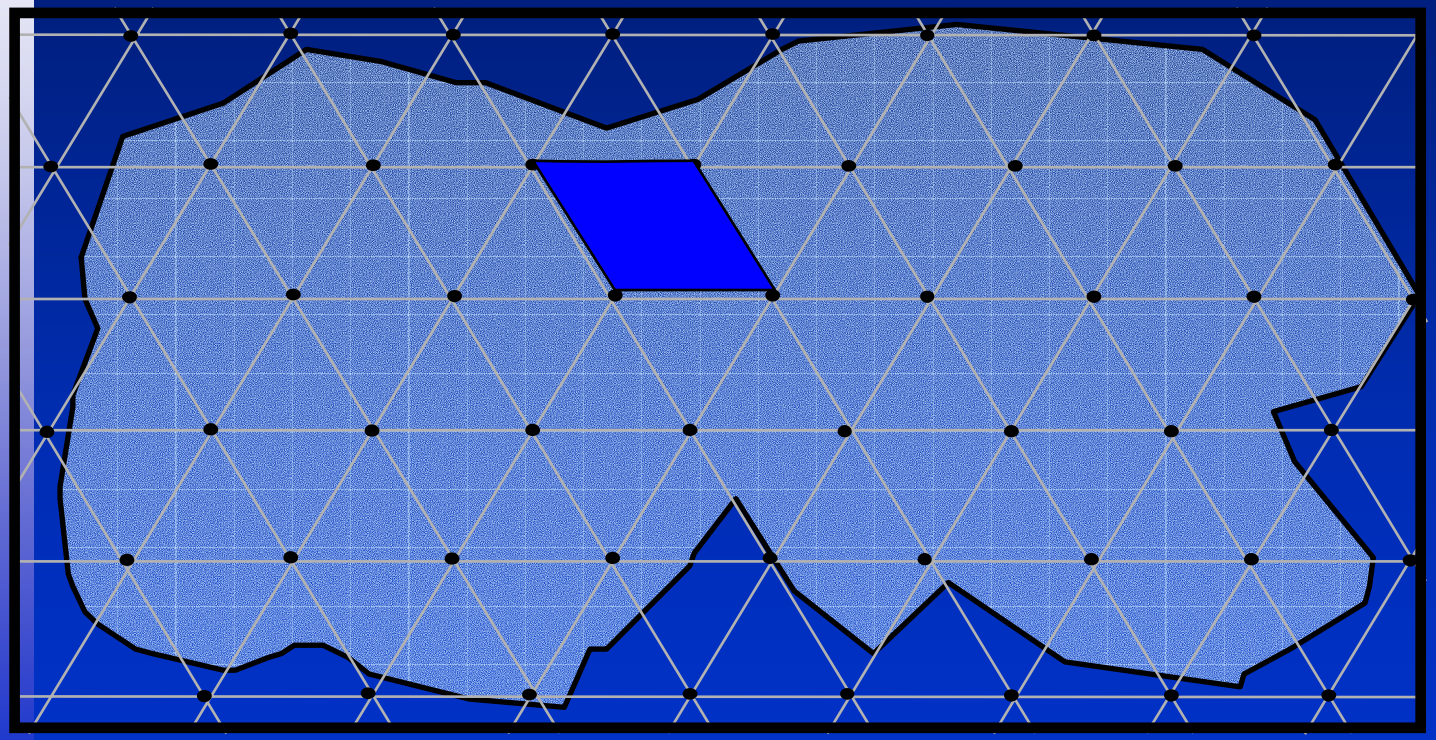
If the concentration equals the DCGL over the entire survey unit...



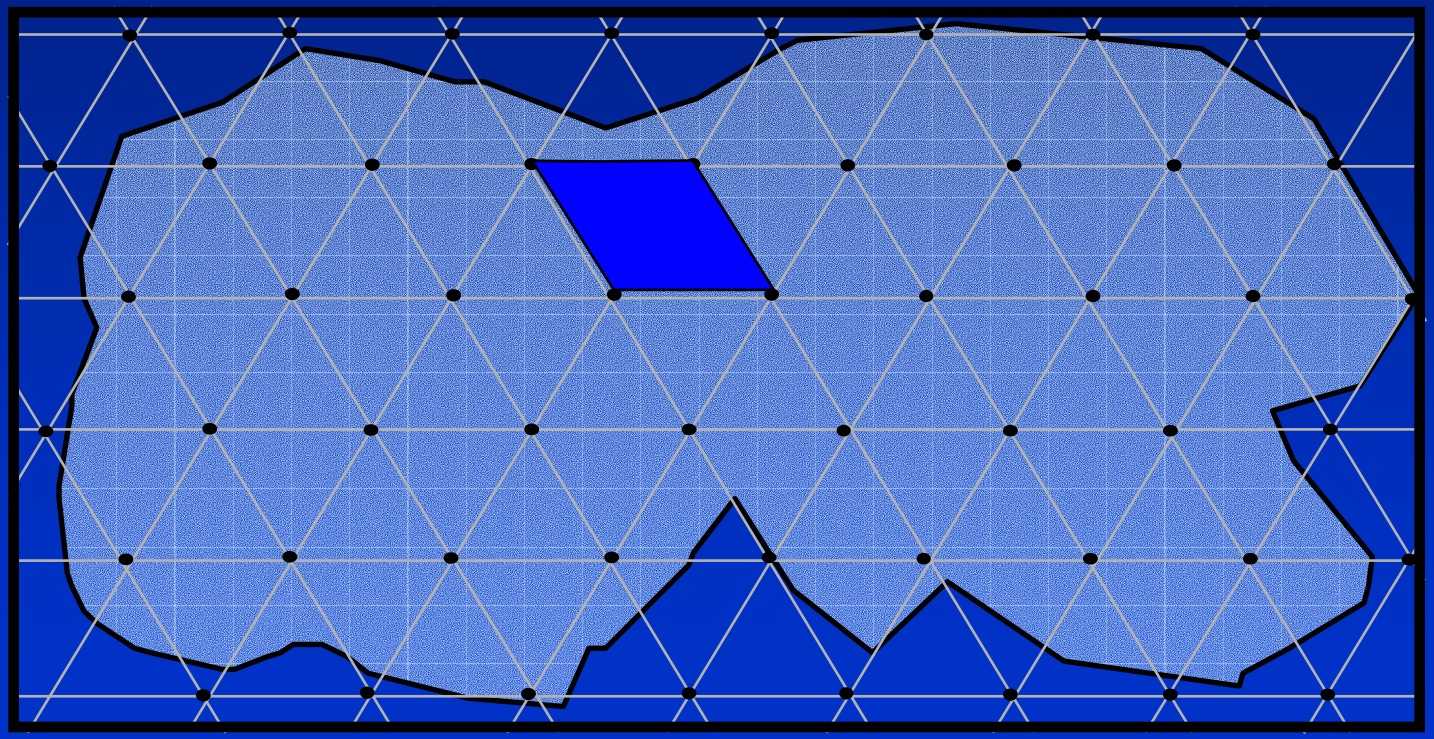
the resulting dose is 25 mrem/y

If the residual radioactivity is confined to a smaller area...



. . . the concentration must be ***higher*** to give 25 mrem/y.

The concentration needed in the grid area to give 25 mrem/y is the $DCGL_{EMC}$



$$DCGL_{EMC} = (\text{Area Factor}) \times (DCGL_W)$$

The scanning MDC must be low enough to detect a concentration of $DCGL_{EMC}$.

If scanning MDC > $DCGL_{EMC}$, *reduce* the distance between sample points, L, so that the *area* $0.866L^2$ is *small* enough and the *area factor* is *large* enough that

scan MDC < $DCGL_{EMC}$

= (Area Factor) times $DCGL_W$)

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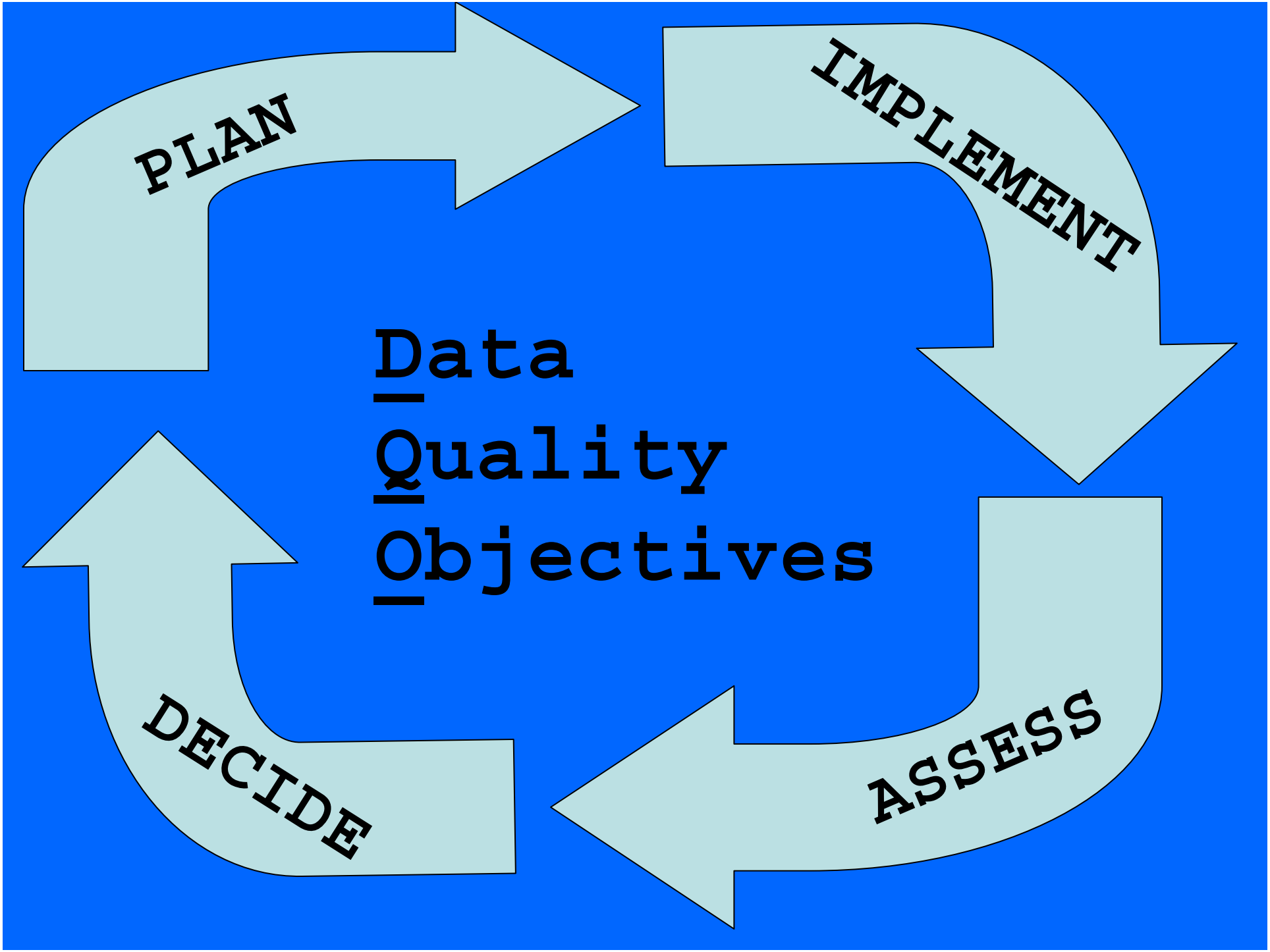
PLAN
IMPLEMENT
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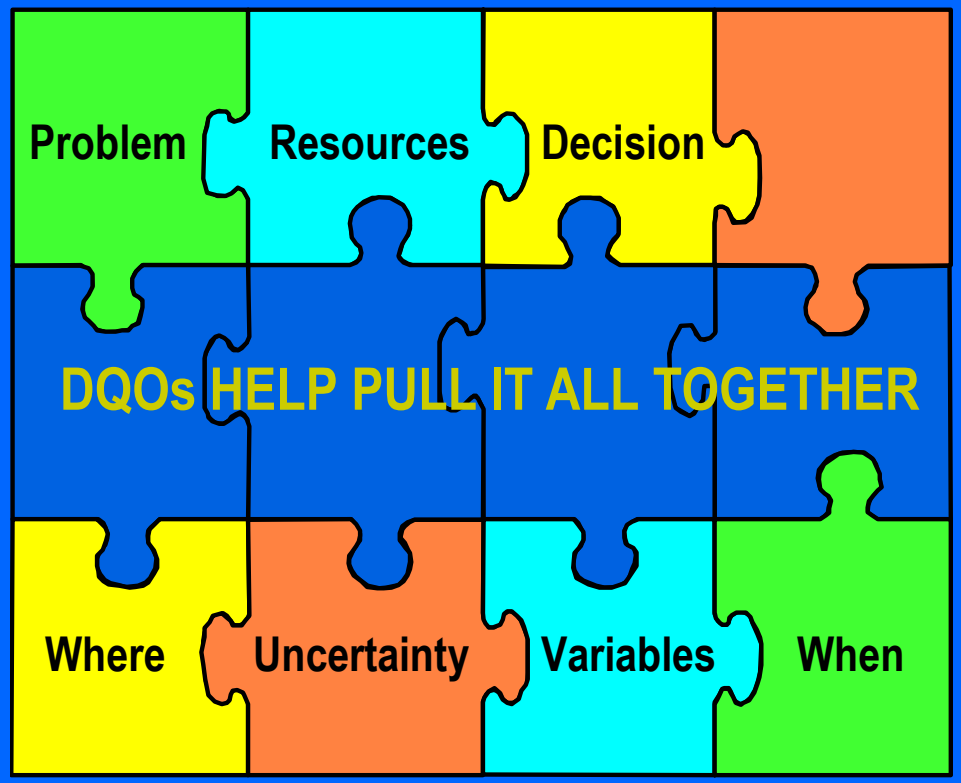
Data
Quality
Objectives



It has been demonstrated that the DQO Process greatly strengthens the planning process by *improving planning efficiency*, *promoting defensibility* of data, and *saving resources*

Step	Product
1. STATE THE PROBLEM	Clear description of the problem for a specific project.
2. IDENTIFY THE DECISION	Decision that will be needed to address the problem.
3. IDENTIFY INPUTS TO THE DECISION	Information that will be needed to make the decision.
4. DEFINE THE STUDY BOUNDARIES	Description of statistical population for which the decision will be made.
5. DEVELOP A DECISION RULE	How parameter of interest and action level will be used to make a decision.
6. SPECIFY LIMITS ON DECISION ERRORS	Acceptable probability of making an incorrect decision.
7. OPTIMIZE DESIGN FOR OBTAINING DATA	Optimal probability of making an correct decision.

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Statistical Test

- Conducting a statistical test appropriately requires some thoughtful decisions, e.g,
- What statistic to use
- What sample size to employ
- What alpha and beta to specify, and
- What criteria to establish for rejection the null hypothesis.

Hypothesis Testing

- **Null Hypothesis (Ho): Residual radioactivity exceeds the release criteria.**
  - **Ho is the baseline condition, assumed to be true in the absence of strong evidence to the contrary**
- **Decision Errors occur when Ho is rejected when it is true (Type I) , or when Ho is accepted when it is false (Type II)**

Decision Errors

Decision	True State	Consequences
Deciding a survey unit is clean...	...when it actually isn't (H_0).	Type I α
Deciding a survey unit isn't clean...	...when it actually is (H_A).	Type II β

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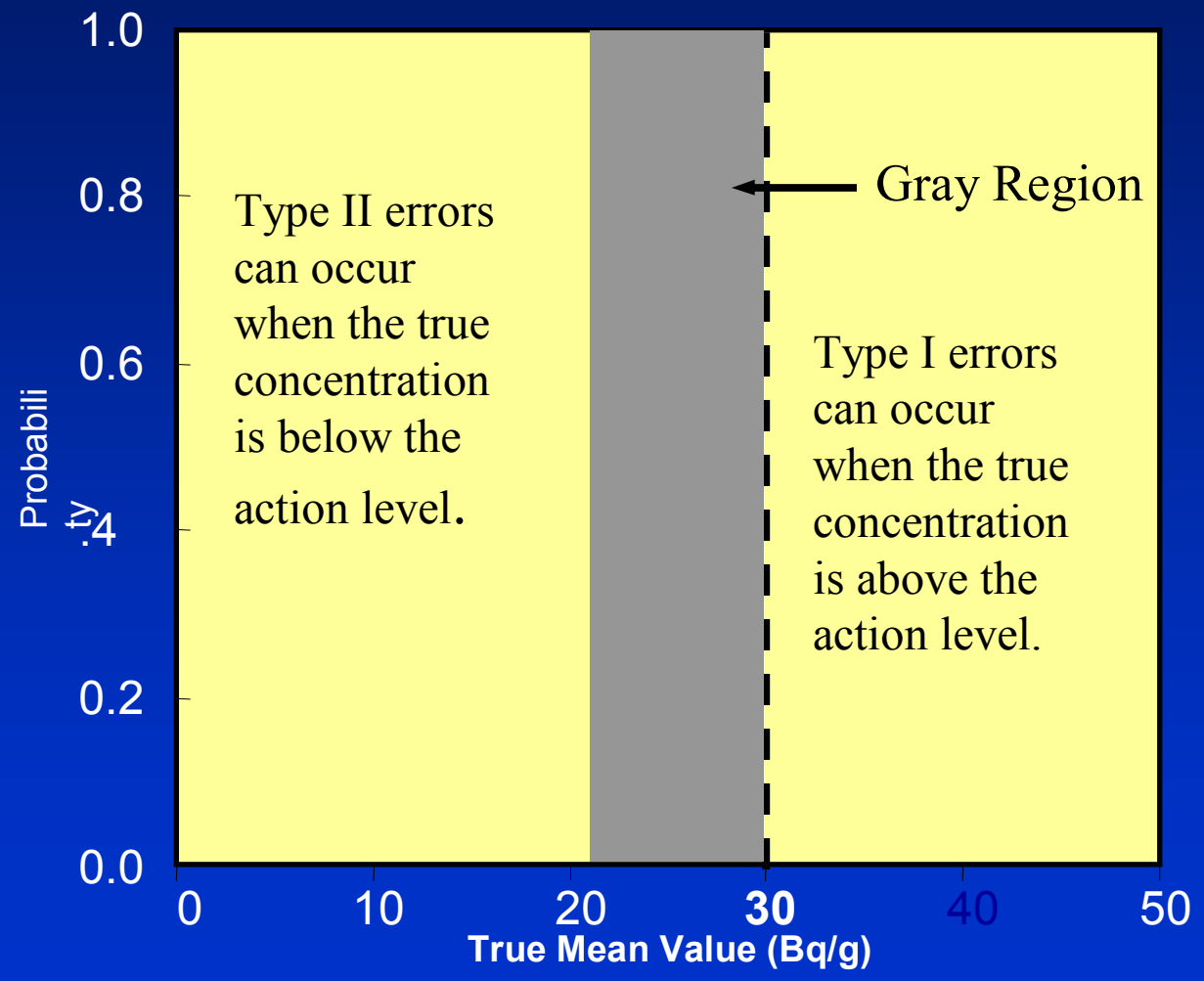

$H_0 \geq 30$ Bq/g

$H_A < 30$ Bq/g

Determine the Statistical Test

Scenario A - Default scenario

- **Background is not an issue - Sign Test**
- **Background is an issue - Wilcoxon Rank Sum Test (WRS Test)**
  - **Different surfaces- Sign Test on differences**
- **If more than one radionuclide is present in a survey unit and anyone of them requires the use of the WRS Test, use the WRS Test**

- **Scenario B- More complex -use would have to be justified**

COMPASS

- Software to facilitate designing final status radiological surveys.
- prospective power curves - determining what level of confidence the user is willing to accept for a particular number of measurements or samples for a survey unit.
- After performing the final status survey, use to assesses the data for comparison to the release criteria.

Spatial Analysis and Decision Assistance (SADA)

- Calculate sample size based on Sign Test and WRS Test; incorporating DCGLs, decision variables, area factors, instrument sensitivity
- Develop initial sample design (MARSSIM grid or simple random)
- Post sampling analysis (A site passes or fails)
- Detecting and Defining Elevated Areas

Data Quality Assessment:

- **DQA is the statistical evaluation of data to assure that the data are right type and quality for decision making**
  - **Review the DQOs**
  - **Preliminary Data Review**
  - **Select Statistical Test**
  - **Draw conclusions**

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Developing an Integrated Survey Design

- Survey methods and techniques
- Survey instrument selection
- Survey coverage based on classification
- Instrument selection case study

Survey Methods and Techniques

- Surface scans (indoors and land areas)
- Surface activity measurements
- Soil sampling
- Miscellaneous samples

Survey Methods and Techniques

- **Surface scans**
  - **moving a detector over a building surface or soil at a specified rate to detect the presence of radiation - i.e. elevated radiation levels**
  - **monitor audible output of meter for detectable changes in count rate**
  - **mark locations of elevated direct radiation and ensure scan results documented in report**

Survey Methods and Techniques

- **Surface scans (cont.)**
  - **structure surfaces are scanned for alpha, beta and gamma emitters, while land areas are scanned for gamma radiation**
  - **scanning is an inexpensive way to survey large areas; it is <u>not</u> a measurement technique that can be assessed with statistics**

Survey Methods and Techniques

- **Surface activity measurements**
  - **determine the quantity of surface activity at both systematic and judgmental locations**
  - **MDC of instrument measurement system should be between 10 to 50% of DCGL**
  - **ISO-7503 approach for surface activity assessment; data reported in dpm/100 cm^2**

ISO-7503 METHODOLOGY

- **Conventional approach (vs. ISO-7503) often overestimated the efficiencies due to calibration with high-backscatter sources - typically not representative of real surface conditions.**
- **ISO-7503 separates total efficiency into instrument and surface efficiency components - needed flexibility to account for field conditions.**

Survey Methods and Techniques

- **Soil sampling**
  - **collect samples that accurately represent radionuclide concentrations at sample location**
  - **generally collect surface soil (0 to 15 cm depth)**
  - **depending on analysis, 100 grams to 1 kg of soil are collected**

Survey Instrument Selection

- Selection of instruments requires knowledge of contaminant and site conditions
  - scans, direct measurements, lab analyses
- Consider the DQOs for the instrument
  - accuracy of the measurement and its MDC
  - scanning and measurements may be performed as a single activity, if positioning, sensitivity and recording are adequate

Survey Instrumentation

- Field survey instruments
  - gas proportional (3 modes of operation)
    - alpha-only (using voltage setting)
    - beta-only (using Mylar thickness)
    - alpha plus beta
  - Geiger-Mueller (measures primarily beta)
  - zinc sulfide (alpha measurements)
  - sodium iodide (gamma scans)

Survey Instrumentation

- Greater sensitivity - lower levels of contamination detected
- Sensitivity depends
  - Sensitivity of instrument
  - Ability of Surveyor (Human Factors)
- Minimum Detectable Concentration

Scan Sensitivity

- Consider human factors in scanning
  - is the signal from "background only" or "background plus radioactive contamination"?
- NRC report evaluated scan sensitivity for an "ideal observer" through computer simulations, and performed field tests to evaluate model
  - NUREG/CR-6364, "Human Performance in Radiological Survey Scanning"

Human Factors During Scanning

- Bias toward "false alarms" where surveyor expects contamination–bias toward "misses" when not expected
- Surveyor influenced by relative costs of "misses" and "false alarms"
- During extended periods of scanning
  - vigilance decrement - less likely to find contamination if it does exist
  - probe is usually moved more quickly

Survey Coverage for Structures and Land Areas

- **Surface activity measurements/soil samples for <u>Class 1 areas</u>**
  - **number of data points from statistical tests; additional samples may be necessary for evaluating small areas of elevated activity**
  - **surveyed on a random-start systematic pattern**
  - **scan coverage: 100%**

Survey Coverage for Structures and Land Areas

- **Surface activity measurements/soil samples for <u>Class 2 areas</u>**
  - **number of data points from statistical tests**
  - **surveyed on a random-start systematic pattern, but larger size of survey units and greater spacing between samples than Class 1 areas**
- **Scan coverage: 10 to 100%**

Survey Coverage for Structures and Land Areas

- **Surface activity measurements/soil samples for <u>Class 3 areas</u>**
  - **number of data points from statistical tests**
  - **surveyed on a random start to ensure that measurements are independent**
  - **<u>background reference area</u> measurements and samples are also collected randomly**
- **Scan coverage: judgmental**

Investigation Levels

- **Radionuclide-specific levels used to indicate when additional investigations may be necessary**
- **If exceeded, first step is to confirm measurement/sample**
- **Results of all investigations and corresponding actions must be documented**

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Lessons Learned from Regulatory Reviews of Survey Plans

Attributes a Survey Plan Should Include

- Reliance on applicable guidance documents
  - MARSSIM
  - NUREG-1505 (statistics report)
  - NUREG-1507 (instrument selection report)
  - EPA QA/G-4, EPA QA/G-9, ANSI/ASQC-E4 (data quality reports)
- Avoidance of common mistakes

Common Survey Issues

- **Insufficient explanation of quality control procedures, data quality assessment, release criteria and action levels**
- **Survey procedures are not provided or incomplete**
- **Improper instrument selection for site conditions**
- **Inadequate technical basis for survey unit classification**
- **Misapplication of release criteria (DCGL)**

Observed Improvements in Decommissioning Surveys

- Direct use of MARSSIM guidance
- Combining survey types to save resources
- Reducing the scope of a survey based on preliminary survey results
- Use of existing data to demonstrate compliance with the release criterion