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Ranked Set Sampling

A Tool for Estimating Mean Constituent Concentrations in Soil

Rio Algom Mining LLC – Nuclear Regulatory Commission Public Meeting
Radioactive Materials License SUA-1473
January 23, 2019

Ambrosia Lake West Mill Facility

- Former uranium mill located near Grants, NM that has been licensed by the NRC since NM became an agreement state for 11e(2) byproduct material in 1986.
- Has been in decommissioning since 2003.
- Title II UMTRCA site known to DOE as "Ambrosia Lake West".
- The facility is owned by Rio Algom Mining LLC (RAML), a wholly owned subsidiary of BHP.
- Soil Decommissioning Plan (SDP) was approved in 2006.

Impoundments 1 and 3.

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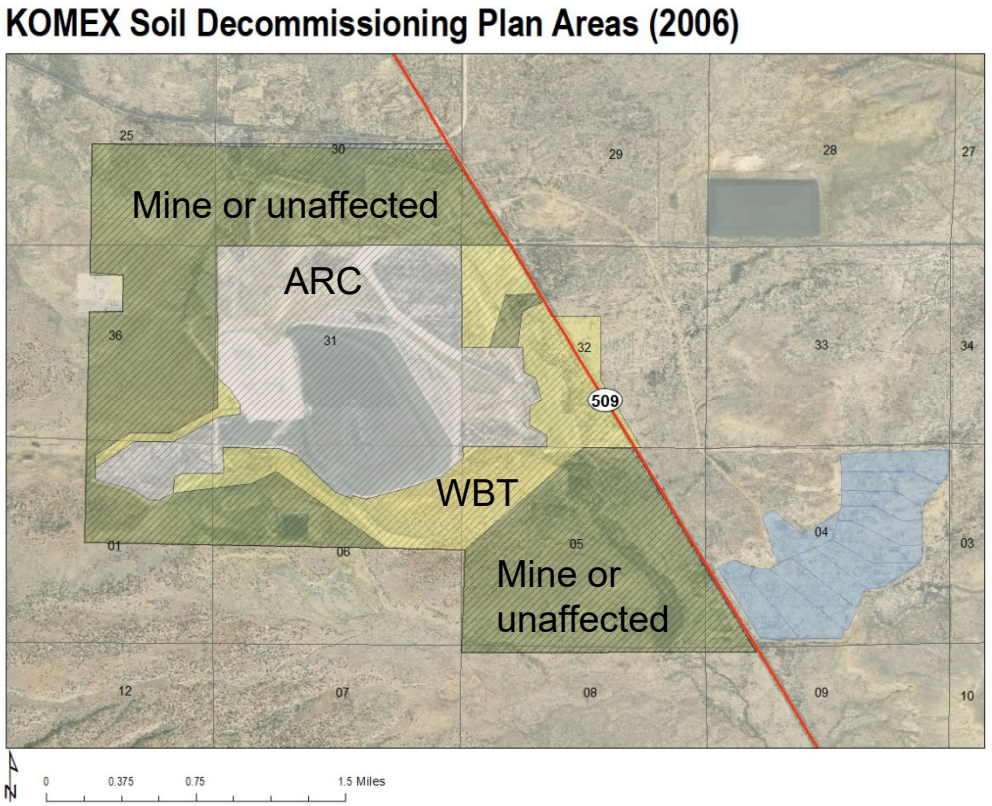
Summary of the Mill's Soil Decommissioning Plan

Out of scope areas for the SDP:

- Mill and mining unaffected areas
- Area affected by mining activities but not milling

In-scope areas for the SDP:

- Section 4 ponds
- Areas impacted by windblown tailings (WBT)
- Areas of potential deep contamination where the Alternate Release Criteria (ARC) can be applied
- Pipeline from Pond 9 to Section 4 ponds
- Haul ways and roads



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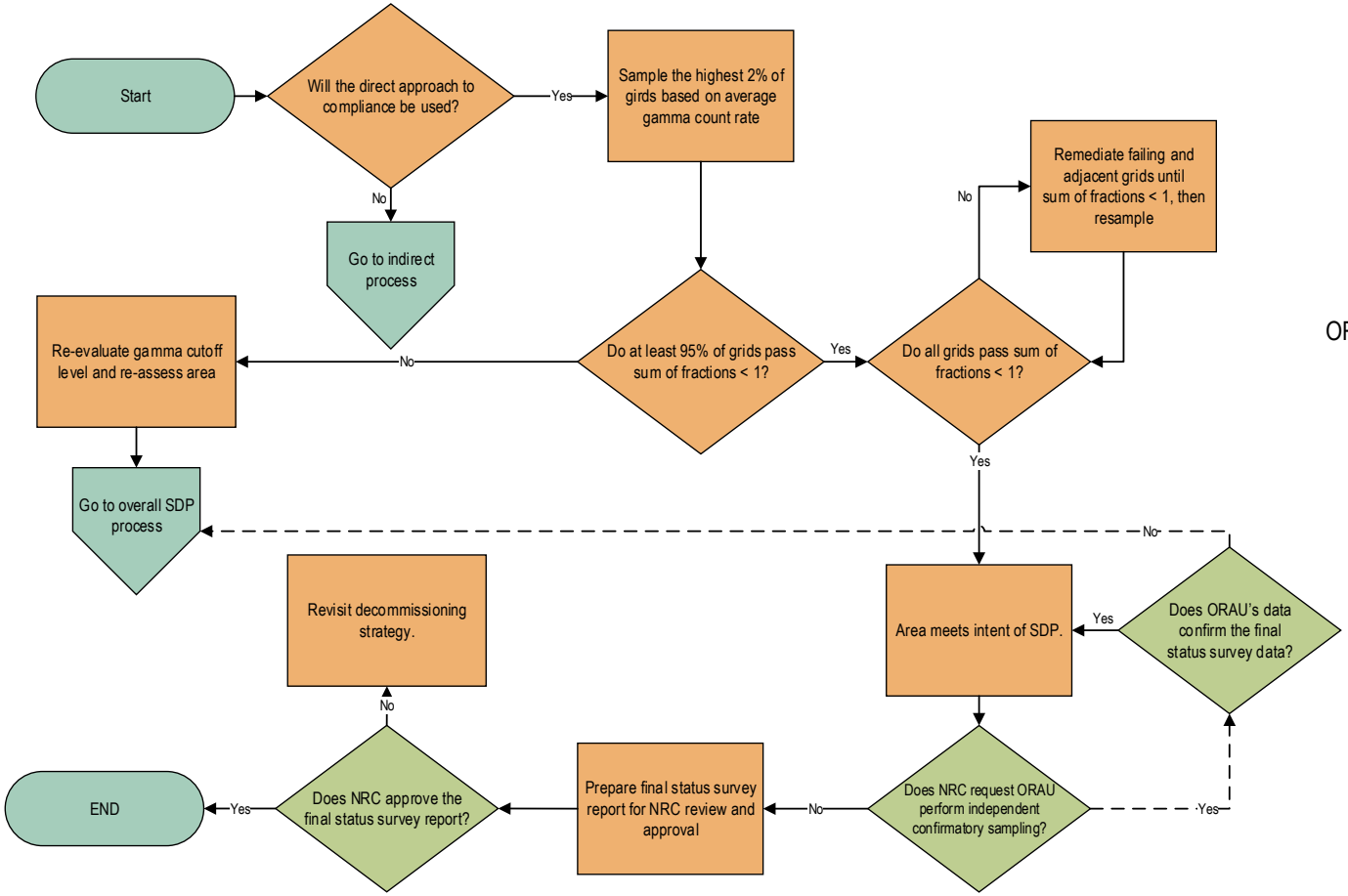
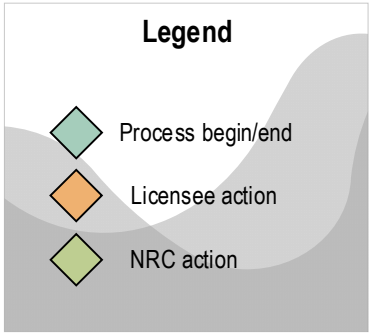
WBT Affected FSS Approach





ORAU – Oak Ridge Associated Universities
SDP – Soil Decommissioning Plan

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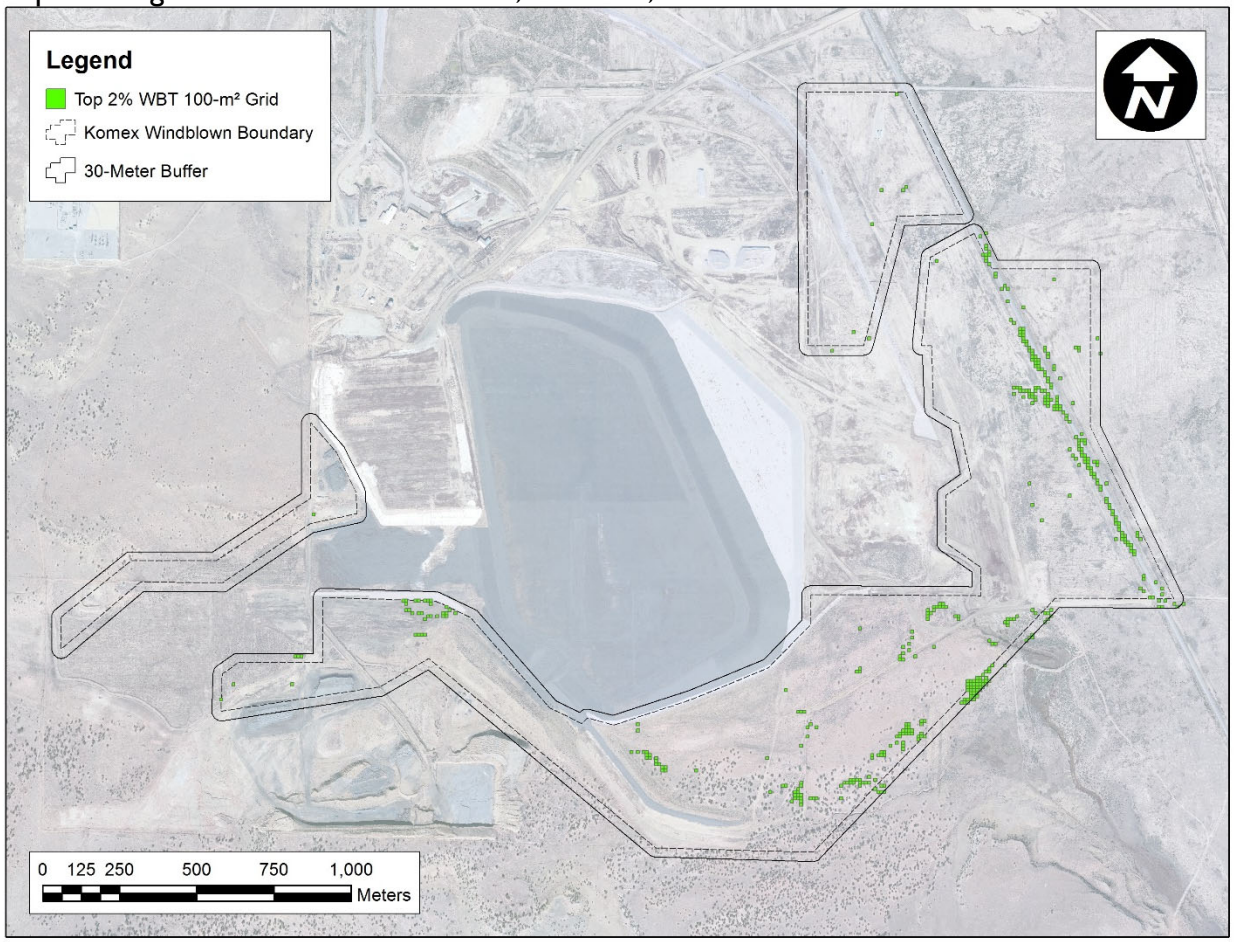
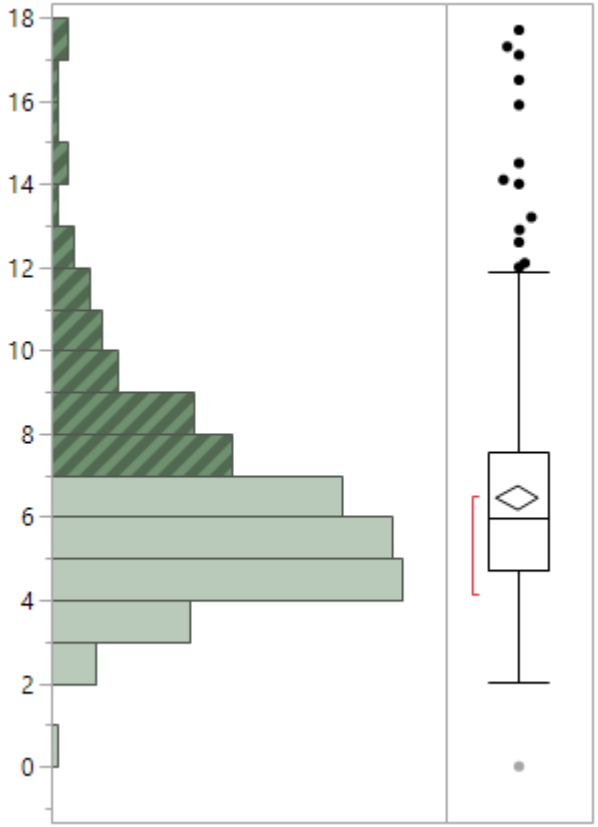
WBT Affected FSS Results

Top 2 % of grids in WBT Affected Areas, below 25,000



Grid Mean Ra-226 (5 pt composite) - pCi/g



313 samples collected Aug/Sept 2017
100 samples greater than 7 pCi/g

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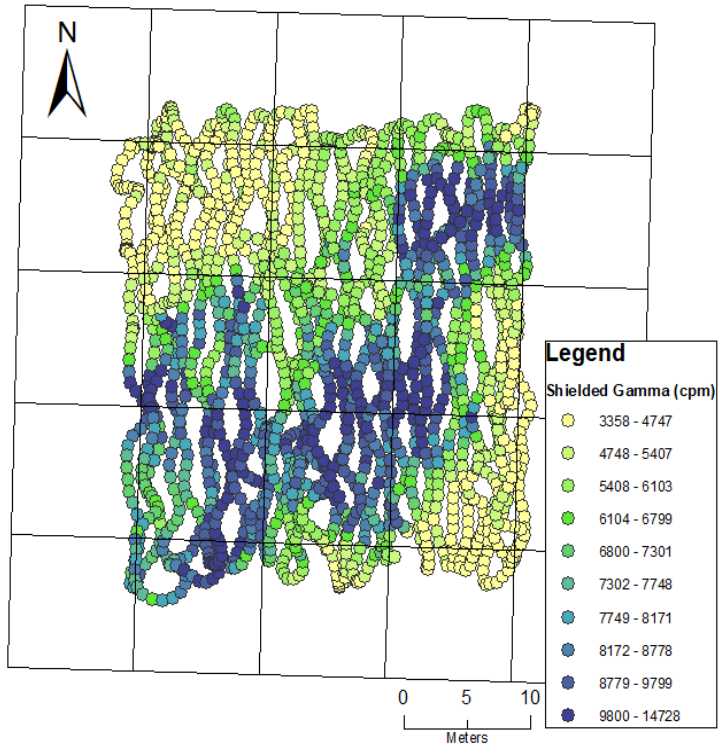
WBT Challenges

- Vegetation in the WBT impacted area may have historically acted as a filter, creating radionuclide deposition patterns that are spatially heterogeneous at small-scale.
- Shielded gamma survey is resilient to the observed type of spatial heterogeneity.
- 5-point composite sampling is not adequate for estimating the true mean grid-concentration of radionuclides in an extremely heterogeneous environment.
- After investigating other techniques, Ranked Set Sampling (RSS) was selected as more resilient to small scale spatial heterogeneity than traditional 5-point composite sampling, and was piloted in 30 decommissioning grids during July 2018.



Shielded gamma survey of 9 WBT impacted grids.

Typical vegetation in the Ambrosia Lake Valley.

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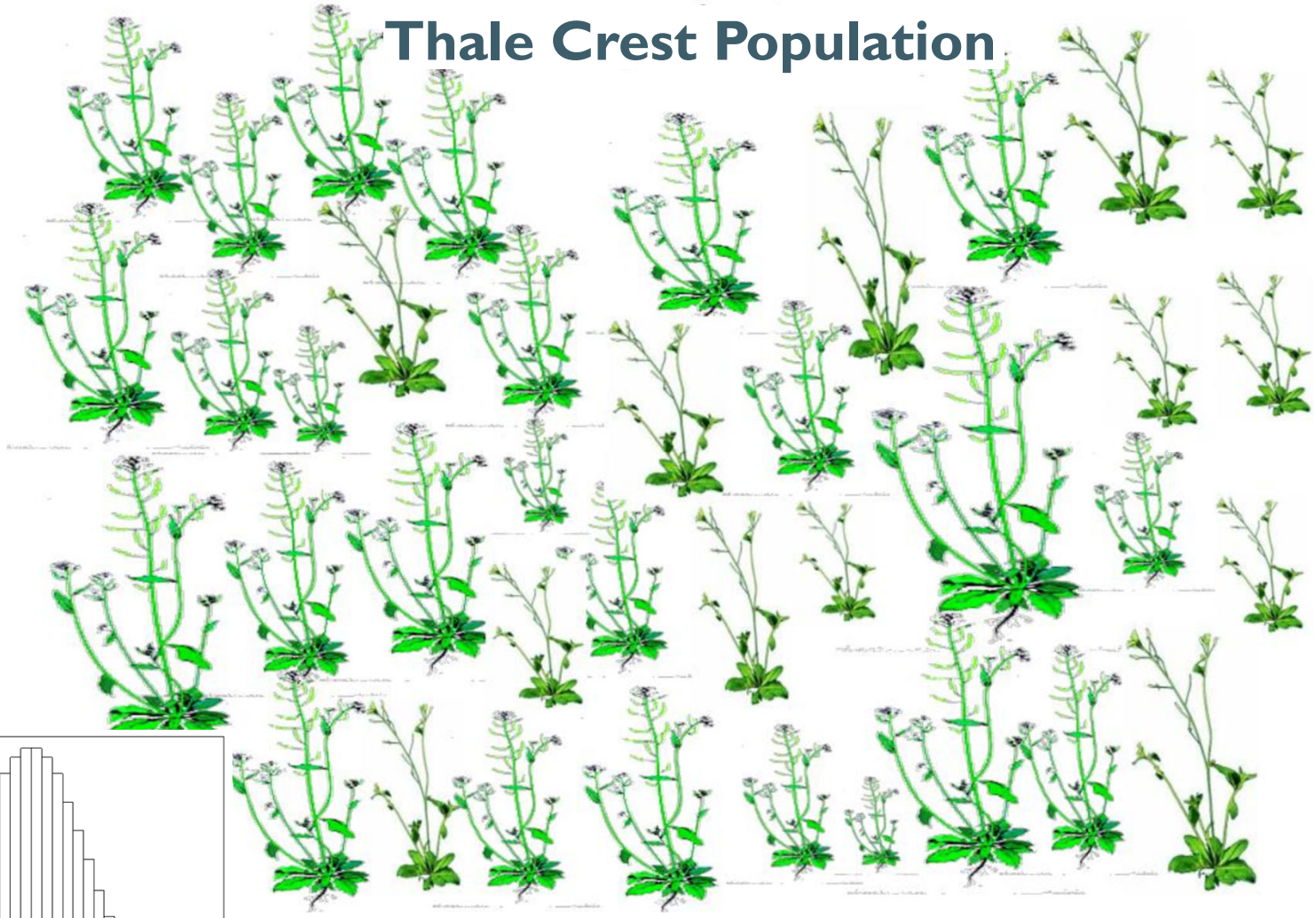
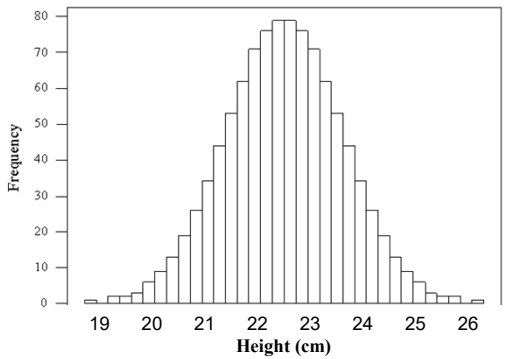
Sampling Example

Height of *Arabidopsis thaliana* (Thale Crest)

Thale Crest Population





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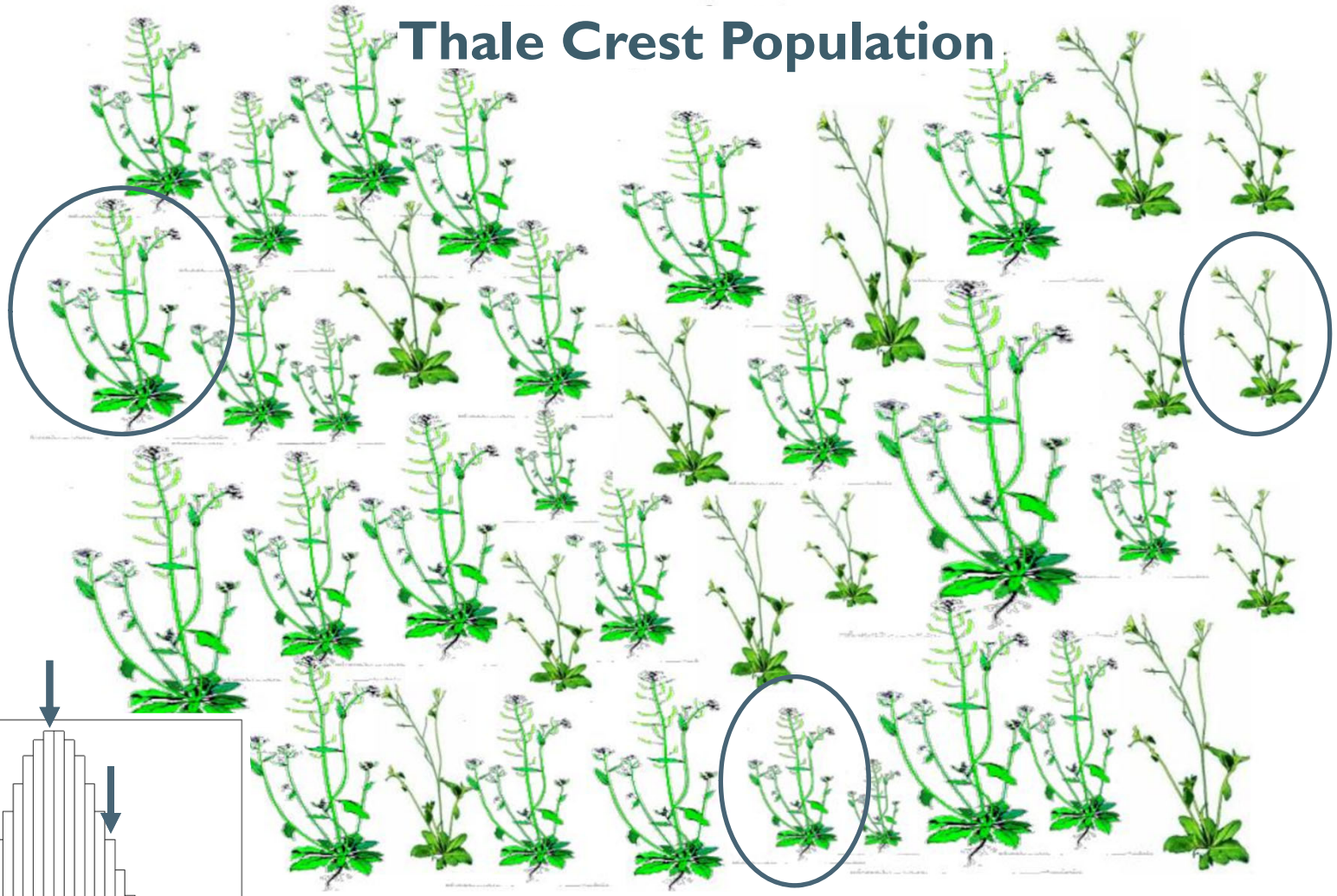
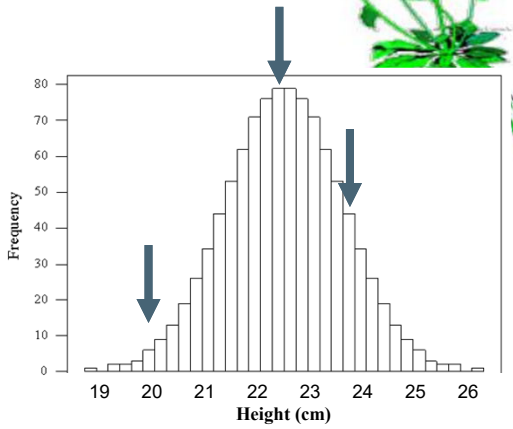
Sampling Example

Height of Thale Crest – Simple Random Sampling





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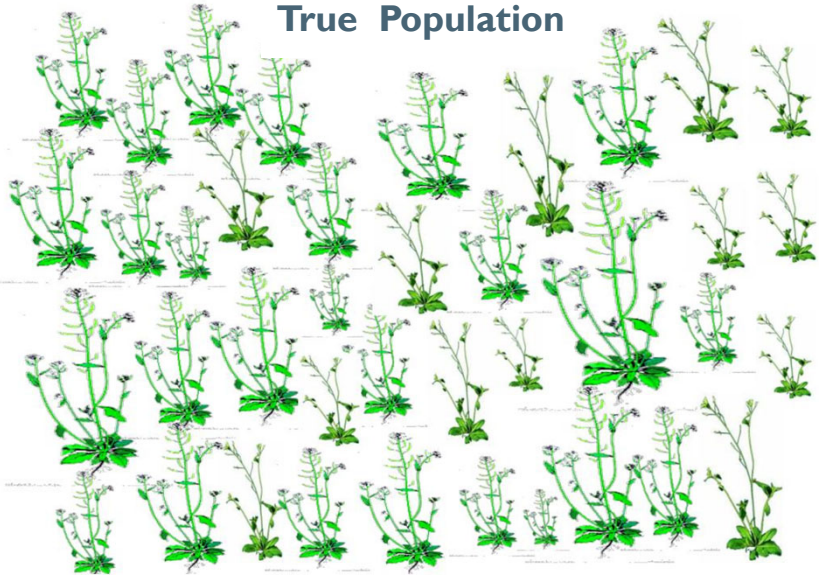
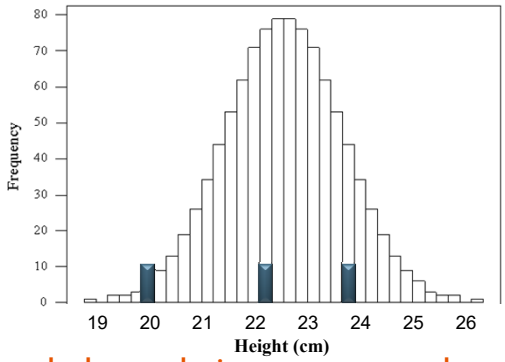
Sampling Example

Height of Thale Crest – Simple Random Sampling

Sampled Population

True Population





Does the sampled population represent the true population?

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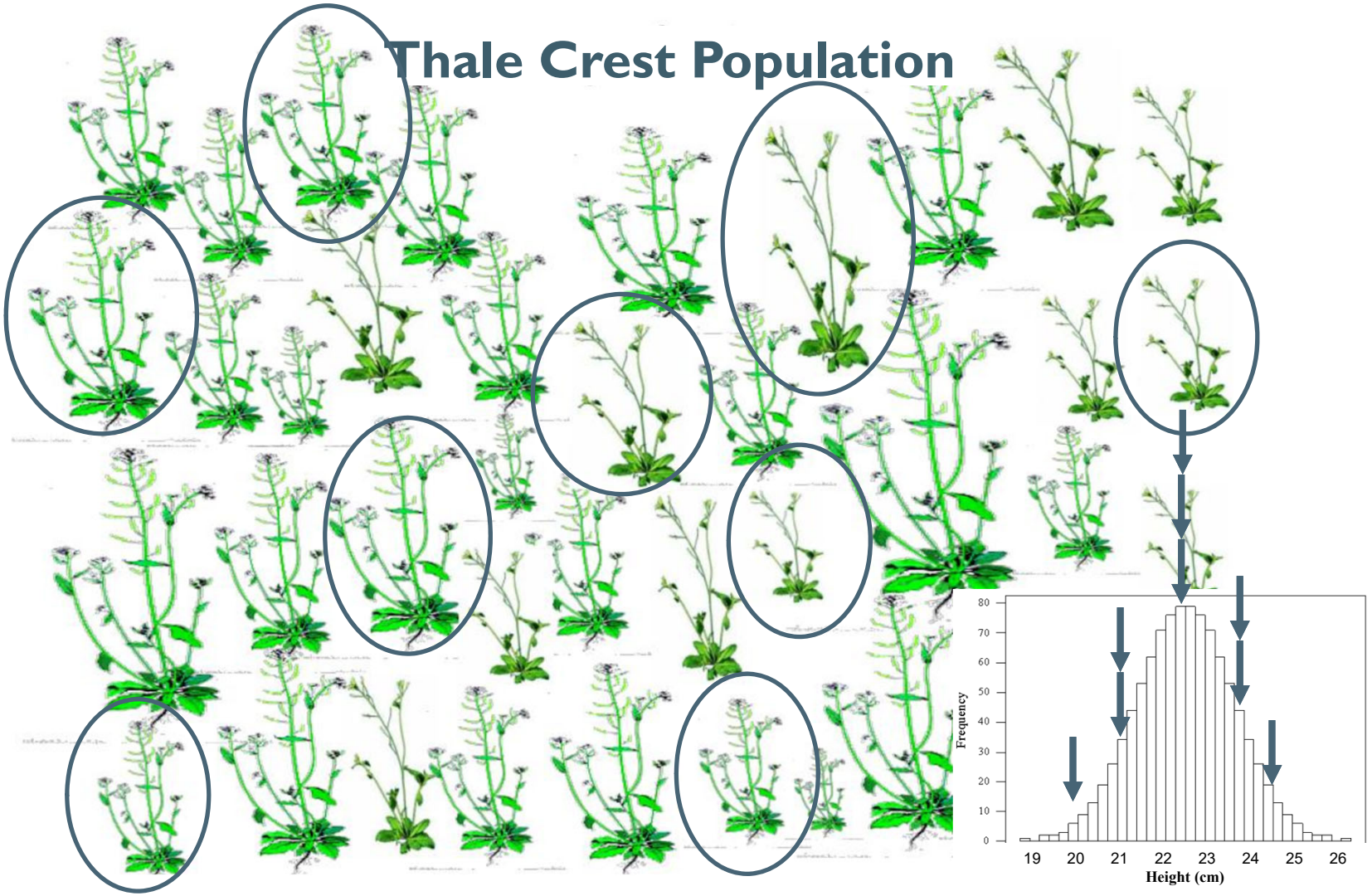
Sampling Example

Height of Thale Crest – Ranked Set Sampling



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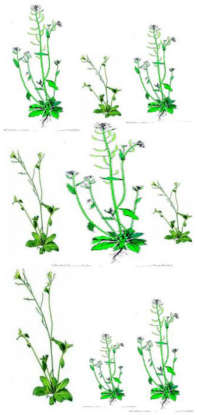
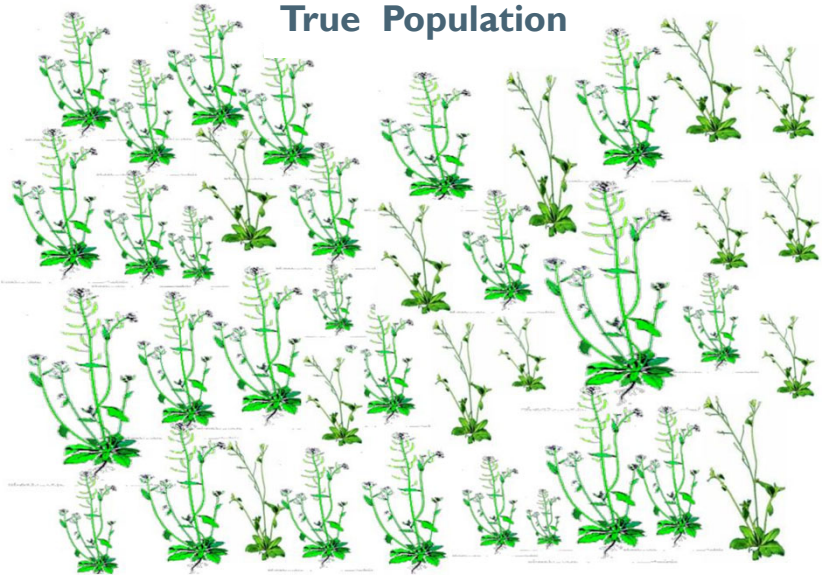
Sampling Example

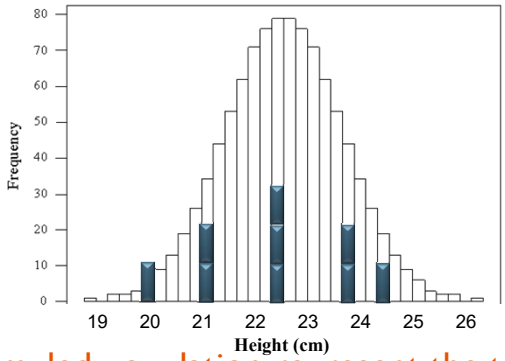
Height of Thale Crest – Ranked Set Sampling

Sampled Population



True Population





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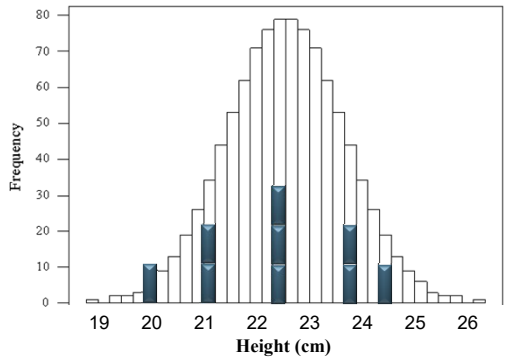

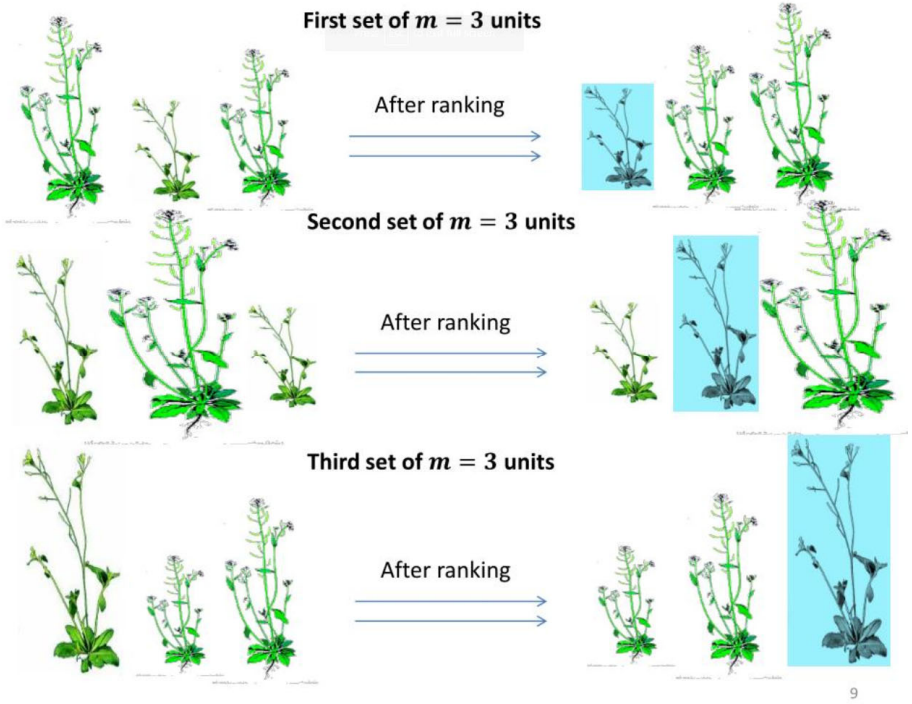

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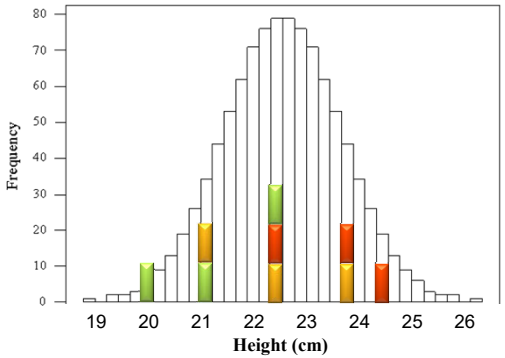

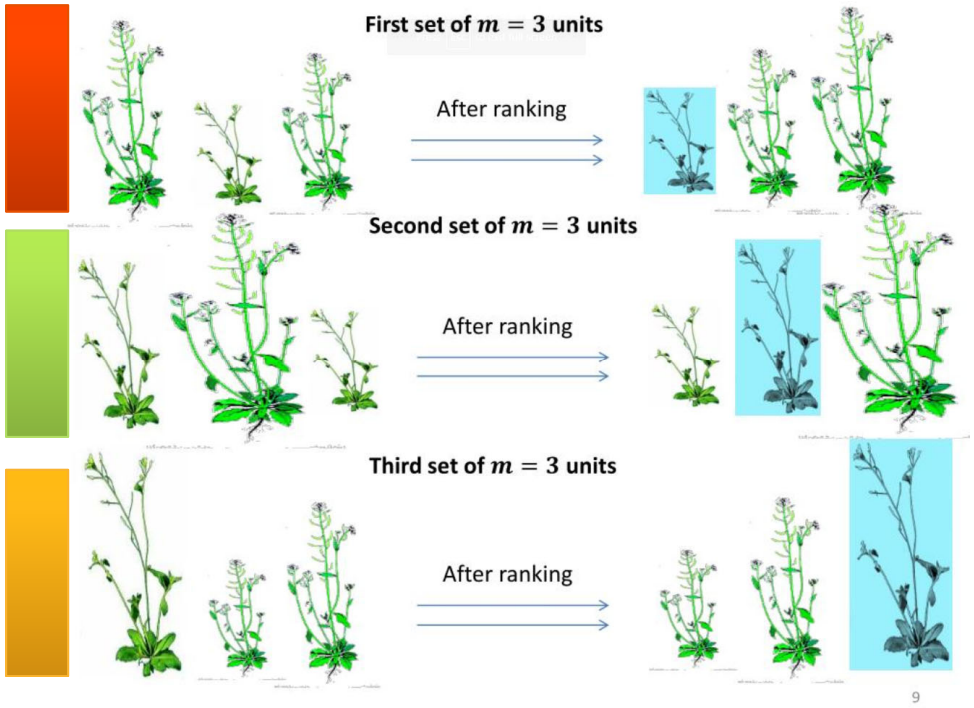

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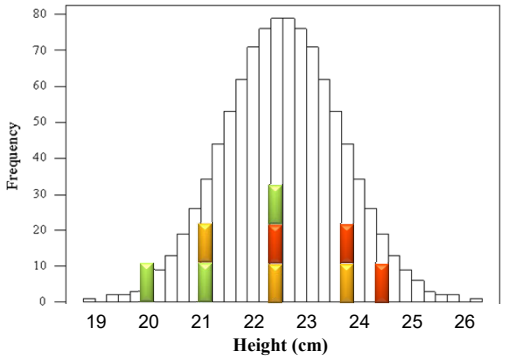

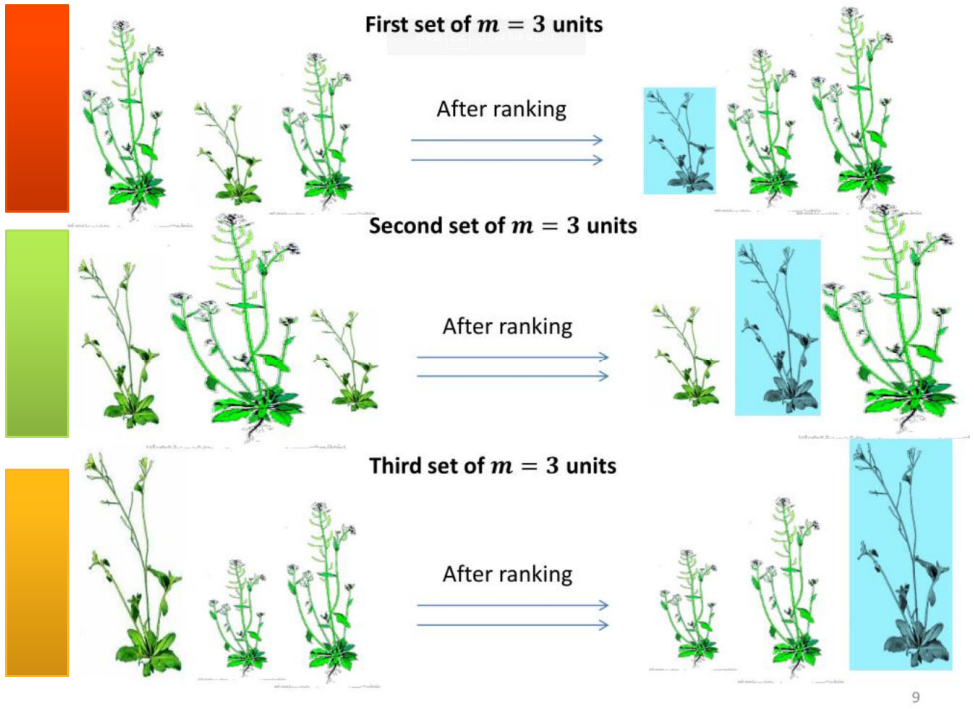

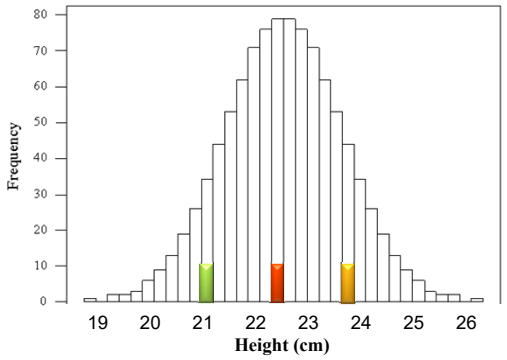

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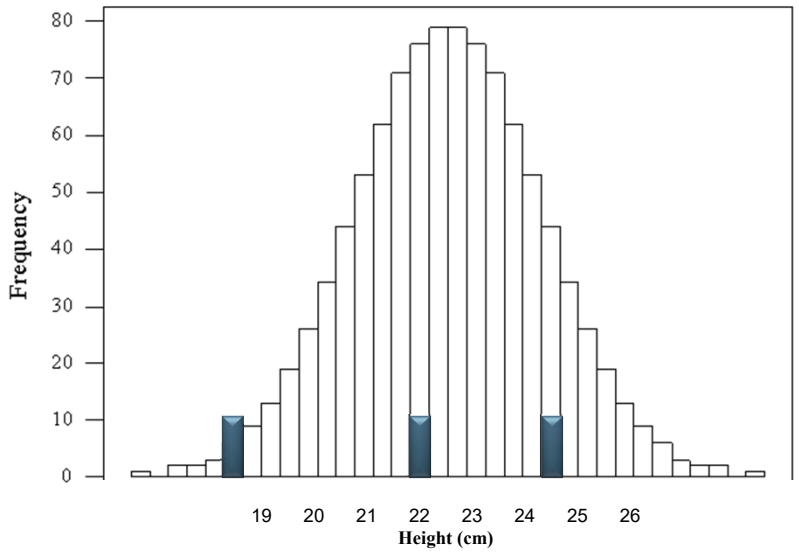
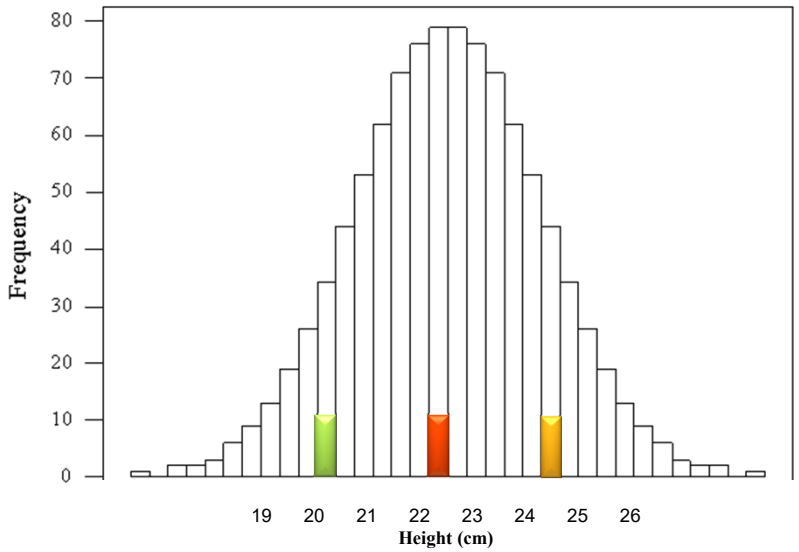
Sampling Example

Height of Thale Crest – Comparison

Simple Random Sampling



Ranked Set Sampling



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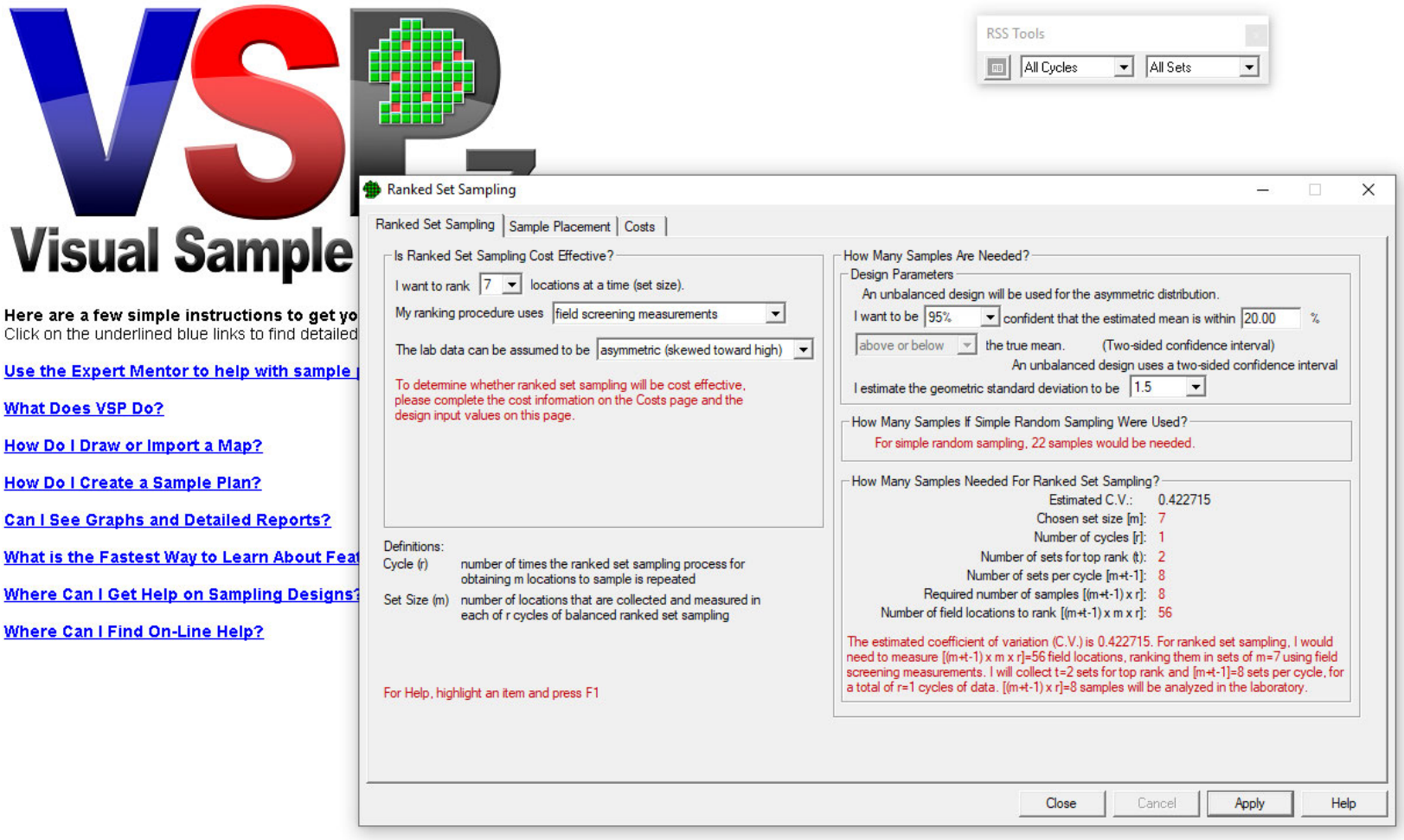
Sampling Example

Concentration of ^{226}Ra – Ranked Set Sampling



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Sampling Example

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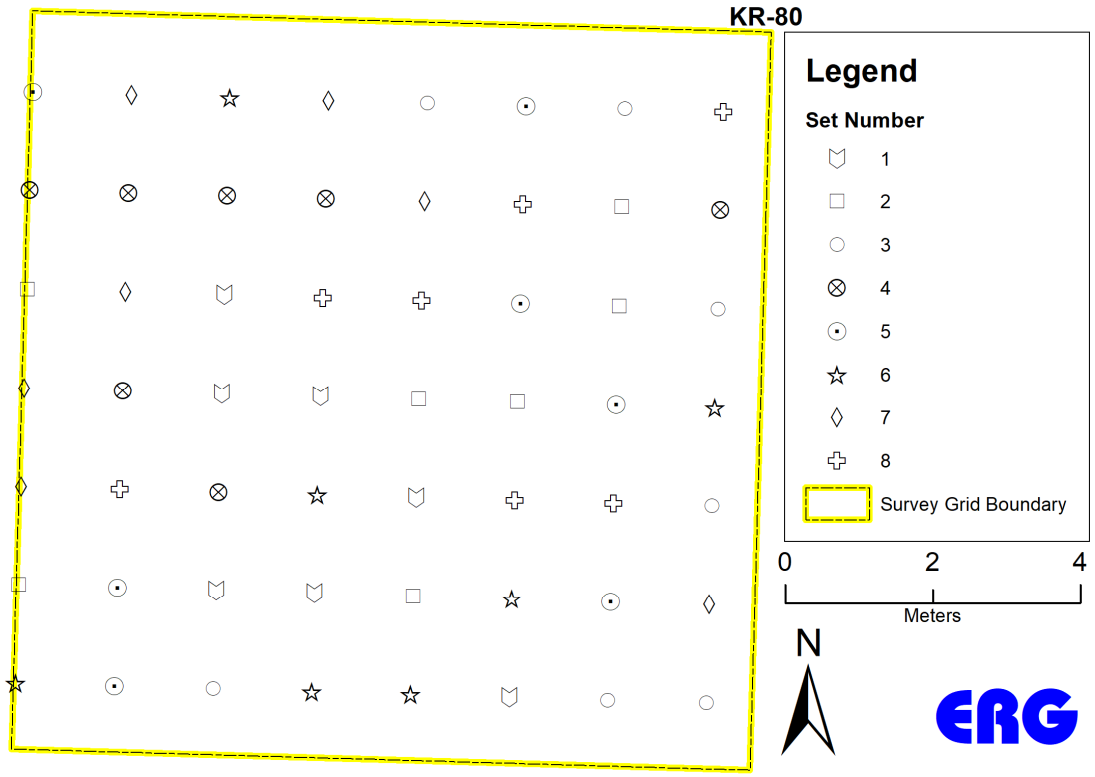

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Sampling Example

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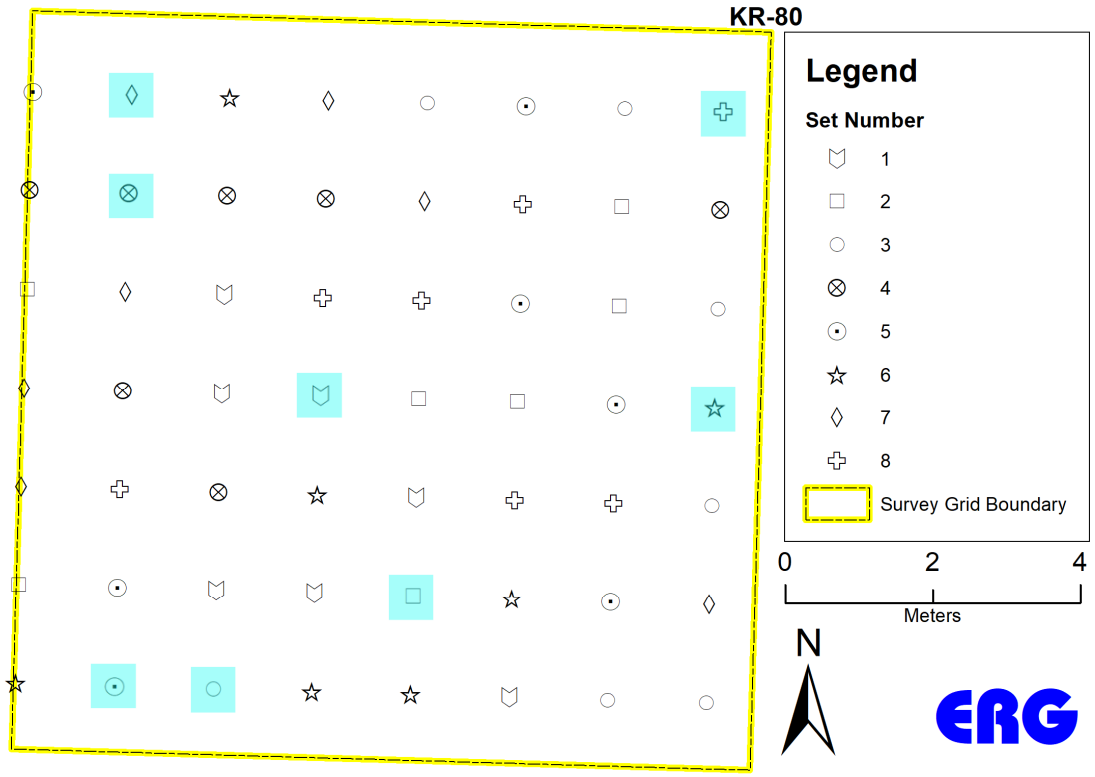

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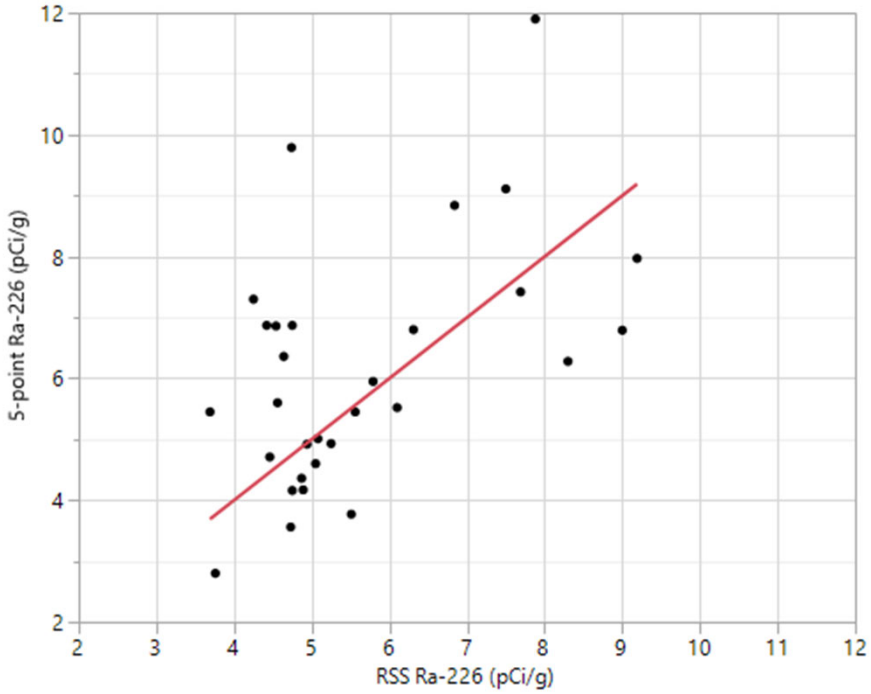
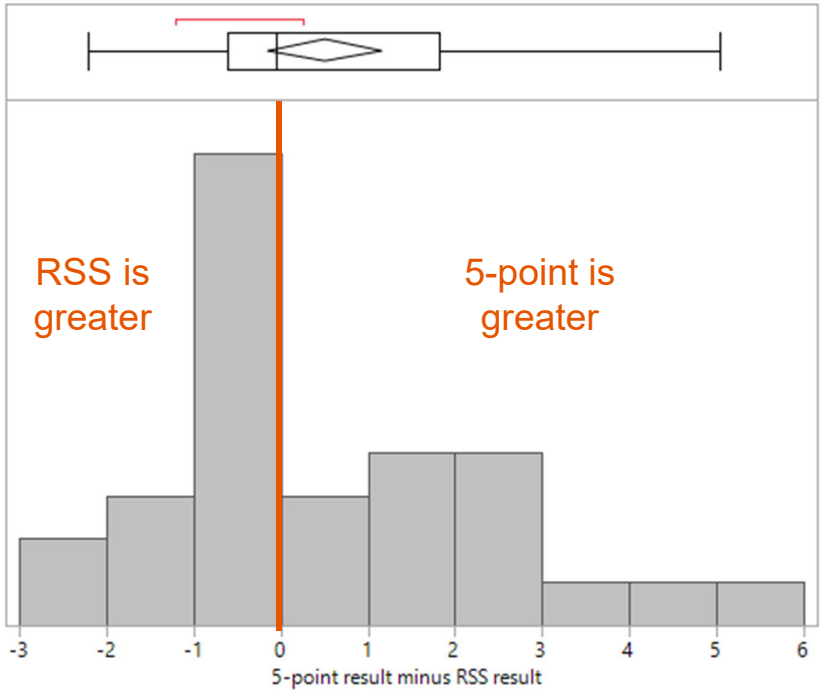
Sampling Results

Concentration of ^{226}Ra – Ranked Set Sampling





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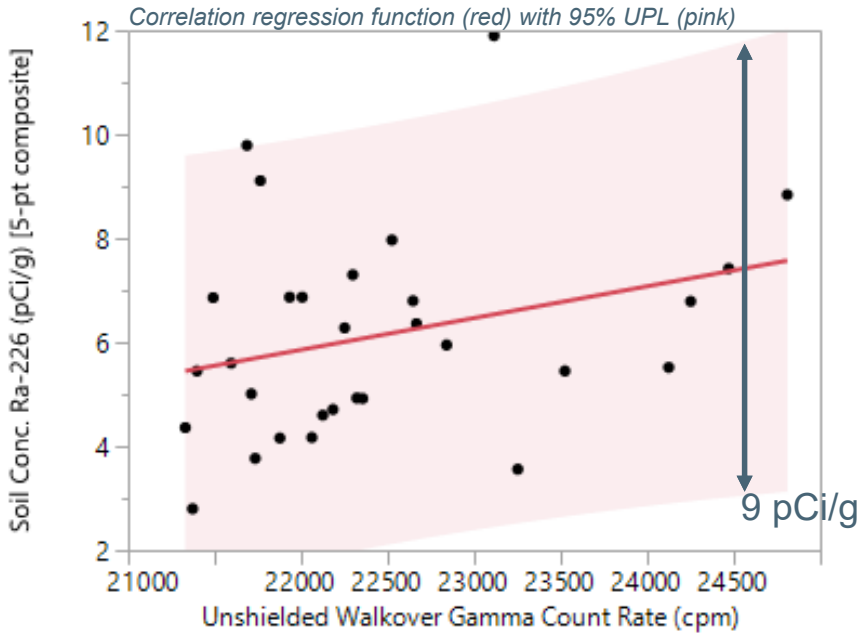
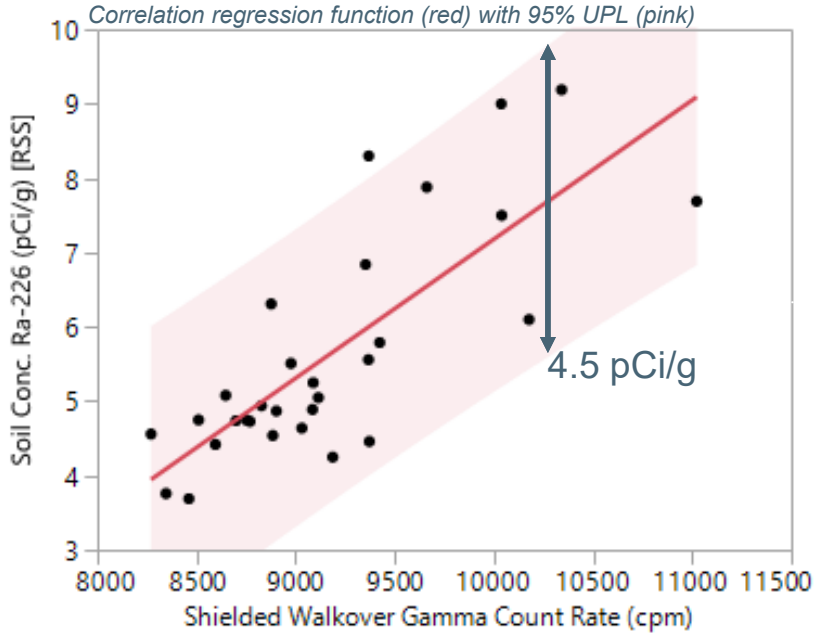
Grid Level Correlation

2018 Pilot

Correlation adjusted R^2	Correlation methods
0.05	5 point composite + unshielded gamma
0.15	5 point composite + shielded gamma
0.31	RSS + unshielded gamma
0.60	RSS + shielded gamma

Comparison of regression adjusted R^2 values within 30 test grids using different measurement combinations.





Proposed Path Forward

New Tools:

1. RSS (versus 5-point) used to measure average concentration of ^{226}Ra in a grid.
2. Shielded (versus unshielded) gamma survey used as an indicator of radium-226 in surface soil.

Decommissioning with New Tools:

1. A predictive gamma guideline value is required to guide cleanup efforts and to implement the FSS in WBT affected areas. Steps:
    1. Resurvey the WBT affected areas using a shielded gamma detector
    2. Identify areas exceeding a shielded gamma guideline value corresponding to 7 pCi/g of ^{226}Ra in soil
2. Implement the WBT remedy in grids exceeding the shielded gamma guideline value.
3. Perform confirmatory shielded gamma survey within those grids to which the WBT remedy has been applied.
4. Perform a final status survey using Ranked Set Sampling.
   All existing sampling requirements prescribed within the approved SDP will be implemented as written, except for the soil sampling method.

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Discussion Topics

The approved SDP is silent on whether the gamma survey data used to rank grids and calculate a gamma guideline value should be collected with or without a shield. Therefore, a shielded gamma survey is acceptable under the SDP as written.

The approved SDP prescribes the use of 5-point composite sampling for measuring radionuclide concentrations in soil.

How could RSS be incorporated into the Site's decommissioning plan?

- Site Procedural Change
- Follow the SDP Indirect Approach
- Administrative Change / Acknowledgement
- License Amendment

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Thank you for
your attention.
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