



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.

Summary of the Mill's Soil Decommissioning Plan

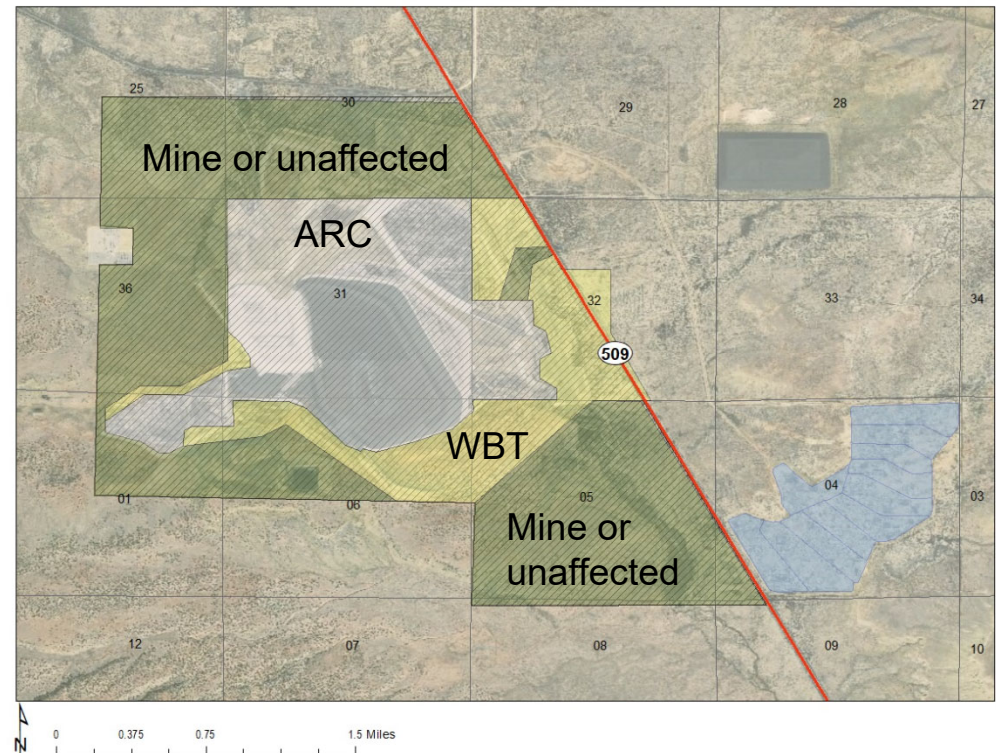
Out of scope areas for the SDP:

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

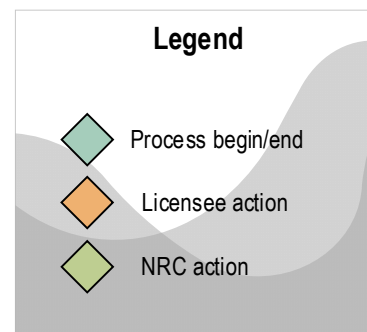
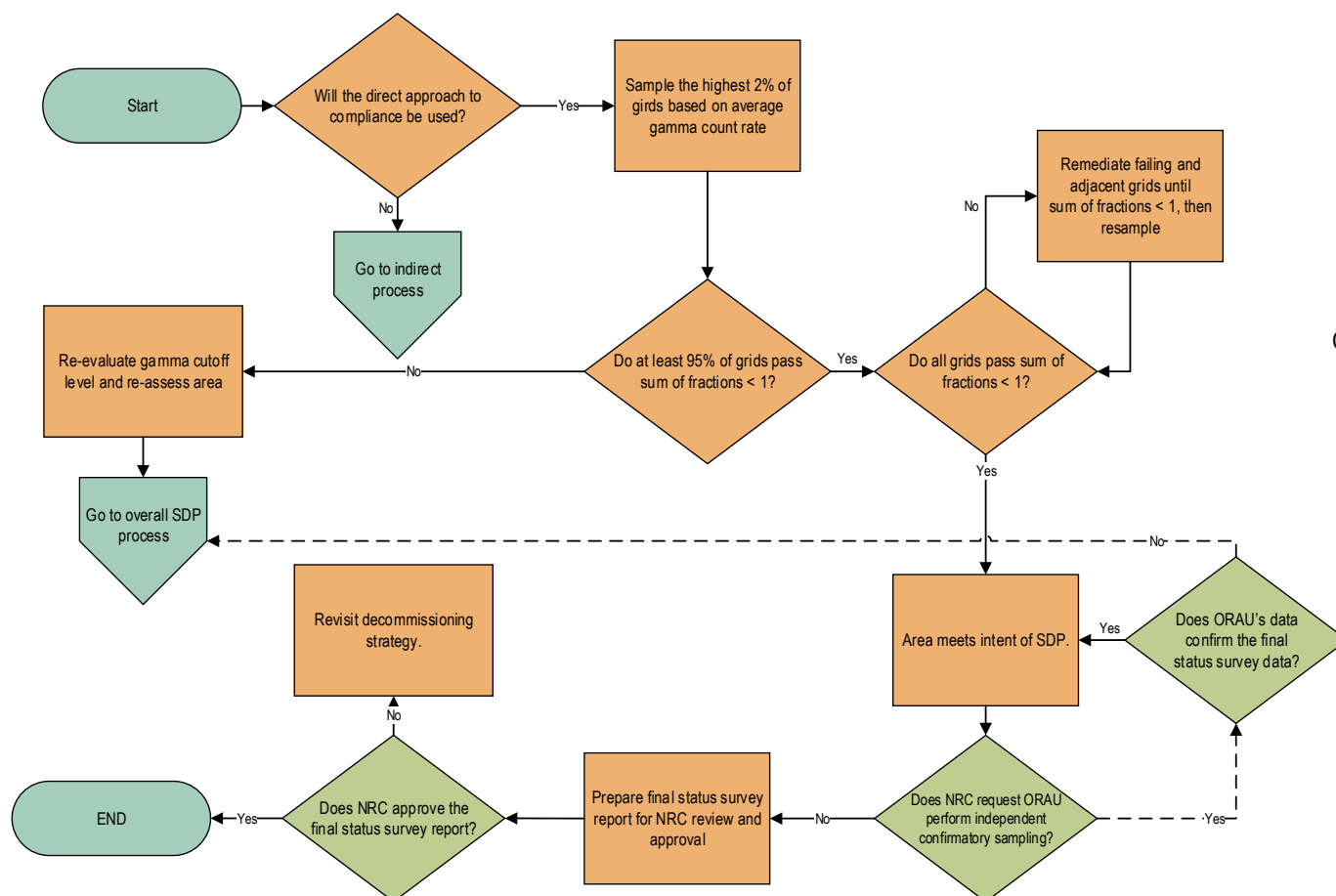
In-scope areas for the SDP:

- 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

KOMEX Soil Decommissioning Plan Areas (2006)



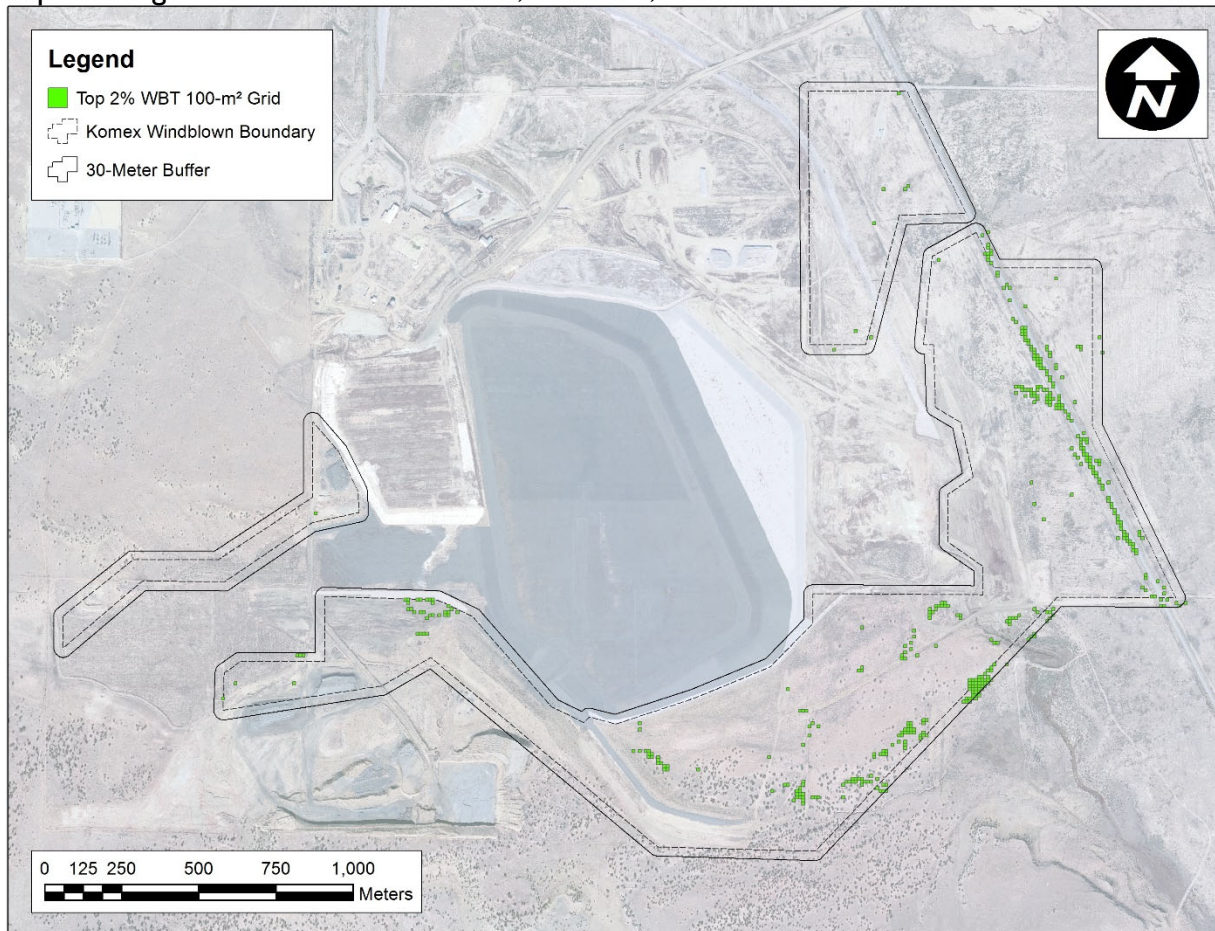
WBT Affected FSS Approach



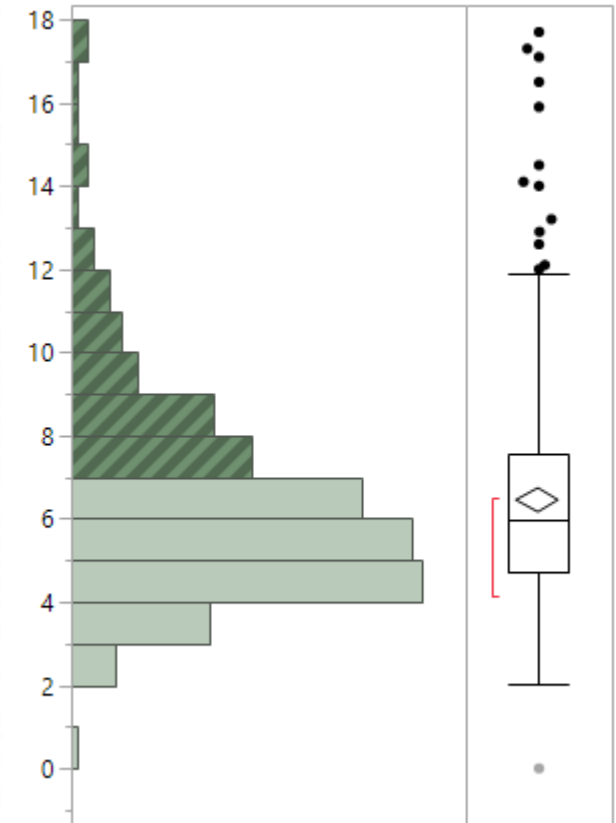
ORAU – Oak Ridge Associated Universities
SDP – Soil Decommissioning Plan

WBT Affected FSS Results

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

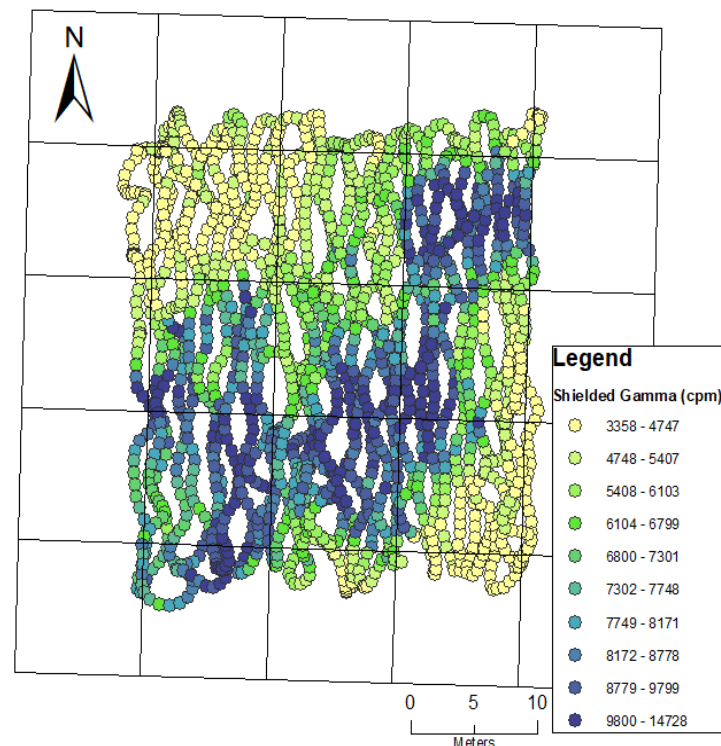


Grid Mean Ra-226 (5 pt composite) - pCi/g



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.

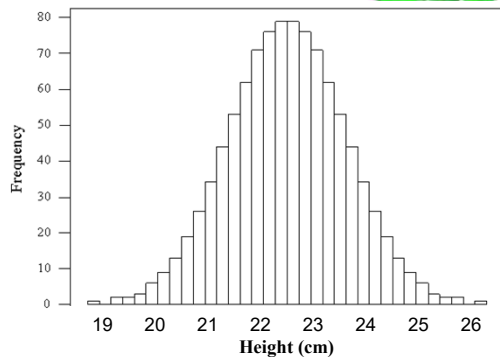
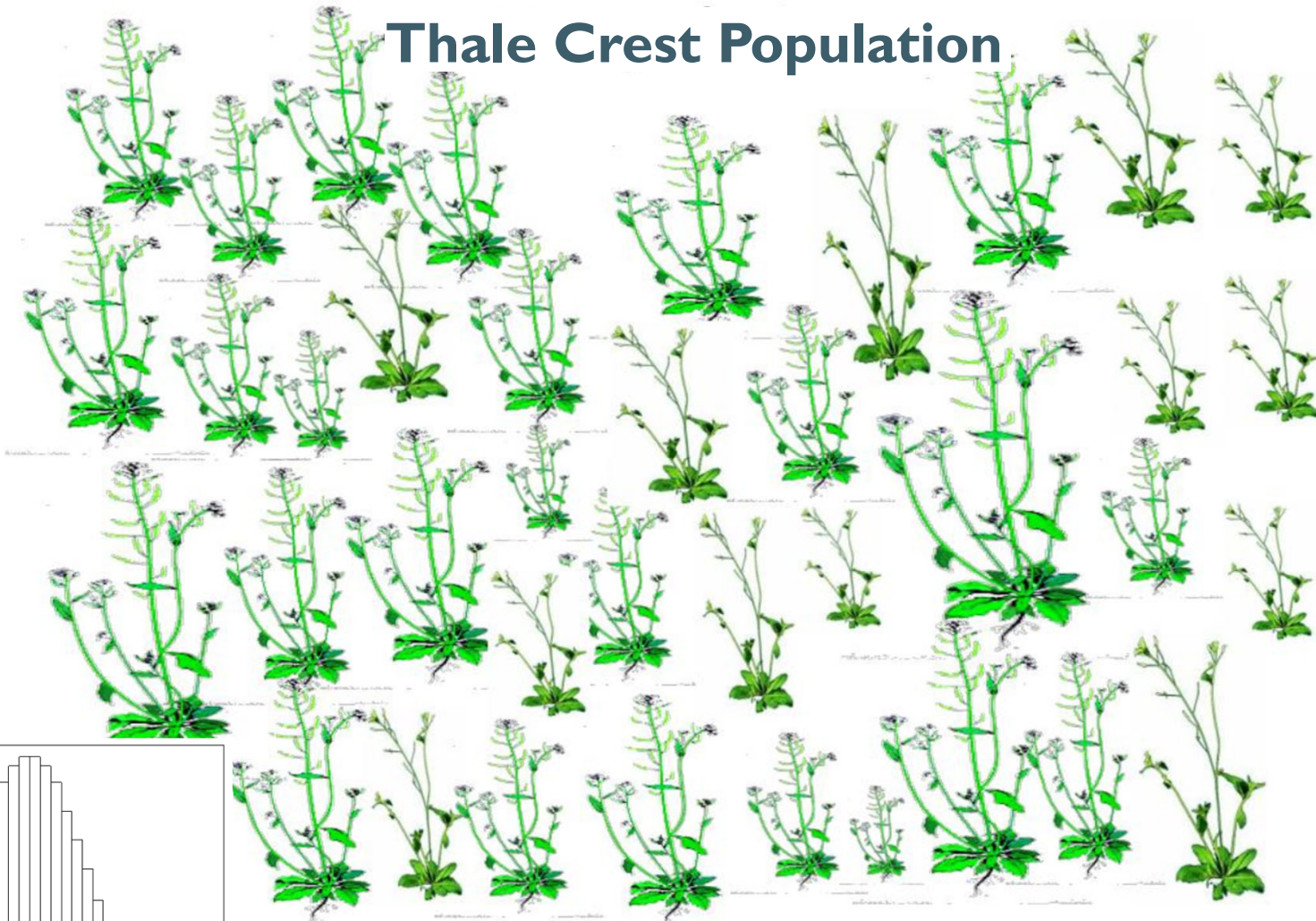


Typical vegetation in the Ambrosia Lake Valley.

Sampling Example

Height of *Arabidopsis thaliana* (Thale Crest)

Thale Crest Population



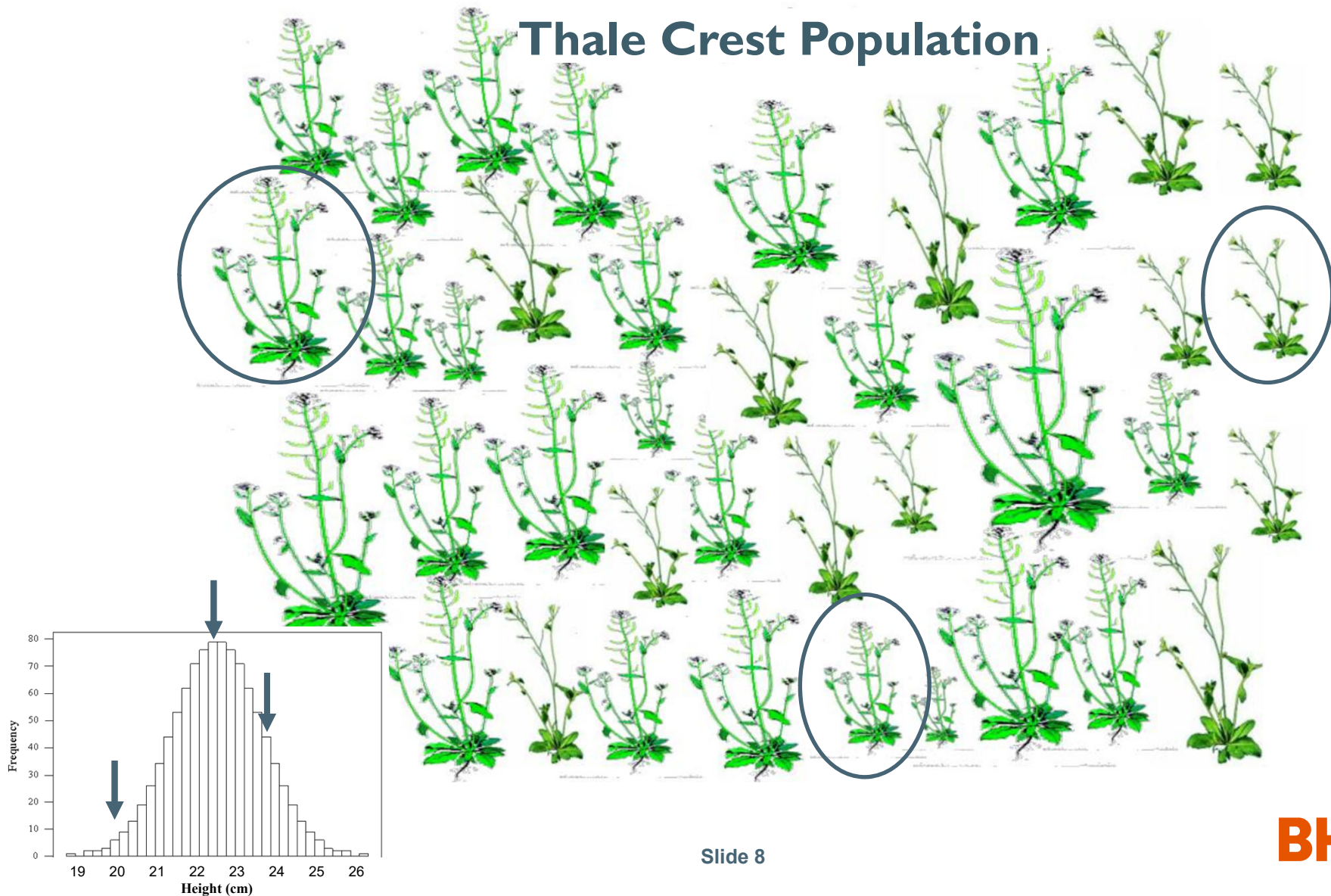
Slide 7

BHP

Sampling Example

Height of Thale Crest – Simple Random Sampling

Thale Crest Population



Slide 8

BHP

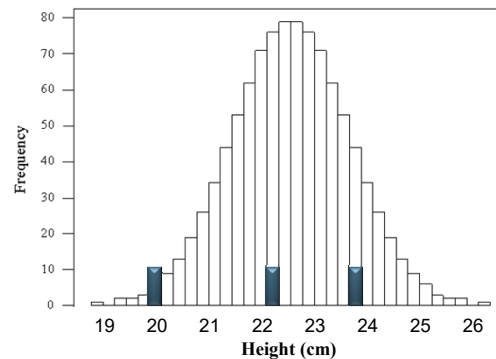
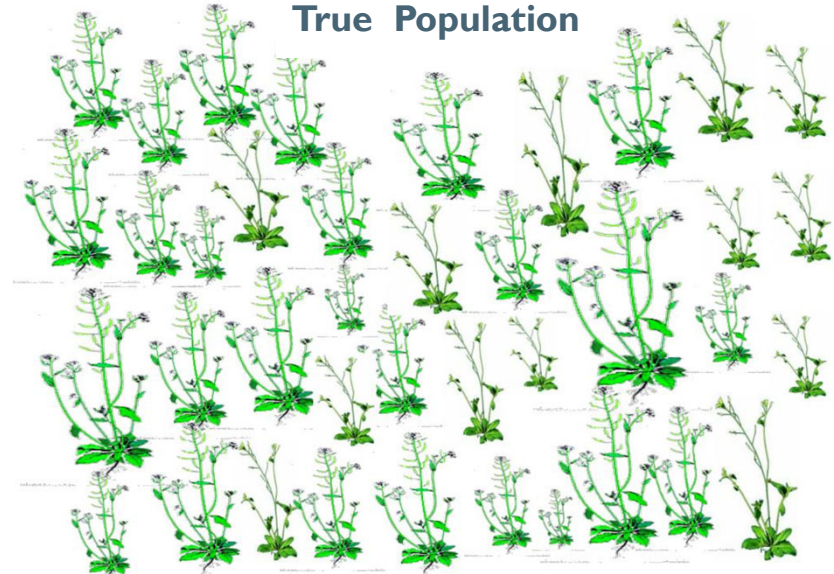
Sampling Example

Height of Thale Crest – Simple Random Sampling

Sampled Population



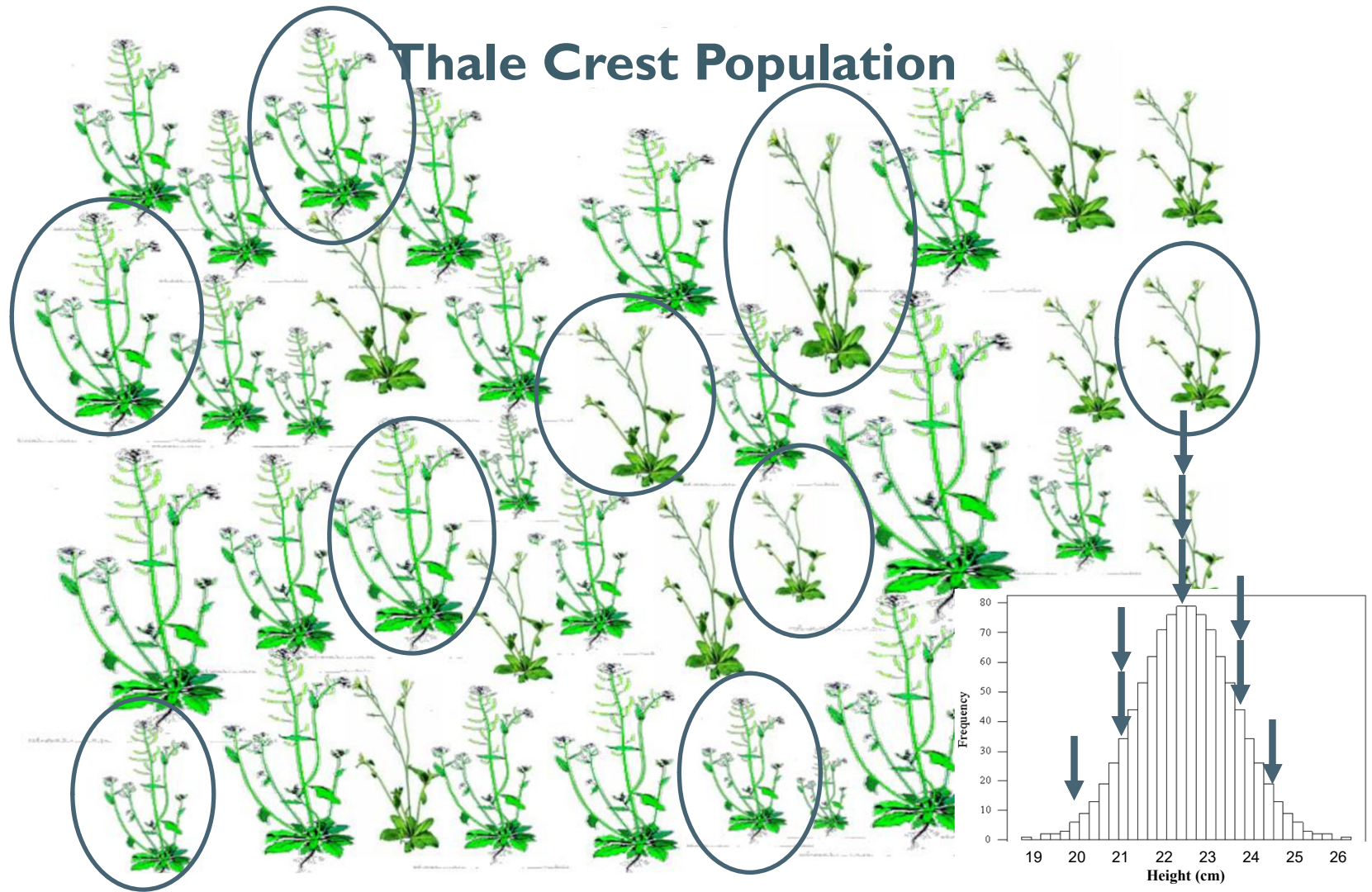
True Population



Does the sampled population represent the true population?

Sampling Example

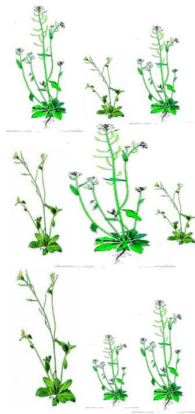
Height of Thale Crest – Ranked Set Sampling



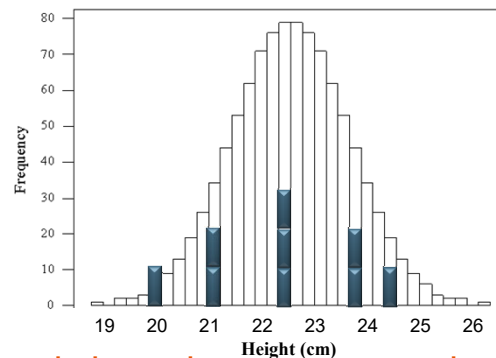
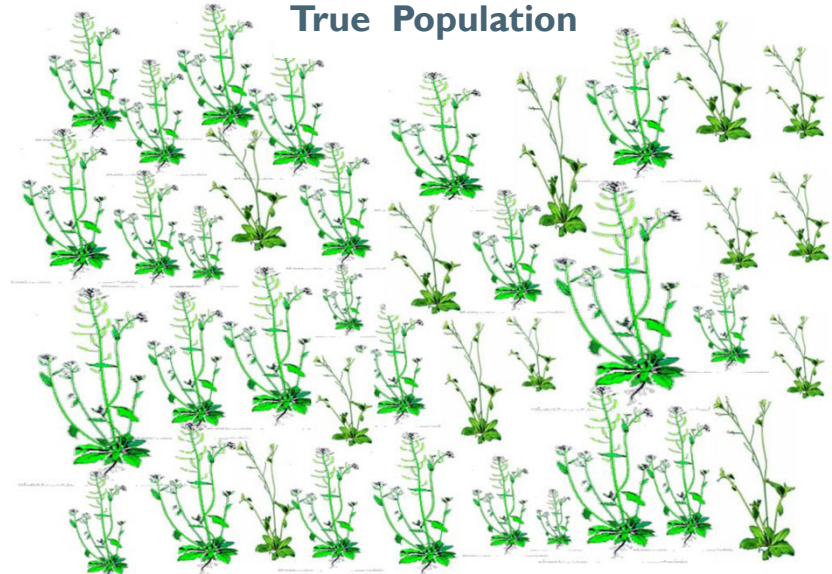
Sampling Example

Height of Thale Crest – Ranked Set Sampling

Sampled Population



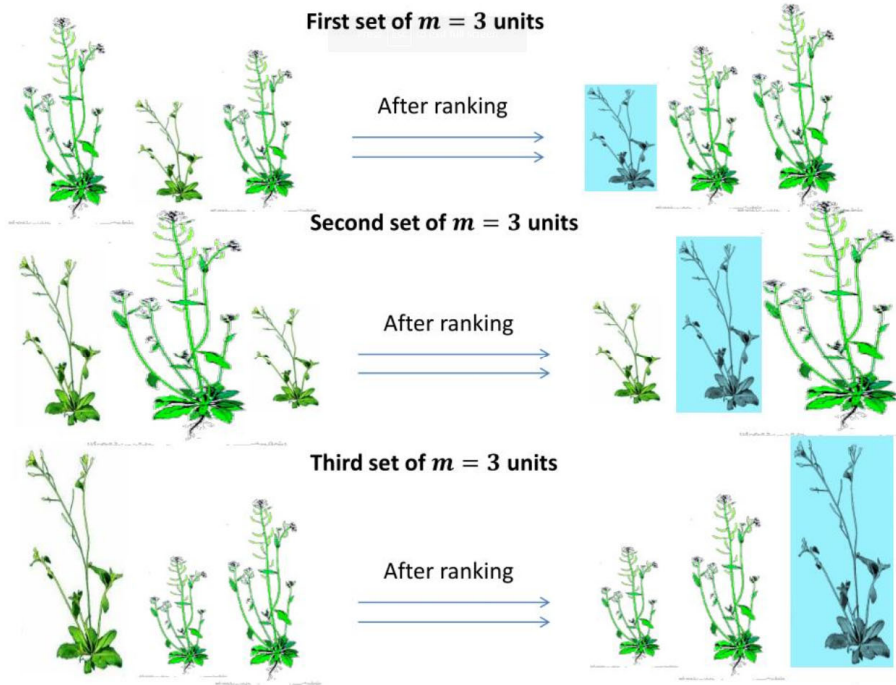
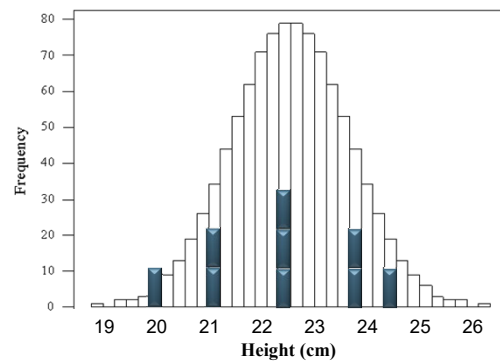
True Population



Does the sampled population represent the true population?

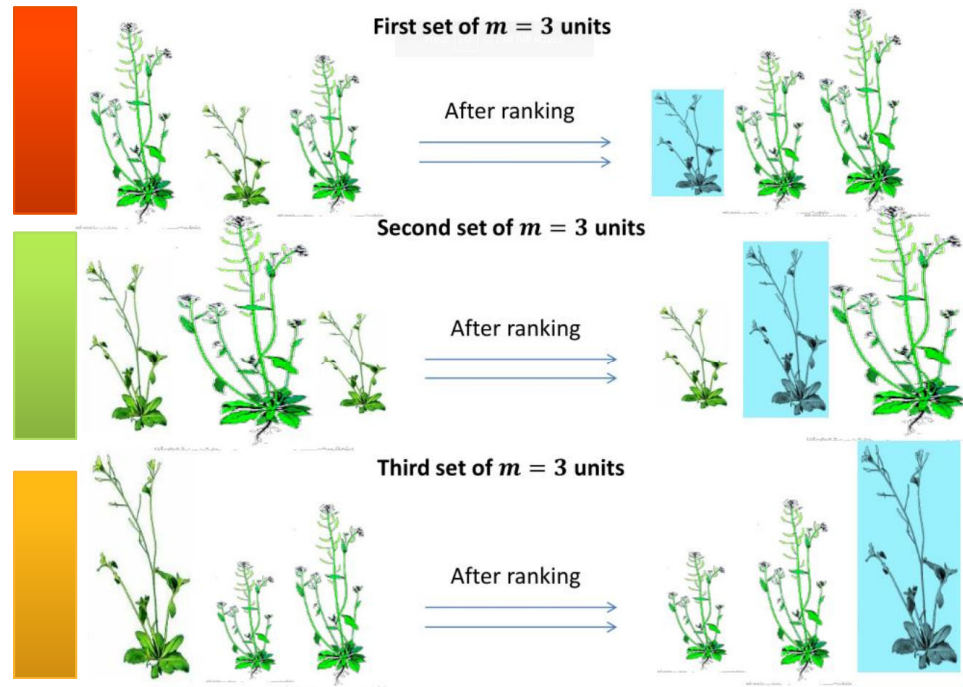
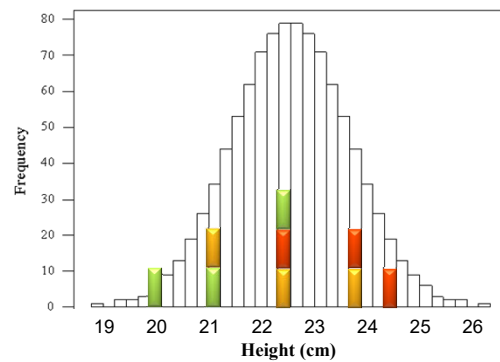
Sampling Example

Height of Thale Crest – Ranked Set Sampling



Sampling Example

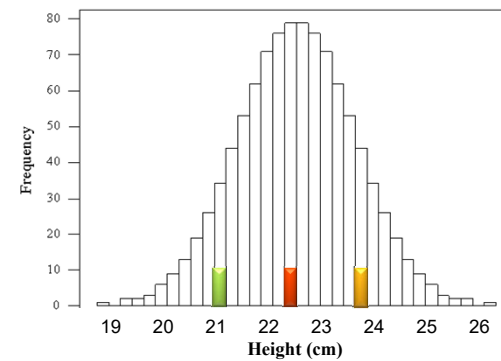
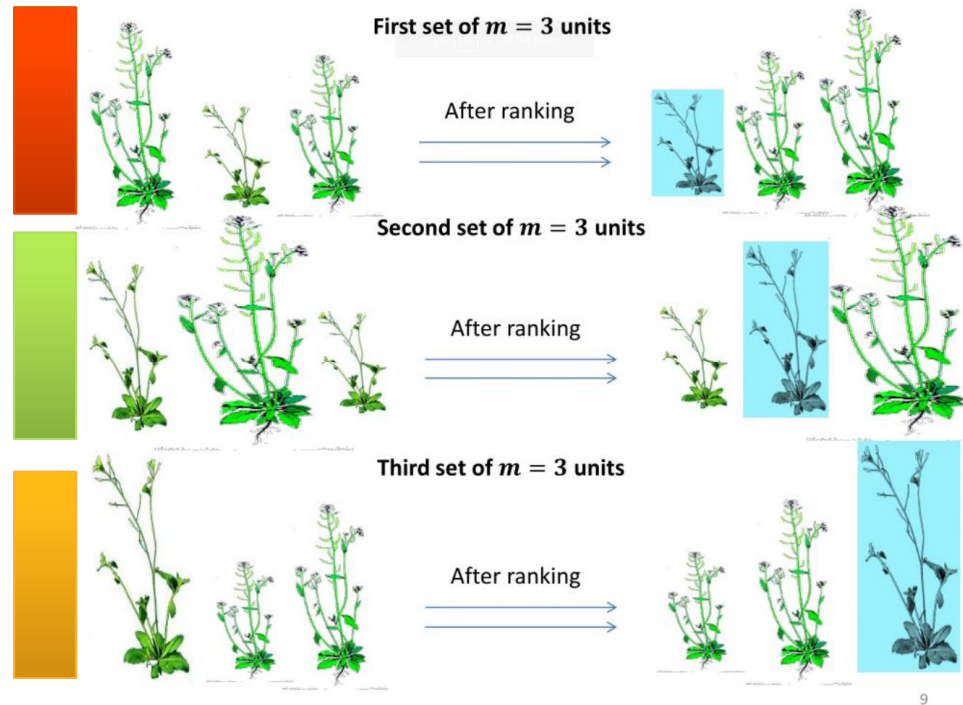
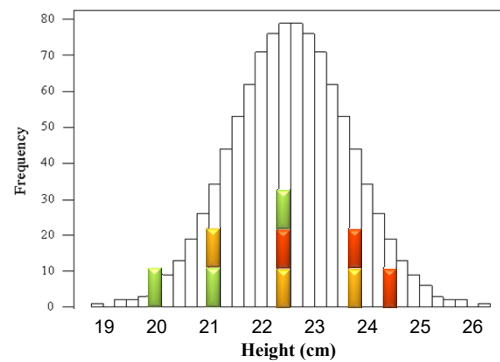
Height of Thale Crest – Ranked Set Sampling



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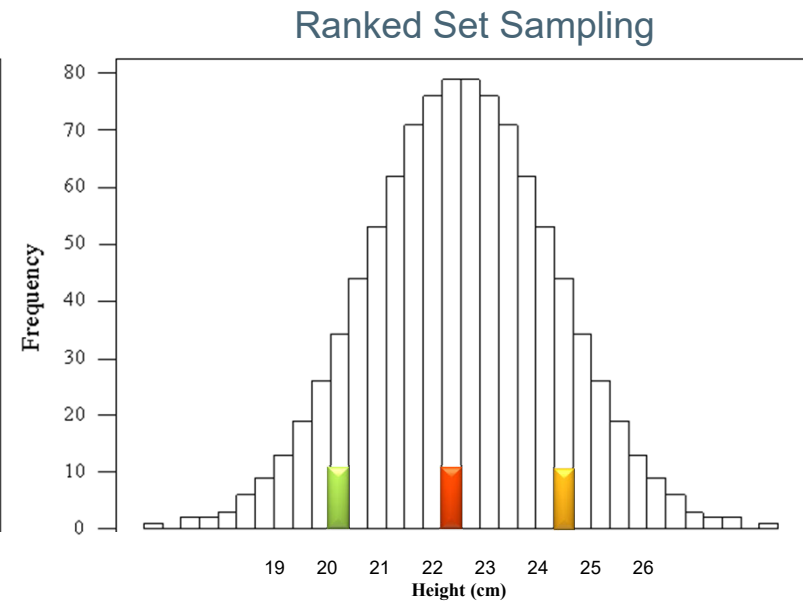
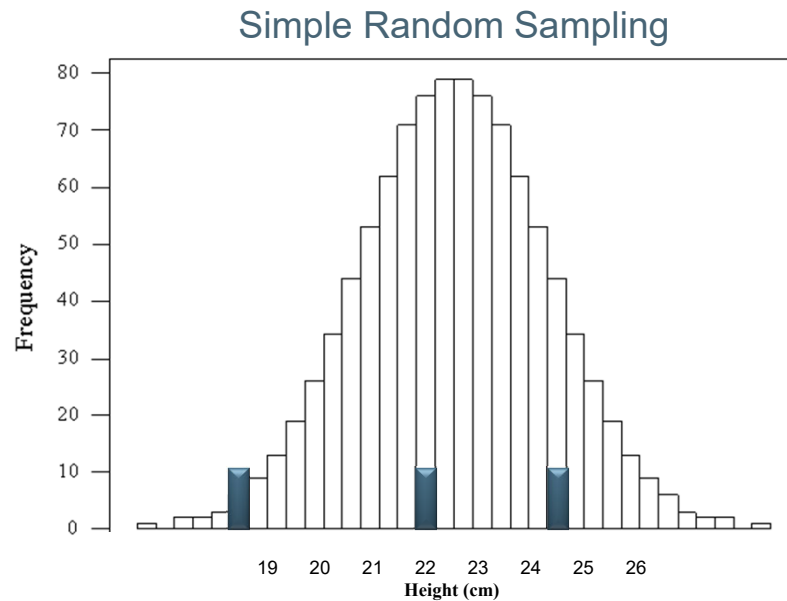
Sampling Example

Height of Thale Crest – Ranked Set Sampling



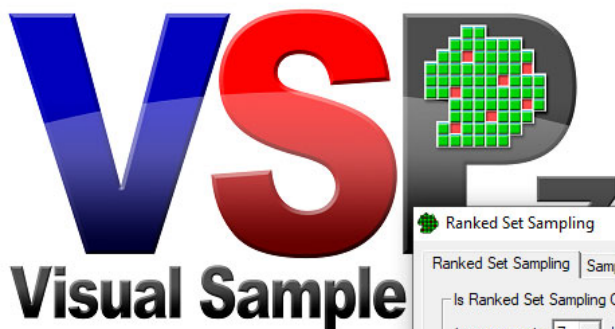
Sampling Example

Height of Thale Crest – Comparison



Sampling Example

Concentration of ^{226}Ra – Ranked Set Sampling



Here are a few simple instructions to get you started. Click on the underlined blue links to find detailed information.

[Use the Expert Mentor to help with sample collection.](#)

[What Does VSP Do?](#)

[How Do I Draw or Import a Map?](#)

[How Do I Create a Sample Plan?](#)

[Can I See Graphs and Detailed Reports?](#)

[What is the Fastest Way to Learn About Features?](#)

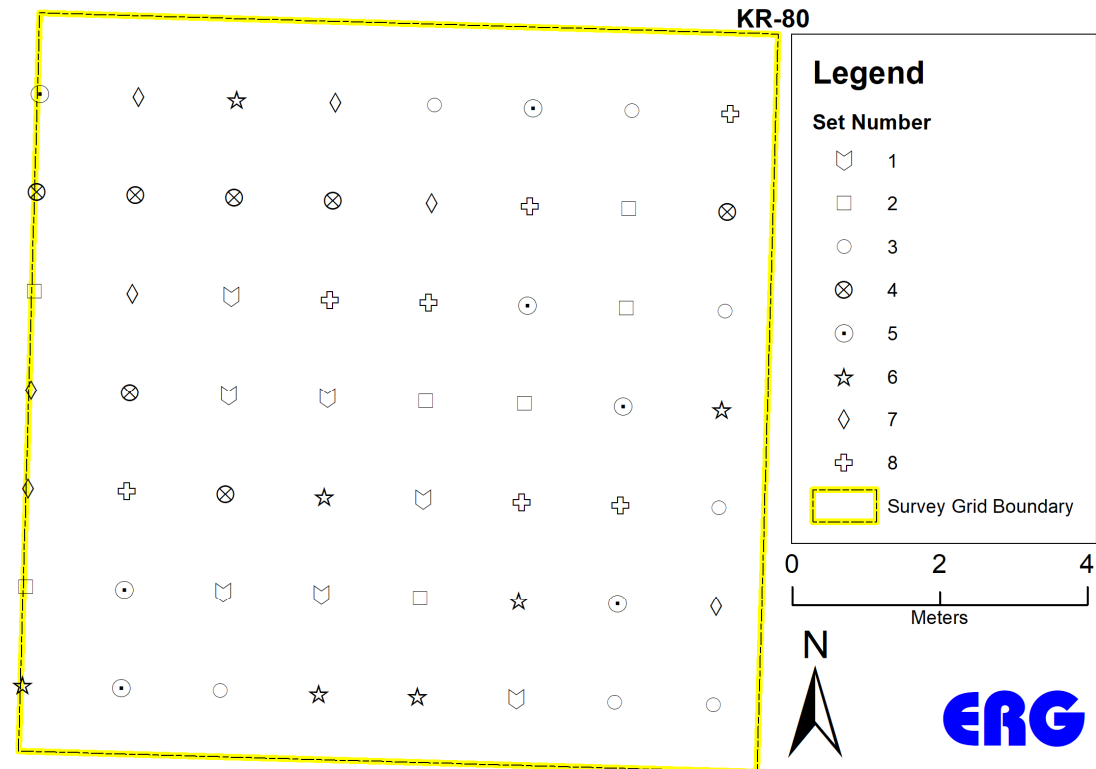
[Where Can I Get Help on Sampling Designs?](#)

[Where Can I Find On-Line Help?](#)

The screenshot shows the 'Ranked Set Sampling' window of the VSP software. The window has a title bar with a green icon and the text 'Ranked Set Sampling'. Below the title bar is a tabbed interface with three tabs: 'Ranked Set Sampling', 'Sample Placement', and 'Costs'. The 'Ranked Set Sampling' tab is active. The main area is divided into two columns. The left column is titled 'Is Ranked Set Sampling Cost Effective?' and contains a form with the following fields: 'I want to rank' (7), 'locations at a time (set size)', 'My ranking procedure uses' (field screening measurements), and 'The lab data can be assumed to be' (asymmetric (skewed toward high)). Below these fields is a red text box that reads: 'To determine whether ranked set sampling will be cost effective, please complete the cost information on the Costs page and the design input values on this page.' The right column is titled 'How Many Samples Are Needed?' and contains a form with the following fields: 'Design Parameters' (An unbalanced design will be used for the asymmetric distribution.), 'I want to be' (95%), 'confident that the estimated mean is within' (20.00) %, 'above or below' (above or below), 'the true mean. (Two-sided confidence interval)', 'An unbalanced design uses a two-sided confidence interval', and 'I estimate the geometric standard deviation to be' (1.5). Below these fields are two sections: 'How Many Samples If Simple Random Sampling Were Used?' (For simple random sampling, 22 samples would be needed.) and 'How Many Samples Needed For Ranked Set Sampling?' (Estimated C.V.: 0.422715, Chosen set size [m]: 7, Number of cycles [r]: 1, Number of sets for top rank [t]: 2, Number of sets per cycle [(m+t-1)]: 8, Required number of samples [(m+t-1) x r]: 8, Number of field locations to rank [(m+t-1) x m x r]: 56). At the bottom of the right column is a red text box that reads: 'The estimated coefficient of variation (C.V.) is 0.422715. For ranked set sampling, I would need to measure [(m+t-1) x m x r]=56 field locations, ranking them in sets of m=7 using field screening measurements. I will collect t=2 sets for top rank and [(m+t-1)]=8 sets per cycle, for a total of r=1 cycles of data. [(m+t-1) x r]=8 samples will be analyzed in the laboratory.' At the bottom of the window are four buttons: 'Close', 'Cancel', 'Apply', and 'Help'.

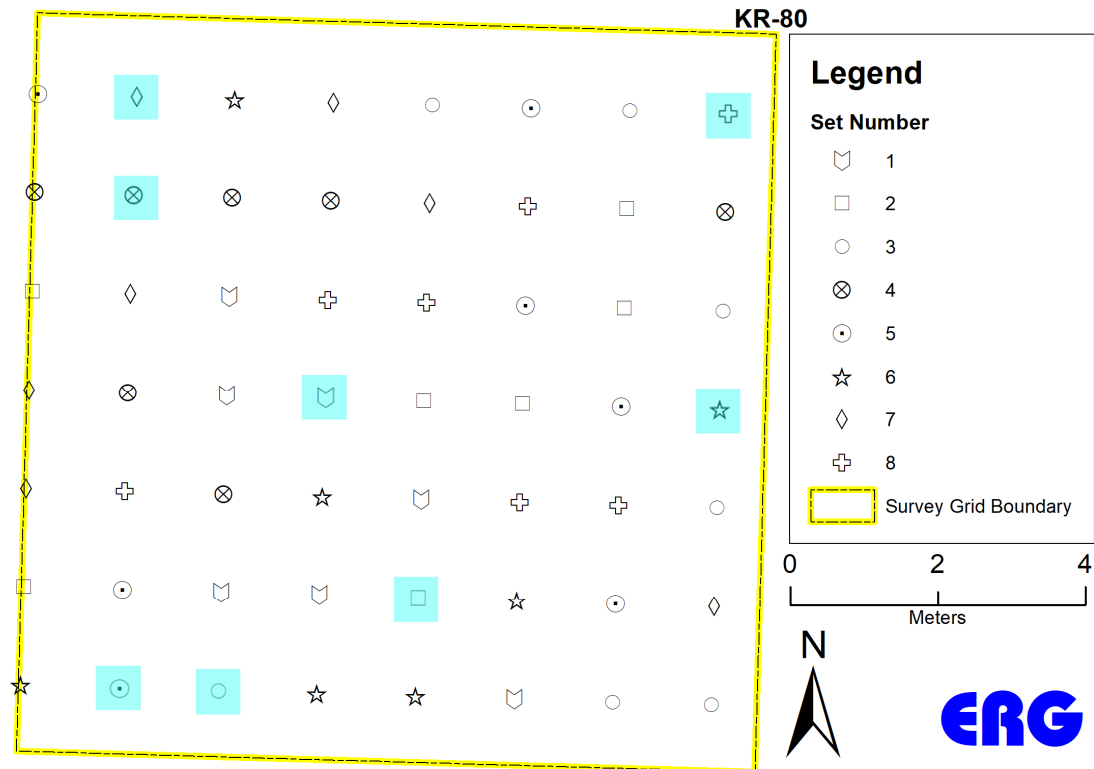
Sampling Example

Concentration of ^{226}Ra – Ranked Set Sampling



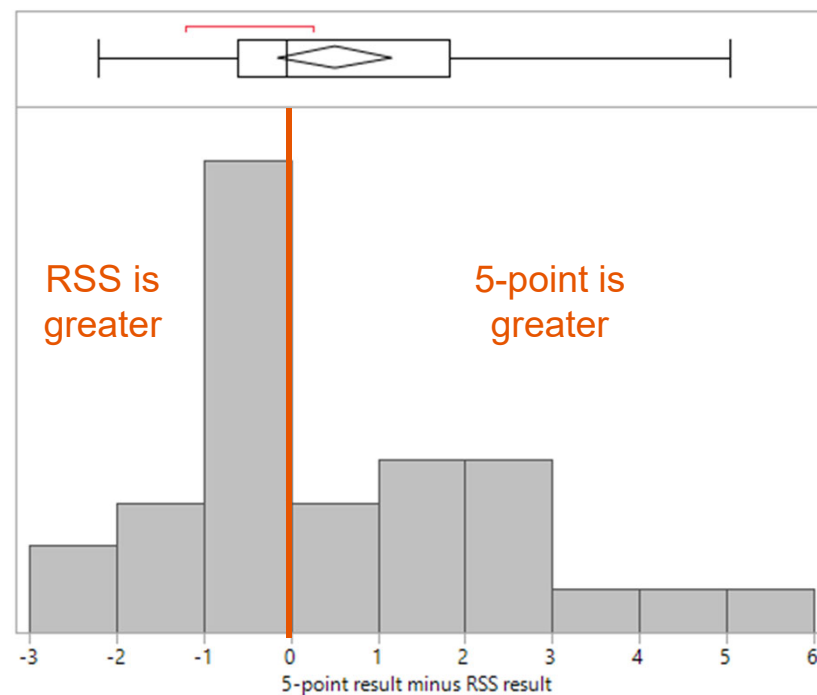
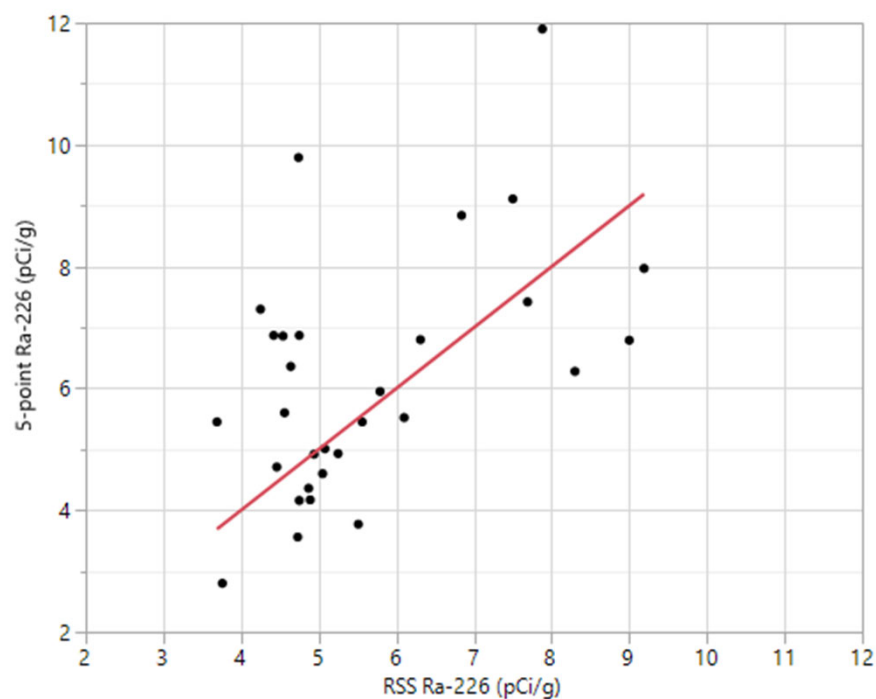
Sampling Example

Concentration of ^{226}Ra – Ranked Set Sampling



Sampling Results

Concentration of ^{226}Ra – Ranked Set Sampling

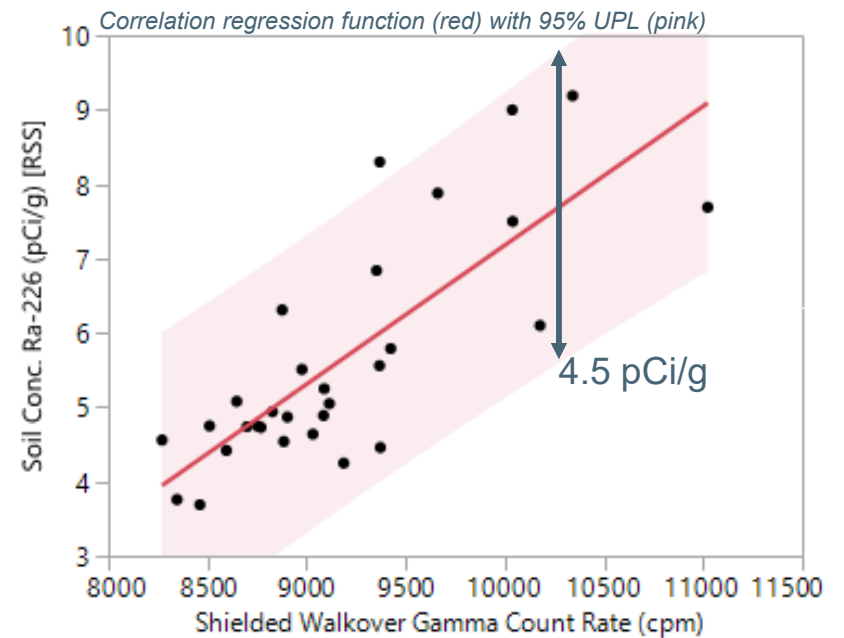
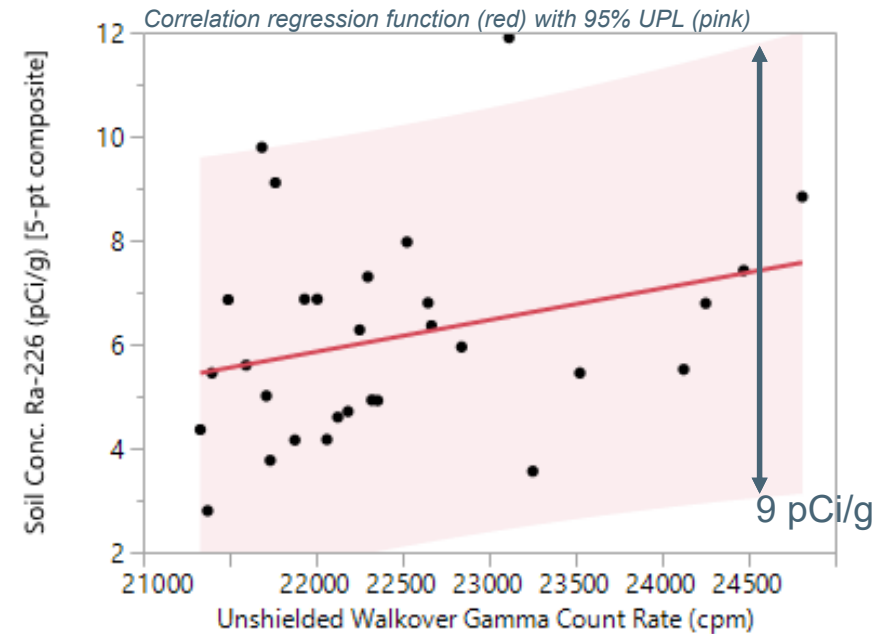


Grid Level Correlation

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.

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

A landscape photograph of a dirt road at sunset. The sky is filled with dramatic, colorful clouds in shades of blue, purple, and orange. The sun is low on the horizon, casting a warm glow. In the foreground, a dirt road leads towards the horizon. On the right side of the road, there is a blue container. In the background, there are some trees and a utility pole.

Thank you for
your attention.

BHP