Rio Algom Mining LLC

April 1, 2019

ATTN: Mr. James Webb
Mail Drop T5-A10
Division of Decommissioning, Uranium Recovery, & Waste Programs
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
11545 Rockville Pike
Rockville, MD 20852-2738

Re: Ambrosia Lake Facility
License SUA-1473, Docket Number 40-8905
Final Status Survey Work Plan for Windblown Tailings Affected Areas

Dear Mr. Webb,

Rio Algom Mining LLC (RAML) respectfully submits the attached Final Status Survey Work Plan for the Windblown Tailings Affected Areas of the Ambrosia Lake Facility.

This work plan is proposed as a supplement to the U.S. Nuclear Regulatory Commission (NRC) - approved Soil Decommissioning Plan (SDP) referenced in license condition 32 of Radioactive Materials License SUA-1473. The objective of this Work Plan is to provide the background and supporting logic for modifying the current Final Status Survey (FSS) integrated survey approach presented in the SDP (unshielded and 5-point composite sampling) to a shielded gamma survey and Ranked-Set Sampling (RSS) approach.

We look forward to the NRC's review of the work plan. Please contact me at (916) 947-7637 with any questions.

Sincerely,

Sandra L. Ross, P.G.
US Closed Sites Manager
Rio Algom Mining LLC

cc: NRC Document Control

Final Status Survey Work Plan
Windblown Tailings Affected Areas
Rio Algom Mining LLC Ambrosia Lake Facility

March 29, 2019

Prepared for:

Rio Algom Mining LLC

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Section 1.0 Introduction

This Work Plan describes the basis and approach for using shielded gamma survey and ranked set sampling (RSS) to conduct the Final Status Survey (FSS) of the windblown tailings (WBT) affected area at Rio Algom Mining LLC's (RAML's) Ambrosia Lake facility, Figure 1. This is a modified integrated survey approach for conducting the WBT FSS and is proposed as a supplement to the Soil Decommissioning Plan (SDP) (Komex, 2006) approved by the United States Nuclear Regulatory Commission (NRC) as license condition number 32 of Radioactive Materials License SUA-1473. This approach should improve the confidence level of remediation and release decisions related to the WBTs affected areas.

The objective of this Work Plan is to provide the background and supporting logic for modifying the current FSS integrated survey approach (unshielded and 5-point composite sampling) presented in the SDP (Komex, 2006) to a shielded gamma survey and RSS to meet the clean-up criterion defined in 10 CFR 40 Appendix A, Criterion 6(6). This Work Plan is organized into the following sections:

Section 1.0 – Introduction. Presents the purpose and objective of the Work Plan

Section 2.0 –Background. Presents background information, results and limitations of previous FSS surveys performed in accordance with the SDP, and modified surveying and soil sampling pilot study results.

Section 3.0 – Proposed Work. Presents the proposed scope of work to survey, remediate, and conduct the FSS for the windblown affected area using the modified sampling approach.

Section 4.0 – Affected Sections of SDP. Compares and selects the proposed integrated survey techniques to other FSS survey methodologies and identifies which sections of the SDP will be altered with the adoption of the proposed modified approach.

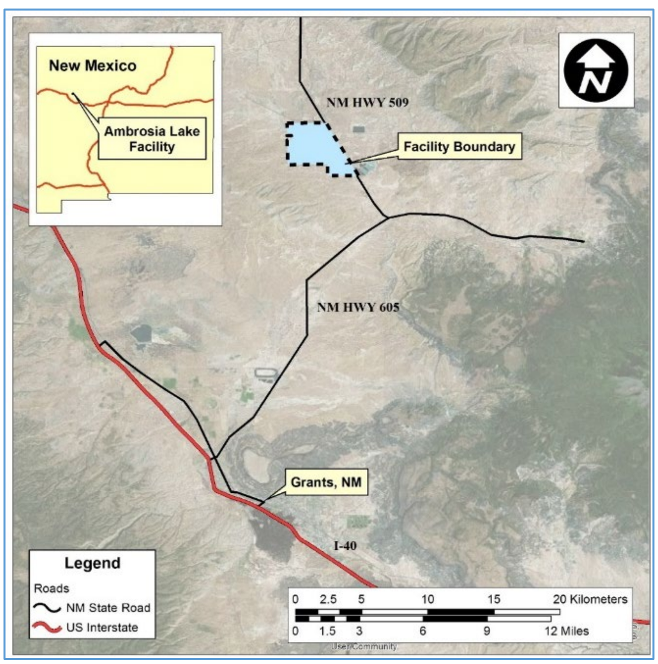

Figure 1. Site Location - Rio Algom Mining LLC Ambrosia Lake facility

Section 2.0 Background

The RAML Ambrosia Lake facility processed uranium ore beginning in 1958 and ending in early 1985. Approximately 33 million tons of uranium ore were processed at the facility. Since closing of the mill, remediation and decommissioning activities have been ongoing. All mill structures have been razed and disposed of in on-site tailings impoundments. All tailings impoundments have been stabilized and capped pursuant to NRC-approved plans. Specifically, this Work Plan focuses on areas of the facility designated as WBT affected areas (Figure 2).

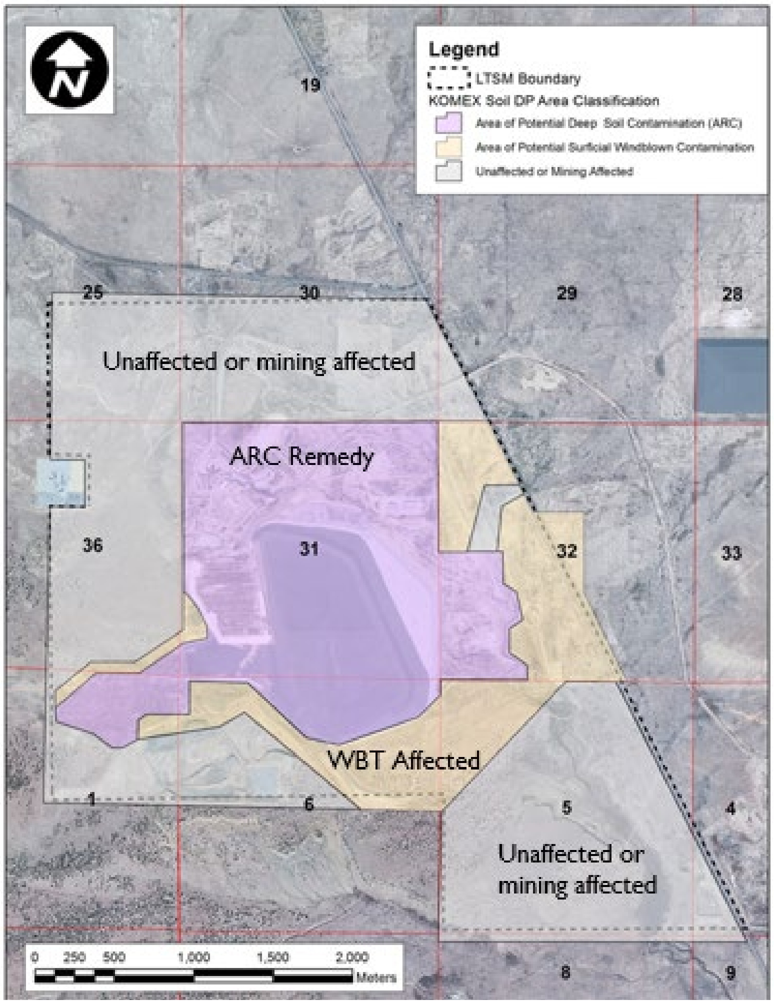

Figure 2. Potential Extent of Surficial Windblown Tailings

2.1 Previous WBT's Final Status Survey Activities

From 2016 through 2018, RAML conducted field and desktop investigations in support of decommissioning in the WBT affected areas, which consists of approximately 550 acres subdivided into

22,285 grid blocks 10 meters by 10 meters (100 m^2) in size. An overview of the FSS process for the WBT's is presented on Figure 3.

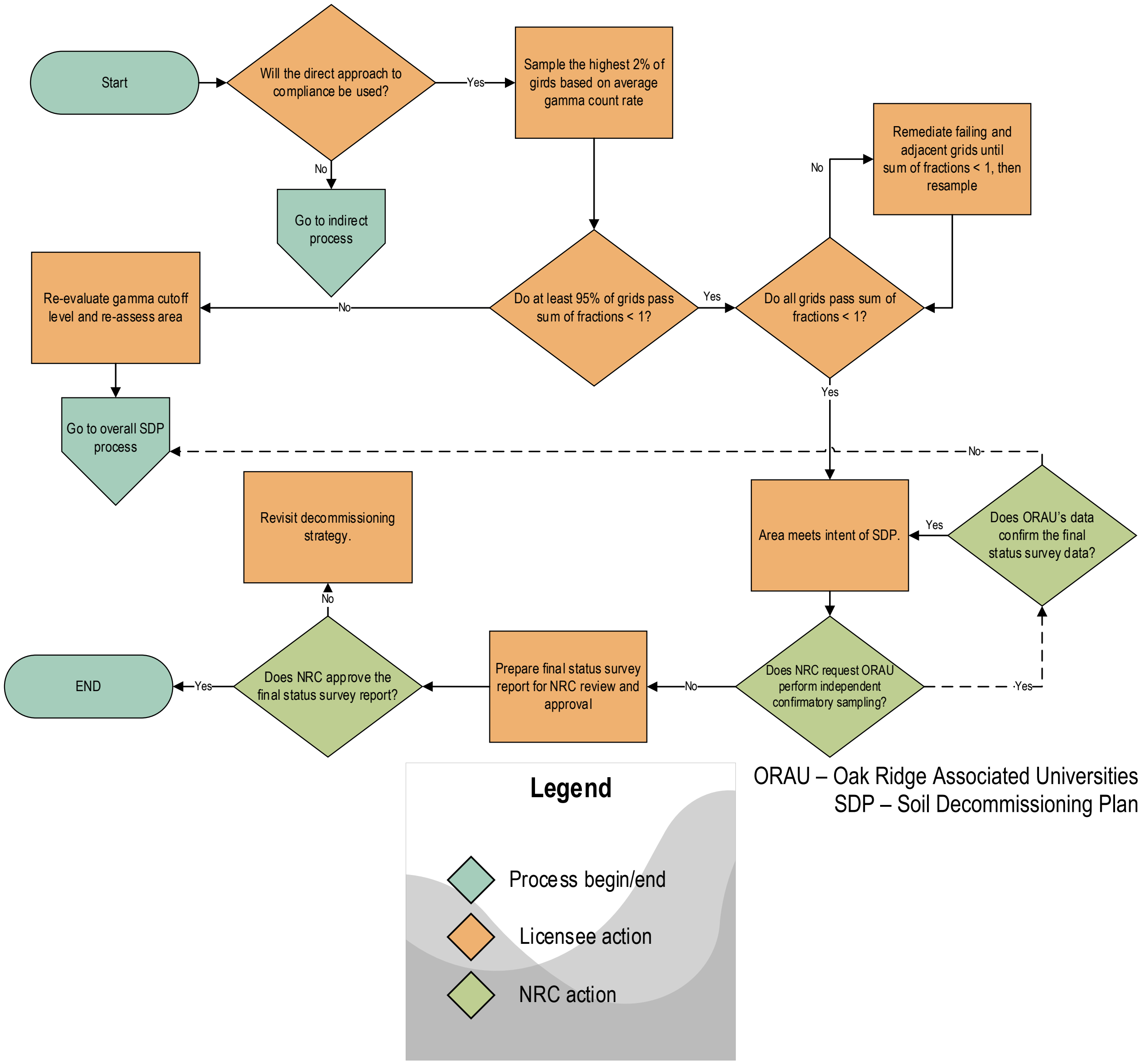

Figure 3. Final Status Survey Approach - Windblown Tailings Affected Areas

All WBT affected area surveys have been conducted pursuant to Section 8 of the SDP (Final Status Survey Plan) and the Quality Assurance Project Plan (QAPP) (RAML, 2016). WBT affected areas radionuclides of concern (RoCs) include total uranium, thorium-230 (Th-230), and radium-226 (Ra-226) pursuant to Section 2.1 or 8.1.1.2 of the SDP.

Soil cleanup levels for RoCs pursuant to 10 CFR 40 Appendix A Criterion 6(6) are 38 pCi/g for total uranium, 17 pCi/g for Th-230, and 7 pCi/g for Ra-226 (SDP Table 5.1 or Section 8.1.1.3). In WBT affected areas, Ra-226 is the primary driver of radiological dose and release decisions, however compliance with the soil cleanup level is determined using a sum of fractions (SOF) approach.

2.1.1 2016 Gamma Survey

An unshielded gamma survey of the WBT affected areas was conducted in 2016. Surveying was conducted on 6 foot transect spacing pursuant to Section 8.1.2.2.1 of the SDP. The gamma survey results indicated that all grids exceeding the 29,000 counts per minute (cpm) gamma guideline value as defined in Section 6.0 of the SDP were in areas (Figure 4) affected by mine related material or in engineered or natural drainages affected by mined areas.

2.1.2 2016 Soil Sampling Methodology Pilot Study

A soil sampling methodology pilot study was conducted in 2016 to evaluate the efficacy of the 29,000 cpm gamma guideline value in identifying areas requiring clean-up. Based on the results of the 2016 unshielded gamma survey, RAML conducted 5-point composite sampling per the SPD, Section 8.1.2.2.2 (Figure 5). The top ten average gamma grids below the 29,000 cpm gamma guideline value were sampled. The

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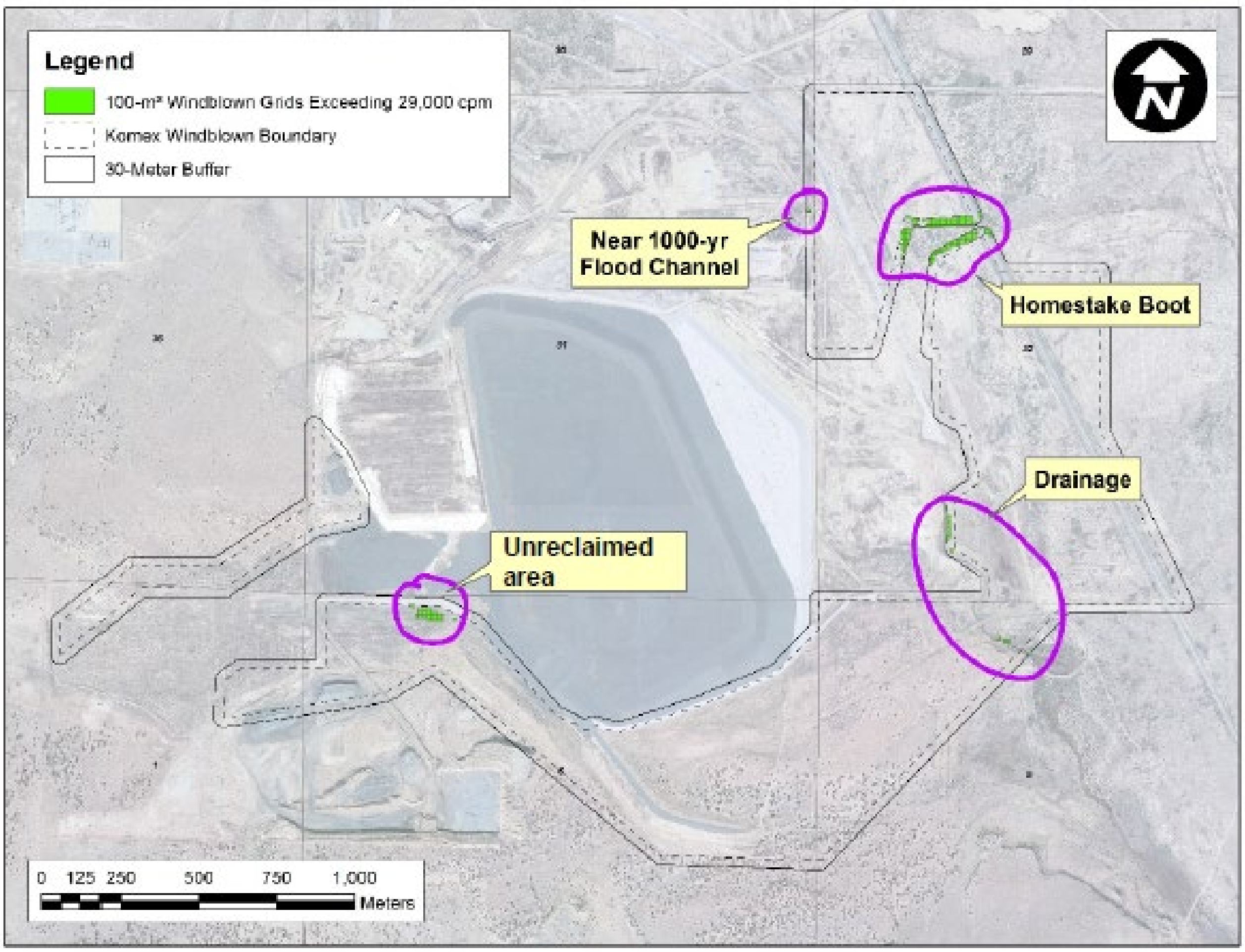


Figure 4. Grids Exceeding 29,000 cpm, Unshielded Gamma Survey, 2016

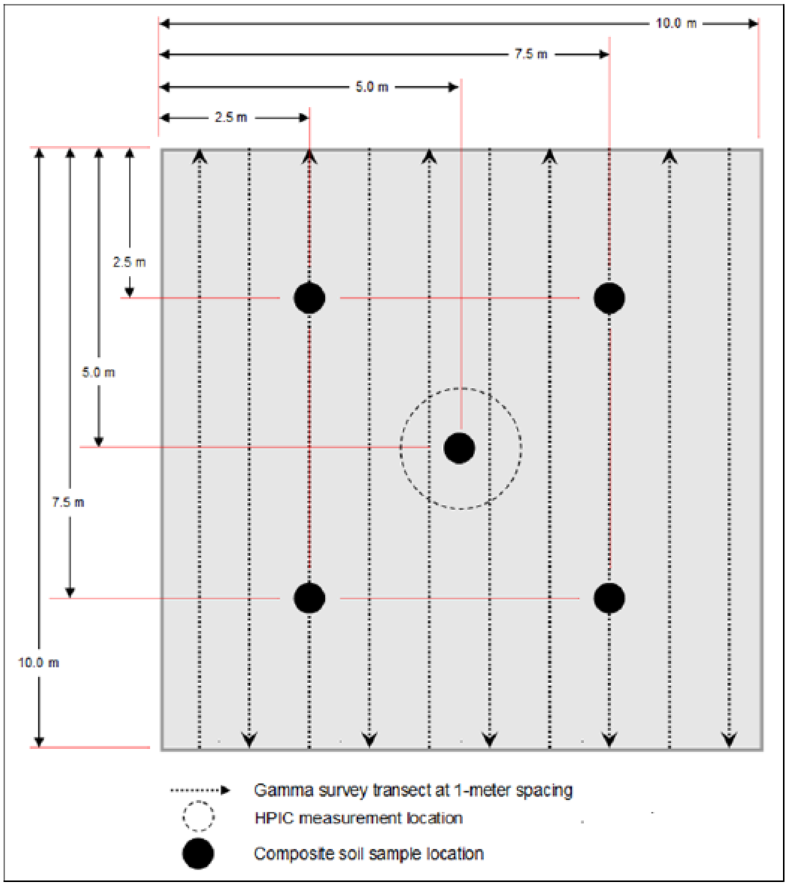
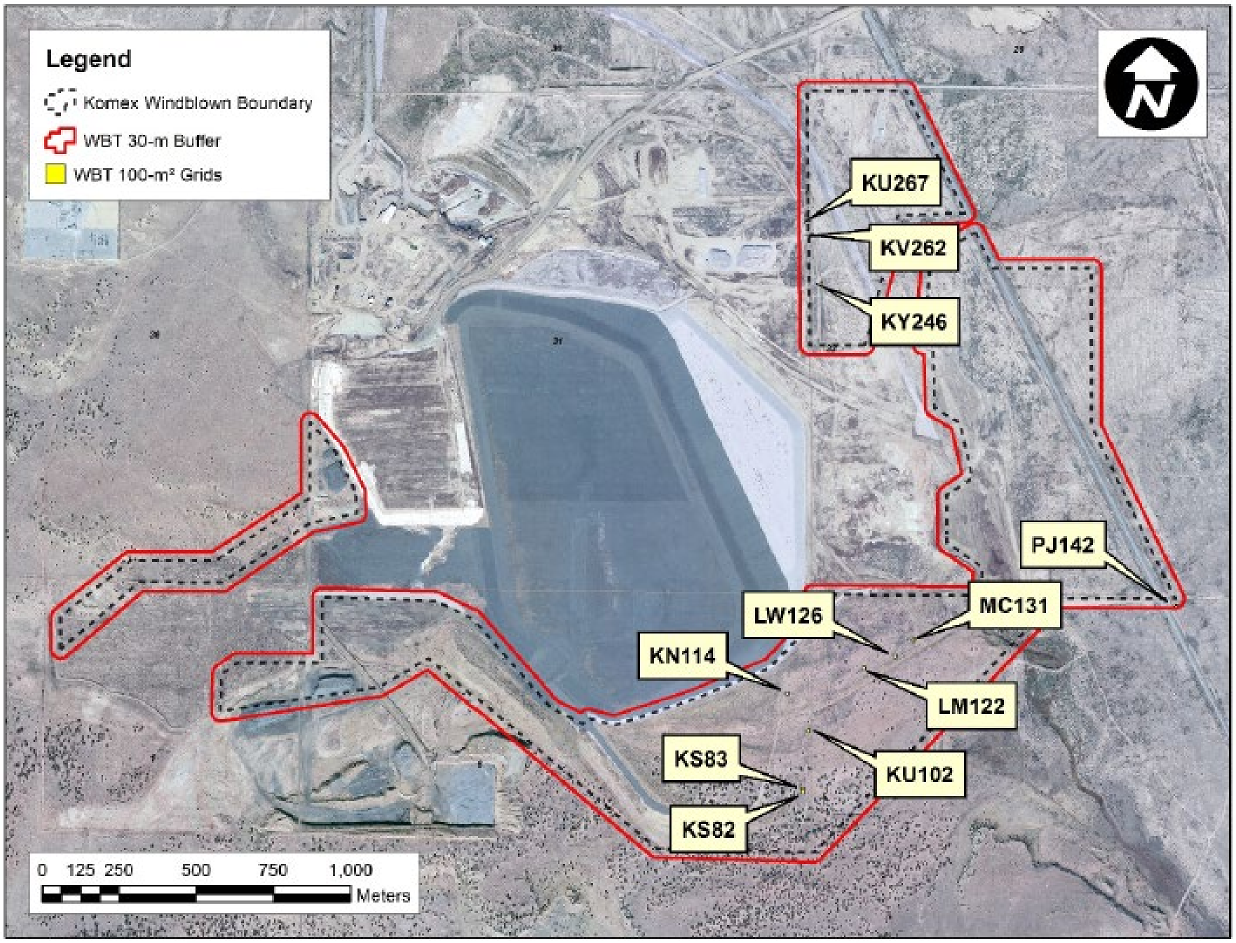


Figure 5. 5-point Composite Sampling Configuration, Section 8.1.2.2.2 SDP

sampling locations are shown on Figure 6. After location corrections due to accessibility and terrain, eleven composite samples were analyzed, but only one location passed clearance criteria using the sum of fractions (SOF) rule and clean-up levels specified in the SDP (Figure 6. 5-point Composite Soil Sample Locations, 2016
Table 1).

The results of the 2016 soil sampling methodology pilot study demonstrated that the 29,000 cpm gamma guideline value was an ineffective predictor of grid SOF. The study also demonstrated that additional WBT affected areas needed to be remediated and that the SDP gamma guideline level was too high to comply with the 95% SOF pass-rate required by the SDP.



KT-270 was not sampled since it was on ARC rock cover
KS-246 was sampled in lieu of KT-270 (next highest grid average)
KY-83 was sampled as a precaution in case other samples were excluded (next highest grid)

Figure 6. 5-point Composite Soil Sample Locations, 2016

Table 1. Results Soil Sampling Methodology Pilot Study

Soil Sample Results (2016)

Sample ID	Uranium-238 (pCi/g)	Thorium-230 (pCi/g)	Radium-226 (pCi/g)	SOF using Cleanup Levels	SOF using Benchmark Concentrations	Average Gamma (cpm)
MC131	3.94	14.2	14.8	3.1	2.2	27761.3
LW126	5.72	23.5	22.9	4.8	3.3	27195.4
LM122	1.52	17.5	16.1	3.4	2.3	26989.9
KN114	0.057	46.4	22.5	5.9	3.3	28177
KU102	2.27	28.2	12.5	3.5	1.8	27013.7
KS82	0.00	5.58	5.74	1.1	0.8	25810.3
KV262	3.53	453	14.5	28.8	3.0	27085.9
KU267	4.17	454	8.68	28.1	2.2	26257.2
KY246	0.00	79.2	5.97	5.5	1.0	25689.7
KS83	1.24	2.55	2.99	0.6	0.4	25758.7
PJ142	1.10	15.3	10.4	2.4	1.5	26025.3

KT-270 was not sampled since it was on ARC rock cover
KY-246 was sampled in lieu of KT-270
KS-83 was sampled as a precaution in case other samples were excluded (next highest grid)

Figure 7 presents the results of correlation between the 2016 unshielded gamma survey and 2016 5-point composite soil sampling.

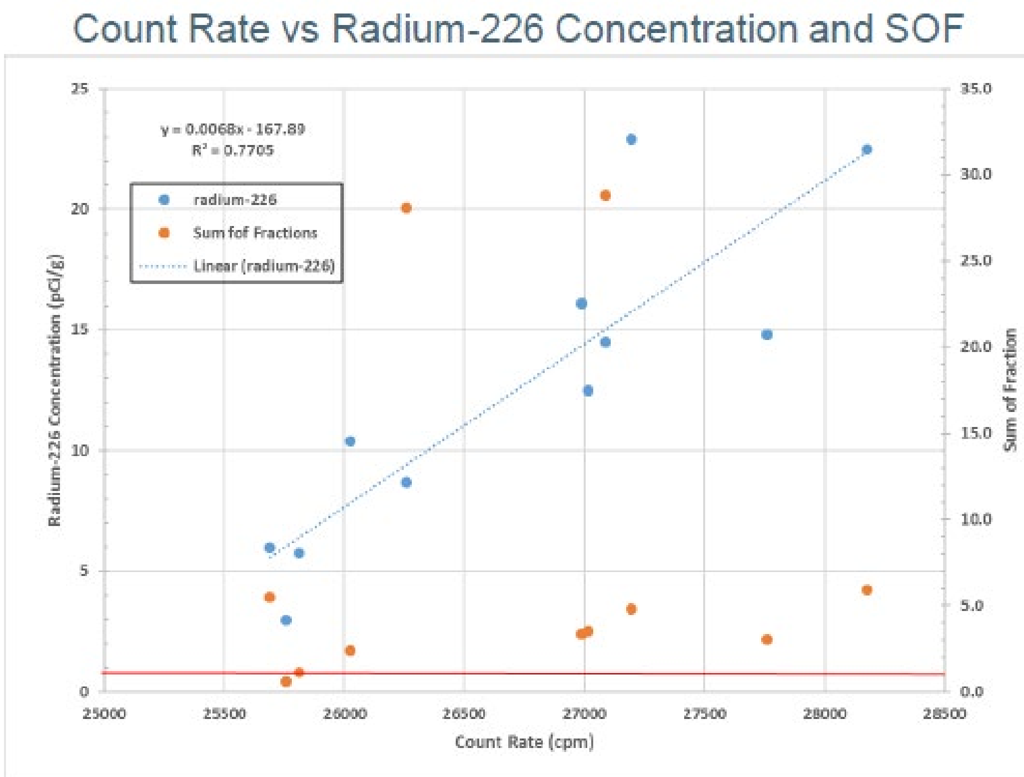


Figure 7. Correlation Study - 2016 Gamma Survey and Soil Sampling

A reduced gamma guideline value of 25,000 cpm (more conservative than the SDP value) was adopted as a result of this study.

2.1.3 2017 FSS Soil Samples and Correlation Study

Work proceeded with a reduced gamma guideline level of 25,000 cpm based on the 2016 soil sampling methodology pilot study, and in 2017 RAML began implementing the FSS as prescribed in Section 8.1 of the SDP. Soil samples were collected beginning in July 2017 using 5-point composite sampling (described in Section 8.1.2.2.2 of the SDP and diagrammed in Figure 1). Samples were analyzed for uranium-238 (U-238) and Ra-226 by gamma spectroscopy and Th-230 by alpha spectroscopy. Sample locations included the highest 2% of grid blocks below the gamma guideline value based on average gamma response (Figure 8). 446 samples were planned in grid blocks plus 45 replicate samples (approximately 10%), for a total of 491 planned samples.

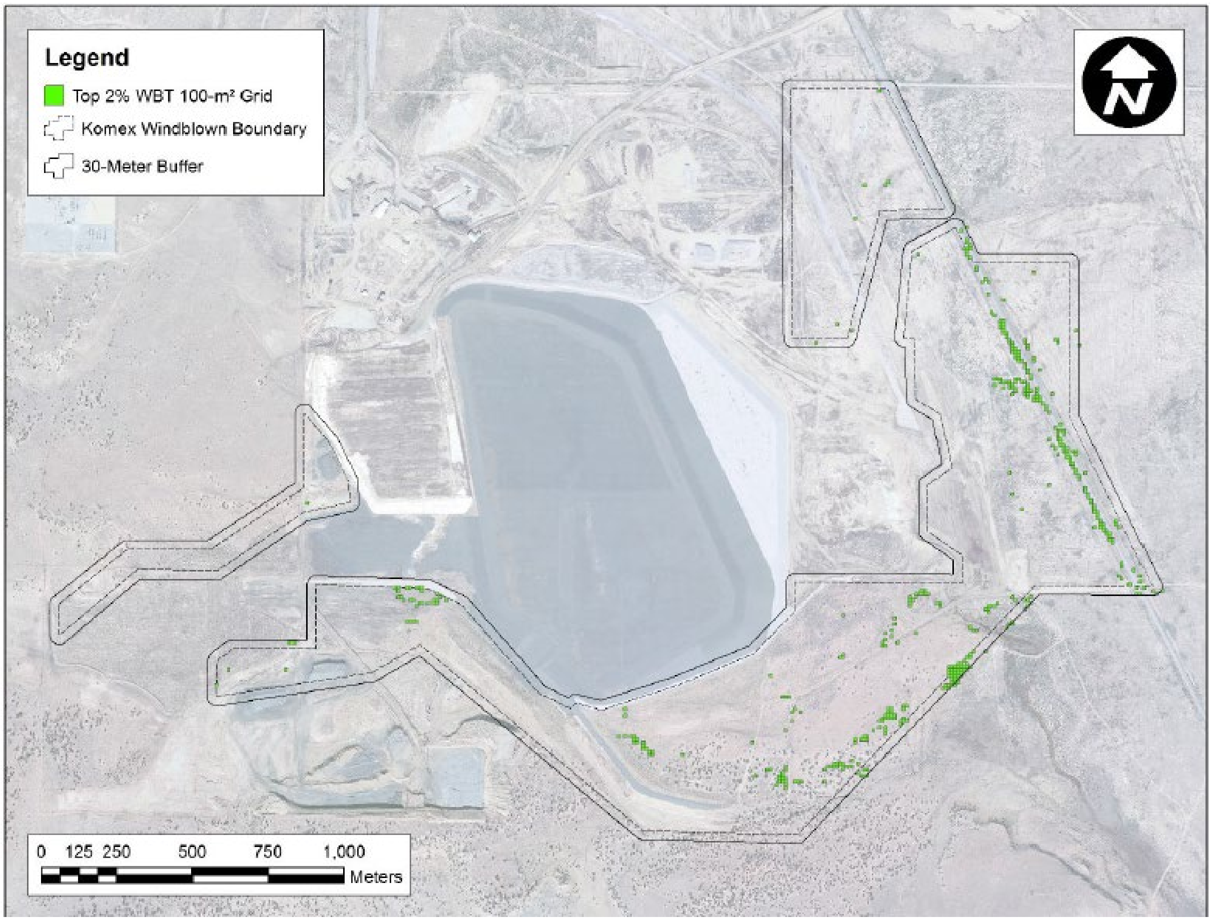


Figure 8. Top 2% of grids below 25,000 cpm

However, as initial results returned from the analytical laboratory, statistical analysis made it clear that the grid blocks were going to fail the FSS criteria (i.e. greater than 5% of top 2% grids fail SOF < 1). Of 313 samples collected in July and August 2017, 100 samples were greater than 7 pCi/g Ra-226. These data are represented on the right side of the plot (Figure 9). To further the development of a new guideline value, the study goal was altered to collect supplementary correlation data and better understand the reasons for the failure of the 25,000 cpm gamma guideline value. Further sampling in October 2017 included 26 additional surface samples from 10 by 10-meter grids in which the average gamma count rates ranged from approximately 13,000 to 20,000 cpm (see Figure 9 and Figure 10).

The correlation study of the 2017 FSS data found poor correlation (Figure 9 and Figure 10) between grid-mean gamma count rate and soil concentration of Ra-226. The dataset was exceptionally variable, with the only discernable trend being a slight increase in the concentration of Ra-226 with increasing mean unshielded gamma count rate. Figure 9 demonstrates that the 25,000 cpm gamma guideline level was ineffective and that grid-mean concentration of Ra-226 (assessed via a 5-point composite sampling pursuant to the SDP) was poorly correlated ($R^2 = 0.24$, $p < 0.001$) with grid-mean unshielded gamma count rate.

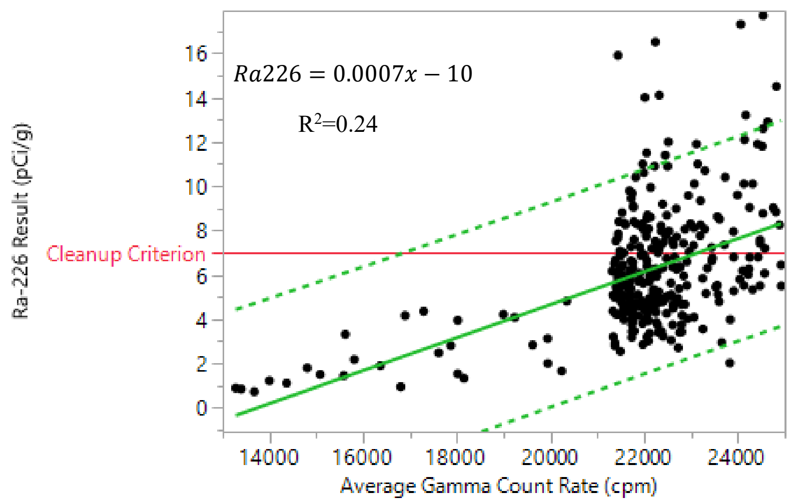


Figure 9. Concentrations of radium-226 as a function of average gamma count rates. *Notes:* Red dashed line represents the clean-up level for radium-226. Green dashed lines represent the 95th prediction interval of the model.

The variability of the dataset could be reduced by focusing on the 26 samples collected during October 2017. Figure 10 plots concentrations of Ra-226 (measured via 5-point composite sampling) in samples where average gamma count rates ranged from approximately 13,000 to 20,000 cpm. While the R^2 of 0.32 is higher than that in the model presented in Figure 9, the model continues to be insufficiently predictive for making remediation or release decisions: extrapolating the upper 95th prediction limit line to the clean-up level results in a gamma guideline level of approximately 23,000 cpm, but Figure 9 demonstrates that a 23,000 cpm gamma guideline level would still result in an unacceptably high number of samples (i.e., greater than 5 percent) failing to meet the clean-up criterion of 7 pCi/g Ra-226.

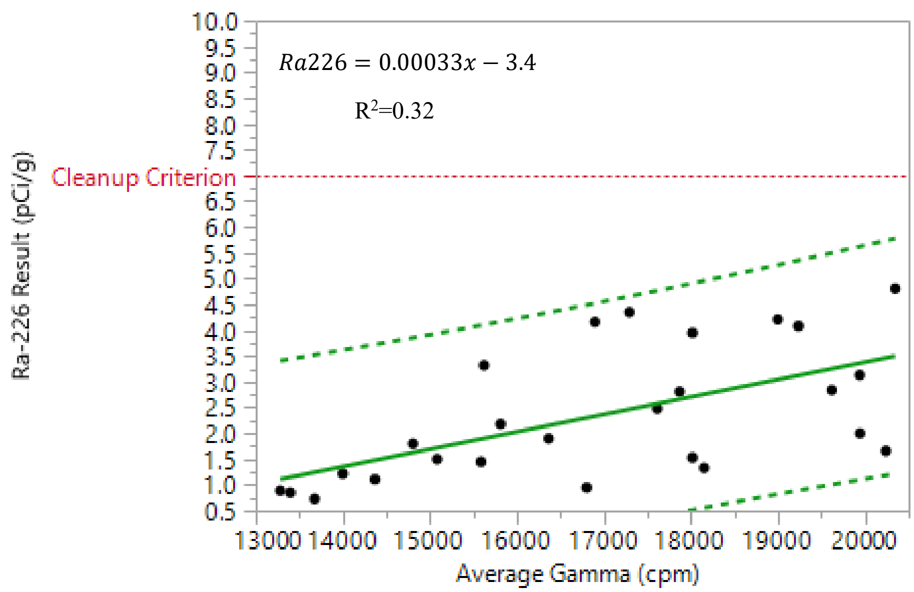


Figure 10. Concentrations of radium-226 as a function of average gamma count rate (26 correlation samples). *Notes:* Red dashed line represents the clean-up level for radium-226. Green dashed lines represent the 95th prediction interval of the model.

Figure 11 shows the spatial distribution of gamma count rate coefficients of variation within the WBT affected areas. In general, areas with high variability in gamma count rates occur in areas near engineered structures such as former ponds, diversion channels, and roadways. Subsequent investigations focused on possible explanations for correlation lack-of-fit:

1. Systematic errors in the sampling or survey procedures,
2. Systematic uncertainty in the laboratory subsampling method,
3. Systematic uncertainty in the laboratory analytical method, and/or
4. Real heterogeneity in the soils being sampled.

Procedures are in place to limit uncertainty for systematic errors, and the FSS soil collection process was audited by a third party to verify that personnel executing the work followed survey procedures. In support of numbers 2 and 3 above, the independent analytical laboratory, GEL, is certified by the National Environmental Laboratory Accreditation Program. Thus, it is most likely that the measurement methods (e.g., unshielded gamma survey and 5-point composite sampling) are poor estimators of grid-mean concentration of Ra-226 due to confounding environmental factors, although the exact confounding factor(s) were not identified during the 2017 FSS.

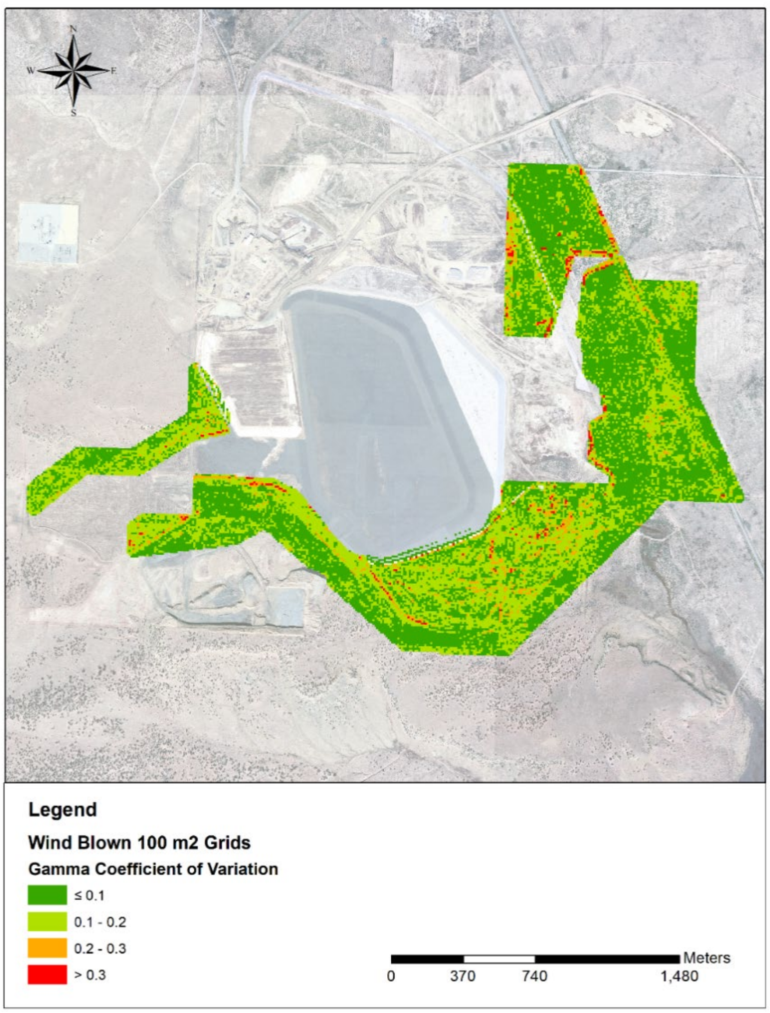


Figure 11. Spatial distribution of coefficients of variation in the grid blocks of WBT affected areas

2.1.4 2018 Follow Up Data

Because the 2017 FSS executed according to the requirements of the SDP failed to demonstrate appropriate comparison of WBT affected areas against the release criterion, ongoing work in 2018 had two goals:

1. Understand why the 2017 FSS failed, including failure of grids to meet the Ra-226 release criterion and failure of the sampling method (unshielded gamma survey) to accurately measure the true mean.
2. Propose and test methods to determine whether/where additional windblown remediation is necessary and demonstrate compliance with the FSS release criterion.

The source(s) of the correlation model's lack-of-fit must explain both the increased variability and observed slight rightward tailing of the model's residuals (i.e., a tendency to overpredict Ra-226 concentrations, see Figure 12).

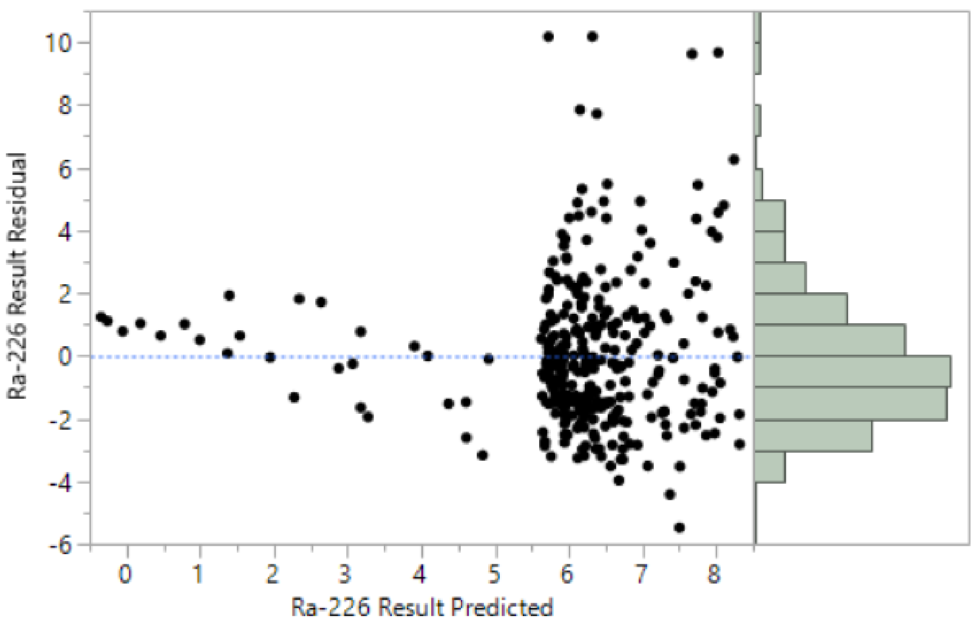


Figure 12. Statistical analysis of the 2017 FSS data set demonstrating high variability and rightward-tailed residuals

Five potential confounding variables and sources of data variability were identified and analyzed:

1. Soil sample collection method,
2. Interfering gamma signal from another radionuclide source,
3. Presence of anthropogenic radionuclides below grade,
4. Inter-instrument variability, and/or
5. Small-scale spatial heterogeneity.

The full investigation is described in a 2018 technical memorandum (ERG, 2018). Small-scale spatial heterogeneity (see Figure 13) was identified as the most likely cause of the variability observed in the final status survey dataset and was the subject of field investigations and supplemental statistical analysis that occurred between April-May 2018. Sources of small-scale spatial heterogeneity could include inconsistent remediation, vegetative cover, and/or multiple contaminating events and secondary environmental transport. In the end, the observed heterogeneity is likely due to a combination of factors. While it is not necessary to understand the precise cause of spatial variability, RAML believes that vegetative cover is the most likely explanation. Much of the windblown area is covered by medium-sized brush; in April 2018 health physics personnel used an unshielded gamma scintillometer to make qualitative field measurements in and around this brush and observed significant increases in gamma count rate on the upwind side of individual plants relative to the downwind side. The observed effect is likely due to the tendency of vegetation to filter out windblown material, resulting in small-scale spatial heterogeneity in gamma count rate on the upwind side of plants. Spatial heterogeneity was not observed, or was much less prominent, in areas dominated by small grasses and forbs, or devoid of plant cover altogether (e.g., duned areas).

Shielded gamma surveys are a tool for characterizing areas that exhibit a high degree of spatial heterogeneity. In a shielded survey, the detector's field of view is much smaller than in an unshielded gamma survey, reducing the influence distant gamma-shine on an individual measurement. To evaluate the utility of shielded surveys within the windblown area, ERG performed a shielded walkover gamma survey on 21 grids previously evaluated during the windblown final status survey (Figure 13). The shielded gamma survey was conducted on an approximate 1 meter transect spacing so that the gamma survey would be sensitive to even very small-scale spatial heterogeneity.

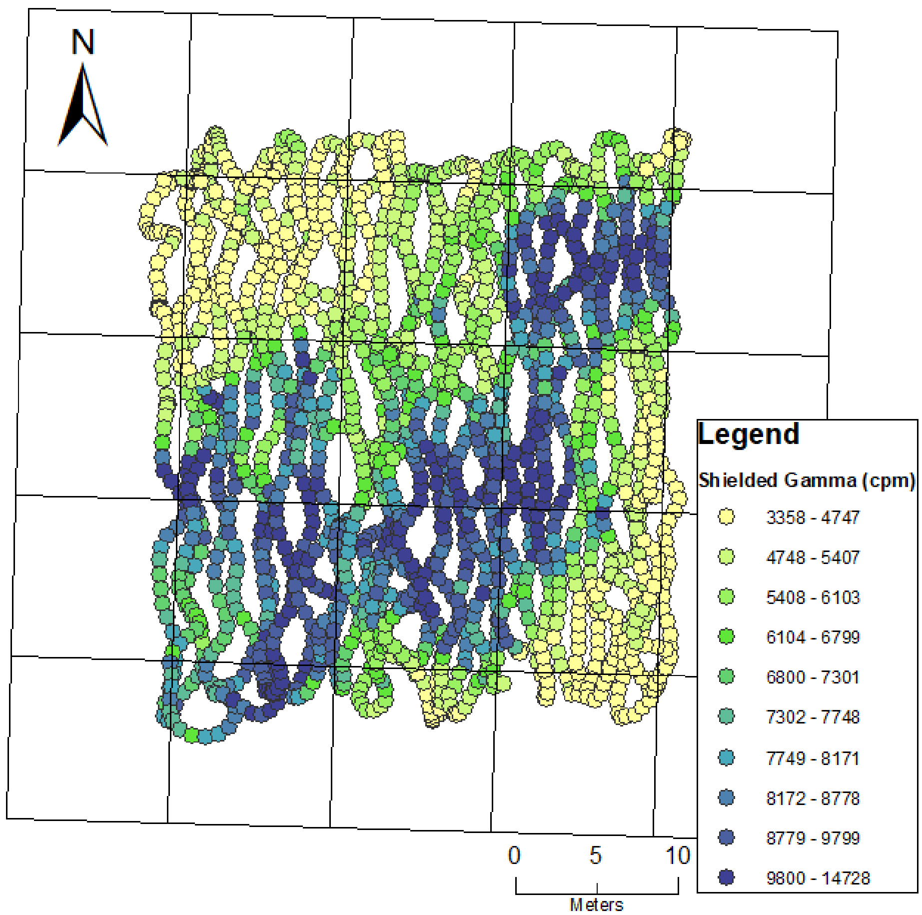


Figure 13. Shielded gamma survey data overlaid with nine ten-by-ten-meter windblown grids. The observed small-scale heterogeneity makes it difficult to sample in a representative manner and confounds estimation of the grid's mean Ra-226 soil concentration.

2.1.5 2018 Pilot RSS Survey

Further work in 2018 investigated techniques which would be more resilient to small scale spatial heterogeneity. Ranked set sampling (RSS), an alternate method for estimating grid-mean concentrations of Ra-226 in soil, is a technique recognized by the U.S. Environmental Protection Agency (EPA) as a more accurate method for characterizing the mean soil concentration of a radionuclide (EPA, 2002), particularly at sites with high degrees of spatial heterogeneity. Further discussion of this selection is included in Section 3.1.2 of this Work Plan.

RSS is more labor intensive than traditional 5-point composite sampling. Because of the increased cost, efficacy was evaluated in a subset of grids prior to implementation at scale. A pilot study was completed in July 2018 to determine whether these tools are sufficiently resilient to small-scale spatial heterogeneity to be useful in RAML decommissioning surveys.

RSS and shielded gamma survey were implemented within 30 randomly-selected windblown grids to test the efficacy of these tools at the site. The RSS survey was designed using Visual Sample Plan (VSP, 2018) with the input statistical parameters (e.g., geometric standard deviation) derived from the 2017 FSS dataset. The survey goal was to estimate the grid-mean soil concentration of Ra-226 to within 20 percent. To achieve this level of accuracy, 56 locations per grid were screened with a static shielded gamma count rate and the screening locations were divided into seven sets of eight ranked measurements. A diagram is provided in Figure 14. Seven soil subsamples were collected and homogenized per grid, with the sampled locations determined by the gamma measurement ranks. The composited soil sample was sent to GEL laboratories for quantification of Ra-226, Th-230, and U-238 via the methods prescribed in the approved SDP.

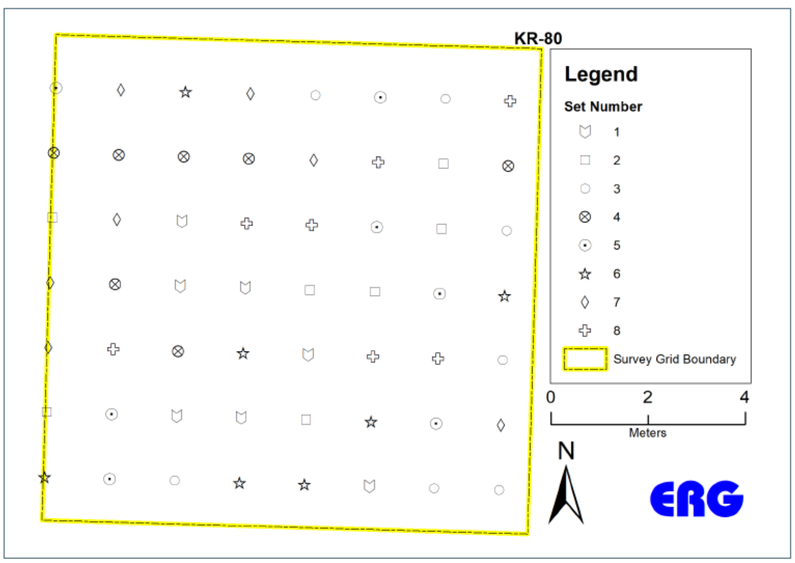


Figure 14. Example use of RSS method to determine sample locations

Table 2 summarizes the improvement in correlation (and therefore, the increasing resilience of the sampling method to the observed small-scale spatial heterogeneity) by examining the improvement in R^2 as methods more resilient to small-scale spatial heterogeneity are correlated. As more resilient methods are introduced, the adjusted R^2 value for the correlation between the soil-sampling method and the *in-situ* gamma measurement method improves from 0.05 to 0.60 in the 30 grids evaluated during the pilot study.

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

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

Figure 15 plots soil concentration of Ra-226 *predicted via gamma count rate* against soil concentration of Ra-226 *measured via RSS*. Among the 30 grids piloted during the RSS study, there were zero type 1 errors and fourteen type 2 errors, indicating that the regression model is very conservative when used as a basis for remediation and release decisions, and that it may be possible to optimize a shielded gamma guideline value derived from the shielded gamma correlation study to use as an indicator for a grid's remediation status (i.e., to raise the gamma guideline value with a goal of decreasing type 2 error rate, without an unacceptable increase in type 1 error rate as a result).

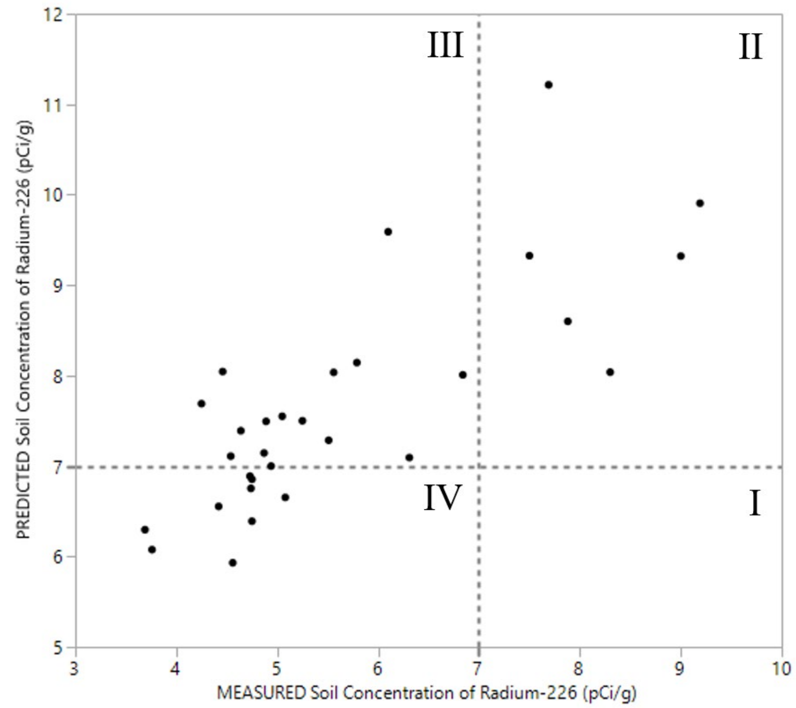


Figure 15. Plot of measured versus predicted concentrations of radium-226 in soil at each of the thirty RSS pilot grids. Grey dashed lines illustrate the cleanup level, and quadrants are plotted to indicate decision error types (Quadrant I represents type 1 errors, II and IV represent correct decisions, and III represents type 2 errors).

While the 2018 RSS pilot significantly improved the gamma to Ra-226 correlation, there are limitations to the method: real uncertainty remains within the correlation model, as assessed via the adjusted R^2 of 0.6. Regardless, these tools are much improved estimators of grid-mean Ra-226 concentration in soil compared to the methods described within the approved SDP.

2.2 Reasoning to Supplement the SDP

The underlying assumption of the SDP FSS process is that the prescribed sampling tools are effective estimators of the mean concentration of Ra-226 in soil. Under this assumption, it is possible to:

1. Correlate mean gamma count rate with the mean soil concentration of Ra-226 within a grid,
2. Rank the grids from most-contaminated to least, and
3. Sample soil the most contaminated grids (top 2%) to demonstrate compliance with the soil cleanup criterion (i.e., 7 pCi/g of Ra-226 and sum of fractions for other constituents).

Logically, since the most contaminated grids (the top 2% based on gamma signature) are those in which soil sampling occurs, the licensee and the NRC may conclude that all remaining grids (i.e., those not in the top 2%) meet the soil cleanup value, and that the entire WBT affected area conforms to the soil cleanup criterion.

Ultimately, recent FSS efforts indicate that unshielded gamma survey and 5-point composite soil sampling, as prescribed in the SDP, are poor estimators of mean radionuclide concentrations in surface soil at the facility and are therefore not reliable indicators of whether an individual ten-by-ten-meter grid, the spatial basis for the soil standard, has been adequately remediated.

Studies conducted in 2018 support the conclusion that environmental conditions at the site significantly confound the underlying assumptions of the decommissioning tools prescribed within the SDP, and that within the WBT affected areas:

1. Grid-mean unshielded gamma count rate does not correlate well with the grid-mean concentration of Ra-226 in soil. Thus, the set consisting of the top 2% of grids, identified based on mean gamma count rate, is not necessarily the set of grids containing the top 2% grid-man Ra-226 soil concentrations, and,

2. The 5-point composite soil sampling method prescribed in the approved SDP does not reliably estimate the true mean concentration of windblown radionuclides in soil and produces unacceptably high type 1 and type 2 error rates.

As a result of confounding environmental conditions, it is not possible to demonstrate compliance with the facility's soil cleanup criterion (i.e. 7 pCi/g Ra-226) using the tools prescribed in the SDP, even when the SDP's FSS process is followed precisely.

After investigating other techniques, shielded gamma survey and RSS were selected as more resilient to small scale spatial heterogeneity than unshielded gamma survey and the 5-point composite sampling prescribed in the SDP.

Section 3.0 Proposed Work

The proposed FSS work will adhere to the process provided in the SDP, except shielded gamma surveying will be used to develop an appropriate gamma guideline value, and RSS will be substituted for 5-point composite sampling. These two new tools will improve statistical representativeness of the results. In general, the purpose of this work is to improve the precision and reduce variability of FSS results so that the WBT affected areas may be accurately compared against existing release criteria. Section 4 of this Work Plan addresses which specific sections of the SDP will be adjusted in completion of this work.

Work will adhere to the guidelines specified in the QAPP and implement site-specific RAML procedures:

1. ESP-010 Radiation Survey Using GPS Unit
2. ESP-012 Soil Sampling for Radionuclides

3.1 New Tools

3.1.1 Shielded Gamma Survey

Shielded (versus unshielded) gamma survey will be used as an indicator of Ra-226 in surface soil. The gamma scan will use a 2-inch by 2-inch Ludlum Model 44-10 sodium iodide (NaI) detector shielded with a Ludlum Model 44-10 collimator coupled to a Ludlum Model 3000 scaler/ratemeter, or equivalent. The transect spacing will also be reduced from 6 feet (prescribed in SDP) to 3 feet to account for the smaller field of view of the shielded detector. The use of standardized shielding and narrower transect spacing are the only differences between the proposed method and equipment and the approach used in previous unshielded surveys.

3.1.2 Ranked Set Sampling

RSS (versus 5-point composite sampling) will be used to measure average concentration of Ra-226 in a grid. In RSS, field measurements such as collimated, scalar gamma counts guide soil sampling to ensure that that surveyors representatively and nonparametrically sample successive fractions from the distribution of soil concentrations within a survey unit. Because the complete distribution is being sampled and a composite of the complete distribution is sent for laboratory analysis, the composite's concentration is a better estimate of the true mean than a traditional 5-point composite sample (the current method described in the SDP).

Guidance is available from the EPA (2002) for choosing a sampling design for environmental data collection. Table 3 presents a list of sample designs described in the EPA guidance and reviews why RSS is the best approach for the WBT affected areas at RAML's Ambrosia Lake facility as opposed to the other methods. In general, RSS is effective, cost-efficient, and appropriate for the scope of the study and current understanding of small-scale spatial heterogeneity in the WBT affected areas. Use of this approach will not affect other portions of the SDP and will be able to effectively demonstrate compliance decisions.

Table 3. Sampling designs presented in EPA guidance and applicability to WBT affected areas

Sample Design	Applicability to Windblown Tailings (WBT) Affected Area
Judgmental	Inferences are based on professional judgment, not statistical scientific theory. Probabilistic statements about parameters are not possible.
Simple Random	Only useful when the population of interest is relatively homogeneous.
Stratified	Only useful when the area can be subdivided based on expected contamination levels. Greater precision can be obtained if the measurement of interest is strongly correlated with the variable used to make the strata.
Systematic and Grid	Useful when searching for hot spots or estimating spatial patterns or trends over time – hot spots must be larger in size than the grid size.
Ranked Set	Highly useful and cost efficient in obtaining better estimates of mean concentration levels in soils by explicitly incorporating a field screening method to pick specific sampling locations. Appropriate when an inexpensive auxiliary variable (i.e. gamma scan) is available to rank population units with respect to the variable of interest (radium concentration). If the ranking method and the analytical method are not well-correlated, ranked set sampling becomes simple random sampling.
Adaptive Cluster	Only useful for inexpensive, rapid sampling techniques.
Composite	Insensitive to small scale spatial heterogeneity.

3.2 Decommissioning with New Tools

The steps of the proposed work will be as follows (see generic approach in Figure 3). Work will adhere to the approach outlined in the approved SDP (except for specific differences described in Section 4 of this Work Plan) as well as the site-specific QAPP and relevant procedures.

3.2.1 Resurvey the WBT affected areas using a shielded gamma detector

A predictive gamma guideline value is required to guide cleanup efforts and to implement the FSS in WBT affected areas. Initial work will develop a correlation between shielded gamma measurements and Ra-226 concentrations and identify a shielded gamma guideline value corresponding to 7 pCi/g of Ra-226 in soil (a supplement to Section 6.0 of the SDP). Grids exceeding the shielded gamma guideline value, and adjacent grids, will be treated with the WBT remedy, as required in Section 7 of the SDP. Finally, a confirmatory shielded gamma survey will be performed within those grids to which the WBT remedy has been applied.

3.2.2 Perform a Final Status Survey using Ranked Set Sampling

FSS work will proceed in the WBT affected areas with the collection of soil samples. Soil samples will be collected at the highest 2% of grid blocks below the shielded gamma guideline value based on average gamma response. The RSS design will be re-optimized using VSP based on the statistical parameters of the shielded gamma survey data set. Within each of the grids:

1. Grid will be screened with static shielded gamma count rate measurements at locations determined using VSP;
2. Screening locations will be divided into sets of ranked measurements (see Figure 14 example);
3. Soil subsamples will be collected and homogenized per grid, with the sampled locations determined by the gamma measurement ranks; and
4. Composited soil samples (one sample per grid) will be sent to GEL laboratories for quantification of Ra-226, Th-230, and U-238 via the methods described in the approved SDP.

3.2.3 Correlation Study and Final Status Survey Decisions

Based on previous work, the RSS and shielded gamma survey should be adequate as a basis for remediation and release decisions at RAML's Ambrosia Lake facility. Correlation will be evaluated between the measured shielded gamma count rates and Ra-226 concentrations, and the top 2% of grids will be compared to the clean-up requirements. If at least 95% of the sampled grids have a sum of fractions less than 1, and subsequent remediation achieves 100% of sampled grids with sum of fractions less than 1, then the intent of the SDP will have been achieved and the WBT affected areas may be suitable for release.

3.3 Proposed Schedule

RAML expects to execute a shielded gamma survey of the windblown area during Spring 2019, with a summary report provided to NRC in Summer 2019. The final status survey, to include ranked set sampling in lieu of 5-point composite sampling, is expected to occur during Fall of 2022, following additional soil remediation in the WBT affected area.

Section 4.0 Affected Sections of the SDP

The work proposed in this plan primarily impacts Section 8 of the SDP (Final Status Survey Plan). Area boundaries, radionuclides of concern, and clean-up requirements are unchanged in this approach. All existing sampling requirements prescribed within the approved SDP will be implemented as written, except for the soil sampling method.

Table 4 provides a summary of specific sections of the SDP which have been clarified or altered by this Work Plan. This modified approach meets the clean-up performance criteria and confirmation sampling objective.

Table 4. Affected sections of the SDP

SDP Section	SDP Requirement	RSS Work Plan Requirement	Change
6.0 Gamma Guideline Value	Proposed gamma guideline value of 29,000 cpm based on 7.0 pCi/g Ra-226 (5 pCi/g plus 2.0 pCi/g background)	New gamma guideline value developed for shielded detector	Shielding the detector results in reduction of the overall gamma count rate and therefore requires reducing the guideline value
8.1.2.2.1 Scanning Survey and Table 8-1 Radiation Detection Instruments	Gamma scan using a NaI(Tl) radiation detector coupled to a handheld scaler/ratemeter	Gamma scan using a 2-inch by 2-inch Ludlum 44-10 NaI detector with a Ludlum Model 44-10 collimator and a Ludlum Model 3000 scaler/ratemeter, or equivalent	Specify shielding to provide a more accurate survey count rate that is representative of soil concentrations
	The distance between the paths will be approximately six feet.	The distance between the paths will be approximately three feet.	Decrease transect spacing to account for the smaller field of view of the shielded detector
8.1.2.2.2 Soil Sampling	Soil plugs will be collected from five evenly spaced locations across a 100 m^2 grid (5-point composite sampling)	Soil plugs will be collected from locations determined by ranking discrete static gamma counts in each 100 m^2 grid (Ranked Set Sampling)	Ranked Set Sampling will replace 5-point composite sampling for grids where soil samples are collected

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Section 5.0 References

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