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Title:	Sampling and Analysis Plan for Verification Sampling of LANL-Derived Residual Radionuclides in Soils within Tract A-18-2 for Land Conveyance
Author(s):	Ruedig, Elizabeth
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Sampling and Analysis Plan

for Verification Sampling of LANL-Derived Residual Radionuclides in Soils within Tract A-18-2 for Land Conveyance

August 2017

1.0 Overview

Public Law 105-119 directs the U.S. Department of Energy (DOE) to convey or transfer parcels of land to the Incorporated County of Los Alamos or their designees and to the Department of Interior, Bureau of Indian Affairs, in trust for the Pueblo de San Ildefonso. Los Alamos National Security is tasked to support DOE in conveyance and/or transfer of identified land parcels no later than September 2022. Under DOE Order 458.1, *Radiation Protection of the Public and the Environment* (O458.1, 2013) and Los Alamos National Laboratory (LANL or the Laboratory) implementing Policy 412 (P412, 2014), real property with the potential to contain residual radioactive material must meet the criteria for clearance and release to the public.

This Sampling and Analysis Plan (SAP) is a second investigation of Tract A-18-2 for the purpose of verifying the previous sampling results (LANL 2017). This sample plan requires 18 project-specific soil samples for use in radiological clearance decisions consistent with LANL Procedure ENV-ES-TP-238 (2015a) and guidance in the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM, 2000). The sampling work will be conducted by LANL, and samples will be evaluated by a LANL-contracted independent lab. However, there will be federal review (verification) of all steps of the sampling process.

2.0 Background for A-18-2

2.1 Site location

Site Location and History

Tract A-18-2 is located in Bayo canyon, northeast of Los Alamos County's wastewater treatment plant (Figure 1). The Tract is situated in Santa Fe County and is adjacent to property owned by Los Alamos County and land held in trust for the Pueblo de San Ildefonso by the Bureau of Indian Affairs. It is in Bayo canyon downstream (east) of the historic Technical Area 10, which was conveyed to Los Alamos County in 1967 (Ferenbaugh et al, 1982).

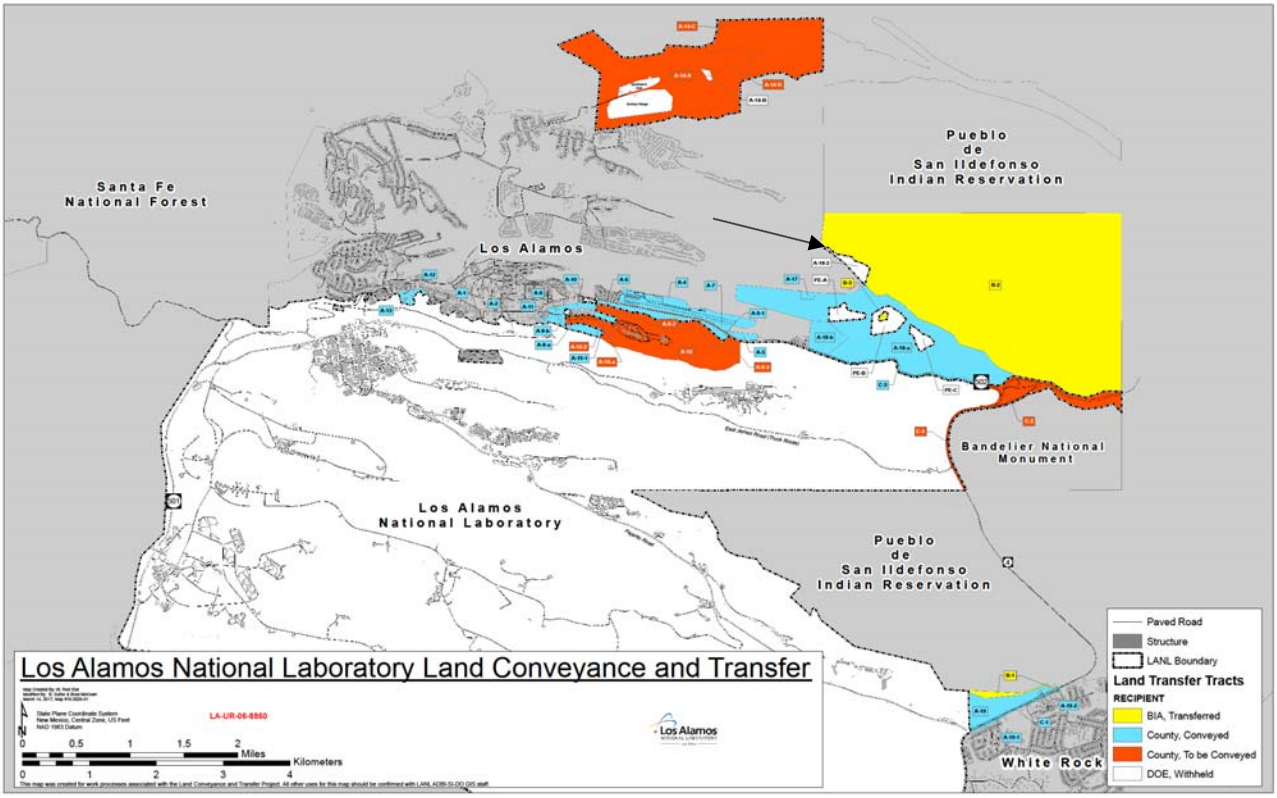

Figure 1. Arrow points to Tract A-18-2

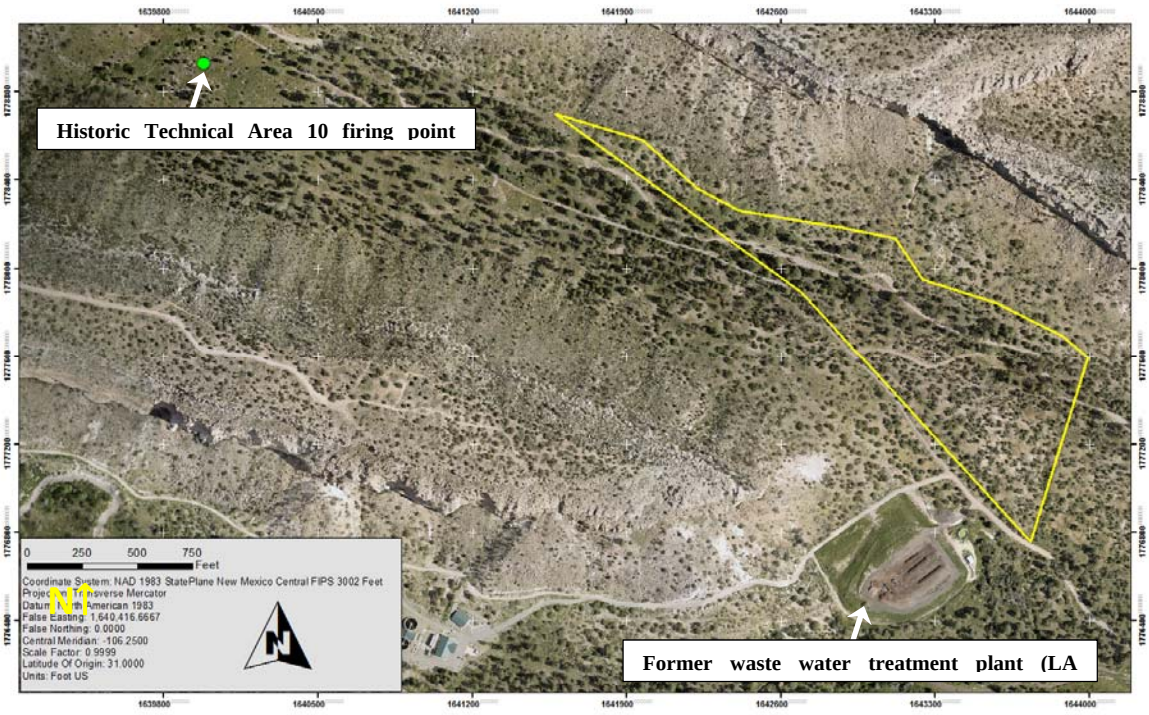

Figure 2. Aerial view of Tract A-18-2 (yellow outline) and its spatial relation to Los Alamos County's former waste water treatment plant and the historic Technical Area 10 firing point. ***Note***: Map locations and boundaries are approximate and subject to change.

2.2 General history

Historical records indicate that the Lab has never had operations on Tract A-18-2 (except for a groundwater monitoring well). However, the historic TA-10 firing site and radiochemical laboratory were located upstream of Tract A-18-2 in Bayo canyon (see Fig 1). TA-10 was the site of the RaLa (Radioactive Lanthanum) experiments in the 1940s and 1950s, which involved the atmospheric dispersion of large amounts of lanthanum-140 as part of the development of early plume models. Due to lanthanum-140's short half-life (40.2 days), none of this material remains in Bayo canyon today. However, the lanthanum also contained trace strontium-90 as a radiochemical impurity and measurable strontium-90 remains in the environment near the RaLa/TA-10 site, which has been remediated several times (Blackwell 1963, LANL 1990, LANL 1995, LANL 1996). The northern extent of Tract A-18-2 is about 500m east of the TA-10 firing point.

2.3 Current use

Tract A-18-2 is unoccupied, vacant land. The only structure or facility on the Tract is a groundwater monitoring well.

2.4 Historical evaluation of LANL radiological impact

The Bayo canyon drainage is considered an Area of Concern (AOC), labeled C-00-004, and runs through the center of Tract A-18-2. C-00-004 is the ephemeral streambed at the bottom of Bayo canyon. Areas of Concern have the potential to contain residual radioactive material (in this case, due to downstream transport of Sr-90 from the RaLa site) but measurements may not have confirmed the AOC's status. Previous measurements taken by LANL (2017) have not detected elevated levels of LANL-derived radionuclides within the A-18-2 streambed or within the Tract as a whole.

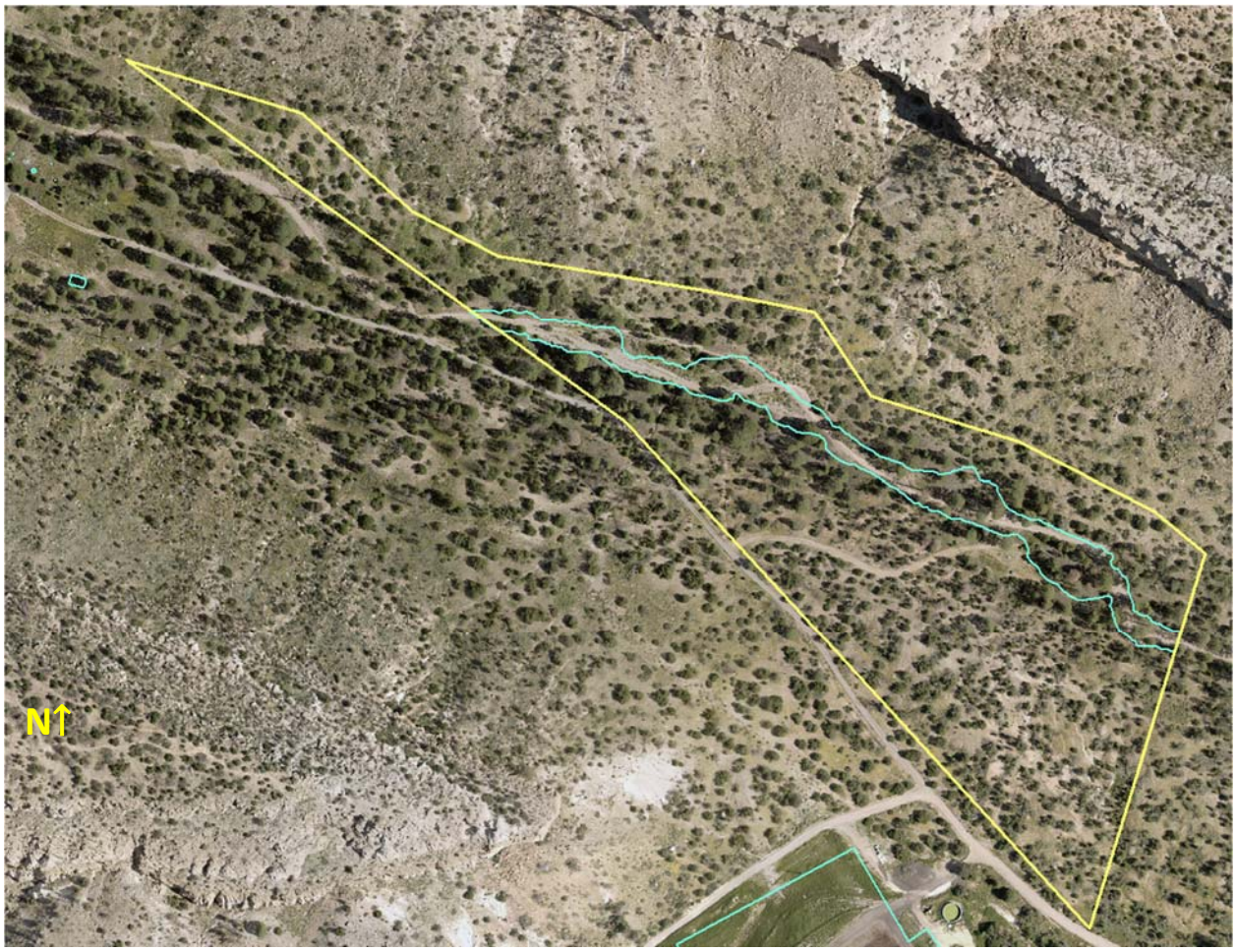

Figure 2. Area of Concern C-00-004 (blue), located within Tract A-18-2 (yellow). Also visible is AOC 00-018(b) to the southwest – the County's former waste water treatment plant, and several small PRSs west of the Tract associated with the former-TA-10/RaLa experiments.

2.4.1 Adjacent properties with known or suspected subsurface radioactivity

Both subsurface and surface radioactivity remain in the land northwest of Tract A-18-2, as a result of legacy experiments which released strontium-90 into the environment (see section 2.2).

2.5 Preliminary results from process knowledge and surveys for residual radioactivity

Guidance from MARSSIM (2000) was used to develop this SAP in conjunction with the results of previous sampling within Tract A-18-2 (LANL 2017). The site was evaluated as MARSSIM class 3.

3.0 Data Quality Objectives

3.1 Objective of the SAP

The objective of this SAP is to confirm, within the stated statistical confidence limits, that the mean levels of radioactive residual contamination in soils in A-18-2 are documented in appropriate units and estimated doses are below the dose limits of 25 mrem/y (250 µSv/y) for public release of real property.

3.2 Decision identification

The principle study question is: Does the residual radioactive contamination exceed ALs for the proposed exposure scenario the decision area? The decision alternatives are:

- If results from the soil radioactive contamination measurements are at or above the AL (collectively), then the site is not a candidate for land transfer.
- If results from the soil radioactive contamination measurements are below the AL (collectively), then the site is a candidate for land transfer.

3.3 Inputs into the decision

Recreational future-use scenarios were assumed for the purpose of selecting ALs and defining the MARSSIM Upper Bound of the Gray Region. 25 mrem/y (250 µSv/y) was the assumed dose constraint.

Data to be used in the analysis include surface soil/sediment concentration measurements for radionuclides. The unity (sum of fractions) rule will be applied. The formula for the unity rule is:

$$\frac{C_1}{AL_1} + \frac{C_2}{AL_2} + \frac{C_3}{AL_3} \ldots\ldots \frac{C_n}{AL_n} \leq 1$$

where $C_{1\text{-}n}$ and $AL_{1\text{-}n}$ are the upper-bound estimates of the mean concentrations for radionuclides (e.g., upper 95% values) and Authorized Limits 1 through n, respectively.

3.4 Study boundaries

The study is limited to Tract A-18-2, as identified in Figure 1. Analysis for samples from this Tract will include gamma spectroscopy (EPA 901.1, EPA 1980a) and radiochemical analysis for strontium-90 (EPA 905.0, EPA 1980b).

3.5 Decision rule

A-18-2 will be analyzed as a single decision area. The decision rule is based on the following:

- Null hypothesis: mean residual contamination levels in soil/sediment in the decision area combined over all radionuclides is *at* or *above* the AL and *likely* to result in an all-pathway radiation dose to the receptor above 25 mrem/yr (250 μSv/y)
- Alternative hypothesis: mean residual contamination levels in soil/sediment in the decision area combined over all radionuclides is *below* the AL and *not likely* to result in an all-pathway radiation dose to the receptor above 25 mrem/yr (250 μSv/y).

3.6 Limits on decision errors

The distribution for the preliminary data is *not* assumed to be normal. The acceptable statistical errors for this analysis are:

- Type 1 error less than 0.05 (incorrectly reject null hypothesis, i.e., conclude contamination level is less than the AL when in fact it is than the AL)
- Type 2 error less than the 0.1 (incorrectly fail to reject null hypothesis, i.e., conclude soil contamination level is greater than the AL when in fact it is less than the AL)

3.7 Optimization and evaluation for number of samples required

Previous sampling (LANL 2017) within A-18-2 indicated that mean concentration of strontium-90 (the radionuclide of primary concern) within the Tract was 0.051 pCi/g, with a standard deviation of 0.181 pCi/g. Tract A-18-2 will be transferred under the recreational future-use scenario, and LANL's AL for this scenario/radionuclide combination is 12,000 pCi/g (LANL 2016). Combining this information with the decision error limits, MARSSIM requires 11 samples. Even evaluating the existing conditions against the most-restrictive residential future-use scenario (36 pCi/g), MARSSIM still requires that 11 randomly gridded samples be taken. We propose to collect 18 total samples as part of this independent verification: 12 gridded, predetermined samples, and 6 biased samples to be field-located. VSP plotted 12 samples to optimize the triangular-grid pattern, even though MARSSIM statistics require only 11 samples. All calculations were performed by VSP (VSP Development Team 2015), and a pre-generated VSP report is included as Attachment 1 to this SAP.

3.9 Statistical evaluation of the survey results

All the applicable data that has passed the MQO evaluation will be used to determine the upper-bound estimate of the mean for soil concentrations (generally, the 95% value) for each radionuclide. The EPA software ProUCL (2013) will be used to determine this value. The statistical decision as to whether the residual soil contamination levels (i.e., the 95% UCLs) are below the ALs will be evaluated using the following criteria. All analyses and results will be documented.

Decision Criteria:

1) If all individual sample results are ≤ the AL, then no further action is required and the site passes the criteria for the specific use.
2) If all individual samples or the UCL are > the AL, then the site is not a candidate for release and site remediation followed by resampling is necessary before the Tract can be released.

3) If the UCL is below the AL but some individual measurements are above the AL, then statistical analysis is needed. Non-parametric statistical approaches will be used to evaluate the null hypothesis. If contamination is present in background, the Wilcoxon Rank Sum test is used, and if contamination is not present in background or very low relative to the AL, the Sign Test is used. For this Tract, the Sign Test will be used with a $p < 0.05$ decision threshold for significance. See MARSSIM Chapter 8 for details and examples (2000).
4) Alternatively, one could confirm that the ratio of the 95% UCL of the average concentration divided by the AL and the sum of hot spot activity ratios do not exceed unity:

$$\frac{\overline{C}_{UCL}}{C_{AL}} + \sum_{i=1}^{n} \frac{C_{i,C>AL}}{C_{AL} * AF} \leq 1$$

Here $\overline{C}_{UCL}$ is the 95% upper bound estimate of the concentration mean, C_{AL} is the AL (25 mrem/yr (250 μSv/y)), $C_{i,c>AL}$ is the sample concentration for a single sample above the AL (i.e., has elevated measured concentrations), and AF is the Area Factor [ratio of effective dose calculated for area of contamination normalized to effective dose calculated for 10,000 m^2 (RESRAD default)]. If the result of this calculation is > 1, the site is a candidate for further characterization of the nature and extent of the contamination, remediation of the site, follow up confirmatory sampling, and reanalysis against the decision criteria in this section. Area Factors are dependent on the exposure scenario and should be calculated individually.
5) If there are multiple radionuclides (i) being evaluated in a sampling unit, the sum of the ratios should be less than or equal to 1.
6) The dose assessment based on the soil measurements will include the sum of doses from all radionuclides, and this sum will be compared to the 3 mrem/yr (30 μSv/yr) threshold for follow-up ALARA analysis.

4.0 Measurement Quality Objectives (MQOs) and applicable procedures

4.1 MQOs

1) Detection Capability: Minimum Detection Concentration should be below the MARSSIM-defined Upper Bound of the Gray Region (i.e. AL for the radionuclide of interest).
2) The degree of measurement uncertainty (combined precision and bias) should be reported and the level should be reasonable relative to the needed accuracy of the decision and accounted for in the statistical analysis.
3) Range of the instrument and measurement technique should be appropriate for the concentrations expected.
4) The instrument and measurement technique should be specific for the radionuclide(s) being measured. Specificity is the ability of the measurement method to measure the radionuclide of concern in the presence of interferences.
5) For field instruments, the instrument should be rugged enough to consistently provide reliable measurements. However, in this case, all samples will be analyzed in the laboratory.

4.2 Procedures used to meet these MQOs

1) Collection of valid soil sample appropriate for the dose assessment,
    a. ENV-ES-TP-006 (2015b) *Sampling soil and vegetation at facility sites.*
    b. QAPP-0001 (2008) *Quality and assurance project plan for the soils, foodstuffs, and non-foodstuff biota monitoring project.*
2) Soil sample analysis will use EPA-approved analytical procedures for each radionuclide. The following will be used by the independent laboratory:
    a. EPA Method 901.1 *Gamma emitting radionuclides in drinking water* (EPA 1980a)
    b. EPA Method 905.0 *Radioactive strontium in drinking water* (EPA 1980b)

After the measurements are completed, the laboratory results in units equivalent to the ALs will be evaluated with respect to the MQOs, as stated above.

5.0 Results of the analysis for sampling number and locations

12 randomly-gridded soil samples will be collected, along with 6 samples collected at bias locations, as determined by the field team. VSP was used to plan sample locations.

Predetermined sample locations may be field-relocated for safety or other reasons (such as moving a sampling location off of a rock-outcropping), at the discretion of the sampling team.

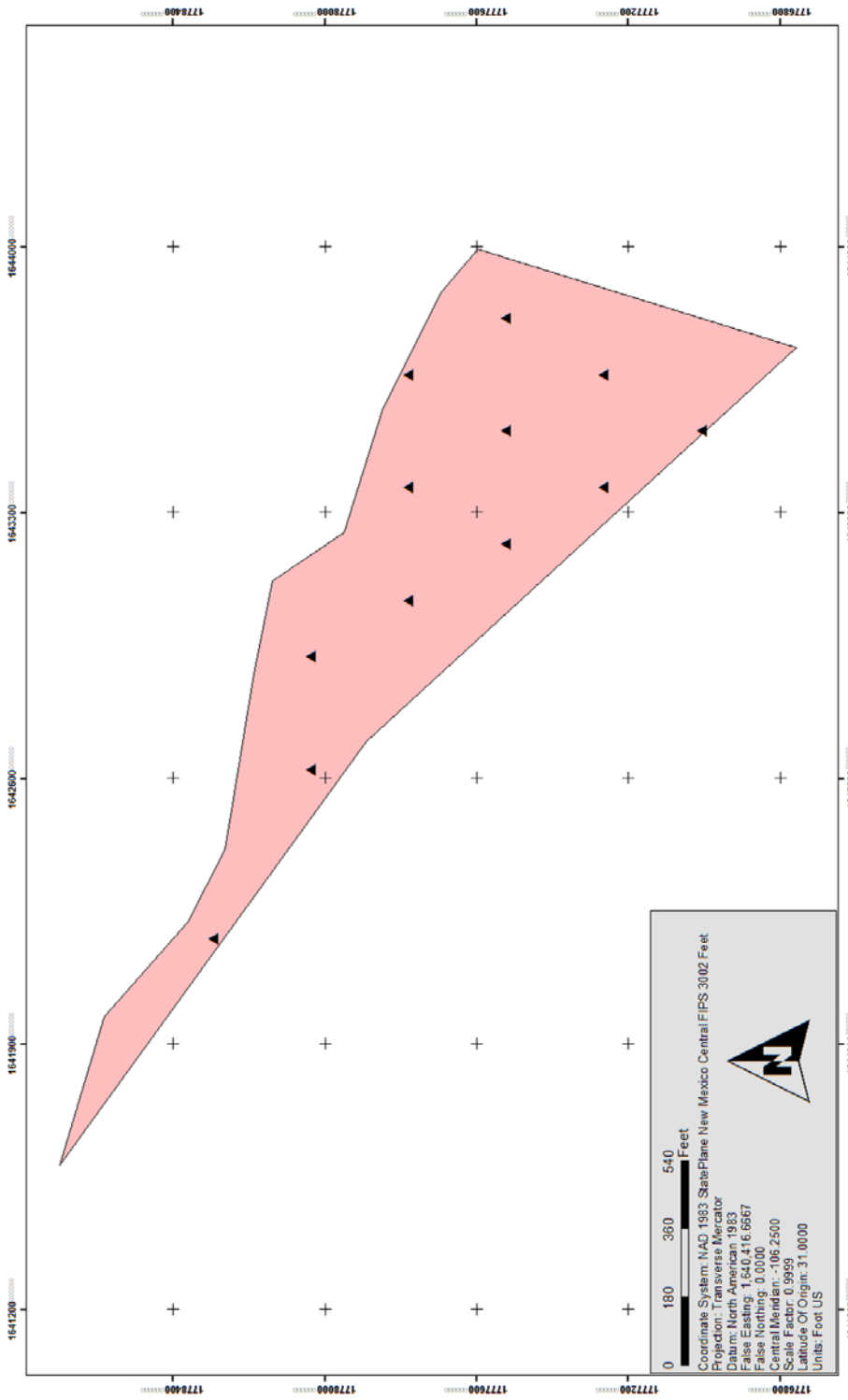

Figure 3. General locations of the 11 grid samples (triangles) in A-18-2. Additionally, 7 biased samples will be collected at locations determined by the field team.

Table 1. Sample locations in NAD1983, NM State Plate Central, ft.

#	Label	Type	X Coordinate	Y Coordinate
1	Random-1	Random Grid	1643515	1777009
2	Random-2	Random Grid	1643367	1777266
3	Random-3	Random Grid	1643664	1777266
4	Random-4	Random Grid	1643218	1777524
5	Random-5	Random Grid	1643515	1777524
6	Random-6	Random Grid	1643813	1777524
7	Random-7	Random Grid	1643069	1777781
8	Random-8	Random Grid	1643367	1777781
9	Random-9	Random Grid	1643664	1777782
10	Random-10	Random Grid	1642623	1778039
11	Random-11	Random Grid	1642920	1778039
12	Random-12	Random Grid	1642177	1778297
13	Bias-1	Bias	TBD	TBD
14	Bias-2	Bias	TBD	TBD
15	Bias-3	Bias	TBD	TBD
16	Bias-4	Bias	TBD	TBD
17	Bias-5	Bias	TBD	TBD
18	Bias-6	Bias	TBD	TBD

6.0 References

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Attachment 1: *VSP Report*

Attachment 1: *VSP Report*

Systematic sampling locations for comparing a median with a fixed threshold (nonparametric - MARSSIM)

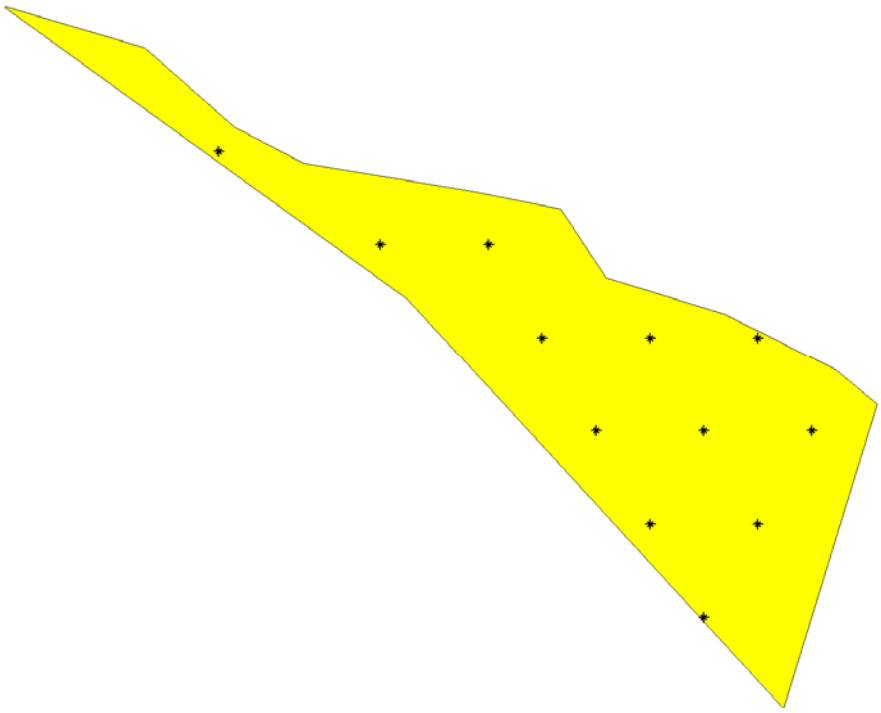
Summary

This report summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design developed. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean or median to a fixed threshold
Type of Sampling Design	Nonparametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The median(mean) value at the site exceeds the threshold
Formula for calculating number of sampling locations	Sign Test - MARSSIM version
Calculated number of samples	9
Number of samples adjusted for EMC	9
Number of samples with MARSSIM Overage	11
Number of samples on map [a]	12
Number of selected sample areas [b]	1
Specified sampling area [c]	1019960.56 ft^2
Size of grid / Area of grid cell [d]	297.466 feet / 76631.1 ft^2
Grid pattern	Triangular

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid cell gives the linear and square dimensions of the grid used to systematically place samples.



Area: Area 1						
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**	**Sample Area**
1643515.4364	1777008.7810			Systematic		
1643366.7034	1777266.3941			Systematic		
1643664.1694	1777266.3941			Systematic		
1643217.9704	1777524.0072			Systematic		
1643515.4364	1777524.0072			Systematic		
1643812.9024	1777524.0072			Systematic		
1643069.2373	1777781.6203			Systematic		
1643366.7034	1777781.6203			Systematic		
1643664.1694	1777781.6203			Systematic		
1642623.0383	1778039.2334			Systematic		
1642920.5043	1778039.2334			Systematic		
1642176.8393	1778296.8466			Systematic		

Primary Sampling Objective
The primary purpose of sampling at this site is to compare a site median or mean value with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the median(mean) value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the median(mean) value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative one, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A nonparametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A nonparametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that typical parametric assumptions may not be true.

Both parametric and non-parametric equations rely on assumptions about the population. Typically, however, non-parametric equations require fewer assumptions and allow for more uncertainty about the

statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than if a non-parametric equation was used.

VSP offers many options to determine the locations at which measurements are made or samples are collected and subsequently measured. For this design, systematic grid point sampling was chosen. Locating the sample points systematically provides data that are all equidistant apart. This approach does not provide as much information about the spatial structure of the potential contamination as simple random sampling does. Knowledge of the spatial structure is useful for geostatistical analysis. However, it ensures that all portions of the site are equally represented. Statistical analyses of systematically collected data are valid if a random start to the grid is used.

Nuclides
The following table summarizes the analyzed nuclides.

Nuclides Analyzed by Study		
Nuclide	**$DCGL_W$**	**$DCGL_{EMC}$**
Analyte 1	36	

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Sign test (see PNNL 13450 for discussion). For this site, the null hypothesis is rejected in favor of the alternative one if the median(mean) is sufficiently smaller than the threshold. The number of samples to collect is calculated so that if the inputs to the equation are true, the calculated number of samples will cause the null hypothesis to be rejected.

The formula used to calculate the number of samples is:

$$n = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4(SignP - 0.5)^2}$$

where

$$SignP = \Phi\left(\frac{\Delta}{s_{total}}\right)$$

$\Phi(z)$ is the cumulative standard normal distribution on $(-\infty,z)$ (see PNNL-13450 for details),
n is the number of samples,
S_{total} is the estimated standard deviation of the measured values including analytical error,
Δ is the width of the gray region,
α is the acceptable probability of incorrectly concluding the site median(mean) is less than the threshold,
β is the acceptable probability of incorrectly concluding the site median(mean) exceeds the threshold,
$Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is $1-\alpha$,
$Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is $1-\beta$.

Note: MARSSIM suggests that the number of samples should be increased by at least 20% to account for missing or unusable data and uncertainty in the calculated value of n. VSP allows a user-supplied percent overage as discussed in MARSSIM (EPA 2000, p. 5-33).

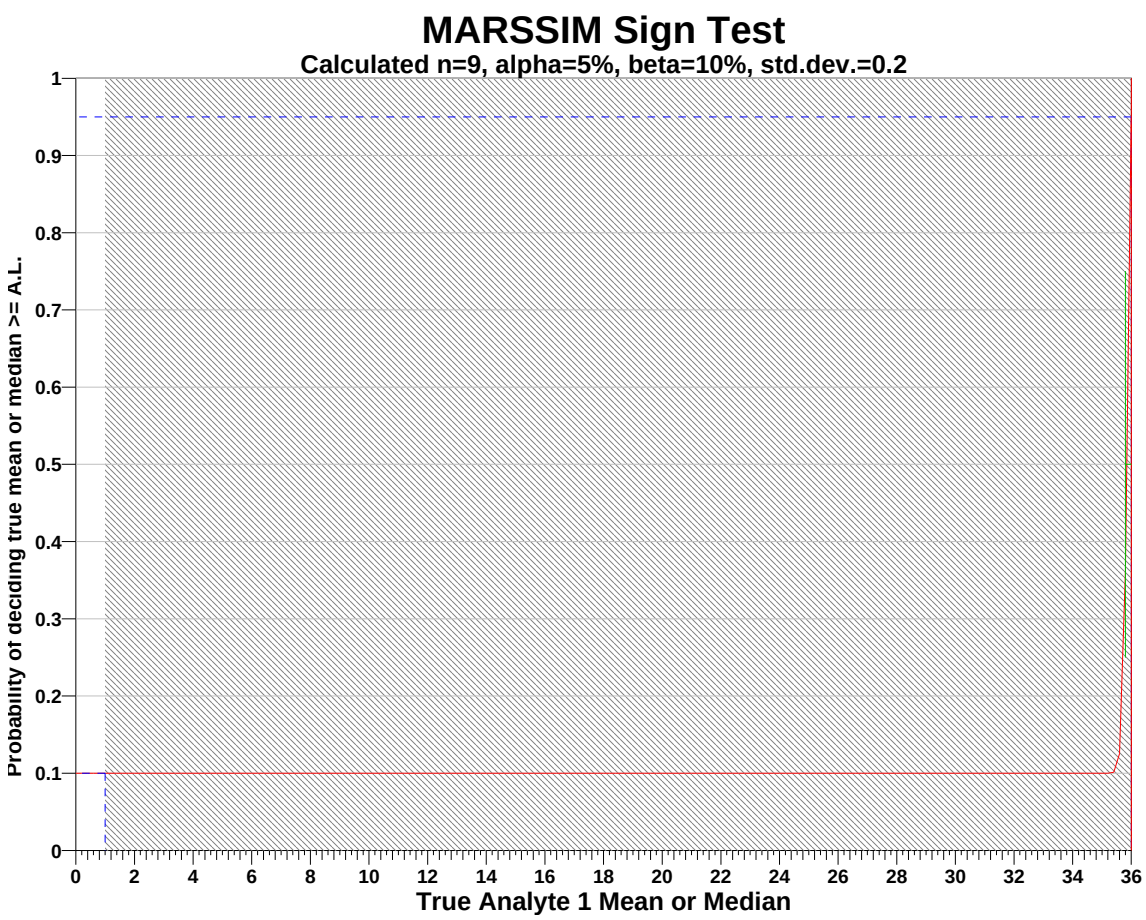
For each nuclide in the **Nuclides Analyzed by Study** table, the values of these inputs that result in the calculated number of sampling locations are:

Nuclide	n^a	n^b	n^c	Parameter					
				S	Δ	α	β	$Z_{1-\alpha}$ [d]	$Z_{1-\beta}$ [e]
Analyte 1	9	9	11	0.2	35	0.05	0.1	1.64485	1.28155

[a] The number of samples calculated by the formula.
[b] The number of samples increased by EMC calculations.
[c] The final number of samples increased by the MARSSIM Overage of 20%.
[d] This value is automatically calculated by VSP based upon the user defined value of α.
[e] This value is automatically calculated by VSP based upon the user defined value of β.

Performance
The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true median(mean) values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at 1-α on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at 1-α. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions

The assumptions associated with the formulas for computing the number of samples are:

1. the computed sign test statistic is normally distributed,
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis

The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that $\mu >$ action level and alpha (%), probability of mistakenly concluding that $\mu <$ action level. The following table shows the results of this analysis.

Number of Samples							
AL=36		α=5		α=10		α=15	
		s=0.4	s=0.2	s=0.4	s=0.2	s=0.4	s=0.2
LBGR=90	β=5	14	14	11	11	10	10
	β=10	11	11	9	9	8	8
	β=15	10	10	8	8	6	6
LBGR=80	β=5	14	14	11	11	10	10
	β=10	11	11	9	9	8	8

	β=15	10	10	8	8	6	6
LBGR=70	**β=5**	14	14	11	11	10	10
	β=10	11	11	9	9	8	8
	β=15	10	10	8	8	6	6

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Note: values in table are note adjusted for EMC