LA-UR-12-26429
Approved for public release; distribution is unlimited.

Title:	Dose Assessment of LANL-Derived Residual Radionuclides in Soils Within Tract A-8-b for Land Transfer Decisions
Author(s):	Whicker, Jeffrey J
Intended for:	Report Environmental Programs

Dose Assessment of LANL-Derived Residual Radionuclides in Soils Within Tract A-8-b for Land Transfer Decisions

October 2012-Final

1.0 Background for A-8-b Dose Assessment

1.1 Site Location[1]

The Land Conveyance and Transfer A-8-b sub-parcel (Tract A-8-b) is a portion of DP Road-1 South Tract lying entirely to the south of DP Road and to the west of Material Disposal Area (MDA) B and along the northeast boundary with Tract A-8-a (Figure 1). The DP Road-1 South Tract is located along DP Road between the western boundary of Technical Area (TA) 21 and the major commercial districts of the Los Alamos townsite. Access onto the site is from DP Road.

Both commercial and Los Alamos National Laboratory (LANL) properties lie immediately north of Tract A-8-b. LANL properties include a storage facility and machine shop building located in Tract A-11 (previously conveyed to Los Alamos County). Los Alamos Canyon abuts A-8-a on the south side (previously conveyed to the Los Alamos School Board). Adjacent properties include MDA B, which is identified in LANL records as Potential Release Site (PRS) 21-015 and there are several Solid Waste Management Units (SWMUs) and an Area of Concern (AOC) in Tract A-8-a. Recent and past activities within these adjacent properties potentially impacted Tract A-8-b. The legal property boundary description of DP Road-1 South Tract is provided by the US Army Corps of Engineers' *Land Survey Plat, Los Alamos National Laboratory, Tract A-8, Being a Part of DP Road Site, Los Alamos, New Mexico*, recorded by the Los Alamos County Clerk on March 18, 2003.

1.2 Sampling and Analysis Plan

The sampling and analysis plan (SAP) for Tract A-8-b (Appendix A) was developed using a MARSSIM (MARSSIM 2000) approach, as required in DOE O 458.1 and LANL procedures (LANL 2012a, b). The objective of the SAP was to confirm, within the stated statistical confidence limits, that the mean levels of potential radioactive residual contamination in soils in Tract A-8-b are documented, in appropriate units, and are below the 15 mrem yr^{-1} Screening Action Levels (SALs), as derived in LANL (2005). The sampling and analysis plan (SAP) for Tract A-8-b followed the LANL (2012a) procedure EDA-QP-238, "Dose assessment data quality objectives for land transfers into the public domain." The coordinates and depths for the sampling locations are provided in Table 1.

1.2.1Preliminary Results from Surveys for Residual Contamination

As detailed in the Sampling and Analysis Plan (SAP) for Tract A-8-b, previous measurements of soil concentrations were used as preliminary data used to determine the potential for soil contamination in the tract and the standard deviation was used in the Sign Test to determine the number of samples required in the final survey of tract A-8-b, as outlined in MARSSIM.

The preliminary analysis showed soil concentrations are near background levels and significantly below the SALs for each specific radionuclide (Table 2). This preliminary data set suggested that the tract met the criteria for a Class 3 area under MARSSIM (impacted by LANL operations, but soil is expected to be near background values). However, in consideration of historical use,

[1] Text modified slightly from Pope, J., Smith, V., Swanton, B., Schumann, P.B. 2007. Environmental Baseline Survey for A-8-a Subparcel, DP Road-1 south tract. Los Alamos National Laboratory report LA-UR-07-0136. Also see final draft (LANL 2012c).

proximity to MDA-B where higher soil concentrations were found, and a likely possibility of residential use in the future, Tract A-8-b was classified as a Class 2 area under MARSSIM, effectively requiring double the number of samples. As a Class 2 area under residential use, Tract A-8-b was divided into two approximately 10,000 m^2 sections and sampling locations were randomly selected in each section. Surface soils (0 -1 ft) were collected at each location and soil samples from deeper soils were collected from every other location on the tract. Details are provided in the SAP (Appendix A).

1.3 Statistical Analysis

The principle study question was: Does the residual radioactive contamination exceed Authorized Limits (ALs), individually or collectively, for the residential exposure scenario?

The decision alternatives were:

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

The decision rule was based on the null hypothesis that the mean residual contamination levels in soil and/or sediment in Tract A-8-b, individually or combined over all radionuclides, are above the ALs and likely to result in an all pathway radiation dose to the critical receptor above 15 mrem yr^{-1}. The alternative hypothesis is that the mean residual contamination levels in soil and/or sediment in Tract A-8-b, individually or combined over all radionuclides, is below the AL and unlikely to result in an all pathway radiation dose to the critical receptor above 15 mrem yr^{-1}.

The assumed future land use and exposure pathway assumes residential use. The radionuclides analyzed for and the respective residential AL are provided in Table 2. The 15 mrem yr^{-1} ALs used in this analysis were calculated using RESRAD (RESRAD 2001) and documented in LANL (2005).

1.3.1 Statistical Evaluation of the Survey Results

All the applicable data that has passed the Measurement Quality Objective (MQO) evaluation will be used to determine the upper-bound confidence level (UCL) estimate of the mean for soil concentrations (generally, the 95 percent value) for each radionuclide. The EPA software ProUCL (EPA 2010) was used to determine the UCLs. The data for Am-241 concentrations were based only on gamma-spectral analysis because of inadequate chemical recovery for the alpha spectral analysis done at the independent laboratory. The Am-241 gamma spectral analysis measurements did pass DQOs, as required for the comparisons to the ALs. U-235 was also measured with both alpha and gamma spectral analysis, but for this radionuclide, the results from the alpha-spectral analysis were used because the chemical recoveries were adequate and the detection levels were lower.

The statistical decision as to whether the residual soil contamination levels (i.e., the 95 percent UCLs) are below the authorized limits and were evaluated using the following criteria.

Decision Criteria:

1) If all samples are ≤ residential ALs, then no further action is required and the site passes the criteria for residential occupation. No further actions are needed.
2) If all samples or the UCL are > the AL, then the site is not a candidate for release and site remediation is needed followed by resampling before it can be released.
3) If the UCL is below the AL but some individual measurements are above the AL, then statistical analysis is needed. Generally, non-parametric statistical approaches are used to evaluate the null hypothesis. If contamination is present in background, the Wilcoxon Rank Sum test is suggested, and if contamination is not present in background or very low relative to the AL, use the Sign Test. For Tract A-8-B, the Sign Test will be used with a $p < 0.05$ decision threshold for significance. See MARSSIM chapter 8 for details and examples.
4) Because of multiple radionuclides, we also tested that the ratio of the upper-confidence level (UCL) of the average concentration divided by the AL and the sum of the ratios did not exceed 1, as show in eqn. 1. Because there was no indication or reasonable physical mechanism to create hot spots, we assumed that the contamination was homogeneously distributed across the tract.

$$\sum_{i-1}^{n} \frac{\overline{C}_{UCL,i}}{C_{AL}} \leq 1 \qquad \text{(eqn.1)}$$

Here $\overline{C}_{UCL}$ is the 95 percent upper bound estimate of the concentration mean, C_{AL} is the resident AL (15 mrem yr^{-1}).

1.3.2 ALARA Evaluation

LANL policy P410 "Los Alamos National Laboratory Environmental ALARA Program" (LANL 2011) requires an ALARA evaluation based on procedure SOP-5254 "Performing ALARA Analysis for Public Exposures" (LANL 2009). If the calculated individual dose exceeds 3 mrem yr^{-1}, then a quantitative ALARA evaluation is performed.

1.4 Instrumentation and Measurement Quality Objectives

The main objectives are to determine appropriate analysis technique for each radionuclide and ensure Measurement Quality Objectives (MQOs) are satisfied. One should be confident that the measurement results are valid and appropriate for the decisions being made.

1.4.1 Measurement Quality Objectives:

- Detection Capability: Minimum Detection Concentration (MDC) should be below the MARSSIM defined Lower Bound of the Gray Region (LBGR).
- The degree of measurement uncertainty (combined precision and bias) should be reported and the level reasonable relative to the needed accuracy of the decision and accounted for in the statistical analysis.
- Range of the instrument and measurement technique should be appropriate for the concentrations expected.

- 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.

- 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.

2.0 Results and Analyses of Measurements

Tables 3 and 4 provide the measurements of soil concentrations for the randomly selected locations. Averages, standard deviations, 95 percent UCLs, and ALs for each of the radionuclides are also provided in these tables. Results show that all radionuclides were at (within 2 standard deviations) or below regional background soil concentrations and that all concentrations were below the ALs and meet the real property release criteria. Combining all radionuclides by using Eqn. 1, the sum of the ratios of the 95 percent UCL without background subtraction divided by the ALs was 0.046 and 0.035 for the surface and at depth samples, respectively. This translated to a potential dose to a hypothetical resident of 0.7 mrem yr^{-1} for surface soils and 0.52 mrem yr^{-1} for deeper soil. If surface soil results are combined with depth soils, the potential dose is about 0.6 mrem yr^{-1}.

2.1 ALARA Analysis

Tables 3 and 4 show that the estimated dose was 0.7 and 0.5 mrem yr^{-1} for samples collected on the surface and at depth, respectively. Because these doses do not exceed the threshold of 3 mrem yr^{-1} for performing a quantitative ALARA analysis, no further ALARA analysis is required in accordance with PD410, Los Alamos National Laboratory Environmental ALARA Program, and the calculated doses of 0.7 and 0.5 mrem yr^{-1} (or the combined dose of 0.6 mrem yr^{-1}) are therefore considered ALARA.

2.2 Quality Assurance

Soils were collected according to procedures and the laboratory analysis techniques were appropriate for the specific radionuclides, as required in the SAP for A-8-b (Appendix A). The analysis at the independent laboratory was within their predefined boundaries and met all quality assurance requirements. Only qualified data was used in this analysis and minimum detectable concentrations were below the LBGR. Thus, all measurement quality objectives were met for this data set.

2.3 Conclusion

Given that 1) all the measurements were below the ALs for each individual radionuclide, 2) the sum of the ratios was below 1, and 3) the resulting combined calculated dose was less than the 15 mrem yr^{-1} for a hypothetical resident, we conclude that Tract A-8-b is a candidate for conveyance to the public for residential use.

3.0 REFERENCES

EPA (Environmental Protection Agency), 2010. ProUCL Version 4.1 User Guide (draft). EPA/600/R-07/041.

LANL (Los Alamos National Laboratory), 2005, "Derivation and Use of Radionuclide Screening Action Levels, Revision 1." (LA-UR-05-1849, ER2005-0127)

LANL (Los Alamos National Laboratory), 2009. Performing ALARA Analysis for public Exposures. ENV-ES procedure SOP-5254. Document can be found at web site address: http://www.lanl.gov/community-environment/environmental-stewardship/_assets/docs/qa/dose-assessment/SOP-5254.pdf verified 20 Sept. 2012.

LANL (Los Alamos National Laboratory), 2011. ALARA Policy P410 Los Alamos National Laboratory Environmental ALARA Program. Document can be found at web site address https://policy.lanl.gov/pods/policies.nsf/LookupDocNum/PD410/$file/PD410.pdf verified 20 Sept. 2012.

LANL (Los Alamos National Laboratory), 2012a. Dose assessment data quality objectives for land transfers into the public domain. LANL procedure EDA-QP-238.

LANL (Los Alamos National Laboratory) 2012c, Environmental Baseline Survey Report for Land Conveyance of Tract A-8-b Sub-parcel DP Road-1 South Tract. LA-UR-12-24508.

LANL (Los Alamos National Laboratory) 2012b. Environmental Radiation protection. LANL Policy P412.

MARSSIM (Multi-Agency Radiation Survey and Site Investigation Manual), 2000. NUREG-1575, EPA 402-R-97 Rev.1, DOE/EH-0624, Rev.1

Pope, J., Smith, V., Swanton, B., Schumann, P.B. 2007. Environmental baseline survey for A-8-a Subparcel, DP Road-1 south tract. Los Alamos National Laboratory draft report LA-UR-07-0136.

RESRAD, 2001. User's manual for RESRAD Version 6.0. Argonne National Laboratory Report ANL/EAD-4.

Ryti, R.T., Longmire, P.A., Broxton, D.E., Reneau, S.L., McDonald, E.V. 1998. Inorganic and radionuclide data for soils, canyon sediments, and Bandeleir tuff at Los Alamos National Laboratory. Los Alamos National Laboratory report LA-UR-4847.

Figure 1. Map of Tract A-8-b within PRS 21-021-99 and showing specific locations of SWMUs and AOCs (from Pope et al. 2007).

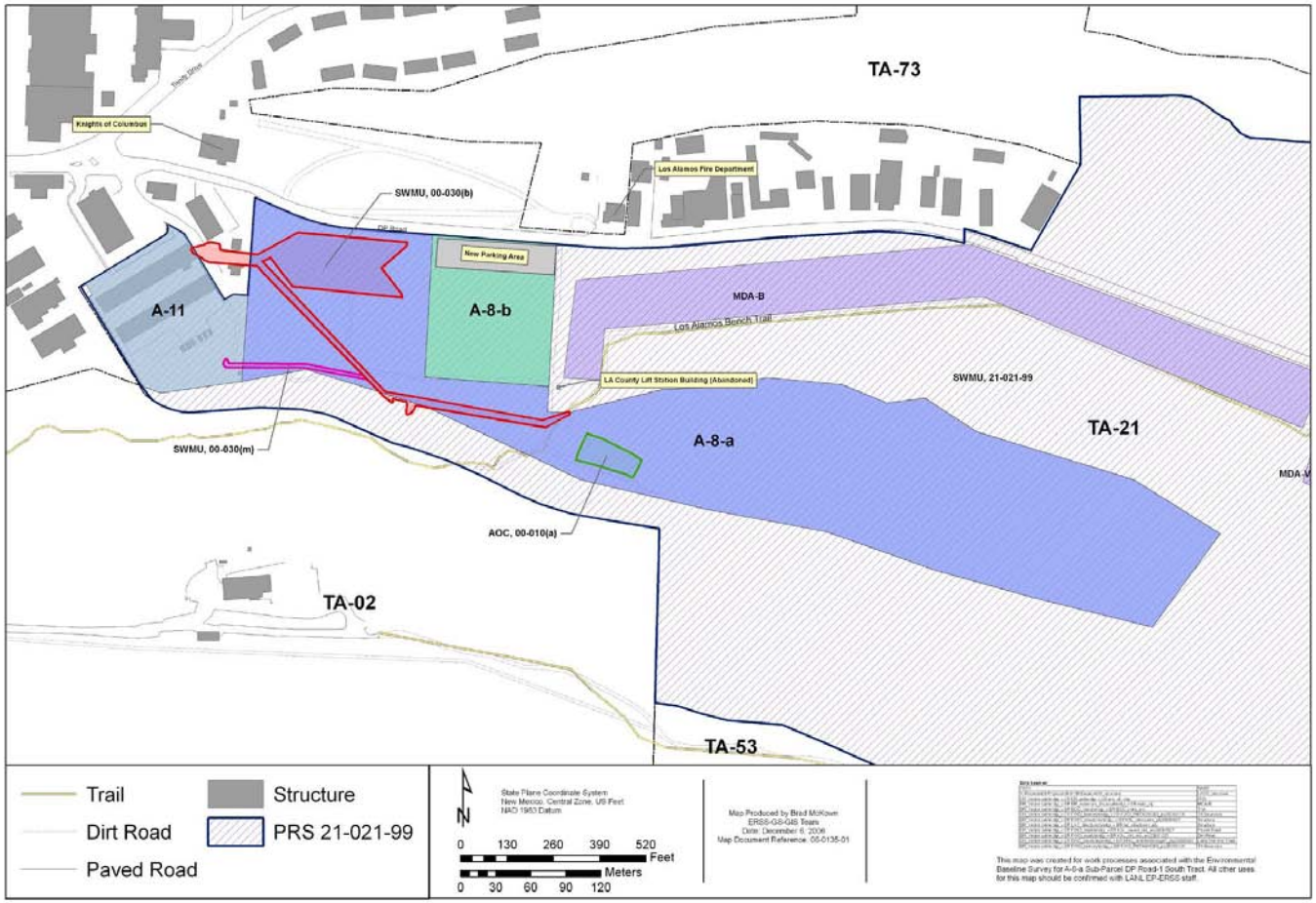


Table 1. Sample locations in Tract A-8-b. Upper and Lower samples (shaded rows) are from same location with the upper sample being a surface soil sample and the lower sample being taken at depth. All other samples were surface soil. FDUP designates field duplicate samples.

Sample ID	Y Coordinate	X Coordinate	Elevation (ft)	Parcel	Notes
RE21-12-21858	1775148.195	1628804.696	7233	A-8-b/DA1	UPPER
RE21-12-21859	1775148.195	1628804.696	7233	A-8-b/DA1	LOWER
RE21-12-21860	1775165.424	1628805.368	7234	A-8-b/DA1	
RE21-12-21861	1775204.827	1628873.349	7235	A-8-b/DA1	
RE21-12-21862	1775245.499	1628986.467	7233	A-8-b/DA1	UPPER
CARE-12-21915	1775245.499	1628986.467	7233	A-8-b/DA1	UPPER, FDUP
RE21-12-21863	1775245.499	1628986.467	7233	A-8-b/DA1	LOWER
RE21-12-21864	1775183.033	1629009.313	7231	A-8-b/DA1	UPPER
RE21-12-21865	1775183.033	1629009.313	7231	A-8-b/DA1	LOWER
RE21-12-21866	1775255.093	1628780.383	7237	A-8-b/DA1	
RE21-12-21867	1775215.268	1628845.405	7236	A-8-b/DA1	
RE21-12-21868	1775141.938	1628942.744	7230	A-8-b/DA1	UPPER
RE21-12-21869	1775141.938	1628942.744	7230	A-8-b/DA1	LOWER
CARE-12-21916	1775141.938	1628942.744	7230	A-8-b/DA1	LOWER, FDUP
RE21-12-21870	1775131.859	1628968.026	7161	A-8-b/DA1	
RE21-12-21871	1775116.117	1628895.852	7230	A-8-b/DA1	UPPER
RE21-12-21872	1775116.117	1628895.852	7230	A-8-b/DA1	LOWER
RE21-12-21873	1775092.078	1629034.236	7227	A-8-b/DA1	
RE21-12-21874	1775051.817	1628840.209	7230	A-8-b/DA2	UPPER
RE21-12-21875	1775051.817	1628840.209	7230	A-8-b/DA2	LOWER
RE21-12-21876	1774983.449	1628863.873	7229	A-8-b/DA2	UPPER
RE21-12-21877	1774983.449	1628863.873	7229	A-8-b/DA2	LOWER
RE21-12-21878	1775033.553	1628773.314	7232	A-8-b/DA2	
RE21-12-21879	1774998.544	1628727.84	7228	A-8-b/DA2	UPPER
RE21-12-21880	1774998.544	1628727.84	7228	A-8-b/DA2	LOWER
RE21-12-21881	1774975.9	1628931.471	7225	A-8-b/DA2	
RE21-12-21882	1775027.088	1628976.957	7223	A-8-b/DA2	
RE21-12-21883	1774960.104	1628999.025	7225	A-8-b/DA2	UPPER
RE21-12-21884	1774960.104	1628999.025	7225	A-8-b/DA2	LOWER
RE21-12-21885	1774925.893	1629022.299	7219	A-8-b/DA2	
RE21-12-21886	1774908.397	1628955.214	7224	A-8-b/DA2	
RE21-12-21887	1774898.869	1628752.402	7229	A-8-b/DA2	UPPER
RE21-12-21888	1774898.869	1628752.402	7229	A-8-b/DA2	LOWER
RE21-12-21889	1774888.448	1628820.516	7224	A-8-b/DA2	UPPER
RE21-12-21890	1774888.448	1628820.516	7224	A-8-b/DA2	LOWER

Table 2. Summary statistics for measurements in surface soil within Tract A-8-b for identified radionuclides, as used in the development of the SAP (Appendix A). For comparison, background soil concentrations and 15 mrem yr^{-1} residential SALs are provided. Units are pCi g^{-1}.

Radionuclide	Am-241	H-3	Cs-137	Pu-238	Pu-239	U-234	U-235	U-238
Mean	0.015	-0.462	0.122	0.009	0.164	0.87	0.135	0.792
Standard Deviation	0.032	0.492	0.133	0.028	0.290	0.218	0.061	0.198
Background Conc. (Ryti et al. 1998)	0.013	0.1	1.65	0.023	0.054	2.59	0.2	2.29
Residential 15 mrem yr^{-1} AL	30	750	5.6	37	33	170	17	87

Table 3. Results from surface soil samples taken from A-8-b. Measurements are in pCi g^{-1}.

	Sampling from Surface Locations (0 – 30 cm depth)								
RADIONUCLIDE	**Am-241**	**Cs-137**	**Tritium**	**Pu-238**	**Pu-239**	**Sr-90**	**U-234**	**U-235**	**U-238**
	0.015±0.056	0.001 ± 0.029	-0.543 ± 0.589	0 ± 0.009	-0.004 ± 0.010	-0.057 ± 0.136	0.902 ± 0.088	0.057 ± 0.018	0.536 ± 0.06
	0.031±0.102	-0.019 ± 0.050	0.179 ± 0.653	-0.021 ± 0.038	-0.004 ± 0.034	0.093 ± 0.148	0.713 ± 0.146	0.025 ± 0.029	0.923 ± 0.089
	-0.027±0.161	-0.003 ± 0.037	-0.84 ± 0.757	0.072 ± 0.077	-0.007 ± 0.036	0.036 ± 0.110	0.669 ± 0.134	0.053 ± 0.033	0.75 ± 0.152
	0.057±0.107	-0.016 ± 0.075	-0.334 ± 0.591	0 ± 0.022	0.008 ± 0.024	0.009 ± 0.131	0.804 ± 0.180	0.052 ± 0.042	0.814 ± 0.154
	-0.013±1.101	0.024 ± 0.053	-0.455 ± 0.651	-0.019 ± 0.033	0.018 ± 0.021	0.09 ± 0.153	0.662 ± 0.130	0.033 ± 0.025	0.902 ± 0.195
	-0.014±0.214	0.035 ± 0.046	-0.544 ± 0.731	0.024 ± 0.058	0.026 ± 0.043	0.053 ± 0.152	0.87 ± 0.166	0.034 ± 0.027	0.657 ± 0.13
	0.001±0.087	-0.006 ± 0.046	0.86 ± 0.718	-0.014 ± 0.033	-0.014 ± 0.025	-0.065 ± 0.098	0.77 ± 0.148	0.048 ± 0.032	0.754 ± 0.151
	0.016±0.108	-0.014 ± 0.038	-0.264 ± 0.666	-0.013 ± 0.028	-0.011 ± 0.021	-0.095 ± 0.156	0.725 ± 0.148	0.018 ± 0.02	0.82 ± 0.155
	-0.005±0.200	0.104 ± 0.062	-0.06 ± 0.687	0.004 ± 0.036	0.054 ± 0.044	-0.035 ± 0.148	0.662 ± 0.131	0.029 ± 0.023	0.818 ± 0.161
	0.002±0.096	0.034 ± 0.044	-0.399 ± 0.699	0.006 ± 0.063	-0.009 ± 0.026	0.03 ± 0.127	0.804 ± 0.147	0.014 ± 0.019	0.802 ± 0.149
	0.03±0.090	0 ± 0.089	0.523 ± 0.669	-0.049 ± 0.032	0.014 ± 0.036	0 ± 0.144	0.845 ± 0.157	0.032 ± 0.033	0.818 ± 0.149
	0.066±0.126	-0.008 ± 0.049	0.213 ± 0.628	0.004 ± 0.045	0.047 ± 0.042	0.353 ± 0.273	0.909 ± 0.247	0.016 ± 0.031	0.904 ± 0.171
	0±0.078	0.015 ± 0.029	-0.332 ± 0.293	-0.006 ± 0.030	0.077 ± 0.044	0.037 ± 0.181	0.42 ± 0.104	0.012 ± 0.021	0.653 ± 0.203
	0.028±0.044	-0.001 ± 0.097	0.21 ± 0.380	-0.013 ± 0.013	0.008 ± 0.029	-0.123 ± 0.182	0.887 ± 0.084	0.028 ± 0.013	0.419 ± 0.104
	-0.017±0.109	0.222 ± 0.045	-0.317 ± 0.376	-0.004 ± 0.004	0.058 ± 0.024	0.025 ± 0.171	0.801 ± 0.082	0.058 ± 0.02	0.743 ± 0.075
	0.021±0.038	0.027 ± 0.024	-2.903 ± 0.471	0.006 ± 0.006	0.085 ± 0.024	0.065 ± 0.227	0.75 ± 0.079	0.024 ± 0.012	0.985 ± 0.094
	-0.023±0.047	0.014 ± 0.020	-2.953 ± 0.467	0.006 ± 0.009	0.022 ± 0.011	0.044 ± 0.183	0.834 ± 0.188	-0.034 ± 0.024	0.851 ± 0.086
	-0.058±0.071	0.014 ± 0.024	-1.522 ± 0.463	0.003 ± 0.006	0.003 ± 0.006	0.217 ± 0.361	0.979 ± 0.098	0.063 ± 0.022	0.735 ± 0.201
	0.008±0.042	0.019 ± 0.019	-0.37 ± 0.291	0.013 ± 0.009	0 ± 0.008	0.036 ± 0.174	0.736 ± 0.076	0.035 ± 0.015	0.696 ± 0.078
	-0.036±0.098	-0.01 ± 0.025	-0.778 ± 0.418	0 ± 0.007	0.026 ± 0.015	0.127 ± 0.142	1.351 ± 0.111	0.055 ± 0.016	0.674 ± 0.072
	0.033±0.054	-0.017 ± 0.027	-0.334 ± 0.379	-0.005 ± 0.005	0.057 ± 0.024	0.145 ± 0.138	0.696 ± 0.071	0.027 ± 0.012	0.809 ± 0.08
	0.03±0.066	-0.029 ± 0.046	0.941 ± 0.402	0.004 ± 0.008	0.07 ± 0.023	-0.052 ± 0.139	1.139 ± 0.108	0.025 ± 0.017	0.975 ± 0.097
	0.032±0.071	0.004 ± 0.026	-0.191 ± 0.361	0.015 ± 0.010	-0.004 ± 0.004	0.027 ± 0.135	0.908 ± 0.091	0.047 ± 0.018	0.827 ± 0.086
							0.894 ± 0.100	0.027 ± 0.016	0.873 ± 0.099
Mean± 1STD	0.01 ± 0.03	0.02 ± 0.05	-0.44 ± 0.95	0.00 ± 0.02	0.02 ± 0.03	0.04 ± 0.10	0.82 ± 0.18	0.03 ± 0.02	0.78 ± 0.13
95% UCL	0.018	0.065	0.420	0.020	0.051	0.079	0.890	0.051	0.827
Background Conc. (Ryti et al. 1998)	0.013	1.65	0.1	0.023	0.054	1.31	2.59	0.2	2.29
SAL	30	5.6	750	37	33	5.7	170	17	87
Ratio (UCL/SAL)	0.001	0.012	0.001	0.001	0.002	0.014	0.005	0.003	0.01
Sum of ratios	0.046	**Potential Dose (mrem yr^{-1})**	0.7						

Table 4. Results from soil samples taken at depth from A-8-b. Measurements are in pCi g^{-1}.

	Sampling Locations at Depth (> 30 cm and above bedrock)								
RADIONCULIDE	**Am-241**	**Cs-137**	**Tritium**	**Pu-238**	**Pu-239**	**Sr-90**	**U-234**	**U-235**	**U-238**
	0.003 ± 0.112	0.025 ± 0.052	-0.091 ± 0.746	-0.017 ± 0.051	0.009 ± 0.017	0.019 ± 0.12	0.751±0.138	0.032±0.024	0.644 ± 0.124
	0.01 ± 0.132	-0.005 ± 0.211	-0.584 ± 0.629	0.007 ± 0.042	-0.017 ± 0.015	0.147 ± 0.149	0.495±0.0117	0.018±0.025	0.551 ± 0.125
	0.049 ± 0.146	0.004 ± 0.039	-0.297 ± 0.656	0.019 ± 0.047	0.005 ± 0.024	-0.106 ± 0.217	0.78±0.148	0.022±0.023	0.697 ± 0.138
	0.006 ± 0.117	0 ± 0.019	0.096 ± 0.664	-0.011 ± 0.025	0.016 ± 0.03	0.083 ± 0.161	0.575±0.132	0.031±0.031	0.692 ± 0.148
	-0.038 ± 0.148	-0.013 ± 0.089	0.973 ± 0.681	-0.015 ± 0.024	0.001 ± 0.004	0.042 ± 0.153	0.625±0.129	0.004±0.012	0.616 ± 0.128
	-0.001 ± 0.097	-0.029 ± 0.057	0.122 ± 0.698	0.004 ± 0.045	0.023 ± 0.032	0.025 ± 0.171	1.237±0.216	0.111±0.052	1.171 ± 0.207
	-0.031 ± 0.084	0.008 ± 0.023	-0.287 ± 0.316	0 ± 0.007	-0.01 ± 0.01	-0.178 ± 0.226	0.727±0.071	0.025±0.013	0.707 ± 0.068
	-0.02 ± 0.168	0.014 ± 0.025	0.679 ± 0.307	-0.003 ± 0.003	0.019 ± 0.011	0.125 ± 0.231	0.483±0.098	0.006±0.031	0.534 ± 0.098
	-0.036 ± 0.097	0.031 ± 0.023	-1.571 ± 0.359	0 ± 0.007	0.004 ± 0.008	-0.068 ± 0.198	0.656±0.074	0.041±0.017	0.584 ± 0.069
	0.027 ± 0.066	-0.002 ± 0.037	-2.306 ± 0.455	0.011 ± 0.011	0 ± 0.009	-0.066 ± 0.142	0.932±0.047	0.024±0.012	0.94 ± 0.087
	-0.004 ± 0.06	-0.012 ± 0.028	-0.177 ± 0.334	0.004 ± 0.008	-0.004 ± 0.004	0.13 ± 0.141	0.603±0.063	0.003±0.005	1.334 ± 0.11
	0.056 ± 0.052	-0.02 ± 0.027	0.525 ± 0.342	0.009 ± 0.014	0 ± 0.009	0.135 ± 0.157	0.528±0.06	0.049±0.017	0.621 ± 0.064
Mean ± 1 STD	0.00 ± 0.03	0.00 ± 0.02	-0.24 ± 0.92	0.00 ± 0.01	0.00 ± 0.01	0.02 ± 0.11	0.70 ± 0.21	0.03 ± 0.03	0.76 ± 0.26
95% UCL	0.018	0.009	0.234	0.006	0.010	0.080	0.810	0.052	0.890
Background Conc. (Ryti et. al 1998)	0.013	1.65	0.1	0.023	0.054	1.31	2.59	0.2	2.29
SAL	30	5.6	750	37	33	5.7	170	17	87
Ratio	0.001	0.002	0.0002	0.0002	0.0003	0.014	0.005	0.003	0.010
Sum of ratios	0.035								
Potential Dose (mrem yr^{-1})	0.52								

Los Alamos
NATIONAL LABORATORY
EST. 1943

APPENDIX A

Sampling and Analysis Plan (SAP) for Assessment of LANL-Derived Residual Radionuclides in Soils within Sub-Parcel A-8-b for Land Transfer Decisions

June 2012

1.0 Background for Tract A-8-B[2]

1.1 Site Location

The A-8-b sub-parcel is a portion of DP Road-1 South Tract lying entirely to the south of DP Road and to the west of Material Disposal Area (MDA) B and along the north east boundary with Sub-parcel A-8-a (Figure 1). The DP Road-1 South Tract is located along DP Road between the western boundary of Technical Area- (TA-) 21 and the major commercial districts of the Los Alamos townsite. Access onto the site is from DP Road.

Both commercial and LANL properties lie immediately north of sub-parcel A-8-b. LANL properties include a storage facility and machine shop building located in sub-parcel A-11 (also slated for land transfer to the County). Los Alamos Canyon abuts A-8-a on the south side. Adjacent properties include MDA B, which is identified in LANL records as Potential Release Site (PRS) 21-015 and there are several Solid Waste Management Units (SWMUs) and an Area of Concern (AOC) in Sub-Parcel A-8-a. Recent and past activities within these adjacent properties potentially impacted Sub-Parcel A-8-b. The legal property boundary description of DP Road-1 South Tract is provided by the US Army Corps of Engineers' *Land Survey Plat, Los Alamos National Laboratory, Tract A-8, Being a Part of DP Road Site, Los Alamos, New Mexico,* recorded by the Los Alamos County Clerk on March 18, 2003.

1.2 General History and Current Use

Prior to LANL occupancy (pre-1943), there was little development in the Los Alamos area. In 1918, Detroit businessman Ashley Pond purchased 800 acres from three homesteaders to begin the Los Alamos Ranch School for Boys. The Ranch School (south of Ashley pond and west of the subject property)—at the center of what is now the Los Alamos townsite—was the only development in the area prior to LANL occupancy.

The Laboratory operations that began on DP Mesa after World War II included warehousing, utility shop work, and a materials testing laboratory. The SWMUs and AOCs located on the sub-parcel (see Figure 1) are all associated with those historical LANL activities. In the past, LANL fueling facilities were located on Sub-parcel A-9, the vacant land north of DP Road directly across from the A-8-a sub-parcel. In the 1960s, following the end of LANL's use of the sub-parcel, the western part of the property was used for a residential trailer park andplayground area.

Currently, there is no LANL activity on the sub-parcel itself. It is unoccupied, vacant land. Air monitoring stations, radiation monitoring stations, and wastewater discharge outfalls associated with LANL's federal, state, or local permits are located near (but not on) the DP Road-1 South Tract.

1.4 Summary of Historical Evaluation of LANL Impact

[2] Portions of Sections 1.0 through 1.4 were directly imported into this document from the Environmental Baseline Survey (Pope et al. 2007) with some modifications.

We determine the A-8-b tract as being potentially impacted by LANL operations because of previous history as a depositional downwind site for stack emissions from the TA-21 DP West facility and the original plutonium facility at TA-1, in addition to deposition from resuspension from historical MDA-B waste operations. Additionally, A-8-b was used recently as a staging area for radioactive waste containers from MDA-B remediation activities. Soil sampling measurements within and around the tract indicate that the soil concentrations can be above regional background levels. While the preliminary results provided in Table 1 indicate Pu-239 concentrations are above background levels, they are not above residential SAL levels.

1.4.1 Specific evidence for radiologically-impacted status includes the following:

1.4.1.1 Investigation from Sub area A-8-b

- Use of site as a laydown area for new, uncontaminated materials being used for MDA-B remediation activities. The site was also used as a staging area for radioactive waste containers from MDA-B remediation activities, but preliminary data suggest the surface soils were not impacted beyond SALs for radionuclides.
- There have been no other radiological operations conducted on the tract.
- There are no storage tanks, underground pipes or other LANL-numbered structures within the subparcel A-8-b.
- There are currently no wastewater treatment and disposal facilities on or associated with this sub-parcel.
- The tract could have been impacted by air deposition of radionuclides from previous LANL operations. Air sampling data collected from a station located near the subject property identified very low concentrations of tritium, plutonium, americium, and depleted uranium, which are believed to result from the resuspension of surface contamination in soil. Levels of uranium were comparable to historical concentrations of natural uranium in Los Alamos County soils. The levels of plutonium and americium measured in air were less than one percent of the EPA public exposure standard. Tritium levels measured in air were comparable to those found at other locations in the eastern part of the Los Alamos townsite.

1.4.1.2 Historical Investigations from neighboring areas

Investigation actions were performed at each of the component SWMUs and AOCs in this consolidated unit (Figure 1). This work included several sampling campaigns to determine nature and extent of contamination, demolition and/or removal of most of the individual components of the various septic systems, backfilling the excavations, and taking confirmatory samples. Based on these assessments, DOE/NNSA and LANL recommended the individual SWMUs and AOCs for no further action (NFA) in separate reports dated 1995, 1996, and 2002, and the consolidated unit was recommended for NFA in 2003. NMED approved individual-unit NFA recommendations for several of the units and ultimately approved consolidated unit 00-030(b)-00 for NFA in 2003. This SWMU consists of potential surface and subsurface chemical and radiological soil contamination deposited from historical air emissions from incinerators, stacks, and filter houses at TA-21. Chemical and radiological contaminant levels in surface soil within Sub-parcel A-8-a have been determined to be consistent with human health and environmental

standards; however, investigations of the remaining portions of SWMU 21-021 outside thesub-parcel boundary are not yet complete.

There is no evidence of storage tanks or pipelines within A-8-b. Regarding the surrounding tract A-8-a, DOE approved the AOC for NFA in 1997, and EPA concurred with the recommendation in 1997 and 2005. It is administratively complete. In letters dated July 7 and October 25, 2005, NMED stated that the Consent Order requirements had not yet been satisfied for the PRSs on and near subparcel A-8-a. However, in a January 18, 2006 letter, NMED wrote that the corrective measures implemented on Sub-parcel A-8-a "…are protective of human health and the environment in light of the transferee's intended use." These measures included 1) the interim actions performed to investigate and address contamination potentially associated with that portion of SWMU 21-021 located on the sub-parcel, and 2) the creation of the "buffer" A-8-b sub-parcel (see Pope et al. (2007) for further information on the re-designation of A-8 as sub-parcels A-8-a and A-8-b). In a February 23, 2006 letter, NMED stated that all of the PRSs in Sub-parcel A-8-a were "complete without [future] controls." The portion of SWMU 21-021 that was investigated as part of the 2004-2005 Voluntary Corrective Action was deemed not to pose an unacceptable risk. In summary, for the PRSs on this sub-parcel, DOE/NNSA, LANL, and NMED believe that further remedial actions or controls are not necessary prior to transfer. Upon receipt of final concurrences by the New Mexico Environment Department (NMED) under the Consent Order, this sub-parcel meets CERCLA Section 120(h) and PL 105-119 requirements for transfer. There are no storage tanks or other LANL-numbered structures within the subparcel. An underground pipeline historically ran north-south across the subject property. It was used to transport radioactive liquid waste from TA-21 to the radioactive liquid waste treatment facility at TA-50. This pipeline was removed in 2002.

1.5 Preliminary Results from Surveys for Residual Contamination

Table A1 in Attachment 1 provides data from measurements made on Tract A-8-b previous to the cleanup operations at MDA B. Additionally, Table A2 in Attachment 1 provides recent data from a MARSSIM-derived sampling plan focusing on surface soil in Tract A-8-b taken after all radioactive waste containers that were used for storage of contaminated soil during MDA-B operations were removed from the tract. These samples were taken to determine radiological requirements for posting and for access control after MDA-B operations were completed. The result showed a 95% UCL-Upper Confidence Level (EPA 2010) of 0.44 pCi/g for Pu-239 (detections only, n=19) with an arithmetic mean and standard deviation of 0.2 ± 0.3 pCi/g. Only two samples showed detectable Am-241 with the highest values of 0.1 pCi/g.

These results suggest that the Tract A-8-b could be classified as a Class 3 area under MARSSIM (impacted by LANL operations, but soil is expected to be near background values). However, due to the higher soil concentrations from MDA-B to the east, and because there is a reasonable likelihood for using the tract for residential use, we propose to treat the tract as a Class 2 area (impacted by LANL operations, and the potential for soil concentrations to be near the SALs). A Class 2 designation subdivides the tract into two plots each with an area <10,000 m^2, as outlined in the MARSSIM procedure. This effectively doubles the number of samples required for Tract A-8-b.

1.5.1 Additional Soil Sampling Results

Additional measurement results of surface soil (the majority at 0-1 ft depths) for Tract A-8-B for the radionuclides Am-241, Cs-137, Sr-90, Pu-238, Pu-239/240, H-3, U-234, U-235, and U-238 were obtained using the RACER database. Only fully qualified data were selected for this analysis and collection dates span the range of 2001 to 2004. The data are provided in Attachment 1. Results show that each radionuclide measurement is near the background value for soil, except for Pu-239/240 (highest result at 0.205 pCi/g), but significantly below the recreational and residential SALs. The higher than background Pu-239/240 results are most likely due to historical stack releases and operations at MDA-B during waste disposal into the trenches.

1.6 Conclusions regarding the classification of Tract A-8-B relative to potential for residual radioactive contamination

After evaluation of the available data, LANL concludes that Tract A-8-b meets the requirements of a Class 3 area (i.e., possibly impacted by LANL operations, but sites are expected to be substantially below SALs and close to background values), as defined in MARSSIM. This conclusion is supported by data contained in the LANL Environmental Baseline Survey (Pope et al. 2007) and the results of sampling performed in February of 2012 (Table A2). However, given the use of the tract as a radioactive waste staging area after remediation of MDA-B and the potential residential use of the tract in the future, it is judged appropriate to classify the tract as a Class 2 Area under MARSSIM (MARSSIM 2000) and develop the sampling plan accordingly.

2.0 Data Quality Objectives for Sampling and Analysis Plan

The sampling and analysis plan (SAP) for Tract A-8-b follows the LANL (2012b) procedure EDA-QP-238, "Dose assessment data quality objectives for land transfers into the public domain."

2.1 Objective of the SAP

The objective of this sampling and analysis plan is to confirm, within the stated statistical confidence limits, that the mean levels of potential radioactive residual contamination in soils in the tract A-8-B are documented, in appropriate units, and are below the 15 mrem yr^{-1} Screening Action Levels (SALs), as derived in Mirenda et al. (2006). **These SALs are used by LANL as preapproved Authorization Limits (ALs), as required in DOE Order 458.1 (section 2.k.(6)(f)2 in the contractors Requirements Document), and are identified as ALs in the rest of this SAP with regards to statistical decisions.**

2.2 Decision identification

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

- If results from the soil radioactive contamination measurements are at or above the ALs

(collectively), the site is not a candidate for land transfer.

- If results from the soil radioactive contamination measurements are below the ALs (collectively), the site is a candidate for land transfer.

2.3 Inputs into the Decision

A statistical summary of the preliminary measurements are provided in Table 1. Data used for analysis for Am-241, Pu-238 and Pu-239 were from the most recent data (to ensure evaluation of any post MDA-B clean up impacts). Other radionuclides were evaluated using all data from the RACER database. Standard deviations for U-234 and U-238 (n=1) were determined by dividing the concentration by four.

The assumed future land use and exposure pathway assumes residential use. The radionuclides analyzed for and the respective residential SALs are provided in Table 1. Derivation of the SALs are provided in Mirenda (2006). The 15 mrem yr^{-1} SALs were calculated using RESRAD (RESRAD 2001).

Table 1. Summary statistics for each radionuclide and the 15 mrem yr^{-1} concentrations for residual soil concentrations for residential use. These ALs were used as used for development of the sampling plan. Units are pCi g^{-1}.

	Am-241	H-3	Cs-137	Pu-238	Pu-239	U-234	U-235	U-238
Mean	0.015	-0.462	0.122	0.009	0.164	0.87	0.135	0.792
Standard Deviation	0.032	0.492	0.133	0.028	0.290	0.218	0.061	0.198
Res. 15 mrem/yr AL	30	750	5.6	37	33	170	17	87

Data to be used in the analysis will be the soil concentration measurements resulting from this sampling and analysis plan.

The unity rule will be applied because there are multiple radionuclides in the analysis. The formula used in for the unity rule is:

$$\frac{C_1}{AL_1} + \frac{C_2}{AL_2} + \frac{C_3}{AL_3} \ldots\ldots \frac{C_n}{AL_n} \leq \mathbf{1} \qquad \text{(eqn. 1)}$$

where $C_{1\text{-}n}$ and $AL_{1\text{-}n}$ are the upper-bound estimates of the mean concentrations for radionuclides and Authorized Levels 1 through n, respectively.

2.4 Study Boundaries

The study is limited to Tract A-8-b, as identified in Figure 1 and described in the Environmental Baseline Survey (Pope et al. 2007). The tract available for sampling is shown in Attachment 2.

As concluded from historical information and previous soil sampling, the list of radionuclides in the analysis will include H-3, Sr-90, Cs-137, Am-241 (alpha spectrometry), Pu-238, Pu-239/240, U-234, U-235, and U-238. Individual doses are evaluated out to 1000 years.

2.5 Decision Rule

The decision rule is based on the null hypothesis that the 95% UCL residual contamination levels in soil and/or sediment in Tract-A-8-B combined over all radionuclides is above the AL and likely to result in an all pathway radiation dose to the critical receptor above 15 mrem yr^{-1}. The alternative hypothesis is that the 95% UCL residual contamination levels in soil in Tract A-8-b combined over all radionuclides are below the SALs and not likely to result in an all pathway radiation dose to the critical receptor above 15 mrem yr^{-1}.

2.6 Limits on Decision Errors

The acceptable statistical errors for this analysis are that Type I error (i.e., conclude contamination levels at site are < AL when in fact it is > AL) has a probability of $p < 0.05$; and the Type II error is (i.e., conclude soil contamination level is > AL when in fact is < AL) has a probability of $p < 0.1$. Normality of the distribution for the preliminary data is not assumed.

2.7 Optimization of Design Process

The survey design is optimized by analyzing historical data and using process knowledge. Specifically, the level of residual contamination on the tract in near background and any added radionuclides are most likely from deposition from nearby historical stack emissions and historical MDA-B waste disposal operations. In addition, the tract was used post-MDA-B remediation to stage radioactive waste containers. While the historical sampling data and process knowledge would point to the determination of the area as Class 3, the entire tract will be treated as a Class 2 area optimizing the number of required sample locations by reducing the likelihood of resampling the area in the future.

2.8 Statistically-Based Evaluation for Number of Samples Required using MARSSIM

The RACER data GIS tool was used to download a map of the tract, which was then incorporated into Visual Sampling Plan (VSP) software (Matzke et al. 2010). The tract was then divided into two separate sampling areas, Decision Area 1 (north area) and Decision Area 2 (south area) (Attachment 2). Each decision area contains approximately one-half of the 3.22 acre parcel. The MARSSIM software within VSP was then used to determine the statistically-based sampling plan for each decision area. The preliminary sampling data in Attachment 1 was used to determine the standard deviations needed for calculating the needed number of samples for each of the identified radionuclides. Standard deviations for U-234 and U-238 (n=1) were determined by dividing the concentration by four. The sampling locations in each decision area were randomly determined.

2.9 Instrumentation and Measurement Quality Objectives

The main objectives are to determine the appropriate analysis technique for each radionuclide and ensure Measurement Quality Objectives are satisfied. One should be confident that the measurement results are valid and appropriate for the decisions being made.

2.9.1 Measurement Quality Objectives:

- Detection Capability: Minimum Detection Concentration (MDC) should be below the MARSSIM defined Lower Bound of the Gray Region (LBGR).

- The degree of measurement uncertainty (combined precision and bias) should be reasonable relative to the needed accuracy of the decision and accounted for in the statistical analysis.

- Range of the instrument and measurement technique should be appropriate for the concentrations expected.

- 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.

- For field instruments, the instrument should be rugged enough to consistently provide reliable measurements.

2.9.2 Procedures used to meet these measurement quality objectives:

1) for collecting valid soil sample appropriate for the dose assessment,
    a. Sampling of soil will be done using LANL (2012a) procedure SOP-5132 "Collection of soil and vegetation samples for the environmental surveillance program." These are surface soil samples appropriate for the deposition pathway and the exposure scenario (i.e., top 5 cm). While subsurface soil contamination from Laboratory originated and fallout radionuclides is not expected, in order to ensure completeness of the tract survey, approximately 10% (as a screen) of the sample locations will additionally be sampled at depth at 10 feet (i.e., a surface soil sample and a soil sample at 10 feet depth will be collected and analyzed)..
    b. Additional quality assurance for the collection of the samples is provided through LANL (2008) procedure QAPP-0001 "Quality and assurance project plan for the soils, foodstuffs, and non foodstuff biota monitoring project."
2) for soil sample analysis using appropriate EPA approved analytical procedures for each radionuclide. The following will be used by the independent laboratory:
    a. Environmental Measurements Laboratory (EML). **The procedures manual of the Environmental Measurements Laboratory**. Report HASL-300; 1997. Radionuclide specific procedures for the radionuclides of Am-241, Pu-239 and U-238 are provided in EML (1997).
    b. Environmental Protection Agency (EPA). **Method 901.1 - Gamma Emitting Radionuclides in Drinking Water***: Prescribed Procedures for Measurement of Radioactivity in Drinking Water*, EPA 600/4-80-032, prepared by EPA's Environmental Monitoring and Support Laboratory, August 1980 (EPA 1980). Available from NTIS, document no. PB 80-224744.
    c. Environmental Protection Agency (EPA). **Method 905.0 - Radioactive Strontium in Drinking Water***: Prescribed Procedures for Measurement of Radioactivity in Drinking Water*, EPA 600/4-80-032, prepared by EPA's Environmental Monitoring and Support Laboratory, August 1980 (EPA 1980). Available from U.S. Department of Commerce, National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161, document no. PB 80-224744.

d. Environmental Protection Agency (EPA). **Method 906.0 - Tritium in Drinking Water***: Prescribed Procedures for Measurement of Radioactivity in Drinking Water*, EPA 600/4-80-032, prepared by EPA's Environmental Monitoring and Support Laboratory, August 1980 (EPA 1980). Available from U.S. Department of Commerce, National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161, document no. PB 80-224744.

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

2.10 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 (EPA 2010) 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 authorized limits will be evaluated using the following criteria. All analyses and results will be documented.

Decision Criteria:

5) If all samples are ≤ residential AL, then no further action is required and the site passes the criteria for residential occupation. No further actions are needed.
6) If all samples or the UCL are > the AL, then the site is not a candidate for release and site remediation is needed followed by resampling before it can be released.
7) If the UCL is below the AL but some individual measurements are above the AL, then statistical analysis is needed. Generally, non-parametric statistical approaches are used to evaluate the null hypothesis. If contamination is present in background, the Wilcoxon Rank Sum test is suggested, and if contamination is not present in background or very low relative to the AL, use the Sign Test. See MARSSIM chapter 8 for details and examples.
8) Alternatively, one could confirm that the ratio of the upper-confidence level (UCL) of the average concentration divided by the AL and the sum of hot spot activity ratios do not exceed 1, as show in Equation 3.

$$\frac{\overline{C}_{UCL}}{C_{AL}} + \sum_{i=1}^{n} \frac{C_{i,C>AL}}{C_{AL} * AF} \leq 1 \qquad \text{(eqn. 2)}$$

Here $\overline{C}_{UCL}$ is the 95% upper bound estimate of the concentration mean, C_{AL} is the resident AL (15 mrem yr^{-1}), $C_{i,c>AL}$ 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 value in eqn. 2 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.

9) If there are multiple radionuclides (*i*) being evaluated in a sampling unit, the sum of the ratios should be less than one, as shown in eqn. 1.

3.0 Results of the Analysis for Sampling Number and Locations

The specific details of the analysis using MARSSIM and the results are provided in Attachment 2 of this report. Results showed that approximately 11 randomly-sited samples were needed within each decision area, for a total of 22 sample locations within the tract, and the approximate locations are shown on Attachment 2. The specific statistical parameter values, analysis, results, and coordinates for the randomly selected sampling locations are provided in the summary report (Attachment 2). All 22 of the indicated samples will be surface soil (0-1 ft depth). Additionally, 11 of the 22 samples (assumes Class 3 at depths > 1 ft) will be selected for at depth samples (e.g., 9-10 ft or until bedrock is encountered) to ensure no contamination above ALs at depth.

4.0 REFERENCES

EML (Environment Monitoring Lab), 1997. HASL-300, The procedures manual of the Environmental Measurements Laboratory.

EPA (Environmental Protection Agency), 1980. EPA 901.1 Gamma emitting radionuclides in drinking water EPA 600/4-80-032 PB 80-224744 National Technical Information Service (NTIS).

EPA (Environmental Protection Agency), 1989. EPA 905.0 Prescribed procedures for measurement of radioactivity in drinking water EPA 600/4-80-032 PB 80-224744 National Technical Information Service (NTIS).

EPA (Environmental Protection Agency), 1989. EPA 906. Tritium Analysis by Liquid Scintillation Counting (EPA Method 906.0) EPA 600/4-80-032 PB 80-224744 National Technical Information Service (NTIS).

EPA (Environmental Protection Agency), 2010. ProUCL Version 4.1 User Guide (draft). EPA/600/R-07/041.

LANL (Los Alamos National Laboratory), 2005, "Derivation and Use of Radionuclide Screening Action Levels, Revision 1." (LA-UR-05-1849, ER2005-0127)

LANL (Los Alamos National Laboratory), 2008. Procedure: QAPP-0001 "Quality and assurance project plan for the soils, foodstuffs, and non foodstuff biota monitoring project."

LANL (Los Alamos National Laboratory), 2012a. Procedure: SOP-5132 "Collection of soil and vegetation samples for the environmental surveillance program."

LANL (Los Alamos National Laboratory), 2012b. Procedure: EDA-QP-238 "Dose assessment data quality objectives for land transfers into the public domain."

MARSSIM (Multi-Agency Radiation Survey and Site Investigation Manual), 2000. NUREG-1575, EPA 402-R-97 Rev.1, DOE/EH-0624, Rev.1

Matzke, B.D., Nuffer, L.L., Hathaway, J.E., Sego, L.H., Pulsipher, B.A., McKenna, S., Wilson, J.E., Dowson, S.T., Hassig, N.L., Murray, C.J., Roberts, B. 2010. Visual Sampling Plan Version 6.0 user's guide. Pacific Northwest National Laboratory report PNNL-19915.

Mirenda, R. 2006. Derivation and use of radionuclide screening action levels, Revision 1. Los Alamos National Laboratory Report LA-UR-1849, Los Alamos, New Mexico.

NMED, 2005. Compliance Order on Consent. *(Consent Order) issued pursuant to the New Mexico Hazardous Waste Act (HWA), NMSA 1978, § 74-4-10, and the New Mexico Solid Waste Act (SWA), NMSA 1978, § 74-9-36(D)*. Entered into by the New Mexico Environment Department, the United

States Department of Energy, and the Regents of the University of California, Santa Fe, NM, March 1, 2005.

Pope, J., Smith, V., Swanton, B., Schumann, P.B. 2007. Environmental baseline survey for A-8-a subparcel, DP Road-1 south tract. Los Alamos National Laboratory report LA-UR-07-0136.

RACER 2012. Web address for database access: < http://www.racerdat.com/>

RESRAD, 2001. User's manual for RESRAD Version 6.0. Argonne National Report ANL/EAD-4.

Swanton, B.A., Isaacson, J., Nisengard, J., Schumann, P.B., Pope, J., Smith, V., Birdsall, K.T., Bertino, P.M., 2006. Environmental baseline survey results for Tract A-10, DP Road-3 east (DP canyon). Los Alamos National Laboratory report LA-UR-06-5607.

4.1 HISTORICAL RECORDS AND OTHER PERTINENT DOCUMENTS

Code of Federal Regulations, Title 40, Part 312, *Innocent Landowners, Standards for Conducting All Appropriate Inquiries.*

Compliance Order on Consent (Consent Order) issued pursuant to the New Mexico Hazardous Waste Act (HWA), NMSA 1978, § 74-4-10, and the New Mexico Solid Waste Act (SWA), NMSA 1978, § 74-9-36(D). Entered into by the New Mexico Environment Department, the United States Department of Energy, the Regents of the University of California, and the State of New Mexico Attorney General, Santa Fe, NM, March 1, 2005.

DOE (Department of Energy), 1999a. *Final Site-Wide Environmental Impact Statement for Continued Operation of Los Alamos National Laboratory*, US Department of Energy, DOE/EIS-0238, January 1999.

DOE (Department of Energy), 1999b. *Final Environmental Impact Statement for the Conveyance and Transfer of Certain Tracts Administered by the US Department of Energy and Located at Los Alamos National Laboratory*, US Department of Energy, DOE/EIS-0293, October 1999.

DOE (Department of Energy), 2000a. *Conveyance and Transfer Plan for Certain Land Tracts Administered by the U.S. Department of Energy Located at the Los Alamos National Laboratory, Los Alamos and Santa Fe Counties, New Mexico*, U.S. Department of Energy, Report to Congress Under Public Law 105-119, Unnumbered Report, September 2000.

DOE (Department of Energy), 2000b. *Combined Data Report to Congress to Support Land Conveyance and Transfer under Public Law 105-119*, US Department of Energy, Unnumbered Report, January 2000.

Department of Energy (DOE), 2001, "Biological Assessment for the Conveyance and Transfer of Land Tracts at LANL" (LAUR-01-4663)

Department of Energy (DOE), 2005, "A Biological Assessment of the Potential Effects of the Mexican Spotted Owl Habitat Redelineation on Federally Listed Threatened and Endangered Species" (LACP-05-1031)

DOE (Department of Energy), 2005. *Cross-Cut Guidance on Environmental Requirements for DOE Real Property Transfers*, US Department of Energy, DOE/EH-413/9712, revised March 2005.

Endangered Species Act. United States Code, Title 16, *Conservation*; Chapter 35, Washington, D.C., December 1973.

EPA (US Environmental Protection Agency), 1994. *Military Base Closures: Guidance on EPA Concurrence in the Identification of Uncontaminated Parcels under CERCLA Section 120(h)(4).* Memorandum from Elliot P. Laws, Assistant Administrator, OSWER, to Waste Management

Division Directors, Regions I-X, Regional Counsels, Regions I-X, and Federal Facilities Leadership Council. OSWER Directive 9345. 0-09, EPA 540/F-94/32, Washington, DC. April 19, 1994.

USFWS (US Fish and Wildlife Service). Final Biological Opinion on the Effects to the Mexican Spotted Owl from the Conveyance and Transfer of Ten Land Tracts at Los Alamos National Laboratory to the County of Los Alamos and the Secretary of the Interior in Trust for the Pueblo of San Ildefonso. January 2002.

LANL (Los Alamos National Laboratory), 1998a. *Threatened and Endangered Species Habitat Management Plan,* Los Alamos National Laboratory, August 1998.

LANL (Los Alamos National Laboratory), 1998b. *A Status Report on Threatened and Endangered Species, Wetlands, and Floodplains for the Proposed Conveyance and Transfer Tracts at Los Alamos National Laboratory, Los Alamos, New Mexico,* Los Alamos National Laboratory, July 1998.

LANL (Los Alamos National Laboratory), 1999. *Final Environmental Restoration Report to Support Land Conveyance and Transfer under Public Law 105-119,* Los Alamos National Laboratory, LA-UR-99-4187, August 1999.

LANL (Los Alamos National Laboratory), 2002a. W*atershed Management Sampling Plan,* Los Alamos National Laboratory, October 4, 2002.

LANL (Los Alamos National Laboratory), 2002b. *Environmental Surveillance at Los Alamos During 2001,* Los Alamos National Laboratory, LA-14979-ENV, September 2002.

LANL (Los Alamos National Laboratory), 2004. *Environmental Surveillance at Los Alamos During 2002,* Los Alamos National Laboratory, LA-14085-ENV, January 2004.

LANL (Los Alamos National Laboratory), 2005a. *Investigation Work Plan for Material Disposal Area B, Solid Waste Management [Unit] 21-015, at Technical Area 21.* May 2005.

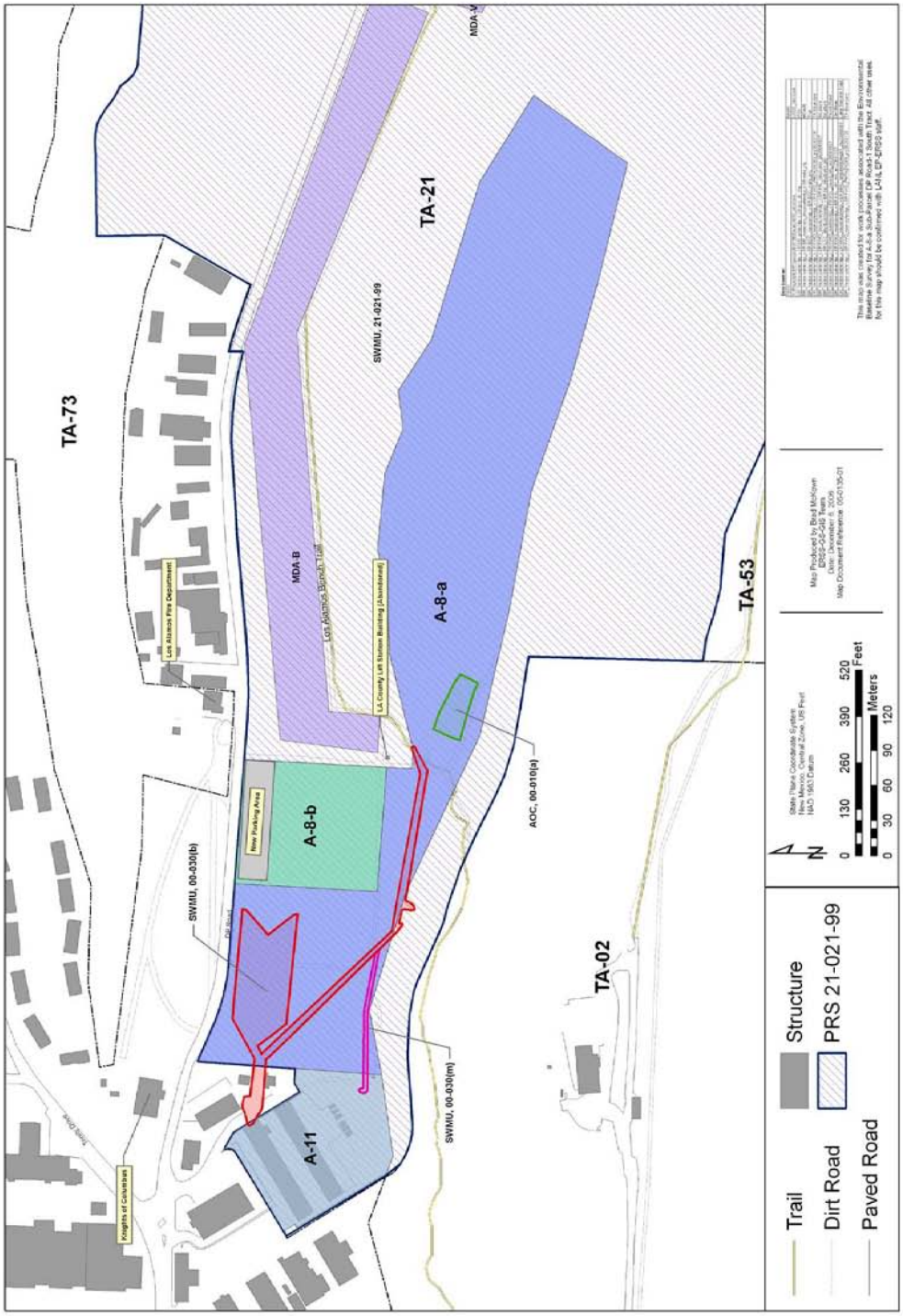
LANL (Los Alamos National Laboratory), 2011. *Environmental Surveillance at Los Alamos During 2010,* Los Alamos National Laboratory, LA-14445-ENV, .

LANL (Los Alamos National Laboratory), 2006, “Programmatic Agreement Between the U.S. Department of Energy, National Nuclear Security Administration, Los Alamos Site Office, The New Mexico State Historic Preservation Office, and the Advisory Council for Historic Preservation Concerning Management of Historic Properties of Los Alamos National Laboratory, New Mexico” (LA-UR-06-1975).

Machen, J., McGehee, E., and Hoard, D., 2011, "Homesteading on the Pajarito Plateau, 1887-1942", Los Alamos National Laboratory Report (LA-UR-11-00793), Los Alamos, New Mexico.

Vierra, B.J. and Schmidt, K.M., eds., 2008, "The Land Conveyance and Transfer Data Recovery Project: 7000 Years of Land Use on the Pajarito Plateau", Los Alamos National Laboratory Report (LA-UR-08-6205), Los Alamos, New Mexico.

Figure 1. Map of subparcels A-8-a and A-8-b within PRS 21-021-99 and showing specific locations of SWMUs and AOCs (map from Pope et al. 2007).



Attachment 1- Soil concentration data from Tract A-8-B

Table A1. Soil concentrations for radionuclides from Tract A-8-B. Standard deviations for U-234 and U-238 (n=1) were determined by dividing the concentration by four.

Radionuclide	Sample ID	Collection Date	Result	Units	Uncertainty	MDA (pCi/g)
Am-241	RE00-04-53551	08/23/04	-0.0708	pCi/g (dry)	0.093	0.3
Am-241	RE00-02-45714	05/10/02	-0.00125	pCi/g (dry)	0.044	0.15
Am-241	RE00-02-45639	05/10/02	0.0218	pCi/g (dry)	0.029	0.093
Am-241	RE00-02-45640	05/10/02	-0.0711	pCi/g (dry)	0.032	0.11
Am-241	RE00-02-45641	05/10/02	-0.0112	pCi/g (dry)	0.03	0.1
Am-241	RE00-02-45679	05/24/02	0.0437	pCi/g (dry)	0.033	0.1
Am-241	RE00-02-45680	05/24/02	-0.0333	pCi/g (dry)	0.061	0.22
Am-241	RE00-02-45681	05/24/02	0.0678	pCi/g (dry)	0.066	0.22
Am-241	RE00-02-46500	07/25/02	-0.02	pCi/g (dry)	0.17	0.29
Cs-137	RE00-04-53551	08/23/04	0.0617	pCi/g (dry)	0.016	0.044
Cs-137	RE00-02-45639	05/10/02	0.163	pCi/g (dry)	0.014	0.023
Cs-137	RE00-02-45714	05/10/02	0.284	pCi/g (dry)	0.022	0.023
Cs-137	RE00-02-45640	05/10/02	0.0426	pCi/g (dry)	0.012	0.025
Cs-137	RE00-02-45641	05/10/02	0.0611	pCi/g (dry)	0.0094	0.018
Cs-137	RE00-02-45679	05/24/02	0.0353	pCi/g (dry)	0.02	0.07
Cs-137	RE00-02-45680	05/24/02	0.0472	pCi/g (dry)	0.031	0.055
Cs-137	RE00-02-45681	05/24/02	0.394	pCi/g (dry)	0.035	0.051
Cs-137	RE00-02-46500	07/25/02	0.006	pCi/g (dry)	0.094	0.18
H-3	RE00-02-45714	05/10/02	-0.143	pCi/g (dry)	0.43	1.4
H-3	RE00-04-53551	08/23/04	0.0557	pCi/g (dry)	0.013	0.041
H-3	RE00-02-45639	05/10/02	0.1	pCi/g (dry)	0.45	1.5
H-3	RE00-02-45640	05/10/02	-0.292	pCi/g (dry)	0.43	1.4
H-3	RE00-02-45641	05/10/02	-0.362	pCi/g (dry)	0.4	1.3
H-3	RE00-02-45679	05/24/02	-1.15	pCi/g (dry)	0.69	2.4
H-3	RE00-02-45680	05/24/02	-0.875	pCi/g (dry)	0.63	2.1
H-3	RE00-02-45681	05/24/02	-1.03	pCi/g (dry)	0.72	2.4
Pu-238	RE00-02-45714	05/10/02	0	pCi/g (dry)	0.00096	0.0026
Pu-238	RE00-02-45639	05/10/02	0.00242	pCi/g (dry)	0.0017	0.0033
Pu-238	RE00-04-53551	08/23/04	0.00799	pCi/g (dry)	0.0085	0.021
Pu-238	RE00-05-57572	12/09/04	0.00828	pCi/g (dry)	0.0064	0.017
Pu-238	RE00-05-57573	12/09/04	0.0233	pCi/g (dry)	0.012	0.02
Pu-238	RE00-02-45640	05/10/02	0.000874	pCi/g (dry)	0.00088	0.0024
Pu-238	RE00-02-45641	05/10/02	-0.000874	pCi/g (dry)	0.0015	0.0081
Pu-238	RE00-02-45679	05/24/02	-0.0111	pCi/g (dry)	0.0091	0.048
Pu-238	RE00-02-45680	05/24/02	0.00169	pCi/g (dry)	0.0043	0.022

Pu-238	RE00-02-45681	05/24/02	0.000712	pCi/g (dry)	0.0031	0.019
Pu-238	RE00-02-46500	07/25/02	-1.00E-07	pCi/g (dry)	0.0028	0.017
Pu-238	MD21-01-0507	11/13/01	0.00313	pCi/g (dry)	0.0022	0.0042
Pu-238	MD21-01-0508	11/13/01	0.00164	pCi/g (dry)	0.0017	0.0045
Pu-239/240	RE00-05-57572	12/09/04	0.0182	pCi/g (dry)	0.006	0.024
Pu-239/240	RE00-05-57573	12/09/04	0.0233	pCi/g (dry)	0.0083	0.028
Pu-239/240	RE00-02-45639	05/10/02	0.0339	pCi/g (dry)	0.0069	0.0089
Pu-239/240	RE00-02-45714	05/10/02	0.0452	pCi/g (dry)	0.0071	0.0071
Pu-239/240	RE00-04-53551	08/23/04	0.205	pCi/g (dry)	0.022	0.028
Pu-239/240	RE00-02-45640	05/10/02	0.00873	pCi/g (dry)	0.0035	0.0094
Pu-239/240	RE00-02-45641	05/10/02	0.0114	pCi/g (dry)	0.0052	0.016
Pu-239/240	RE00-02-45679	05/24/02	0.0176	pCi/g (dry)	0.0069	0.019
Pu-239/240	RE00-02-45680	05/24/02	0.00627	pCi/g (dry)	0.0057	0.024
Pu-239/240	RE00-02-45681	05/24/02	0.0446	pCi/g (dry)	0.012	0.024
Pu-239/240	RE00-02-46500	07/25/02	0.0181	pCi/g (dry)	0.0072	0.017
Pu-239/240	MD21-01-0507	11/13/01	0.0609	pCi/g (dry)	0.011	0.012
Pu-239/240	MD21-01-0508	11/13/01	0.0362	pCi/g (dry)	0.0089	0.018
Sr-90	RE00-02-45714	05/10/02	0.0212	pCi/g (dry)	0.036	0.17
Sr-90	RE00-04-53551	08/23/04	0.0854	pCi/g (dry)	0.035	0.13
Sr-90	RE00-02-45639	05/10/02	0.0901	pCi/g (dry)	0.051	0.21
Sr-90	RE00-02-45640	05/10/02	-0.0223	pCi/g (dry)	0.019	0.11
Sr-90	RE00-02-45641	05/10/02	0.0748	pCi/g (dry)	0.036	0.14
Sr-90	RE00-02-45679	05/24/02	0.298	pCi/g (dry)	0.067	0.21
Sr-90	RE00-02-45680	05/24/02	0.357	pCi/g (dry)	0.072	0.18
Sr-90	RE00-02-45681	05/24/02	0.307	pCi/g (dry)	0.085	0.25
U-234	RE00-02-46500	07/25/02	0.87	pCi/g (dry)	0.11	0.01
U-235	RE00-02-45639	05/10/02	0.138	pCi/g (dry)	0.062	0.13
U-235	RE00-02-45714	05/10/02	0.149	pCi/g (dry)	0.067	0.13
U-235	RE00-04-53551	08/23/04	0.191	pCi/g (dry)	0.079	0.28
U-235	RE00-02-45640	05/10/02	0.121	pCi/g (dry)	0.07	0.15
U-235	RE00-02-45641	05/10/02	0.0316	pCi/g (dry)	0.043	0.1
U-235	RE00-02-45679	05/24/02	0.194	pCi/g (dry)	0.089	0.33
U-235	RE00-02-45680	05/24/02	0.119	pCi/g (dry)	0.097	0.25
U-235	RE00-02-45681	05/24/02	0.158	pCi/g (dry)	0.083	0.3
U-235	RE00-02-46500	07/25/02	0.037	pCi/g (dry)	0.017	0.043
U-235	RE00-02-46500	07/25/02	0.21	pCi/g (dry)	0.14	0.65
U-238	RE00-02-46500	07/25/02	0.792	pCi/g (dry)	0.1	0.028

Table A2. Results from sampling to determine radiological requirements for posting and access after MDA-B operations were completed.

		Preliminary Analytical Results - 3-5-12		
Sample ID	Date Sampled	Am-241 (pCi/g)	Pu-238 (pCi/g)	Pu-239/240 (pCi/g)
MD21-12-10501	2/23/2012	0.00237	-0.00485	0.0109
MD21-12-10502	2/23/2012	-0.00193	0.1	0.00878
MD21-12-10503	2/23/2012	0.0242	-0.00145	0.301
MD21-12-10504	2/23/2012	0.00826	0.1	0.163
MD21-12-10505	2/23/2012	-0.00364	-0.00235	0.0108
MD21-12-10506	2/23/2012	-0.00079	0.000183	0.0484
MD21-12-10507	2/23/2012	0.00402	-0.00389	0.0273
MD21-12-10508	2/23/2012	0.00652	-0.00077	0.0632
MD21-12-10509	2/23/2012	0.00116	0.00202	0.0298
MD21-12-10510	2/23/2012	0.00438	-0.00069	0.0369
MD21-12-10511	2/23/2012	0.000716	-0.00058	0.00081
MD21-12-10512	2/23/2012	0.104	0.00895	1.03
MD21-12-10513	2/23/2012	-0.0037	0.00126	0.0202
MD21-12-10514	2/23/2012	-0.00538	0.00768	0.136
MD21-12-10515	2/23/2012	0.00877	0.00269	0.148
MD21-12-10516	2/24/2012	0.00874	-0.00224	0.0157
MD21-12-10517	2/24/2012	0.00556	0.00123	0.0504
MD21-12-10518	2/24/2012	0.00443	-0.00138	0.0138
MD21-12-10519	2/24/2012	0.000244	-0.00363	0.185
MD21-12-10520	2/24/2012	0.0204	0.00401	0.0669
MD21-12-10521	2/24/2012	0.0183	-0.00128	0.19
MD21-12-10522	2/24/2012	0.00803	-0.00119	0.12
MD21-12-10523	2/23/2012	0.0112	0.00369	0.14
MD21-12-10524	2/23/2012	0.126	-0.00118	1.11
Mean		0.014661	0.008593	0.16362
Standard Deviation		0.031949	0.028348	0.289669

Attachment 2

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

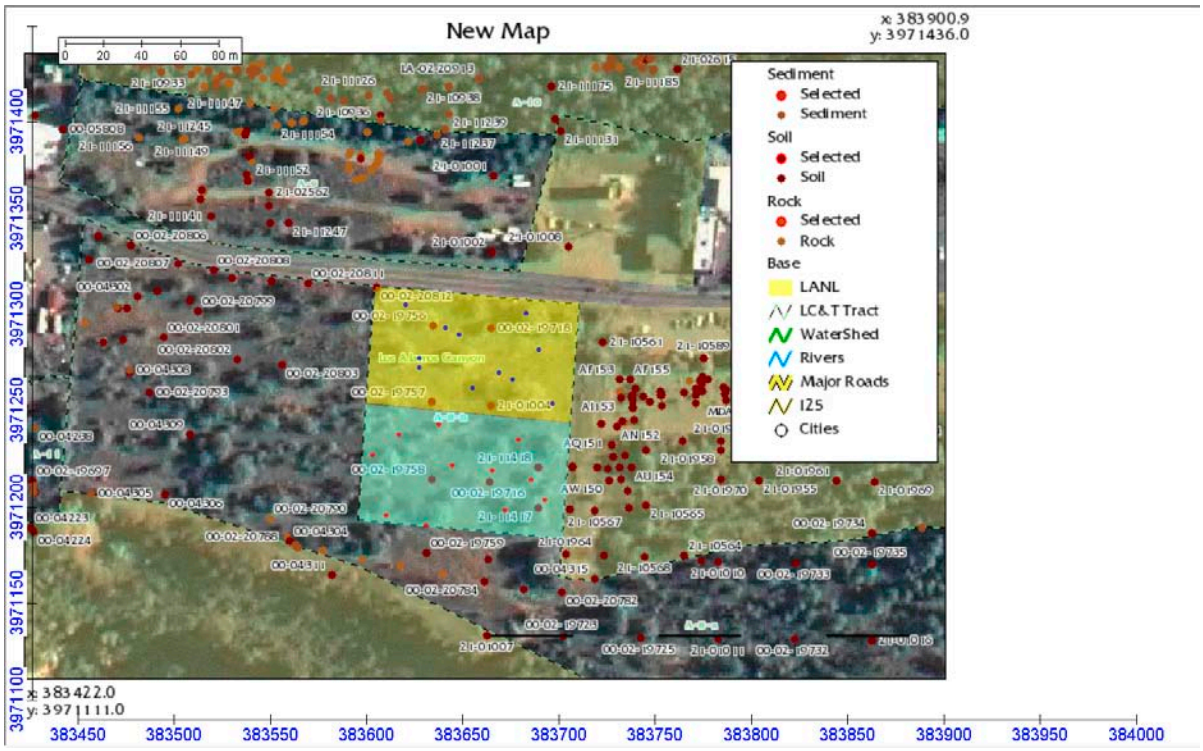
Summary

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	Simple random sampling
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 total number of samples	11
Number of samples on map [a]	11
Number of selected sample areas [b]	1
Specified sampling area [c]	6465.92 m^2
Total cost of sampling [d]	$3,288.00

[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] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.



Area: Decision Area 1

X Coord	Y Coord	Label	Value	Type	Historical
383689.6089	3971282.0266			Random	
383620.2202	3971305.4329			Random	
383675.7311	3971266.4224			Random	
383647.9757	3971289.8287			Random	
383668.7923	3971269.8900			Random	
383641.0368	3971293.2963			Random	
383696.5477	3971254.2858			Random	
383627.1591	3971277.6921			Random	
383682.6700	3971301.0984			Random	
383654.9145	3971262.0879			Random	
383627.3217	3971272.4907			Random	

Area: Decision Area 2

X Coord	Y Coord	Label	Value	Type	Historical
383678.7989	3971235.1671			Random	
383610.0033	3971196.1566			Random	
383665.0398	3971219.5629			Random	
383637.5215	3971242.9692			Random	
383692.5580	3971203.9587			Random	
383603.1237	3971227.3650			Random	
383630.6420	3971190.9552			Random	
383685.6784	3971214.3615			Random	
383616.8828	3971237.7678			Random	
383671.9193	3971198.7573			Random	
383644.4011	3971222.1636			Random	

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 random sampling approach 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.

Locating the sample points randomly provides data that are separated by many distances, whereas systematic samples are all equidistant apart. Therefore, random sampling provides more information about the spatial structure of the potential contamination than systematic sampling does. As with systematic sampling, random sampling also provides information regarding the mean value, but there is the possibility that areas of the site will not be represented with the same frequency as if uniform grid sampling were performed.

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.

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

The formula used to calculate the number of samples is:

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

where

$\Phi(z)$ 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).

The values of these inputs that result in the calculated number of sampling locations are:

Analyte	**n**[a]	**Parameter**					
		S	**Δ**	**α**	**β**	$Z_{1-\alpha}$ [b]	$Z_{1-\beta}$ [c]
Am-241	11	0.0319 pCi/g	20 pCi/g	0.05	0.1	1.64485	1.28155
Pu-239/240	11	0.29 pCi/g	22 pCi/g	0.05	0.1	1.64485	1.28155
Cs-137	11	0.133 pCi/g	3.7 pCi/g	0.05	0.1	1.64485	1.28155
Sr-90	11	0.146 pCi/g	3.8 pCi/g	0.05	0.1	1.64485	1.28155
H-3	11	0.492 pCi/g	500 pCi/g	0.05	0.1	1.64485	1.28155
U-234	11	0.218 pCi/g	113.3 pCi/g	0.05	0.1	1.64485	1.28155
U-235	11	0.06 pCi/g	11.3 pCi/g	0.05	0.1	1.64485	1.28155
U-238	11	0.198 pCi/g	58 pCi/g	0.05	0.1	1.64485	1.28155

[a] The final number of samples has been increased by the MARSSIM Overage of 20.
[b] This value is automatically calculated by VSP based upon the user defined value of α.
[c] This value is automatically calculated by VSP based upon the user defined value of β.

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 □; the upper horizontal dashed blue line is positioned at 1-□ on the vertical axis; the lower horizontal dashed blue line is positioned at □ 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 □ at □and the upper bound of □at 1-□. If any of the inputs change, the number ofsamples 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 randomly.

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

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 μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=87		**α=5**		**α=10**		**α=15**	
		s=0.396	**s=0.198**	**s=0.396**	**s=0.198**	**s=0.396**	**s=0.198**
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 β > action level
α = Alpha (%), Probability of mistakenly concluding that α < action level
AL = Action Level (Threshold)

Recommended Data Analysis Activities

Post data collection activities generally follow those outlined in EPA's Guidance for Data Quality Assessment (EPA, 2000). The data analysts will become familiar with the context of the problem and goals for data collection and assessment. The data will be verified and validated before being subjected to statistical or other analyses. Graphical and analytical tools will be used to verify to the extent possible the assumptions of any statistical analyses that are performed as well as to achieve a general understanding of the data. The data will be assessed to determine whether they are adequate in both quality and quantity to support the primary objective of sampling.

Because the primary objective for sampling for this site is to compare the site median(mean) value with a threshold value, the data will be assessed in this context. Assuming the data are adequate, at least one statistical test will be done to perform a comparison between the data and the threshold of interest. Results of the exploratory and quantitative assessments of the data will be reported, along with conclusions that may be supported by them.