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Title: MARSAME Radiological Release Report for Diamond Drive Widening and Roundabout Construction Projects

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MARSAME Radiological Release Report for Diamond Drive Widening and Roundabout Construction Projects

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1 Summary

Environmental Protection and Compliance, Environmental Stewardship (EPC-ES) has determined that only a portion of the soil associated with the Diamond Drive Widening/Roundabout Projects (Figure 1) meets the criteria for unrestricted release to the public under Department of Energy (DOE) Order 458.1, *Radiation Protection for the Public and the Environment* (DOE, 2020). The remaining soil did not meet the criteria for unrestricted release and must be managed appropriately. These conclusions are based on the known history of the area combined with soil sample data collected in 2022; the findings are consistent with DOE Order 458.1 and Los Alamos National Laboratory (LANL) Functional Series Document EPC-ES-FSD-004, *Environmental Radiation Protection* (LANL, 2021). Sampling and data analysis, as described in this report, were sufficient to meet measurement quality objectives (MQOs) under the *Multi-Agency Radiation Survey and Assessment of Materials and Equipment* (MARSAME) manual (NUREG, 2009) and LANL procedures (LANL, 2020). Final approvals for waste disposition will come from LANL's Waste Management Program.

The scope of this final release report includes excavated soil from the Diamond Drive Widening/Roundabout Projects (Figure 1).

Figure 1. Aerial view of the project area.

2 Introduction

The Diamond Drive study (between West Jemez Road and Pajarito Road) is shaped by the overarching mission of LANL, as well as the desire to create a more aesthetic and appealing campus that enables LANL to attract and retain workers. Design options for Diamond Drive must therefore reconcile safety and security interests, including the flow of large vehicles and transuranic waste package transport (TRUPACT) trucks, with improvements that increase transportation options and afford LANL employees an improved user experience.

AOC C-03-006, a potential environmental radioactivity area, is located within the southern portion of the planned work area along Diamond Drive. Therefore, the potential exists for radiological contamination in soil and/or sediment from excavations from the projects. See Figure 1.

3 MARSAME Survey Description

Soil was characterized to support an off-site disposition decision. A MARSSIM survey approach was utilized to perform the soil sampling for residual radioactive contamination. Since the soil may be sent off-site for disposal, the MARSAME requirements are utilized to evaluate the resulting characterization data.

The primary objective of the MARSAME release report is to confirm, within the stated statistical confidence limits, that the mean levels of potential radioactive residual contamination in excavated soil are documented, in appropriate units, and are at or below background levels. Background levels are provided in Table 1.

Table 1. Background Levels

Radionuclide	Background [pCi/g] (Ryti 1998, Table 6.0-2)
Cs-137	1.65
Pu-238	0.023
Pu-239	0.054
U-234	2.59
U-235	0.20
U-238	2.29

3.1 Survey Quality Objectives

The data quality and survey completeness of the characterization survey were compared to MARSAME requirements for statistical coverage and representativeness. To ensure adequacy of survey coverage, EPC-ES used the statistical software Visual Sample Plan (Matzke BD, 2010). This software generates a MARSAME-compliant sampling plan that provides sufficient and representative data on which to base release decisions. Characterization surveys provide 1) information on the nature and extent of contamination, if any, 2) data to support evaluation of remediation alternatives and technologies, 3) data for determining if the survey plan can be optimized for use in the final survey, and 4) input for the final status survey design (NUREG, 2000).

Surface soil samples collected and reported in the Intellus[1] database were used as input for calculating the relative shift and other statistical parameters used in the Sample and Analysis Plan (Appendix A). Type I error was set at 5% and Type II error was set at 10%, resulting in approximately 11 samples per decision unit using VSP software (Appendix A). Based on characterization survey coverage, no additional sampling is required.

The number and placement of sampling locations were compared to MARSAME (Appendix A) requirements for final release and were found to be adequate in number of measurements and spatial distribution to make valid, statistically-based release decisions.

Figure 1 shows the project area that runs through AOC C-03-006 and the sampling locations can be seen in Figure 2. The sampling team was instructed to take samples as close as possible to the locations on the map, but to use discretion, as necessary.

3.2 Disposition Pathways

Depending on the disposition pathway, the objectives of the measurements were to confirm, within the stated statistical confidence limits, that:

1. If results from the soil radioactive contamination measurements are above the background values in Table 1, the soil is not a candidate for unrestricted off-site release.
2. If results from the soil radioactive contamination measurements are below the background values in Table 1, the soil is a candidate for unrestricted off-site release.

Potential disposition pathways for this project included:

1. If results are above background values but below the Authorized Limits (ALs) for volumetric clearance found in EPC-ES-FSD-004 Table 10-2, soil can be released subject to acceptance criteria of receiver.
2. If results are below background values, soil may be disposed at commercial/municipal landfills using a release criterion of Indistinguishable from Background (IFB).
3. If results are above background and above the ALs, the soils must be disposed as Low Level Waste (LLW).

4 Data Analysis

Table 2 presents a summary of the soil concentration results. Most of the data met the unrestricted release criteria, with several samples exceeding the background levels. Given these results, a portion of the soil is recommended for unrestricted off-site release and the remainder of the soil must stay onsite or be treated as low level waste (LLW). Final approvals for waste disposition will be determined by LANL's Waste Management Program.

[1] https://www.intellusnm.com/gis/home_gis.cfm

Table 2. Soil concentrations of radionuclides (pCi/g)

	Cs-137	Pu-238	Pu-239	U-234	U-235	U-238
N (# of data points)	11	11	11	11	11	11
Mean	0.028	0.023	0.001	0.680	0.061	0.680
Median	0.033	0.003	-0.003	0.630	0.057	0.633
Maximum	0.078	0.234	0.042	1.110	0.150	0.977
Minimum	-0.014	-0.012	-0.012	0.464	-0.045	0.539
STD[a]	0.028	0.070	0.015	0.189	0.053	0.136
UCL (ProUCL 95%)[b]	0.043	0.062	0.010	0.784	0.090	0.754
Background[c]	1.65	0.023	0.054	2.59	0.20	2.29
Authorized Limit[d]	3	3	3	30	30	30

[a] Standard Deviation (STD)
[b] Upper Confidence Level (UCL).
[c] Inorganic and Radionuclide Background Data for Soils, Canyon Sediments, and Bandelier Tuff at Los Alamos National Laboratory; LA-UR-98-4847; R. T. Ryti, P. A. Longmire, D. E. Broxton, Steven L. Reneau, and E. V. McDonald.
[d] Authorized Limit, FSD-EPC-ES-004, Table 10-2.

4.1 Authorized Limit Release Pathway

Materials bearing volumetric radioactivity greater than the Minimum Detectable Activity (MDA) were evaluated by comparison to the preapproved ALs found in Table 10-2 of EPC-ES-FSD-004. The radionuclides of concern for volumetric radioactivity were 1) Americium-241, Cesium-137, Plutonium-238, and Plutonium-239, which have pre-approved release limits of 3 pCi/g; and 2) Uranium-234, Uranium 235, and Uranium 238, which have pre-approved release limits of 30 pCi/g.

Decision Criteria for AL pathway:

- If all measurements are ≤ AL, then no further action is required, and the items are candidates for unrestricted release.
- If all measurements or the 95% upper confidence limit (UCL) are > the AL, then the item is not a candidate for release through the AL release pathway.
- If the UCL for a set of measurements 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 used, and if contamination is not present in background, use the Sign Test.

4.2 Indistinguishable From Background Pathway

Soil bearing volumetric radioactivity greater than the MDA were evaluated by comparison to the background values found in Table 1.

Decision Criteria for Indistinguishable from Background (IFB) pathway:

- If all measurements are: 1) ≤ detectable levels, or 2) < reference background values such as the 95% UCL, then no further action is required, and the items are candidates for unrestricted release.

- If all measurements are > 95% UCL of background, then the item is not a candidate for release through the IFB pathway and the item can be considered for decontamination or decay in storage followed by resampling before it can be released.
- If the mean for a set of measurements is below the 95% UCL background level, but some individual measurements are above the 95%UCL level, 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 (WRS) test is suggested, and if contamination is not present in background, use the Sign Test.

4.3 Sampling Results

The soil sample summary results can be found in Table 2. Analysis of the IFB pathway for unrestricted release shows that the 95% UCL for Pu-238 is above the background value requiring further statistical analysis. One location (250480) is greater than background for Pu-238. The WRS test was performed for this data set against the background. Pu-238 does not pass the WRS test. Sample locations are show in Figure 2 with the location information for each point found in Table 3. Sample 250480 is the only sample that is greater than background for Pu-238, with all other samples being below background. Based on these findings, the soil and concrete south of 250481, north of 250479, east of the parking lot and west of the asphalt road (Area 1 outlined in red in Figure 2) should be separated from the remaining project soil. Soil from this area is not IFB and must be treated as 1) LLW, 2) released using authorized limits, 3) left in place, or 4) relocated within LANL property with proper approvals. The remaining soil, including any concrete and asphalt, in the project area (see Area 2 outlined in blue in Figure 2) is IFB and candidate for unrestricted release.

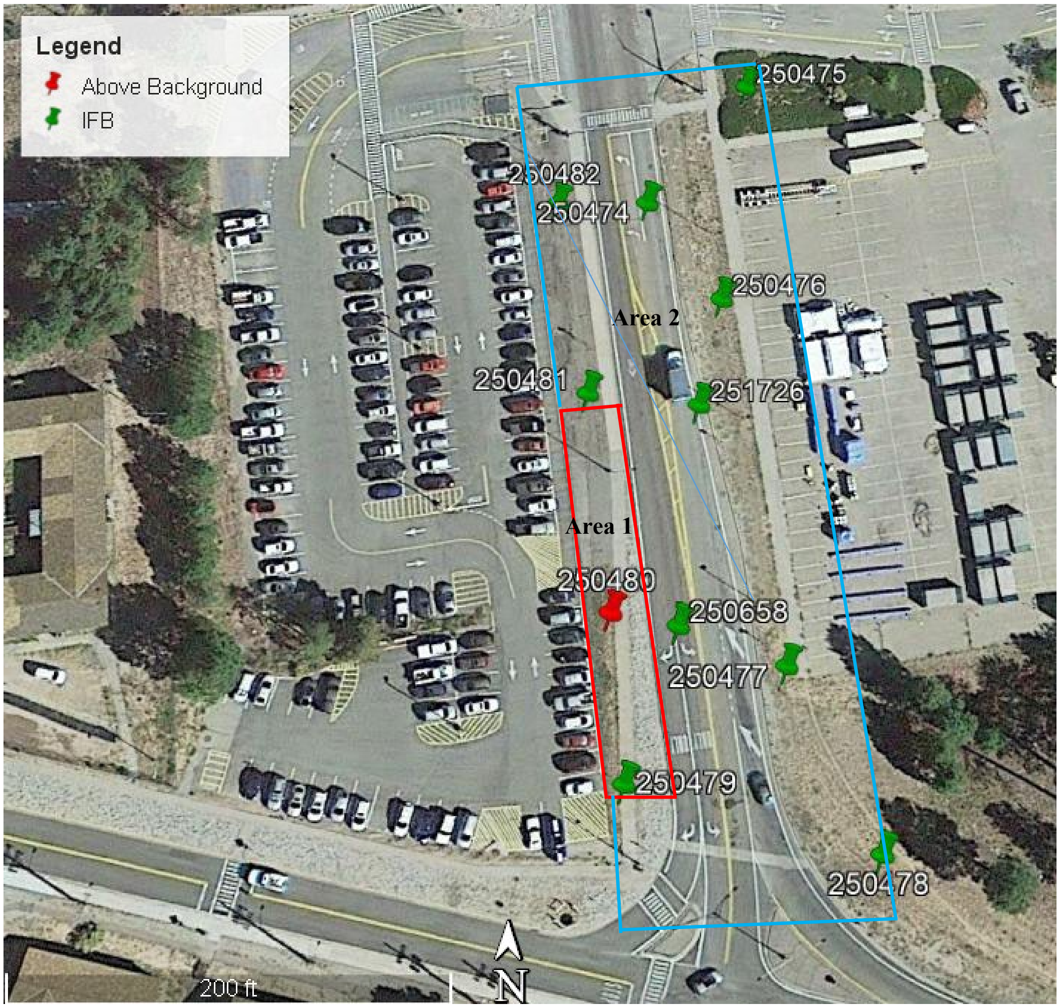

Figure 2. Sample Locations

Table 3. Sample Location Information

Location ID	Latitude (Decimal)	Longitude (Decimal)
250475	35.8702925	-106.3203861
250476	35.8699625	-106.3204225
250477	35.8694485	-106.320291
250478	35.8692117	-106.3201321
250479	35.8692919	-106.3205425
250480	35.8695231	-106.3205781
250481	35.8698222	-106.320642
250482	35.8701018	-106.3207104
250658	35.869499	-106.320462
251726	35.869806	-106.320450
251727	35.870102	-106.320550

Conclusions

Given the process knowledge and sample data presented in this report package, EPC-ES concludes that the soil associated with Diamond Drive Widening/Roundabout Construction Projects must be divided, see Figure 2. Soil coming from Area 1 is a candidate for unrestricted release under DOE Order 458.1. Soil from Area 2 must be treated as 1) LLW, 2) released using authorized limits, 3) left in place, or 4) relocated within LANL property with proper approvals. Final waste disposition decisions for radiological and non-radiological constituents require appropriate approvals from the waste management coordinator.

5 References

DOE. (2020). *Radiation Protection of the Public and the Environment.* DOE O 458.1, Chg 4.

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NUREG. (2009). *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual (MARSAME).* NUREG-1575, Supp. 1; EPA 402-R-09-001; DOE/HS-0004.

Ryti, R. T. (1998). *Inorganic and radionuclide background data for soils, canyon sediments, and Bandelier tuff at Los Alamos National Laboratory.* Los Alamos, NM: Los Alamos National Laboratory Environmental Restoration Project.

6 Acronyms and Abbreviations

Acronym	Definition
DOE	(U.S.) Department of Energy
EPA	(U.S.) Environmental Protection Agency
LANL	Los Alamos National Laboratory
MARSAME	Multi-Agency Radioactive Survey and Assessment of Material and Equipment
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MQO	measurement quality objective
SAP	Sample and Analysis Plan
TA	Technical Area
VSP	Visual Sample Plan

Appendix A: Sample and Analysis Plan Diamond Drive Widening and Roundabout Construction

May 2022

Sample and Analysis Plan for Diamond Drive Widening and Roundabout Construction

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1 Sample and Analysis Plan Overview

1.1 Purpose and Scope of the Sample and Analysis Plan

The Diamond Drive Widening and Roundabout Construction Projects intersect with Area of Concern (AOC) C-03-006, a potential environmental radioactivity area; therefore, the potential exists for radiological contamination in soil and/or sediment from excavations from the projects. The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (NUREG, 2000) survey approach will be used to perform the characterization surveys of soil and/or sediment for residual radioactive contamination. Because materials from the project will be sent offsite for disposal, the Multi-Agency Radiation Survey and Assessment of Materials and Equipment (MARSAME) (NUREG, 2009) requirements will be used to evaluate the resulting characterization data for disposal path decisions, as appropriate.

1.2 Objective of the Sample and Analysis Plan

The objective of this sample and analysis plan (SAP) is to confirm, within the stated statistical confidence limits, that the mean levels of potential radioactive residual contamination in soils are documented to determine if they are at background levels and are candidates for release for offiste disposal. The nominal release criteria for this project are background values in Table 1 (Ryti, 1998).

Table 1. Background Levels

Radionuclide	Background [pCi/g]
Cs-137	1.65
Pu-239	0.054
U-234	2.59
U-235	0.20
U-238	2.29

1.3 MARSSIM Guidance

According to MARSSIM Section 2.4, the six principal steps in the MARSSIM Radiation Survey and Site Investigation Process are as follows:

- Site Identification
- Historical Site Assessment (HSA)
- Scoping Survey
- Characterization Survey
- Remedial Action Support Survey
- Final Status Survey

The first two principal steps (site identification and HSA) have already been completed, and the results are detailed in this document. The purpose of this plan is to satisfy the third and fourth principal steps (scoping and characterization) to assess for radiological impact and, if impacted, to characterize the potential contamination. Although the purpose of this plan is to provide scoping data, the rigor of the sampling is designed to meet the quality objectives of a characterization survey.

The MARSSIM HSA information for these structures is contained in Section 1.5. The water line route runs through several solid waste management units (SWMUs) and potential environmental radioactivity areas, and the potential exists for radiological contamination in excavated materials. The MARSSIM surveys will be used to assess the radioactive contamination. The survey results will be evaluated against MARSAME release requirements and, if release requirements are met, the materials from excavations are candidates for unrestricted release under U.S. Department of Energy (DOE) Order 458.1 (DOE, 2020).

If surveys measure radioactive contamination, in accordance with MARSSIM Chapter 2, Section 2.4.4., "If an area could be classified as Class 1 or Class 2 for the final status survey, based on the HSA and scoping survey results, a characterization survey is warranted. This type of survey is a detailed radiological environmental characterization of the area." Based on the HSA of the Diamond Drive Widening and Roundabout Construction projects, a Class 1 or Class 2 final status survey unit is possible. Although the less-rigorous elements of a scoping survey may be sufficient, a characterization survey structure was used as described below.

According to MARSSIM Chapter 2, Section 2.4.4., the primary objectives of a characterization survey are as follows:

- Determine the nature and extent of the contamination.
- Collect data to support evaluation of remedial alternatives and technologies.
- Evaluate whether the survey plan can be optimized for use in the final status survey.
- Provide input to the final status survey design.

From MARSSIM Chapter 2, Section 2.4.4.: "The characterization survey is the most comprehensive of all the survey types and generates the most data. This includes preparing a reference grid, systematic as well as judgment measurements, and surveys of different media (e.g., surface soils, interior and exterior surfaces of buildings). The decision as to which media will be surveyed is a site-specific decision addressed throughout the Radiation Survey and Site Investigation Process."

Once the scoping survey has been completed according to this plan, the data will be analyzed using the MARSAME statistical methods, and these results will be used to plan for the remedial action support surveys and/or final status surveys, as appropriate.

Notes and Assumptions

The results of this survey are to be used for waste disposal planning purposes. According to MARSSIM Section 2.4.6, ". . . data from other surveys conducted during the Radiation Survey and Site Investigation Process – such as scoping, characterization, and remedial action support surveys – can provide valuable information for planning a final status survey provided they are of sufficient quality." Release of materials is contingent upon material surveys passing a final status survey, as appropriate.

Further restrictions may be imposed by the waste management coordinator.

1.4 Project Overview and Site Identification

Diamond Drive is the principal access road for much of the Los Alamos National Laboratory (LANL) campus and provides direct connections to facilities in Technical Area 3 (TA-03). The roadway is highly utilized by users of all modes of transportation and experiences high levels of congestion during the peak periods. Traffic flow is a critical concern along the corridor both in terms of everyday operations as well as emergency vehicle and safety needs.

The Diamond Drive study (between West Jemez Road and Pajarito Road) is shaped by the overarching mission of LANL, as well as the desire to create a more aesthetic and appealing campus that enables LANL to attract and retain workers. Design options for Diamond Drive must therefore reconcile safety and security interests, including the flow of large vehicles and transuranic waste package transport (TRUPACT) trucks, with improvements that increase transportation options and afford LANL employees an improved user experience.

AOC C-03-006 is located within the southern portion of the planned work area along Diamond Drive. See Figure 1.

Figure 1. Aerial view of the Diamond Drive Widening and Roundabout Construction Area.

1.5 Historical Site Assessment[1]

The work area runs through AOC C-03-006, which is detailed below.

AOC C-03-006 is the site of an unintentional release from a manhole (former structure SM-736) that was connected to a radioactive liquid waste (RLW) line. The manhole was located near the corner of Diamond Drive and Pajarito Road and was part of the former RLW collection system that ran from TA-03 and

[1] All information in this section comes from the LANL Potential Release Site Website, prs.lanl.gov.

other technical areas to the Radioactive Liquid Waste Treatment Facility (RLWTF) at TA-50. In 1974, the manhole overflowed to a storm sewer along Diamond Drive in TA-03 and ultimately discharged to upper Mortandad Canyon through the SWMU 03-054(e) outfall. The overflow resulted from a plug in the industrial waste line and was estimated to be between 500 gal. and 1,000 gal. of RLW. The overflow spilled to the surrounding paved area, traveled north along Diamond Drive, flowed into the storm sewer via a storm-drain grate, and ultimately discharged into upper Mortandad Canyon through the SWMU 03-054(e) outfall. A cleanup of the overflow-impacted area began the day after the release. A collection and pumping system was used to flush the contaminated storm drain. Approximately 176 cubic meters of pavement was removed to the depth of the base course and disposed of at Area G at TA-54. Newly exposed surfaces were monitored, and one section of curbing with radioactivity levels exceeding background levels was removed. Additional surveys and subsequent confirmation sampling determined that no radioactivity exceeding the decontamination criteria (25 pCi/g) was present in the base-course material. The area was restored by repaving and replacing the curb along Diamond Drive and around the manhole, removing the dam built in the stream bed at the base of the canyon, and installing engineering controls. The area was further excavated in 1984 when the manhole and the RLW line were removed as part of the Radioactive Liquid Waste Lines Removal Project.

During the 1995 Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) conducted around AOC C-03-006 and at the SWMU 03-054(e) outfall, eight samples were collected from six locations and submitted for analysis of gamma-emitting radionuclides, isotopic plutonium, isotopic uranium, and tritium. Data from the 1995 RFI are screening level data and showed inorganic chemicals detected above background values (BVs), detected semi-volatile organic compounds (SVOCs), and radionuclides detected or detected above BVs/fallout values.

During the 2009 Phase I Consent Order investigation conducted at AOC C-03-006, 10 samples were collected from 5 locations below the former drain line downgradient and south of the former manhole. Samples were submitted for analysis of target analyte list metals, nitrate, perchlorate, total cyanide, polychlorinated biphenyls, SVOCs, volatile organic compounds, dioxins and furans, gamma-emitting radionuclides, isotopic plutonium, isotopic uranium, and tritium.

Decision-level data for AOC C-03-006 consists of 10 samples collected from 5 locations in 1995 and 2009. The 2015 supplemental investigation report concluded that the nature and extent of contamination have been defined and that no further sampling for extent is warranted. This site does not pose a potential unacceptable risk or dose under the industrial, construction worker, or residential scenarios and poses no potential ecological risk.

1.6 Results from Historical Surveys for Residual Contamination

For the purpose of developing a MARSSIM-based sample plan, previous data were used to determine an expected standard deviation for sample plan development. Surface soil and sediment samples collected and reported in the Intellus[2] database were used; see Table 2. The data in Table 2 are compared with the background values in Table 1.

[2] https://www.intellusnm.com/gis/home_gis.cfm

Table 2. Summary Data and Statistics for Previous Soil/Sediment Measurements from Intellus

Soil Concentrations by Radionuclide (pCi/g)					
	Cs-137	Pu-239/240	U-234	U-235/236	U-238
n*	7	7	7	7	7
average	0.47	0.01	0.59	0.02	0.47
max	0.60	0.02	0.67	0.04	0.60
median	0.53	0.01	0.56	0.02	0.53
STD	0.19	0.01	0.06	0.01	0.19
UCL	0.79	0.02	0.64	0.03	0.79

n = number of data points
max = maximum
STD = standard deviation
UCL = upper confidence limit (ProUCL 5.1)

2 Data Quality Objectives for the SAP

This SAP was prepared in accordance with EPC-ES-FSD-004, *Environmental Radiation Protection* (LANL, 2021), and was developed using EPC-ES-TPP-001, *Data Quality Objectives for Measurement of Radioactivity in or on Items for Transfer into the Public Domain* (LANL, 2020).

Decision Identification

The principal study question is, Does the residual radioactive contamination exceed background levels? The decision alternatives are as follows:

- If results from the soil radioactive contamination measurements are at or above background (collectively), the materials *are not* candidate for release to commercial landfill.
- If results from the soil radioactive contamination measurements are below background (collectively), the materials *are* candidate for release to commercial landfill.

2.1 Study Boundaries

The study is limited to the area where the Diamond Drive widening and roundabout construction area crosses AOC C-03-006. Figure 2 shows the sampling area (decision area) in red and the sample locations. The list of radionuclides in the analysis includes Cs-137, Pu-239, U-234, U-235, and U-238.

Figure 2. Decision Area and Sampling Locations.

Table 3. Sample Location Coordinates

Latitude	Longitude	Sample Material
380803.6018	3970279.4013	Asphalt, Base Course, Soil
380823.3011	3970279.4013	Soil
380813.4515	3970296.4613	Soil
380803.6018	3970313.5214	Asphalt, Base Course, Soil
380793.7522	3970330.5815	Soil
380813.4515	3970330.5815	Soil
380803.6018	3970347.6416	Asphalt, Base Course, Soil
380793.7522	3970364.7017	Soil
380813.4515	3970364.7017	Soil
380803.6018	3970381.7617	Soil
380793.7522	3970398.8218	Soil

2.2 Decision Rule

The decision rule is based on the null hypothesis that the mean residual contamination level in soil and/or sediment is above background and not releasable. The alternative hypothesis is that the mean residual contamination level in soil and/or sediment is below background and releasable.

2.3 Limits on Decision Errors

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

2.4 Statistically Based Evaluation for Number of Samples Required Using MARSSIM

The specific details of the analysis (specific statistical parameter values, analysis, results, and approximate coordinates for the randomly selected sampling locations using MARSSIM) are provided in Appendix A: of this report. Results showed that 24 systematic samples are needed within the decision area. The approximate locations are indicated in Figure 2, and coordinates are provided in Table 3 and Appendix A:. Google Earth was used to plan sampling, and a geo-referenced image file with an associated polygon (.shp) for project area was incorporated into Visual Sample Plan (VSP) software (Matzke BD, 2010). The sampling area was defined inside the initial polygon shown in Figure 2. The MARSSIM application within VSP was then used to determine the statistically based sampling plan.

2.5 Instrumentation and Measurement Quality Objectives

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

2.5.1 *MQOs*

- Detection Capability: Minimum detection concentration should be below the MARSSIM-defined lower bound of the gray region.
- 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.
- 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.

2.5.2 Procedures Used to Meet the MQOs

1. Collection of valid soil sample appropriate for the dose assessment:

   (a) Soil sampling will follow the procedure EPC-ES-TP-003, *Soil and Vegetation Sampling for the Environmental Surveillance Program* (LANL, 2022b). These surface soil samples are appropriate for the deposition pathway and the exposure scenario (i.e., top 5 cm). Subsurface soil samples are not required because depositions would be to surfaces with little migration expected to deeper soil.

   (b) Additional quality assurance for the collection of the samples is provided through procedure EPC-ES-QAPP-0001, *Implementation of the Soil, Foodstuffs, and Biota Program* (LANL, 2022a).

2. Soil sample analysis will use U.S. Environmental Protection Agency (EPA)-approved analytical procedures for each radionuclide. The following will be used by the independent laboratory:

   (a) Environmental Measurements Laboratory (EML) 1997. *The Procedures Manual of the Environmental Measurements Laboratory*. Radionuclide-specific procedures for Am-241, Pu-239, and U-238.

   (b) EPA 1980. Method 901.1 – Gamma Emitting Radionuclides in Drinking Water: Prescribed Procedures for Measurement of Radioactivity in Drinking Water.

   (c) EPA 1980. Method 905.0 – Radioactive Strontium in Drinking Water: Prescribed Procedures for Measurement of Radioactivity in Drinking Water.

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

3 References

DOE (U.S. Department of Energy). (2020). *Radiation Protection of the Public and the Environment.* DOE O 458.1, Chg 4.

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4 Acronyms and Abbreviations

Acronym	Definition
DQO	data quality objective
HDD	horizontal directional drilling
NFA	no further action
NMED	New Mexico Environment Department
AOC	area of concern
BV	background value
DOE	(U.S.) Department of Energy
EPA	(U.S.) Environmental Protection Agency
HSA	historical site assessment
LANL	Los Alamos National Laboratory
MARSAME	Multi-Agency Radioactive Survey and Assessment of Material and Equipment
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MQO	measurement quality objective
RFI	Resource Conservation and Recovery Act Facility Investigation
RLW	radioactive liquid waste
SAP	Sample and Analysis Plan
SVOC	semi-volatile organic chemical
SWMU	solid waste management unit
TA	Technical Area
VSP	Visual Sample Plan

Appendix A: Visual Sample Plan Summary 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]	11
Number of selected sample areas [b]	1
Specified sampling area [c]	3696.78 m^2
Size of grid / Area of grid cell [d]	19.6993 meters / 336.071 m^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 gives the linear and square dimensions of the grid used to systematically place samples. If there was more than one sample area, this represents the largest dimensions used.

Area: Area 1		
X Coord	Y Coord	Type
380803.6018	3970279.4013	Systematic
380823.3011	3970279.4013	Systematic
380813.4515	3970296.4613	Systematic
380803.6018	3970313.5214	Systematic
380793.7522	3970330.5815	Systematic
380813.4515	3970330.5815	Systematic
380803.6018	3970347.6416	Systematic
380793.7522	3970364.7017	Systematic
380813.4515	3970364.7017	Systematic
380803.6018	3970381.7617	Systematic
380793.7522	3970398.8218	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.

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:

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

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).

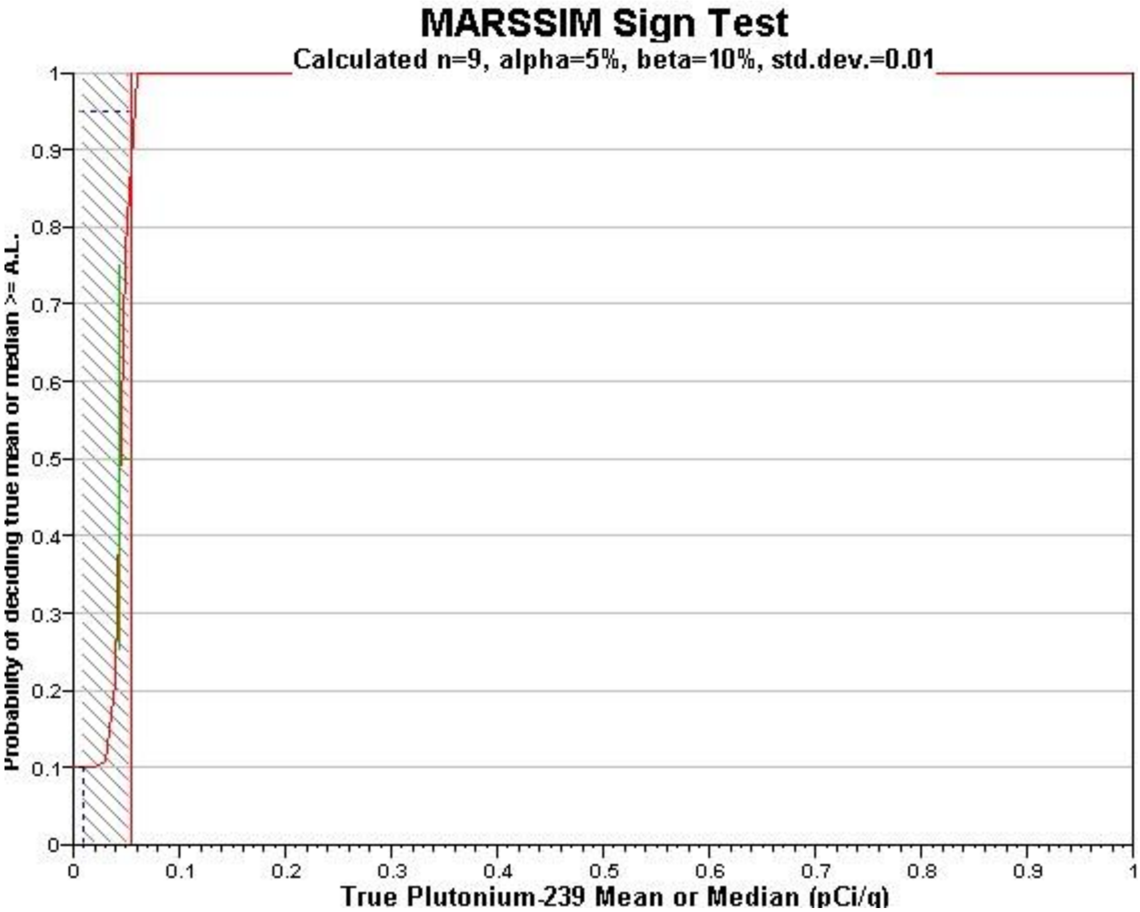
For each nuclide in the table, the values of these inputs that result in the calculated number of sampling locations are:

Nuclide	n[a]	n[b]	n[c]	Parameter					
				S_{total}	Δ	α	β	$Z_{1-\alpha}$ [d]	$Z_{1-\beta}$ [e]
Plutonium-239	9	9	11	0.01	0.044	0.05	0.1	1.64485	1.28155
Uranium-234	9	9	11	0.06	2	0.05	0.1	1.64485	1.28155
Uranium-235	9	9	11	0.01	0.18	0.05	0.1	1.64485	1.28155
Uranium-238	9	9	11	0.19	1.82	0.05	0.1	1.64485	1.28155
Cesium-137	9	9	11	0.01	1.62	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 $1-\alpha$ 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 $1-\alpha$. 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 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=1.65		α=5		α=10		α=15	
		s=0.02	s=0.01	s=0.02	s=0.01	s=0.02	s=0.01
LBGR=90	β=5	287	78	228	62	191	52
	β=10	228	62	176	47	143	39
	β=15	191	52	143	39	114	32
LBGR=80	β=5	78	26	62	21	52	17
	β=10	62	21	47	16	39	14
	β=15	52	17	39	14	32	11
LBGR=70	β=5	39	17	32	14	27	11
	β=10	32	14	24	11	20	9
	β=15	27	11	20	9	16	8

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 not adjusted for EMC.

Total Dose Calculation
The total dose from all sources was calculated based on the user-entered values below.

Total Dose From All Sources		
Area	**Average**	**DCGL**
Survey Unit	0	10
Total Dose Sum of Fractions:		0
Total dose from all sources is below release criteria. 0 < 1		

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