

BUILDING 1103A AREA FINAL STATUS SURVEY PLAN

REV. 0

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LIST OF ACRONYMS AND ABBREVIATIONS

ANL	Argonne National Laboratory	MDC	Minimum Detectable Concentration
APG	Aberdeen Proving Grounds	MDCR	Minimum Detectable Count Rate
ARL	Army Research Laboratory	MDER	Minimum Detectable Exposure Rate
bkg	background	min	minute(s)
CABRERA	Cabrera Services, Inc.	mrem/yr	millirem(s) per year
CFR	Code of Federal Regulations	μR/hr	microroentgens per hour
cm	centimeter(s)	NaI	sodium iodide
cm²	square centimeter(s)	NIST	National Institute of Standards and Technology
cpm	count(s) per minute	NRC	U.S. Nuclear Regulatory Commission
DCGL	Derived Concentration Guideline Level	P	Probability
DCGL_{EMC}	Derived Concentration Guideline Level used for elevated measurement comparison	pCi/g	picocurie(s) per gram
DCGL_w	Derived Concentration Guideline Level used for non-parametric statistical test	QA	Quality Assurance
dpm	disintegration(s) per minute	QC	Quality Control
DP	Decommissioning Plan	RDR	Relative Detector Response
DQO	Data Quality Objective	ROC	Radionuclide of Concern
DU	Depleted Uranium	sec	second(s)
FRER	Fluence Rate to Exposure Rate	SOP	Standard Operating Procedure
FSS	Final Status Survey	SU	Survey Unit
FSSP	Final Status Survey Plan	TEDE	Total Effective Dose Equivalent
GPS	Global Positioning System	¹³⁷ Cs	cesium-137
GWS	Gamma Walkover Survey	⁹⁹ Tc	technetium-99
H_a	alternative hypothesis	²³⁰ Th	thorium-230
H₀	null hypothesis	²³⁴ Th	thorium-234
HP	Health Physicist	²³⁴ U	uranium-234
in.	inch(es)	²³⁵ U	uranium-235
JMC	Joint Munitions Command	²³⁸ U	uranium-238
LBGR	Lower Bound of the Gray Region		
m	meter(s)		
m²	square meter(s)		
m/s	meter(s) per second		
MARSSIM	Multi-Agency Radiological Survey and Site Investigation Manual		

1.0 INTRODUCTION

This *Final Status Survey Plan (FSSP)* has been prepared by Cabrera Services, Inc. (CABRERA), under contract to the U.S. Army Joint Munitions Command (JMC), to support the decommissioning of the Building 1103A Area at Aberdeen Proving Ground (APG). This *FSSP* addresses the applicable radiological surveys, sampling, and data analysis necessary to demonstrate that the Building 1103 Area is suitable for unrestricted release following completion of the decommissioning activities outlined in the *Building 1103A Area Decommissioning Plan (DP)*. The Building 1103A Area is under the control of the U.S. Army Research Laboratory (ARL), and is subject to the requirements of its U.S. Nuclear Regulatory Commission (NRC) license (No. SMB-141). The goal of decommissioning activities described in the *DP* is to facilitate the release of the site for unrestricted use.

The proposed derived concentration guideline levels (DCGLs) for soil and structures for the Building 1103A Area are based on the surface activity screening values published by the NRC in NUREG-5512: *Residual Radioactive Contamination from Decommissioning, Parameter Analysis*, Volume 3, Tables 5.19 (NRC, 1999), and a site-specific soil DCGL developed by Argonne National Laboratory (ANL) for the APG Transonic Range (ANL, 1999), which was contaminated with similar source material (i.e., depleted uranium [DU]). Implementation of this *FSSP* will provide the data necessary to demonstrate compliance with the DCGL for structure surfaces and outdoor areas. Specifically, when the DCGLs are applied to the final status survey (FSS) and the data obtained indicates that the requirements of this *FSSP* have been satisfied, the requirements in Title 10 of the Code of Federal Regulations (CFR) Part 20.1402 for unrestricted release are achieved (NRC, 2006).

2.0 SITE INFORMATION

The Building 1103A Area is a former radioactive material processing and storage facility on Spesutie Island at APG. Historical site activities involving DU have resulted in radiological contamination of the buildings and grounds. ARL has responsibility for this area and desires to initiate the decommissioning process so that the area can be released from its NRC Nuclear Materials License requirements.

The general layout of the Building 1103A Area is shown in Figure 2-1. Floor plans of the main buildings comprising this area (i.e., Building 1103A, Building BRL12, and the freestanding vault) are depicted in Figures 2-2 through 2-4, respectively. Historical activities involved the unloading of DU contaminated targets in the central asphalt area; storage and staging of the targets in one of the three vaults; cutting and machining of the targets in Building 1103A (and, to a lesser extent, BRL12); and storage and reloading of the resulting steel pieces in preparation for decontamination, disposal, or reuse.

A characterization survey was conducted at the site in May 2006 to determine the extent of radiological impact to the buildings and grounds. Upon completion of the survey, limited DU activities in the Building 1103A Area were temporarily resumed. Current activities are similar in nature to historical activities conducted at the site, and are being confined to Building 1103A only. It is expected that work involving DU will permanently cease in 2008, at which time the Army is expected to proceed with decommissioning the site.

2.1 Site Description

The Building 1103A Area consists of 3 primary structures: Building 1103A, Building BRL12, and a Freestanding Vault. The site also includes the land areas adjacent to and between these structures.

2.1.1 Building 1103A

Building 1103A houses the main machine shop used for the disassembly of firing range targets contaminated with DU. The Main Area of Building 1103A is constructed of cinder block exterior walls, a concrete slab floor, and a flat tar-and-chip roof. The ceiling is covered in some places with fiberboard. Under the same roof is a small Entry Area, which includes the furnace room, bathroom, meeting room, and changing room. The Entry Area has a drop-type acoustic tile ceiling, sheetrock walls, and tile flooring. The walls separating the Entry

and Main Areas consist of sheetrock, and are lined with steel plates on the side facing the Main Area.

On the south side of the building is a Shop Area, which is a wood-frame addition to the main building. This area has a concrete slab floor and a pitched shingle roof. Steel plates line the lower portion of the walls in this area, and fiberglass insulation is present between the wood studs and overhead beams.

Building 1103A contains functioning ventilation, electrical, water supply, and sewer systems. The ventilation system has fiber filters on the air intake vents and exposed ductwork attached to the ceiling. The electrical system panel is located in the Shop Area, and electrical conduit runs along the walls and ceiling throughout the building to supply energy to light fixtures and wall outlets. There is a full bathroom in the Entry Area with sink, toilet, and shower facilities. This area was used for personnel and equipment decontamination during building operations involving radioactive material.

2.1.2 Building BRL12

Building BRL12 was built to provide additional space for machining operations associated with the dismantlement of DU-contaminated targets, as well as shielded storage space for staging the contaminated targets prior to disassembly. The main area (i.e., Central Room) of Building BRL12, where machining was performed, has a concrete floor, sheetrock walls (some of which are lined with steel), and acoustic tile ceiling. There are two air conditioning units mounted in the west wall of the building. The only utility system in the building is the electrical system, which is used to power the air conditioners, light fixtures, and wall outlets.

There are steel-lined storage vaults on the north and south ends of Building BRL12. Both vaults have concrete floors and steel-lined walls and ceilings. A single light fixture hangs from the ceiling in each vault. There is also a small office area situated between the main room and the north end vault. The office has sheetrock walls, tiled floor, and acoustic tile ceiling.

2.1.3 Freestanding Vault

The Freestanding Vault is situated directly southeast of Building BRL12. Like the BRL12 end vaults, this vault was used for the storage of contaminated targets. It has a concrete floor, and the walls and ceiling are completely lined with steel. A single light fixture hangs from the ceiling. Attached to the southern end of the vault is a wooden tool shed where maintenance equipment such as a tractor and snow plow are stored.

2.1.4 Pavement and Grounds

The impacted outdoor areas include approximately one-half acre of asphalt pavement between the buildings and vaults (i.e., Central Asphalt), the small parking lot east of the perimeter fence enclosing the Building 1103A Area (i.e., Adjacent Asphalt), and approximately one-half acre of grass-covered grounds within or adjacent to the Building 1103A Area (i.e., Grounds).

Central Asphalt

The Central Asphalt area, which extends from the south side of Building 1103A to the southern fence, was the site of loading, unloading, and staging of contaminated targets, as well as for the transfer of targets among the disassembly buildings and storage areas. On at least one occasion, contaminated items were dismantled on the asphalt in front of Building BRL12 by using an acetylene torch. The asphalt is cracked in many places, allowing for water seepage, and is prone to slight changes in elevation depending on the moisture content of the underlying soil. Small areas of yellow discoloration and/or DU fragments are present in several locations.

Adjacent Asphalt

The Adjacent Asphalt lies east of Building 1103A and north of Building 1103B. It is presently used as a parking lot for employees working in nearby buildings.

Grounds

The Grounds consist of the lawn adjacent to Building 1103A, as well as the grassy areas south and west of the central asphalt. Grounds were included in the survey to evaluate possible impacts due to airborne migration of DU-contaminated dust and/or waterborne migration of DU-contaminated runoff.

2.2 Previous Investigations

In 2006, CABRERA performed a characterization survey of potentially impacted buildings and grounds at the Building 1103A Area. Results of the structures surface contamination surveys and soils volumetric sample analyses completed during the characterization survey are presented in the *Building 1103A Area Characterization Survey Report* (CABRERA, 2007), and summarized below in Tables 2-1 through 2-7. Surface contamination results are presented in units of disintegrations per minute per 100 square centimeters (dpm/100 cm²), and volumetric results are presented in units of picocuries per gram (pCi/g).

Table 2-1: Building 1103A Direct Alpha Measurement Summary

Area	Location	Alpha Activity (dpm/100cm ²)		
		Average	Standard Deviation	Maximum
Main Area	Floor	432	239	864
	Interior Walls	68	42	172
	Ceiling	10	8	26
	Ceiling Horizontal Surfaces	1,245	1,045	2,654
Shop Area	Floor	386	59	428
	Interior Walls	80	62	276
	Ceiling	33	15	52
	Ceiling Horizontal Surfaces	711	771	1562
Entry Area	Floor	87	73	236
	Interior Walls	8	7	20
	Ceiling	*	*	*
	Ceiling Horizontal Surfaces	375	301	812
Exterior Walls	North Wall	22	13	42
	South Wall	43	85	268
	East Wall	13	13	36
	West Wall	12	6	20

dpm/100 cm² = disintegrations per minute per 100 square centimeters

* = characterization survey measurements not obtained

Table 2-2: Building 1103A Removable Alpha Measurement Summary

Area	Location	Alpha Activity (dpm/100cm ²)		
		Average	Standard Deviation	Maximum
Main Area	Floor	60	36	124
	Interior Walls	28	25	88
	Ceiling	0.4	0.7	1.3
	Ceiling Horizontal Surfaces	284	198	644
Shop Area	Floor	7.0	1.5	8.0
	Interior Walls	16	13	56
	Ceiling	7.2	6.2	18
	Ceiling Horizontal Surfaces	159	145	315
Entry Area	Floor	7.8	7.0	20
	Interior Walls	2.2	1.3	4.3
	Ceiling	*	*	*
	Ceiling Horizontal Surfaces	68	69	179
Exterior Walls	North Wall	0.2	0.6	1.0
	South Wall	1.6	3.1	9.9
	East Wall	0.1	0.5	1.0
	West Wall	0.3	1.0	2.3

dpm/100 cm² = disintegrations per minute per 100 square centimeters

* = characterization survey measurements not obtained

Table 2-3: Building BRL12 Direct Alpha Measurement Summary

Area	Location	Alpha Activity (dpm/100cm ²)		
		Average	Standard Deviation	Maximum
Central Room	Floor	76	55	186
	Interior Walls	9	12	40
	Ceiling	19	15	36
North Vault	Floor	4,030	6,132	14,798
	Interior Walls	-1	7	10
	Ceiling	0	0	0
South Vault	Floor	43	23	68
	Interior Walls	1	3	6
	Ceiling	4	0	4
Office Area	Floor	98	*	98
	Interior Walls	**	**	**
	Ceiling	**	**	**
Exterior Walls	North Wall	5	6	12
	South Wall	6	5	12
	East Wall	7	8	22
	West Wall	4	7	12

dpm/100 cm² = disintegrations per minute per 100 square centimeters

* = single measurement obtained

** = characterization survey measurements not obtained

Table 2-4: Building BRL12 Removable Alpha Measurement Summary

Area	Location	Alpha Activity (dpm/100cm ²)		
		Average	Standard Deviation	Maximum
Central Room	Floor	7.4	4.1	14
	Interior Walls	4.4	3.2	8.7
	Ceiling	0.7	0.9	1.3
North Vault	Floor	274	470	1,107
	Interior Walls	0.8	1.0	2.3
	Ceiling	0.4	0.6	0.8
South Vault	Floor	5.9	4.1	12
	Interior Walls	0.3	0.7	1.3
	Ceiling	1.4	1.5	2.4
Office Area	Floor	7.5	*	7.5
	Interior Walls	**	**	**
	Ceiling	**	**	**
Exterior Walls	North Wall	0.9	1.1	2.3
	South Wall	0.6	1.2	2.3
	East Wall	1.0	1.6	3.6
	West Wall	0.3	0.6	1.0

dpm/100 cm² = disintegrations per minute per 100 square centimeters

* = single measurement obtained

** = characterization survey measurements not obtained

Table 2-5: Freestanding Vault Direct Alpha Measurement Summary

Area	Location	Alpha Activity (dpm/100cm ²)		
		Average	Standard Deviation	Maximum
Interior	Floor	46	14	56
	Interior Walls	16	37	104
	Ceiling	1	1	2
Exterior Walls	North Wall	12	3	16
	South Wall	3	7	10
	East Wall	9	16	20
	West Wall	23	10	38

dpm/100 cm² = disintegrations per minute per 100 square centimeters

Table 2-6: Freestanding Vault Removable Alpha Measurement Summary

Area	Location	Alpha Activity (dpm/100cm ²)		
		Average	Standard Deviation	Maximum
Interior	Floor	3.0	2.6	4.8
	Interior Walls	3.3	4.2	12.6
	Ceiling	0.1	0.3	0.3
Exterior Walls	North Wall	1.2	0.7	2.3
	South Wall	0.1	0.8	1.3
	East Wall	1.5	1.1	2.3
	West Wall	0.3	0.6	0.8

dpm/100 cm² = disintegrations per minute per 100 square centimeters

Table 2-7: Soil Sample Results Summary for Land Areas

Location	Maximum Soil Concentration (pCi/g)	
	$^{238}\text{U}^1$	Total DU ²
Average	160	177
Standard Deviation	398	440
Maximum	1,740	1,925

pCi/g = picocuries per gram

¹ = ^{238}U concentration inferred from reported ^{234}Th concentration in biased soil samples.

² = Total DU concentration determined by dividing the ^{238}U concentration by 0.904 (i.e., assumed activity fraction of ^{238}U in DU).

3.0 FINAL STATUS SURVEY REQUIREMENTS

A FSS will be planned and conducted for each survey unit (SU) associated with impacted outdoor soil areas, outdoor solid surfaces (i.e., adjacent asphalt parking lot). The FSSP is prepared in accordance with the guidance presented in the *Multi-Agency Radiological Survey and Site Investigation Manual* (MARSSIM; NRC, 2000) and follows the data quality objective (DQO) process. This ensures that all impacted SUs are surveyed with the necessary rigor that corresponds with their respective contamination potential. The DQO process includes the following seven steps:

- Step 1: State the problem
- Step 2: Identify the decisions
- Step 3: Identify inputs to the decisions
- Step 4: Define the study boundaries
- Step 5: Develop a decision rule
- Step 6: Specify the decisions
- Step 7: Optimize the survey design

The following sections provide the requirements for the planning phase of the FSS, including the identification of radionuclides of concern (ROCs) and DCGLs, classification and survey unit designations, survey planning parameters, instrumentation, measurement and sampling procedures, and the data quality assessments that will be implemented.

3.1 Radionuclides of Concern

ROCs known to be present in the Building 1103A Area are limited to DU isotopes consisting of uranium-234 (^{234}U), uranium-235 (^{235}U), and uranium-238 (^{238}U) and their short-lived decay progeny. The assumed DU composition is based on the isotopic uranium ratios routinely used for shipments of DU waste from APG (Barg, 1995). The activity fractions are calculated from the weight ratios and specific activities of each uranium isotope. The resulting composition consists of ^{234}U , ^{235}U , and ^{238}U activity fractions of 0.084, 0.012, and 0.904, respectively. This composition is similar to the average activity fractions measured in three DU soil samples described in the ANL report *Derived Uranium Guideline for the*

Depleted Uranium Study Area of the Transonic Range, Aberdeen Proving Ground, Maryland (ANL, 1999).

3.2 Derived Concentration Guideline Levels

As described in MARSSIM (NRC, 2000), a DCGL is a derived radionuclide activity concentration that corresponds to a dose-based release criterion; and a DCGL_W is the DCGL used in non-parametric statistical testing to evaluate compliance with the dose-based criterion across a wide area (i.e., SU). For this FSS, the release criterion is based on the 25 millirem per year (mrem/yr) total effective dose equivalent (TEDE) exposure limit specified in 10 CFR 20, Subpart E: *Radiological Criteria for License Termination* (NRC, 2006). The corresponding DCGLs for soil and structures are described below.

3.2.1 Soil DCGL_W

A DCGL_W of 230 pCi/g total DU will be used for evaluating soils at the Building 1103A Area. Of this total DU DCGL_W, 190 pCi/g is attributable to ²³⁸U. Therefore, if ²³⁸U is used as the indicator parameter for evaluating soil sample results, the total DU DCGL_W is not exceeded if the ²³⁸U concentration does not exceed 190 pCi/g. These values were originally developed for use in decommissioning the APG Transonic Range (ANL, 1999), which was contaminated with source material similar to that at the Building 1103A Area. The total DU DCGL_W is based on a resident-farmer exposure scenario, and represents the modeled radioactivity concentration corresponding to a potential dose of 25 mrem/yr over a 1,000-year period.

3.2.2 Structures DCGL_W

The DCGL_W for DU surface activity on structures is based on the screening values published in NUREG/CR-5512, Volume 3, Table 5.19 ($P_{crit} = 0.90$; NRC, 1999). The primary method of obtaining surface activity measurements for both total and removable activity will be through use of alpha monitoring instrumentation. Therefore, the surface activity screening values have been calculated based on the total number of alpha particles emitted in each of the applicable radioactive decay chains and the percent contribution from each of the uranium isotopes present in DU, as shown in Table 3-1. The DCGL_W is calculated using the following formula.

$$DCGL_W = \frac{1}{\left(\frac{f_1}{DCGL_1}\right) + \left(\frac{f_2}{DCGL_2}\right) + \left(\frac{f_3}{DCGL_3}\right)}$$

Where:

- DCGL_W = Combined gross activity DCGL
- f_{1,2,3} = Activity fraction of individual radionuclide
- DCGL_{1,2,3} = DCGL for individual radionuclide

Table 3-1: Surface Activity DCGL_W

ROC		NUREG/CR-5512 Screening Level (dpm/100 cm ²)	Total Alphas per Decay	Alpha Based Screening Level (dpm/100 cm ²)	DU Alpha DCGL _W (dpm/100 cm ²)
DU	90.4% ²³⁸ U	101.0	1	101.0	100
	1.2% ²³⁵ U	97.6	1	97.6	
	8.4% ²³⁴ U	90.6	1	90.6	

dpm /100 cm² = disintegrations per minute per 100 square centimeters

As noted in NUREG/CR-5512 (NRC, 1999), the surface activity screening levels are based on the assumption that the fraction of removable surface contamination is ten percent. Therefore, the removable alpha activity limit applied to the FSS is 10 dpm/100 cm².

3.3 Area Classification Based on Contamination Potential

Based on historical site information and data obtained during the characterization survey, impacted areas at the Building 1103A Area have been subdivided into three categories based on contamination potential as either Class 1, 2, or 3, in accordance with MARSSIM (NRC, 2000). A description of each is provided below:

- Class 1:** Buildings or land areas that have a significant potential for radioactive contamination (based on site operating history) or known contamination (based on previous radiological surveys) that exceeds the DCGL_W.
- Class 2:** Buildings or land areas, often contiguous to Class 1 areas, that have a potential for radioactive contamination but at levels less than the DCGL_W.
- Class 3:** Buildings or land areas that are expected to contain little or no residual contamination based on site operating history or previous radiological surveys.

Furthermore, outdoor solid surfaces, land areas, and buildings have been further subdivided into SUs, which provide the fundamental unit for demonstrating compliance with the applicable DCGL_w.

3.4 Identification of Survey Units

All impacted outdoor surfaces, land areas, and structures have been subdivided into Class 1, 2, or 3 SUs. Each SU represents a portion of the site with similar contamination potential. The MARSSIM-recommended SU sizes are provided in Table 3-2.

Table 3-2: MARSSIM-Recommended Survey Unit Sizes

Class	Recommended Survey Area	
	Structures	Land Areas
1	Up to 100 m ²	Up to 2,000 m ²
2	100 to 1,000 m ²	2,000 to 10,000 m ²
3	No limit	No limit

m² = square meters

Based on the results of characterization surveys and sampling performed, the remediation of land areas will require the removal of pavement in the Central Asphalt area and a six-inch layer of underlying soil. As a result of the asphalt removal, native soil will be exposed and the SUs will be established accordingly.

Land area SUs at the Building 1103A Area have been identified as indicated in Table 3-3. A map of the outdoor land area SUs is provided in Appendix A.

Table 3-3: Land Area Survey Units

Area	Survey Unit	MARSSIM Classification	Matrix
Outdoor Area North	1	1	Soil
Outdoor Area South	2	1	Soil
Adjacent Asphalt Parking Lot	3	2	Pavement
Area Immediately Surrounding the Class 1 Outdoor Areas	4	2	Soil

The remediation of structures will entail the removal of interior fixtures, such as overhead lighting, electrical conduit, ventilation ducting, suspended ceilings, etc. The Building 1103A Shop Area will be removed entirely, leaving behind the concrete floor slab. Similarly, the Storage Shed attached to the Freestanding Vault will be removed. Roofing shingles and tar roof surfacing will be removed from Building 1103A and Building BRL12 roofs, exposing the underlying solid surface for performance of FSS surveys. Remaining structure interior surfaces will be decontaminated, as necessary. The FSS structure SUs are identified in Table 3-4.

Table 3-4: Structure Survey Units

Structure	Area	Survey Unit	MARSSIM Classification
1103A	Floor North	5	1
	Floor South	6	1
	Interior Walls – North and East	7	1
	Interior Walls – West and South	8	1
	Ceiling North	9	1
	Ceiling South	10	1
	Exterior Wall – South	11	1
	Exterior Wall – North, East and West	12	2
	Roof	13	2
	Former Shop Area Concrete Slab	14	1
BRL12	Central Area Floor	15	1
	Central Area Interior Walls - North and East	16	2
	Central Area Interior Walls – West and South	17	2
	Central Area Ceiling	18	2
	North Vault Interior Surfaces	19	1
	South Vault Interior Surfaces	20	2
	Exterior Walls	21	3
Roof	22	3	
Freestanding Vault	Floor, North and East Walls	23	1
	Ceiling, West and South Walls	24	1
	Exterior Walls and Roof	25	2
1103B	Floor	26	3
	Exterior North and West Walls	27	2
1100E	Exterior East Wall	28	3
1100F	Exterior East Wall	29	3

3.5 Background Reference Area and Materials

Although uranium isotopes present in DU are also present in the environment, the concentrations of uranium isotopes naturally present in soil represents a very small fraction of the soil DCGL_w. Therefore, the determination of background uranium concentration in soil is not necessary and will not be considered when comparing soil data with the DCGL_w or when performing statistical tests. Soil sample data will be used for direct comparison with the soil DCGL_w and for performance of the planned non-parametric Sign statistical test without correction for background uranium concentrations.

Structure SUs will also be evaluated using the non-parametric Sign test. Construction material-specific background measurements may be performed in areas of similar construction but without a history of radioactive material use. These material-specific background activity values may then be used to correct direct surface activity measurements for the contribution due to background and natural radioactivity in these materials. However, as a conservative measure, the material-specific background may be assumed to be zero. If used, material-specific background surface material count rates will be subtracted from SU count rates prior to converting the data to units of dpm/100 cm² for comparison with the applicable DCGL_w.

3.6 Reference System

A reference coordinate system will be utilized for FSS measurements and sampling locations. Direct measurements on structural surfaces will be referenced to prominent building features, or a grid system will be used similar to that implemented for the characterization surveys. Soil sample locations will be referenced to global positioning system (GPS) coordinates obtained using hand-held GPS units.

3.7 Survey Design

Structure surface contamination and DU concentrations in soil will be assessed by collecting the required number of systematic gross alpha surface activity measurements and soil samples within each SU. The Sign test will be used for demonstrating compliance with the applicable DCGL_w.

The statistical test (Sign test) is performed to evaluate the SU mean concentration relative to the null hypothesis (H_0). Simply stated, H_0 assumes the residual contamination in the SU exceeds the release criterion. Provided that the statistical test is satisfied at the desired confidence level, then H_0 is rejected and the alternate hypothesis (H_a), residual contamination

meets the release criterion, is accepted. The data needs for the statistical test will be determined through the processes in the following sections.

3.7.1 Number of Sample Locations for Survey Units

The following sections describe the bases for and derivation of the minimum required measurements and samples per SU.

Estimation of Relative Shift

The relative shift describes the relationship of site residual radionuclide concentrations to the $DCGL_w$ and is calculated using the following equation:

$$\frac{\Delta}{\sigma} = \frac{DCGL_w - LBGR}{\sigma}$$

Where:

- DCGL_w = Applicable value from Section 3.2
- LBGR = Lower bound of the gray region; normally established as the estimated mean activity within the survey unit, but may be adjusted to maximize survey design
- σ = Estimate of the standard deviation of the residual radioactivity, or the actual standard deviation obtained from characterization surveys and/or sampling

The DQOs are evaluated for each SU, and the decision errors are selected. The Type 1 error (or probability of incorrectly rejecting H_0 when it is true) is set at 0.05 (i.e., 5%). The Type 2 error (or probability of incorrectly accepting H_0 when it is false) is also set at 0.05. Once these parameters are established and the relative shift is determined, the number of data points required by the statistical test is calculated using MARSSIM Equation 5-2 (NRC, 2000), obtained directly from MARSSIM Table 5.5 (Sign test), or generated using *COMPASS*, *Visual Sample Plan* or *MARSSIM Power* software.

The $DCGL_w$ for soil radioactivity is 230 pCi/g. The LBGR is estimated to be 115 pCi/g, which represents half of the $DCGL_w$, as suggested in MARSSIM. Using an estimated coefficient of variation of 30% and the LBGR as an estimate of the sample mean, a standard deviation of 34.5 pCi/g is calculated. Using these values and the above equation, the relative shift is initially calculated to be 3.3. Because MARSSIM recommends a relative shift of

between 1 and 3, the LBGR was adjusted downward to achieve a value of 3.0. The corresponding number of samples, as specified in MARSSIM, Table 5.5, is 14.

For both buildings and outdoor solid surfaces (i.e., adjacent asphalt parking lot), the $DCGL_w$ for surface alpha radioactivity is 100 dpm/100 cm². The LBGR is conservatively estimated as 70 dpm alpha/100 cm². Using a coefficient of variation of 30% and the LBGR as an estimate of the sample mean, a standard deviation of 21 dpm/100 cm² is estimated. Using these values and the above equation, the relative shift is 1.4. The corresponding number of systematic direct measurement locations, as specified in MARSSIM, Table 5.5, is 20.

Adjustment of the Number of Samples and Direct Measurements Based on Scan Sensitivity

Once the minimum number of samples and direct measurements has been determined for each SU, the scan sensitivity for each Class 1 SU type is evaluated to verify that the sensitivity is sufficient to detect small elevated areas of activity (refer to MARSSIM Section 5.5.2.4). This only applies to Class 1 SUs, as elevated areas of activity are not expected in Class 2 or Class 3 SUs.

As discussed in Section 5.4, outdoor land area gamma scans will be performed using a 3-inch by 3-inch (3-in. x 3 in.) sodium iodide (NaI) detector with a DU scan sensitivity (minimum detectable concentration [MDC]) of 32.9 pCi/g. Because the actual scan sensitivity is lower than the soil $DCGL_w$, no further evaluation is required, and the previously calculated minimum number of samples (14) is confirmed to be acceptable.

Class 1 structure beta scans will be performed using a Ludlum Model 43-37 or Ludlum Model 43-68 gas proportional detectors. The beta scan minimum detectable count rates (MDCRs) for these two detectors are 397 and 185 counts per minute (cpm), respectively. Because both are higher than the structure alpha $DCGL_w$, an evaluation is required to determine whether the number of direct alpha measurements calculated is sufficient to detect elevated areas of activity. Using the higher scan MDCR, the need for adjustment is determined using MARSSIM, Equation 5-4, and the area factors listed in MARSSIM, Table 8.2. The actual beta scan MDCR is 397 cpm (rounded to 400 cpm for simplicity), and the corresponding area factor is 4. From MARSSIM, Table 8.2, this equates to an area of 9 square meters (m²). Dividing the maximum SU size for a Class 1 structure, 100 m², by this area provides the adjusted number of direct measurements, 11 per SU, based on the scan sensitivity. This value is less than the minimum number of direct alpha surface activity measurements previously calculated (20); therefore, no additional direct alpha measurements are necessary.

Determining Measurement/Sampling Locations

Measurement and sampling locations will be established in either a random-start/systematic fashion for Class 1 and Class 2 SUs, or at randomly generated locations for Class 3 SUs. Random-start/systematic locations will follow the recommended guidance using a triangular sampling pattern to increase the probability of identifying small areas of residual activity. The linear spacing (L) between data points on a triangular grid pattern is determined by:

$$L = \sqrt{\frac{A}{0.866 \times N}}$$

Where:

L = Triangular grid spacing between sample locations

A = Area of SU

N = Number of sample locations

And the spacing between rows is calculated as:

$$0.866 \times L$$

For land areas, a unique set of GPS coordinates will be generated for each sample location.

3.8 Integrated Survey Strategy

FSS data collected for structure surfaces consists of beta surface activity scans and direct measurements for alpha surface activity. Gamma scans will be performed on outdoor solid surfaces, such as paved areas, in lieu of beta surface activity scans. Smears samples, although not used in the final data quality assessment, will be collected from each direct alpha systematic and biased measurement location to measure removable alpha surface activity.

FSS of open land areas will consist of gamma scans to identify locations of residual contamination, and soil samples analyzed for the ROCs. Additional biased measurements and samples will be obtained, as necessary, from locations where scans indicate the potential for elevated activity.

3.8.1 Surface Scans

Surface gamma scans will be performed using NaI scintillation detectors over land areas and outdoor solid surfaces, such as paved areas. Surface scans in building SUs, as well as remaining Building 1103A Shop Area concrete pad will be performed using gas proportional

detectors for beta activity. Detectors will be coupled to ratemeters or ratemeter-scalers with audible indicators.

The recommended surface scan coverage of accessible survey unit areas, as discussed in MARSSIM, is provided in Table 3-5.

Table 3-5: MARSSIM-Recommended FSS Scan Coverage

Class	Structures	Land Areas
1	100%	100%
2	10 to 100% floors and lower walls 10 to 50% upper walls and ceilings	10 to 100%
3	Judgmental	Judgmental

3.8.2 Soil Sampling and Surface Activity Measurements

FSS surface and subsurface soil samples will be collected from Class 1 land areas at pre-determined random-start/systematic locations. Additionally, biased samples will be collected from locations where elevated direct gamma radiation is detected by surface gamma scans. Soil samples will be maintained under formal chain-of-custody procedures. Surface soil systematic and biased samples will be analyzed for the ROCs, and results will be reported in units of pCi/g. If a systematic or biased surface soil sample result is greater than or equal to the soil DCGL_W, the subsurface sample from the same sample location will be submitted for analysis. For FSS of Class 2 land areas, only surface soil samples will be collected, and these will be analyzed in the same manner as the Class 1 soil samples. There are no Class 3 land area SUs identified in the Building 1103A Area.

FSS direct measurements to quantify total alpha activity on structure surfaces and outdoor solid surfaces will be performed at pre-determined random-start/systematic or random locations, as applicable. Additional biased direct alpha measurements will be performed at locations of elevated activity identified during the scan survey. Direct alpha measurements will be performed using gas proportional or scintillation detectors coupled to ratemeter-scalers.

Smear samples will be collected at each direct systematic or biased surface activity measurement location to quantify the alpha removable contamination within each structure SU. Direct and removable surface activity data will be converted to units of dpm/100 cm² for comparison to the removable alpha activity limit.

Specific FSS survey and sampling requirements for the various types of SUs at the Building 1103A Area are discussed in the following paragraphs.

Class 1 Land Area SUs

Class 1 land area SUs at the Building 1103A Area include the open area between Building 1103A, Building BRL12, and the Freestanding Vault. These include SUs 1 and 2 in Table 3-3. Following removal of the asphalt in the Central Asphalt Area, the entire area will be divided into two Class 1 survey units. A total of 14 surface and 14 subsurface systematic soil samples will be collected in each SU. A gamma scan will be performed over 100 percent of the affected area, and additional biased surface and subsurface soil samples will be collected, if necessary, based on the gamma scan results. The surface soil samples will be submitted immediately for analysis. Upon receipt and review of the analytical data, subsurface soil samples from locations where the associated surface soil sample analytical results exceed the soil DCGL_w will also be submitted for analysis.

Class 2 Land Area SUs

The Class 2 land area SU surrounds the Class 1 SUs discussed in the previous paragraph. This is identified as SU 4 in Table 3-3. A total of 14 systematic surface soil samples will be collected in each of these SUs. A gamma scan will be performed over 10 to 100 percent of these areas, and additional biased sampling will be conducted, as necessary, based on the gamma scan results.

Class 3 Land Area SUs

There are no Class 3 land area SUs at the Building 1103A Area.

Class 1 Outdoor Solid Surface SUs

There are no Class 1 outdoor solid surface SUs at the Building 1103A Area.

Class 2 Outdoor Solid Surface SUs

A single Class 2 outdoor solid surface SU, the adjacent asphalt parking lot (SU 4), has been identified at the Building 1103A Area. A total of 20 systematic direct alpha measurements will be performed in each of the SUs. A smear will be obtained at each direct measurement location to assess removable contamination. A gamma scan with the NaI detector will be performed over 10 to 100 percent of the accessible surface area, and additional biased direct alpha measurements will be obtained, if necessary, based on the gamma scan results.

Class 3 Outdoor Solid Surface SUs

There are no Class 3 outdoor solid surface SUs at the Building 1103A Area.

Class 1 Structure SUs

Class 1 structure SUs include the concrete pad that remains following the demolition and removal of the Building 1103A Shop Area, as well as many structure surfaces associate with Buildings 1103A, BRL12, and the Freestanding Vault. A total of 20 systematic direct alpha measurements will be performed in each of these SUs. Additionally, a smear will be obtained at each direct alpha measurement location to assess removable alpha contamination. Surface activity beta scans will be performed over 100 percent of the accessible surface area. Additional biased direct alpha measurements will be obtained, if necessary, based on the results of the surface activity scans.

Class 2 Structure SUs

Class 2 structure SUs include portions of the Building BRL12 interior surfaces, portions of the Building 1103A and the Freestanding Vault exterior walls, as well as the roofs of these structures. A single Class 2 SU has also been identified for the Building 1103B north and west exterior wall surfaces. A total of 20 systematic direct alpha measurements will be performed in each of these SUs. Additionally, a smear will be obtained at each direct alpha measurement location to assess removable alpha contamination. Surface activity beta scans will be performed over 10 to 100 percent of the accessible surface area. Additional biased direct alpha measurements will be obtained, if necessary, based on the results of the surface activity scans.

Class 3 Structure SUs

Class 3 structures include the Building BRL12 exterior walls and roof and the Buildings 1100E and 1100F east exterior walls. A total of 20 random direct alpha measurements will be collected in each of the SUs. Additionally, a smear will be obtained at each direct alpha measurement location to assess removable alpha contamination. Surface activity beta scans will be performed over 10 percent of the accessible surface area in each SU at locations of greatest contamination potential.

4.0 SURVEY INSTRUMENTATION AND TECHNIQUES

This section describes the instrumentation and methodology that will be used for direct radiation measurement, smear survey collection, gamma scan survey (i.e., gamma walkover survey [GWS]), and volumetric sample analysis during the FSS of the Building 1103A Area. Specific survey and sampling requirements, including types of surveys and percent coverage, numbers and types of samples, and analytical tests to be performed are discussed in Section 3.8. The MDC and MDCR required for the building surface activity scans, integrated alpha surface activity measurements, and GWS are calculated in accordance with MARSSIM (NRC, 2000) and *NUREG-1507: Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions*, (NRC, 1998).

4.1 Surface Scan Surveys

Building surfaces and outdoor solid concrete surface SUs will be surveyed for radioactivity using direct surface scan and static measurement techniques. Surveys will be performed as described in the following sections and in accordance with the FSS contractor's standard operating procedures (SOPs).

4.1.1 Ludlum Model 43-37

Surface scanning for radioactivity will be performed to identify locations of highest surface activity. Once identified, these locations may be further evaluated by performing integrated alpha activity measurements. Beta scans will be performed on floor surfaces and lower walls using a Ludlum Model 43-37 gas proportional detector (with an active area of 582 cm²), or equivalent. The scan rate for the Ludlum Model 43-37 will not exceed six inches per second as an upper bounding scan rate, with a measurement interval of one observation per second (1/sec). The Ludlum Model 43-37 beta scan MDCR is indicated in Table 4-1. Details of the MDCR calculation for this instrument are presented in Appendix B.

Scans will be performed by moving the active area of the detector over the surface of interest, with the active area of the detector at a maximum height of 2 to 3 in. above the surface. During the scan survey in Class 1 SUs, if the surveyor observes a beta count rate higher than approximately twice the scan MDCR above background, the area will be identified as a potential location for additional biased integrated alpha measurements. During scan surveys in Class 2 and Class 3 SUs, if the surveyor observes a beta count rate higher than the scan MDCR, the area will be identified for additional biased integrated alpha measurements. Scan

assumptions and the action level to be used in identifying potential biased measurement locations using the Ludlum Model 43-37 are provided in Table 4-1.

4.1.2 Ludlum Model 43-68

Some surfaces may not be readily scanned using the Ludlum Model 43-37 detector due to the large size of the detector. These areas may alternatively be scanned with a Ludlum Model 43-68 handheld gas proportional detector (with an active area of 126 cm²), or equivalent. The beta scan assumptions, MDCR, and Class 1 action level for the Ludlum Model 43-68 are provided in Table 4-1. Details of the MDCR calculation for this instrument are presented in Appendix B.

Table 4-1: Beta Surface Scan Sensitivity Assumptions

Detector Model No.	Probe Area (cm²)	Probe Width (cm)	Beta Bkg. (cpm)	Observation Interval (observations/sec)	MDCR (cpm)	Class 1 Scan Action Level (cpm above bkg)
43-37	582	15	1386	1	397	800
43-68	126	9	300	1	185	400

cm = centimeter(s)
 bkg = background
 sec = second(s)

cm² = square centimeter(s)
 cpm = count(s) per minute

4.2 Integrated Direct Surface Measurements

Integrated direct measurements (i.e., static measurements) of surface alpha radioactivity will be performed to compare contaminant concentrations at discrete sampling locations to the building release criterion and facilitate statistical testing. If necessary, interior surfaces may be cleaned prior to surveying to remove dirt and grime that could shield alpha emissions from surfaces of interest. The cleaning implements used and the wastes generated during cleaning will be collected and stored onsite, then decontaminated and/or disposed in accordance with project waste management procedures. Integrated alpha activity measurements may be performed using the Ludlum Model 43-37 gas proportional detector, Ludlum Model 43-68 handheld gas proportional detector (operating in alpha mode only), Ludlum Model 43-89 handheld scintillation detector (with an active area of 126 cm²), or equivalent. The estimated detector sensitivity and relevant assumptions are presented in Table 4-2.

Integrated alpha measurements will be performed in accordance with the FSS contractor's SOP. The net count rate at each location will be calculated as the difference between the measurement count rate and the background count rate.

Table 4-2: Integrated Alpha Measurement Sensitivity Assumptions

Model No.	Count Time (min)	Bkg. Count Time (min)	Probe Area (cm ²)	Total Alpha Efficiency (cpm/dpm)	Alpha Background (cpm)	Alpha Static MDC ¹ (dpm/100 cm ²)
43-37	1	1	582	0.165	23	18
43-68	1	1	126	0.165	5	64
43-89	1	1	126	0.111	3	79

min = minute(s)

Bkg = background

cm² = square centimeter(s)

cpm = count(s) per minute

dpm = disintegration(s) per minute

¹Static alpha measurements will be compared to the building surface DCGL_w (100 dpm/100 cm²).

4.3 Smear Sample Collection and Analysis

Smear samples will be collected at systematic and biased direct surface activity measurement locations to quantify transferable surface alpha radioactivity. Smear samples will be obtained in accordance with the FSS contractor's SOP and analyzed using a Ludlum Model 43-10-1 detector coupled to a Ludlum Model 2929 dual scaler, or equivalent.

Count times for smears will initially be set at 4 minutes for surface smear measurements and 20 minutes for background measurements. Count times may be adjusted, if necessary, in accordance with the OP. If necessary, smears will be allowed to decay for at least 24 hours to eliminate radon progeny prior to onsite measurement. Smears that must be counted immediately will be recounted after at least 24 hours of decay time, if necessary. The smear sample alpha MDC and relevant assumptions are provided in Table 4-3.

Table 4-3: Removable Surface Activity (Smear) Sensitivity Assumptions

Instrument Model No.	Count Time (min)	Bkg. Count Time (min)	Probe Area (cm ²)	Alpha Efficiency (cpm /dpm)	Alpha Background (cpm)	Alpha MDC ¹ (dpm/100 cm ²)
2929	4	20	Smear	0.33	0.8	7

min = minute(s)

Bkg = background

cm² = square centimeter(s)

cpm = count(s) per minute

dpm = disintegration(s) per minute

¹Smear measurements of alpha activity will be compared to the removable activity DCGL_w (10 dpm/100 cm²).

4.4 Gamma Scans

Outdoor gamma scans will be performed in accordance with the FSS contractor’s SOP. Scan surveys on pavement and land areas will be performed using a Ludlum Model 44-20 three-inch by three-inch (3-in. x 3-in.) NaI detector coupled to a Ludlum Model 2221 ratemeter, or equivalent. This instrument will be enabled with a differential GPS so that activity measurements can be spatially referenced.

The MDC for DU in soil is provided in terms of pCi/g in Table 4-4. A more detailed evaluation of the MDC for the GWS instrumentation is presented in Appendix B.

Table 4-4: Gamma Scan Survey Sensitivity Assumptions

Detector Model No.	Survey Speed (m/sec)	Bkg. (cpm)	Observation Interval (observations/sec)	MDCR ¹ (cpm)	MDC (pCi/g)
44-20	0.5	27,000	1	2,484	32.9

m = meter(s)

cpm = count(s) per minute

pCi/g = picocuries per gram

¹ Assumes a surveyor efficiency of 50%

sec = second(s)

MDCR = minimum detectable count rate

MDC = minimum detectable concentration

4.5 Volumetric Sample Collection and Analysis

Volumetric systematic and biased soil samples from land areas will be collected and submitted to an off-site laboratory for analysis by gamma spectroscopy. Samples will be collected in accordance with the FSS contractor’s SOP and analyzed in accordance with the analytical laboratory’s SOP. The analytical test methods used to analyze radionuclides in volumetric samples at the off-site laboratory will be verified as being able to achieve an MDC of 10% of the soil DCGL_w.

Soil samples will be collected using a hand auger or stainless steel trowel, and homogenized in a stainless steel bowl prior to containerization. During the homogenization of soil samples, twigs, stones, and other non-soil items will be removed from the sample material. The FSS contractor’s SOPs will govern the handling, labeling, packaging, preservation, and shipping of samples, as well as sample chain of custody protocol. Field quality control (QC) samples (e.g., duplicate) will be collected and analyzed at a frequency of one per ten target samples. Laboratory QC samples will be prepared and analyzed in accordance with the analytical laboratory’s *Quality Assurance Plan*.

5.0 SURVEY QUALITY ASSURANCE/QUALITY CONTROL

Activities associated with this work plan will be performed in accordance with written operating procedures and/or protocols to ensure consistent, repeatable results and to provide auditable documentation of activities. Topics addressed in project procedures and protocols include, but are not limited to, the following:

- Proper use of instrumentation,
- QC source and background checks, and
- Duplicate measurements.

Specific quality assurance (QA) and QC measures to be implemented during the FSS are described in this section.

5.1 Instrumentation Requirements

The Project Health Physicist (HP) will be responsible for selecting the instrumentation required to complete the FSS. Only instrumentation approved by the Project HP will be used to collect radiological data. The Project HP will be responsible for ensuring that individuals are appropriately trained to use the instrumentation and other equipment, and that the selected instrumentation meets the required detection sensitivities. Instrumentation will be operated in accordance with either a written operating procedure or manufacturers' manual, as determined by the Project HP. The procedure and/or manual will provide guidance to field personnel on the proper use and limitations of the instrument.

Instruments used during the FSS will have current calibration and maintenance records that will be maintained onsite for review and inspection. The records will include, at a minimum, the following types of information: description of equipment, equipment identification (model and serial number), manufacturer, date of last calibration, and calibration due date.

Instrumentation will be maintained and calibrated to manufacturers' specifications to ensure that the required traceability, sensitivity, accuracy, and precision of the equipment/instruments are maintained. Instruments will be calibrated at a facility possessing appropriate NRC and/or Agreement State licenses for performing calibrations using National Institute of Standards and Technology (NIST) traceable sources.

5.2 Instrument QC Source and Background Checks

The following subsections describe the techniques that will be used to evaluate accuracy and precision of measurements obtained using project instrumentation. Daily instrument response check data and calibration certificates for each instrument will be included in an appendix to the FSS Report.

5.2.1 Gross Gamma Instruments

NaI detectors coupled to count rate meters and GPS systems will be used to perform gamma walkover surveys and integrated fixed location measurements, as well as to frisk equipment and personnel. Instruments will be calibrated at least annually at a facility possessing appropriate NRC and/or Agreement State licenses for performing calibrations using NIST-traceable standards.

Gross gamma instruments will be response-checked daily for QC purposes by comparing the instrument response to a cesium-137 (^{137}Cs) source. Response checks will consist of a one-minute integrated count of the ^{137}Cs source positioned in a reproducible geometry (i.e., a jig). The acceptance criteria for these instrument response checks are +/- 20% of the mean response generated using ten initial source checks and ten measurements of ambient background. A response check outside these limits will be cause for evaluation of conditions (e.g., instrument operation, source/detector geometry), and the response check will be repeated once prior to field use of that instrument. Instruments that fail the second response check will be removed from service. During daily response checks, instruments will be inspected for physical damage, battery voltage levels, current calibration, and erroneous readings, in accordance with the FSS contractor's SOPs.

Background checks will be performed daily for each instrument. These checks will be performed to monitor fluctuations in ambient gamma background that could impact the interpretation of the gross gamma measurements, not to monitor the performance of the instruments. The results of the background measurements will be recorded and presented on a control chart.

5.2.2 Alpha/Beta Detectors and Smear Counter

Alpha/beta detectors (e.g., Ludlum Models 43-68, 43-37, and 43-89) and a smear counter (Ludlum Model 2929) will be used to obtain quantitative measurements for final status survey purposes. These instruments will be calibrated at least annually at a facility possessing

appropriate NRC and/or Agreement State licenses for performing calibrations using NIST-traceable standards.

Instruments used for quantitative measurements will be response checked daily by comparing response to designated thorium-230 (^{230}Th) and technetium-99 (^{99}Tc) NIST-traceable sources and to ambient background. Response checks will consist of a one-minute count of the ^{230}Th and ^{99}Tc sources positioned in a reproducible geometry and location within the detector system. Background measurements will be performed in an identical fashion for a twenty-minute count, with the source removed. The acceptance criteria for these instrument response checks will be two and three-sigma of the mean response generated using ten initial source checks and ten measurements of ambient background. A response check outside the two-sigma range, but within the three-sigma range will be cause for a recount prior to further evaluation. A response check outside the two-sigma range on the second count or three-sigma range on the initial count will be cause for further evaluation prior to continued use. A response check outside these limits is cause for an evaluation of conditions (e.g., instrument operation, source/detector geometry) prior to further counts and/or removal of the instrument from service. Instruments must pass a response check prior to field use. During daily response checks, instruments used to obtain radiological data will also be inspected for physical damage, battery voltage levels, current calibration, and erroneous readings, in accordance with the FSS contractor's SOPs.

5.3 Duplicate Measurements

Duplicate measurements will be required for 10% of the total soil samples collected from all SUs. Duplicate measurements of radioactivity concentration will be compared to the initial analytical results by determining a z-score and comparing it against the performance criteria as follows.

The z-score for each data set will be calculated using the following equation:

$$Z\text{-score} = \frac{|\text{Sample} - \text{Duplicate}|}{\sqrt{\sigma_{\text{Sample}}^2 + \sigma_{\text{Duplicate}}^2}}$$

Where:

- Sample = First sample value (original),
- Duplicate = Second sample value (duplicate),
- σ_{Sample} = 2σ counting uncertainty of the sample, and,
- $\sigma_{\text{Duplicate}}$ = 2σ counting uncertainty of the duplicate.

The calculated z-score results will be compared to a performance criterion of less than or equal to 1.96. Calculated z-scores less than 1.96 will be considered acceptable, and values greater than 1.96 will be investigated for possible discrepancies in analytical precision, or for sources of disagreement with the following assumptions of the test:

- The sample measurement and duplicate or replicate measurement are of the same normally distributed population.
- The standard deviations, σ_{Sample} and $\sigma_{\text{Duplicate}}$, represent the true standard deviation of the measured population.

6.0 DATA EVALUATION AND COMPLIANCE DEMONSTRATION

The data generated during the FSS will be reviewed to ensure that the quality and quantity are consistent with the FSSP and design assumptions. Data deemed to be acceptable will be used to evaluate compliance with the DCGLs established for this site, as described below.

6.1 Data Review and Investigation Thresholds

Analytical data received from the off-site laboratory will be reviewed to ensure that the data are of acceptable quality for its intended use. The following types of information will be evaluated:

- Correlation among the FSSP, chain-of-custody, and laboratory reports with respect to sample identification numbers and analytical methods;
- Whether project-specific MDCs were achieved;
- Instrumentation or cross-contamination issues that may have impacted the integrity and/or accuracy of reported results; and
- Comparison of QC sample data to project acceptability criteria.

The FSS measurement data for each SU will be evaluated by comparing the standard deviations of data sets with the assumptions used in establishing the number of data points for each SU. Individual and average data values will be compared with the applicable $DCGL_W$ for the SU, and proper survey area classification will be confirmed. Individual measurements in excess of the $DCGL_W$ for Class 1 and 2 areas will be further investigated by means of additional measurements and evaluation of background.

For Class 3 structure SUs, measurements in excess of 50% of the $DCGL_W$ will be investigated. This is less conservative than the recommendation provided in MARSSIM (NRC, 2000), which suggests that any measurements higher than the MDCR be investigated. However, a higher investigation threshold is necessary due to the low $DCGL_W$ values relative to background. Should a SU require further investigation, reclassification, remediation, and/or re-survey, a determination of the cause will be initiated, and the data conversion and assessment process will be repeated for new data sets.

6.2 Determining Compliance With DCGLs

As discussed in Section 3.2, both soil concentration and surface activity DCGLs have been developed for evaluation of the FSS data. These DCGLs address the mean activity concentration over a wide area (i.e., the $DCGL_w$), and also provide for small areas of elevated contamination in excess of the $DCGL_w$ (i.e., the $DCGL_{EMC}$). Demonstrations of compliance with both requirements for each SU are discussed in the following sections.

6.2.1 Land Area and Structure SUs

Land area systematic soil samples and structure SU direct surface activity measurements will be evaluated using the Sign test. Individual sample activity values and the average SU activity will be calculated. If all values from the random or random-start/systematic locations for a SU are less than the guideline ($DCGL_w$ for Class 1 and 2 land and structure SUs; 50% of the $DCGL_w$ for Class 3 structure SUs), the SU satisfies the criterion and no further evaluation is necessary.

If the average activity value is greater than the guideline, the SU does not satisfy the criterion and further investigation, possible reclassification, remediation, and/or re-survey is required. If the average activity value is less than the guideline, but some individual values are greater, data evaluation using the Sign test will be performed, as follows:

1. List each of the sample results or SU measurements.
2. Subtract each measurement or sample result from the guideline value.
3. Discard all differences that are "0"; determine a revised sample size.
4. Count the number of positive differences; this value is the test statistic, S^+ .
5. Compare the value of S^+ to the critical value in MARSSIM Table I.3 (NRC, 2000) for the appropriate sample size and decision level.

If S^+ is greater than the critical value, the null hypothesis is rejected and the SU meets the established criteria. If S^+ is less than or equal to the critical value, the null hypothesis is not rejected, and the SU does not meet the established criteria; investigation, remediation, reclassification, and/or re-survey should be performed, as appropriate.

6.2.2 Elevated Measurement Comparison Criteria

Soil samples or direct surface activity measurement results from Class 1 SUs that exceed the $DCGL_W$ must also be evaluated for compliance with the $DCGL_{EMC}^1$. The statistical tests for demonstrating compliance are such that some samples/measurements may exceed the $DCGL_W$, yet the null hypothesis may still be rejected. Therefore, both the statistically based and biased samples exceeding the $DCGL_W$ must be compared with a $DCGL_{EMC}$ that corresponds with the size of a given area of elevated activity, defined as the $DCGL_W$ times the Area Factor.

Default area factors for land SUs and structures, obtained from MARSSIM Table 5.6 and Table 5.7 (NRC, 2000), which will be applied to the FSS are provided in Table 6-1 and Table 6-2.

Table 6-1: Land Survey Unit Area Factors

Area (m ²):	1	3	10	30	100	300	1,000	3,000	10,000
²³⁸ U Area Factor:	30.6	18.3	11.1	8.4	6.7	4.4	1.3	1.0	1.0

Table 6-2: Structure Survey Unit Area Factors

Area (m ²):	1	4	9	16	25	36
²³⁸ U Area Factor:	35.7	9.0	4.0	2.2	1.4	1.0

When individual samples or measurements with elevated concentrations are less than the respective $DCGL_{EMC}$, the impact of multiple hot spots on the mean concentration in a SU must also be evaluated. This will be performed using MARSSIM Equation 8-2 (NRC, 2000). Any measurement that exceeds the $DCGL_W$ within a Class 2 or Class 3 SU will be investigated as discussed in Section 6.1, and may require reclassification of the SU.

¹ Soil sample and direct surface activity results from Class 2 and Class 3 survey units are not expected to exceed the $DCGL_W$. Therefore, the $DCGL_{EMC}$ does not apply to Class 2 and Class 3 survey units. A confirmed result from one of these survey units in excess of the $DCGL_W$ will typically require reclassification of all or part of the survey unit to Class 1.

7.0 REPORTING

The results of the FSS will be compiled into a detailed *FSS Report*. The contents of the report will provide all applicable data and documentation necessary to demonstrate the Building 1103A Area is suitable for unrestricted release in accordance with 10 CFR 20, Subpart E.

8.0 REFERENCES

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- NRC, 2006. Title 10, Code of Federal Regulations, Part 20, Subpart E, January 2006.

FIGURES

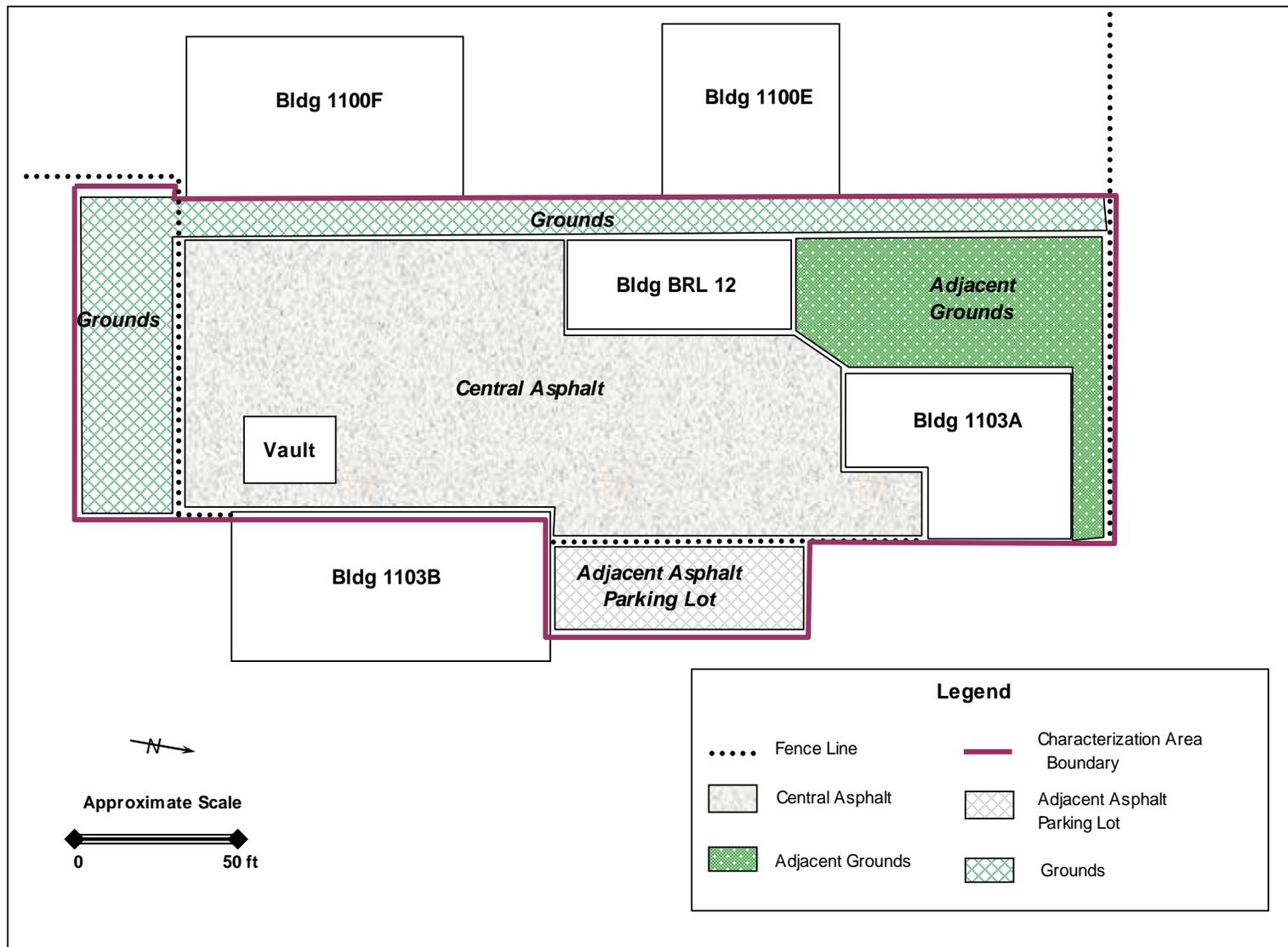


FIGURE 2-1: BUILDING 1103A AREA LAYOUT

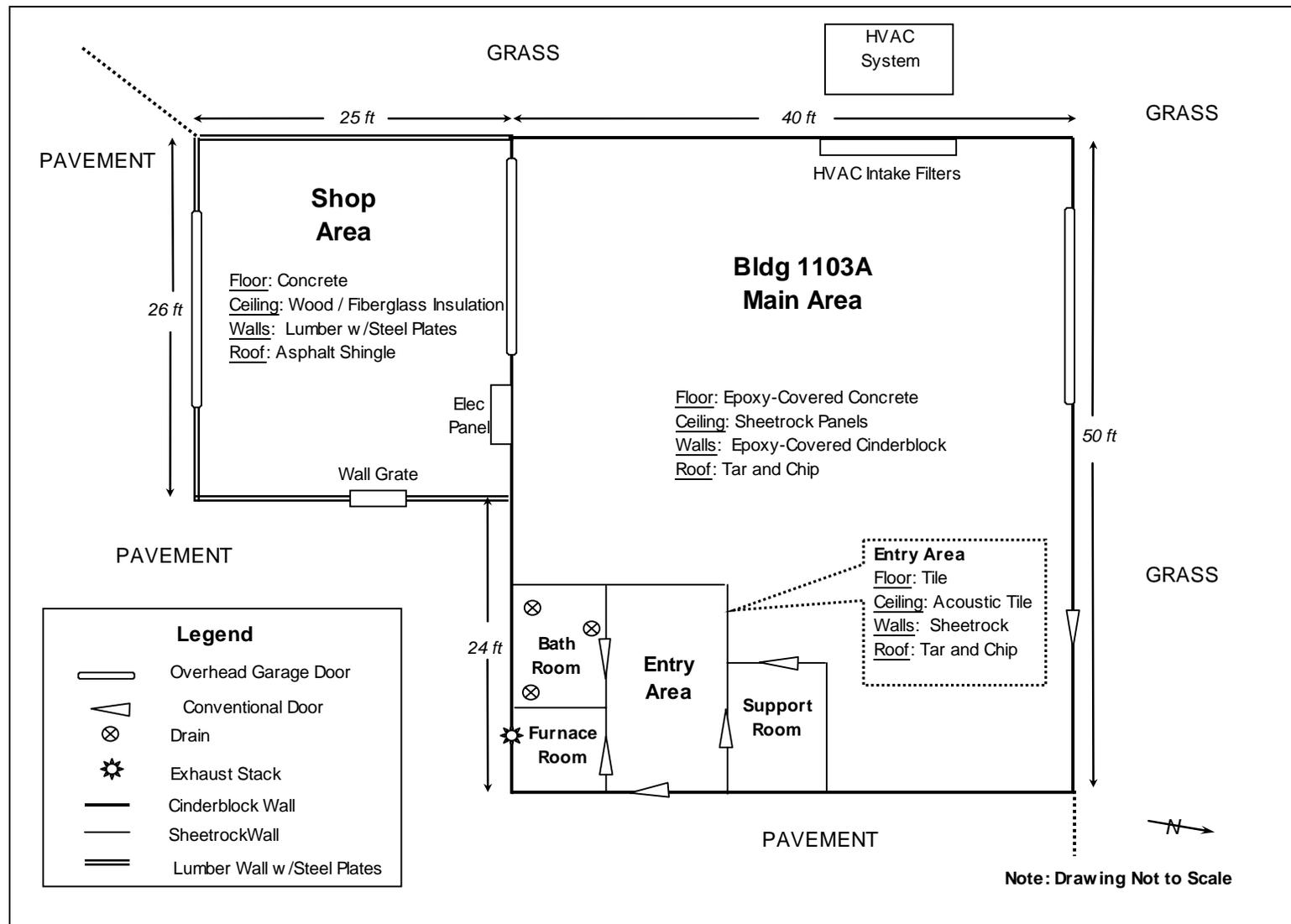


FIGURE 2-2: BUILDING 1103A FLOOR PLAN

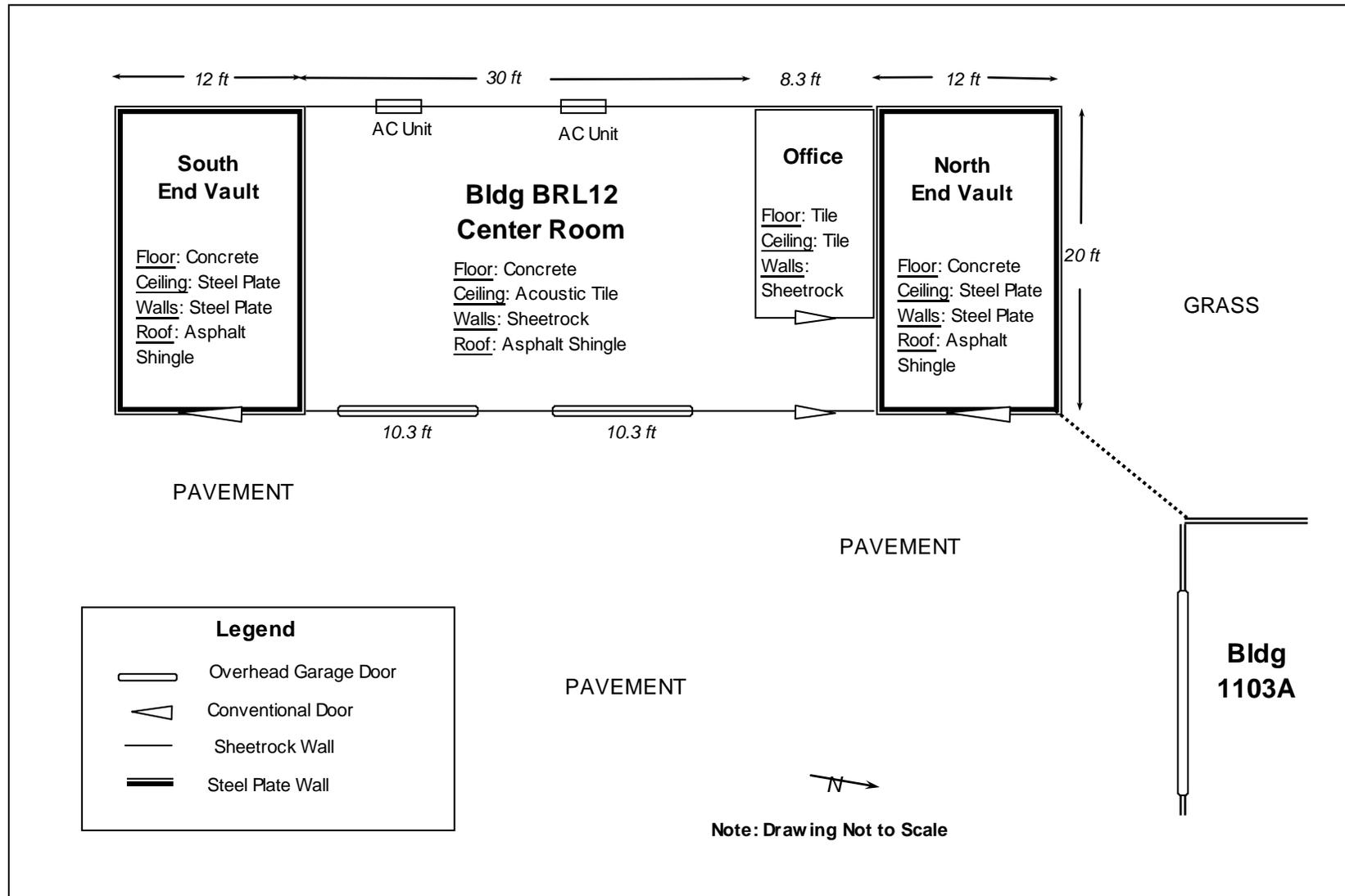


FIGURE 2-3: BUILDING BRL12 FLOOR PLAN

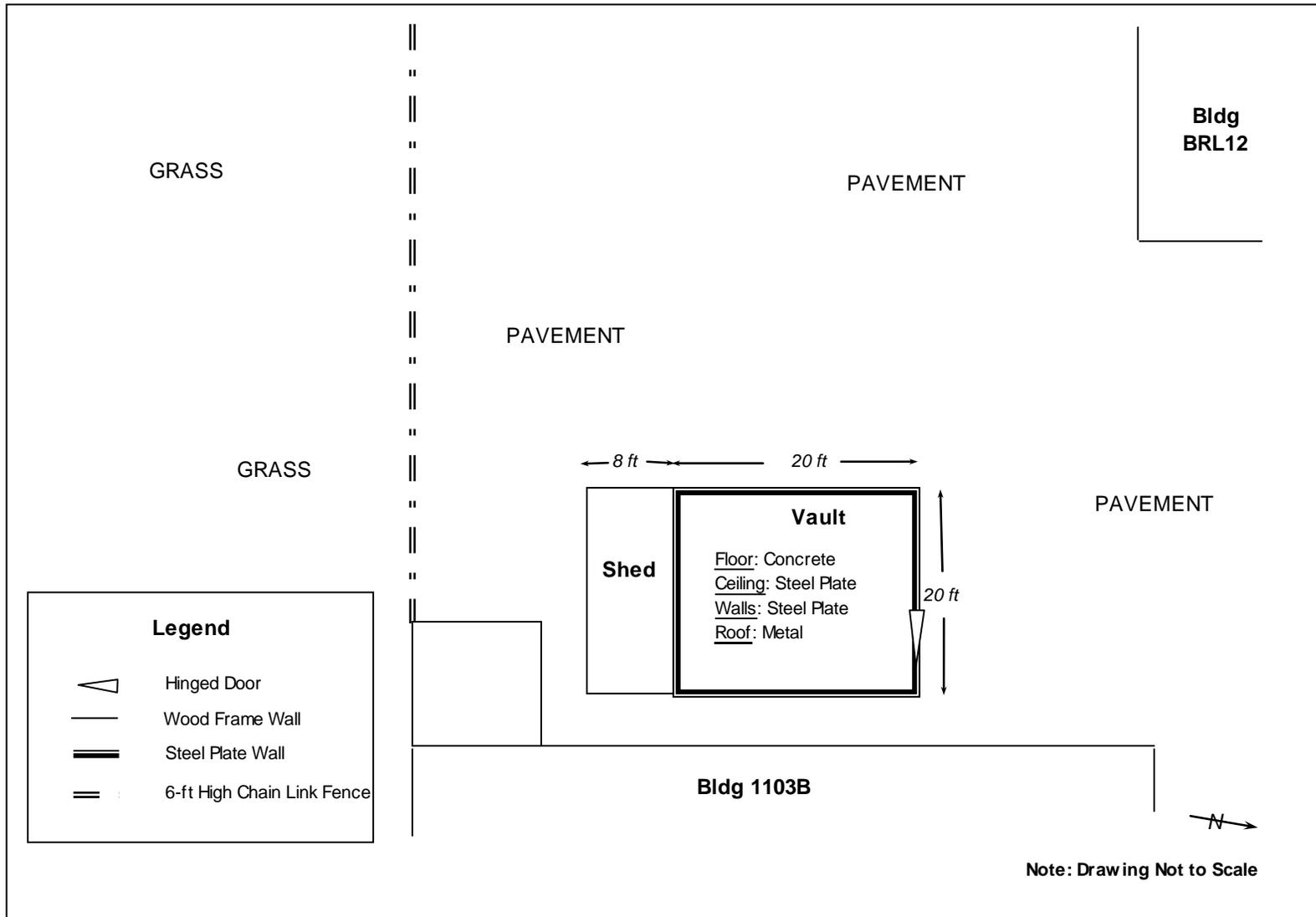
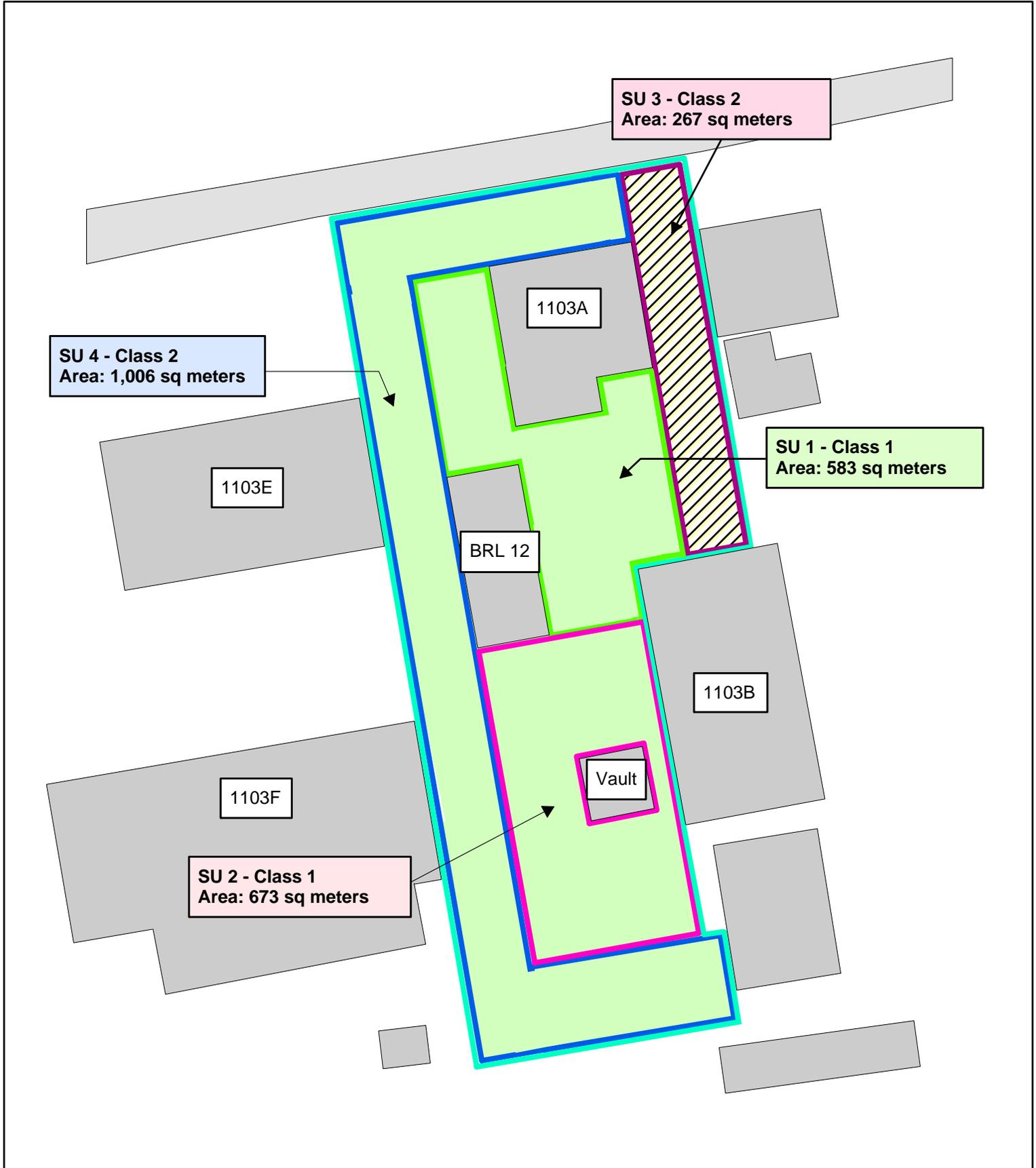


FIGURE 2-4: FREESTANDING VAULT

APPENDIX A

SURVEY UNIT MAPS



	Building	SU 1 - Class 1 Outline
	Paved Parking Area	SU 2 - Class 1 Outline
	Road	SU 3 - Class 2 Outline
	Grass or Soil	SU 4 - Class 2 Outline
	Site Outline	

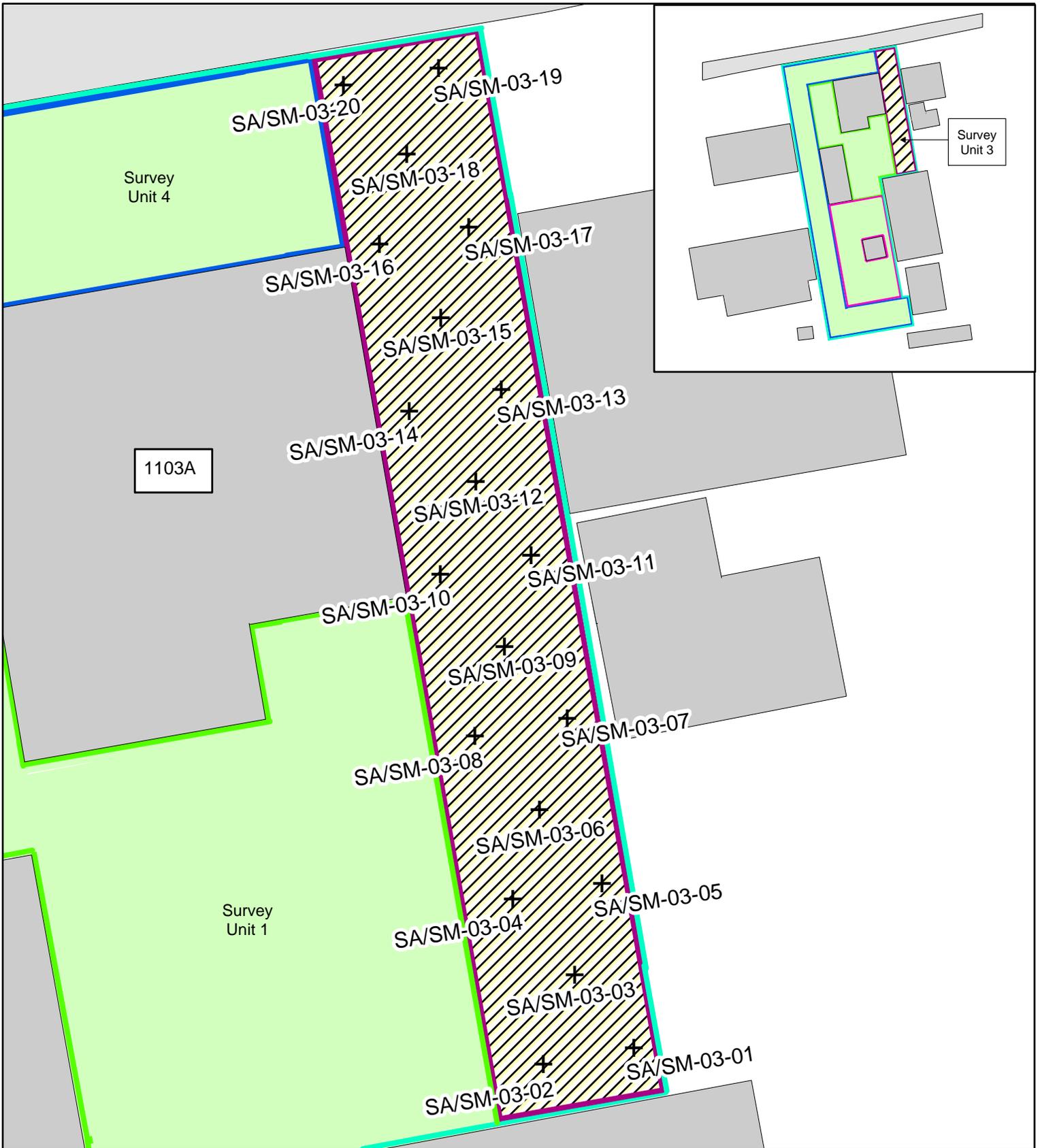
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Contract No: W52P1J-04-D-0007/0006 Project No: 05-3060.06	<h3>Building 1103A Area Land Survey Unit Locations</h3>
Date: Jan 2008 Scale 	



	Building	SU 2 - Class 1 Outline	Subsurface Soil Sample
	Paved Parking Area	SU 3 - Class 2 Outline	
	Grass or Soil	SU 4 - Class 2 Outline	
	Site Outline	Systematic Sample Location	
	SU 1 - Class 1 Outline	Surface Soil Sample	

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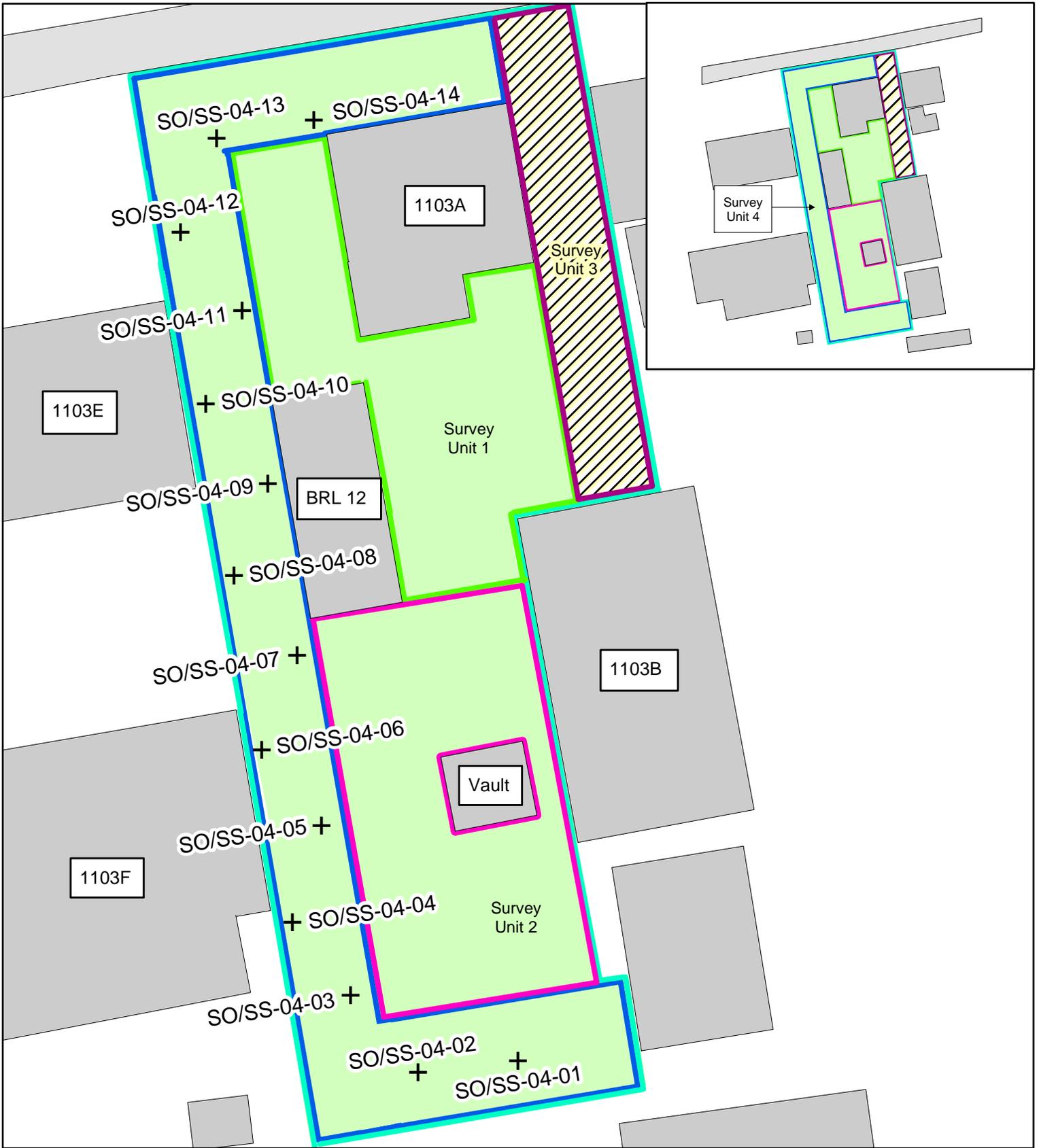
Building 1103A Area
 Survey Unit (SU) 2
 Sample Locations



	Building	SU 1 - Class 1 Outline	SM Smear Sample
	Paved Parking Area	SU 3 - Class 2 Outline	
	Road	SU 4 - Class 2 Outline	
	Grass or Soil	Systematic Sample Location	
	Site Outline	SA Surface Alpha Measurement	

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Date: Jan 2008	
Scale Meters	

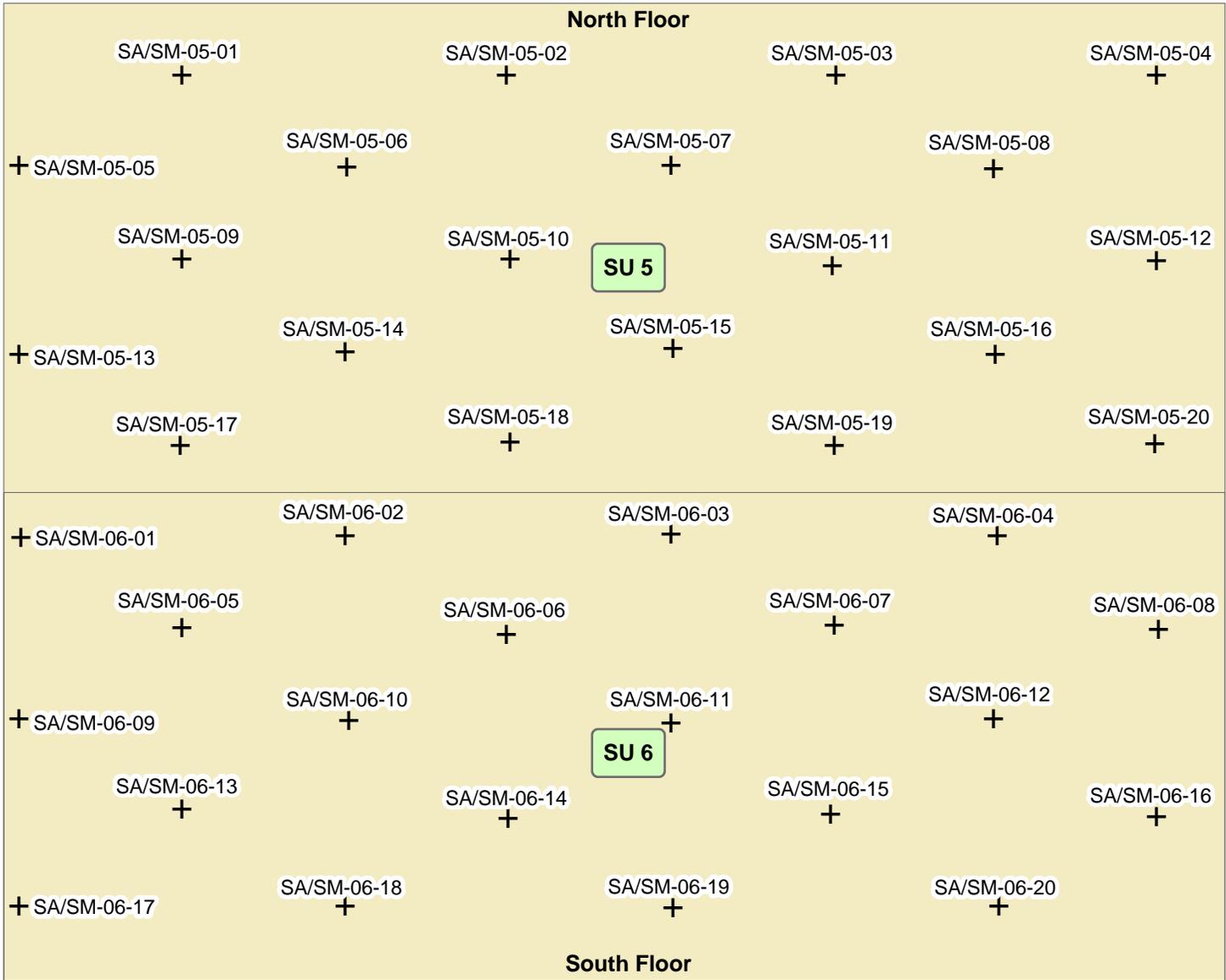
Building 1103A Area Survey Unit (SU) 3 Sample Locations



	Building	SU 1 - Class 1 Outline	SO Surface Soil Sample
	Paved Parking Area	SU 2 - Class 1 Outline	SS Subsurface Soil Sample
Road	SU 3 - Class 2 Outline		
Grass or Soil	SU 4 - Class 2 Outline		
Site Outline	Systematic Sample Location		

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Building 1103A Area Survey Unit (SU) 4 Sample Locations



- + Systematic Sample Location
- SA Surface Alpha Measurement
- SM Smear Sample
- Interior Floor
- SU 5** Survey Unit Class 1

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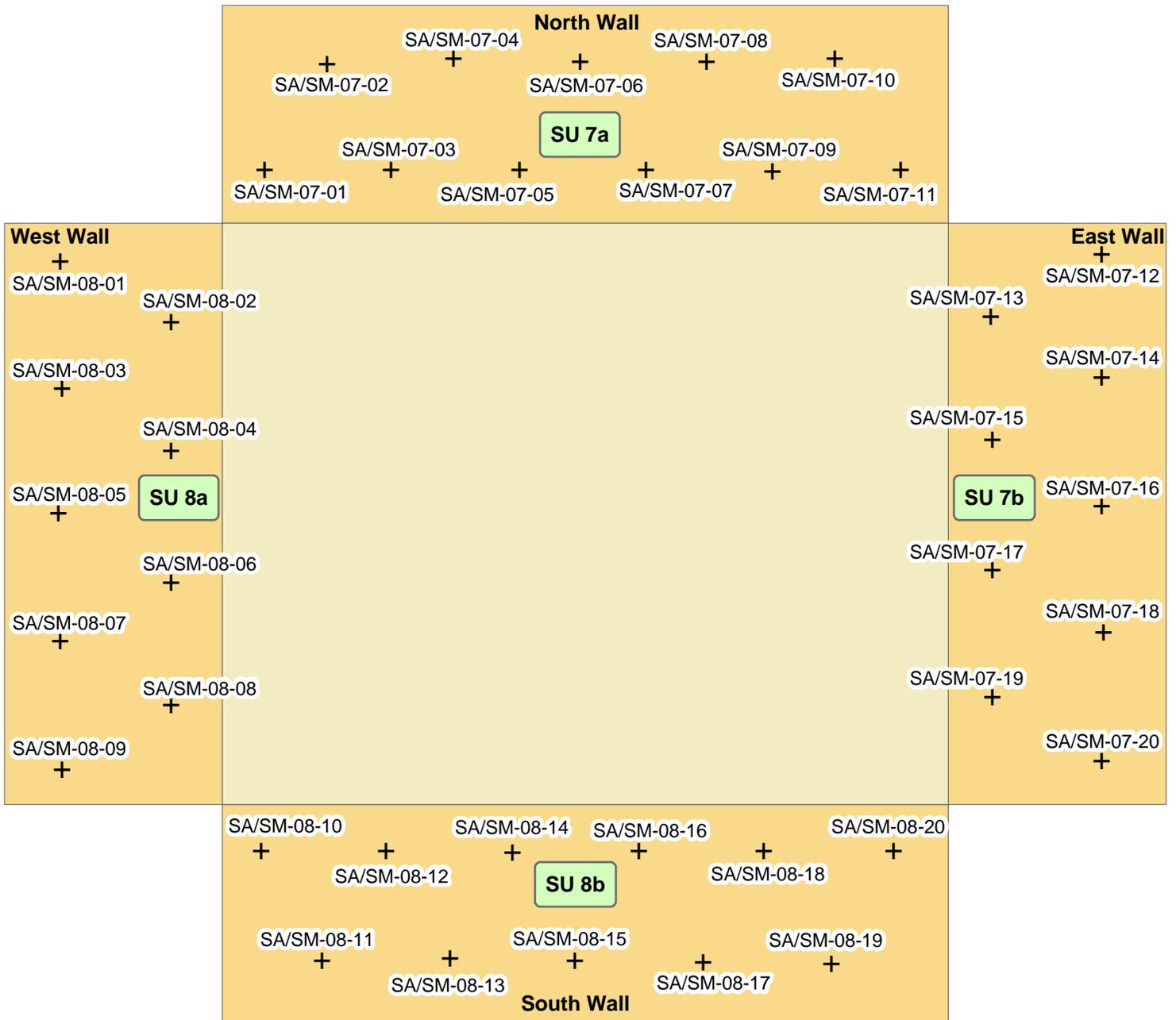


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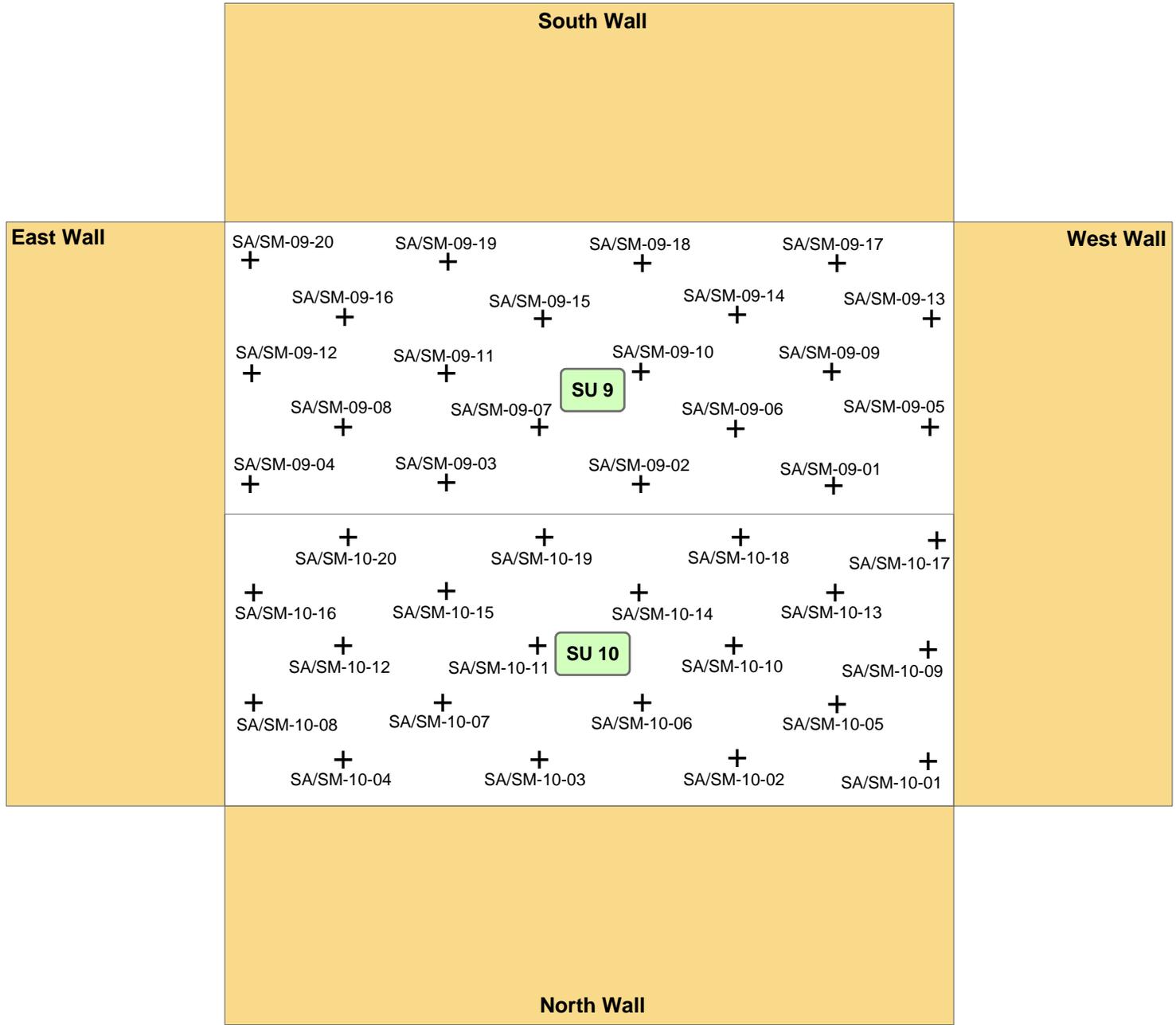
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Project No: 05-3060.06
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Scale
00.51 2 3 4 Feet

Aberdeen Proving Ground Maryland

**Building 1103A
Interior Floor
Survey Unit
Sample Locations**



	Systematic Sample Location	Interior Floor	CABRERA SERVICES 103 E. MT ROYAL AVE OFFICE 2B BALTIMORE, MD 21202	U.S. ARMY JOINT MUNITIONS COMMAND ROCK ISLAND ARSENAL, ILLINOIS
	Surface Alpha Measurement	Interior Wall		
	Smear Sample	Survey Unit Class 1	PREPARED BY: KJ REVIEWED BY: BWD Contract No: W52P1J-04-D-0007/0006 Project No: 05-3060.06 Date: Jan 2008 Scale 0 1 2 4 6 8 Feet	Aberdeen Proving Ground Maryland Building 1103A Interior Wall Survey Unit Sample Locations



	Systematic Sample Location	Interior Ceiling
	SA Surface Alpha Measurement	Interior Wall
	SM Smear Sample	Survey Unit Class 1

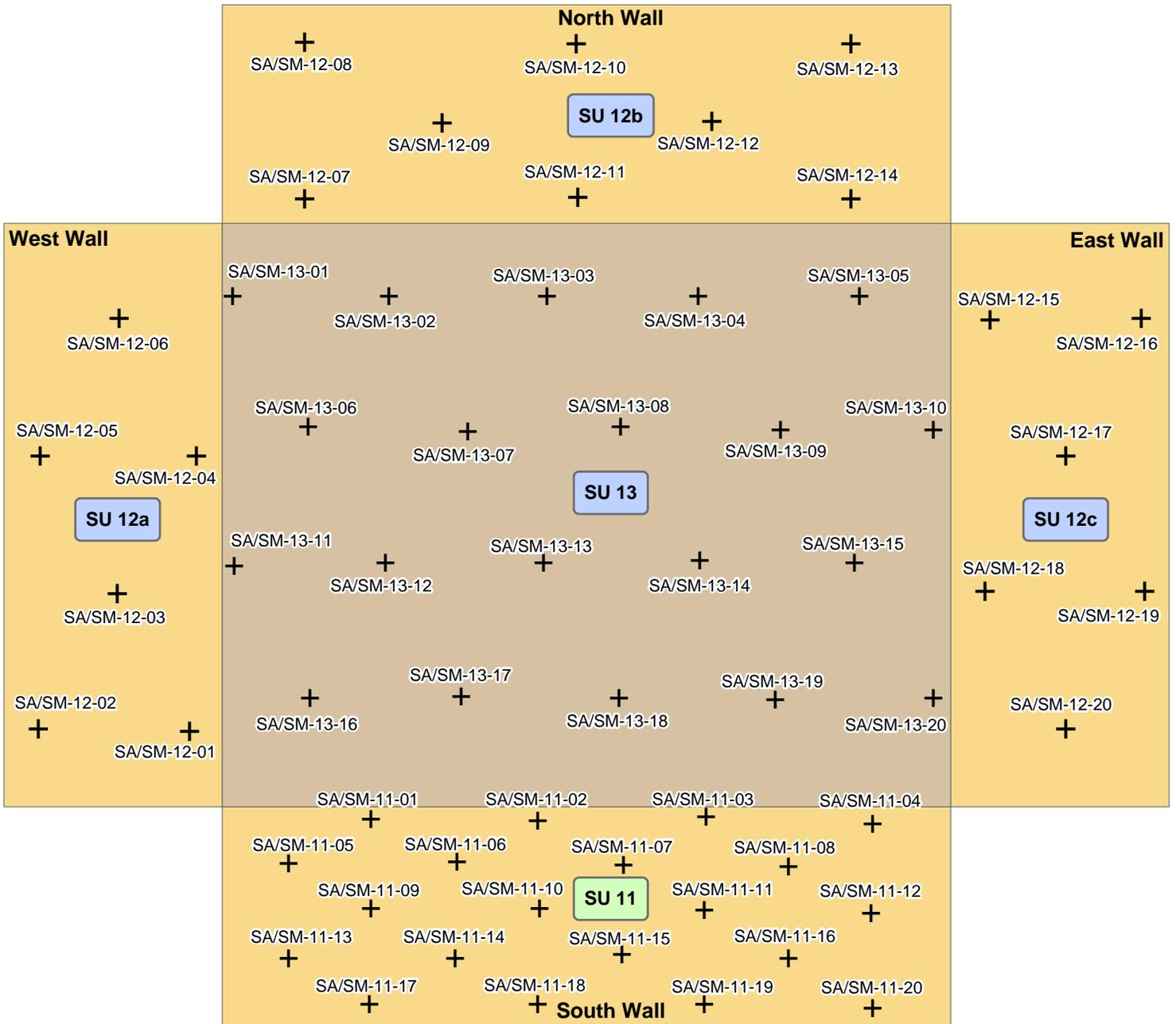
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 0 1 2 4 6 8 Feet

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Building 1103A
 Interior Ceiling
 Survey Unit
 Sample Locations



+ Systematic Sample Location

SA Surface Alpha Measurement

SM Smear Sample

 Exterior Roof

 Exterior Wall

 Survey Unit Class 1

 Survey Unit Class 2

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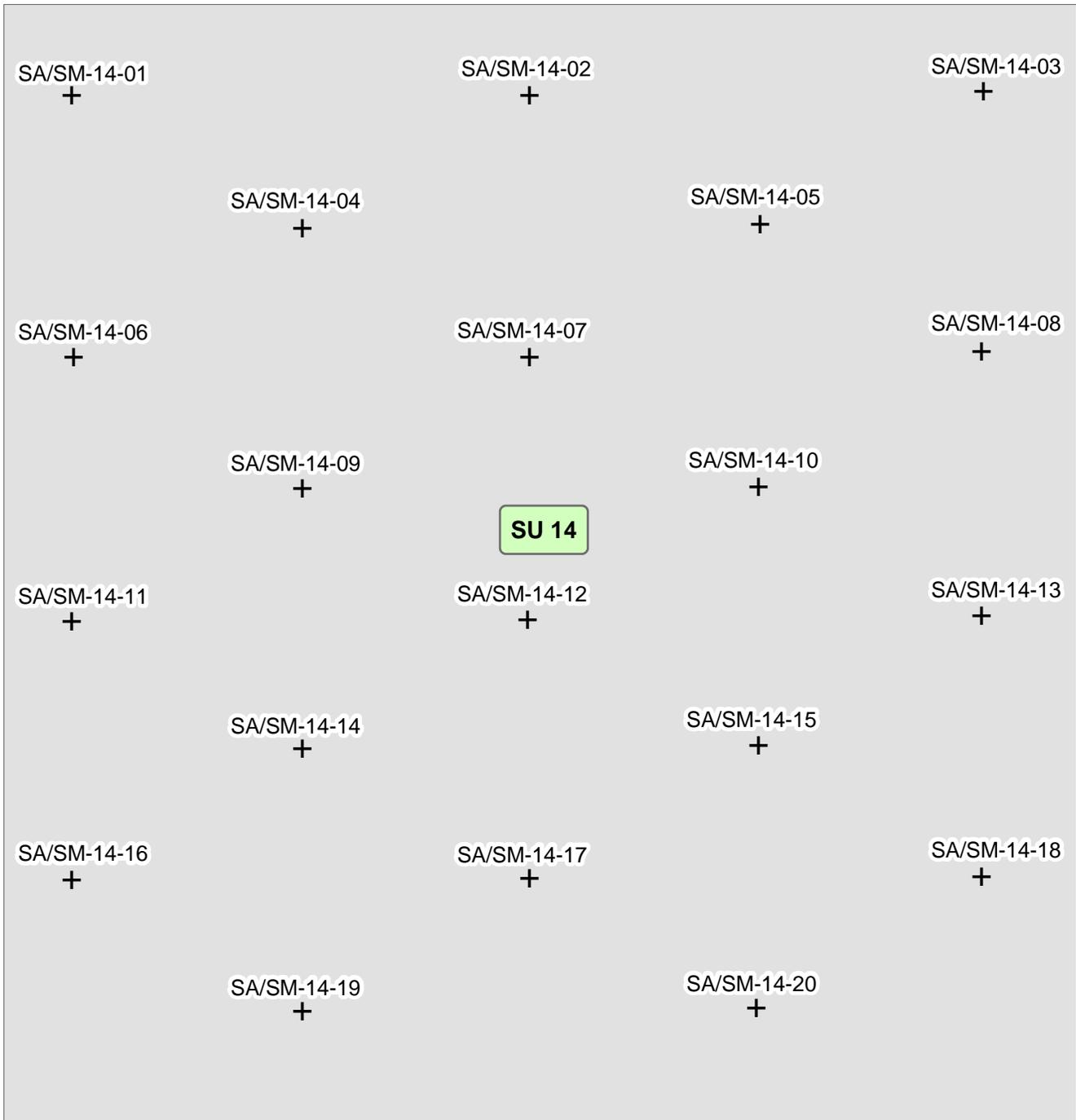
Date: Jan 2008

Scale

0 1 2 4 6 8 Feet

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Building 1103A Exterior Survey Unit Sample Locations

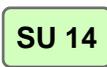


+ Systematic Sample Location



Concrete Floor Slab

SA Surface Alpha Measurement



SU 14 Survey Unit Class 1

SM Smear Sample

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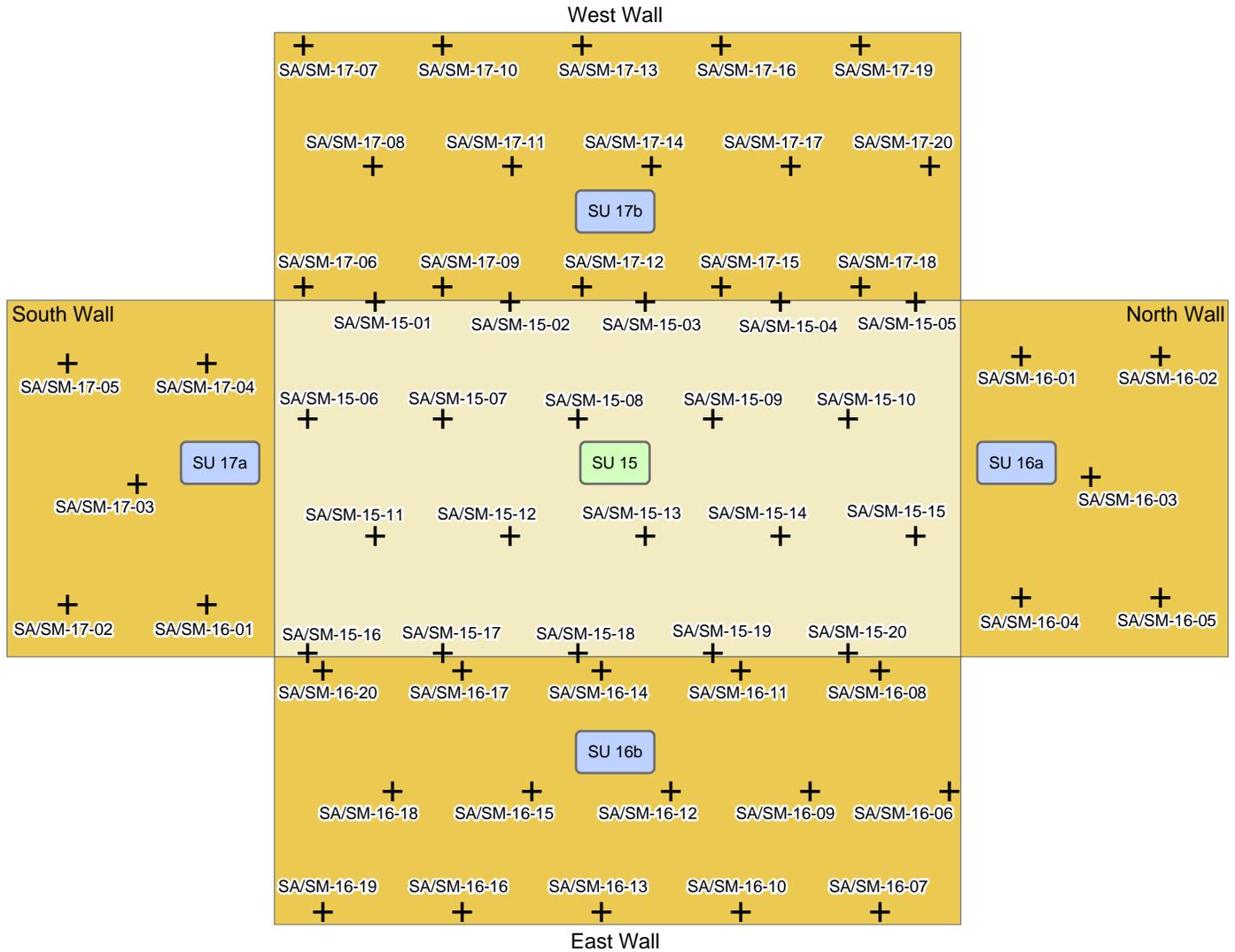
Project No: 05-3060.06

Date: Jan 2008

Scale



**Former Shop Area
Concrete Floor Slab
Survey Unit
Sample Locations**



+ Systematic Sample Location

SA Surface Alpha Measurement

SM Smear Sample



Interior Floor



Interior Wall



Survey Unit Class 1



SU 16a Survey Unit Class 2

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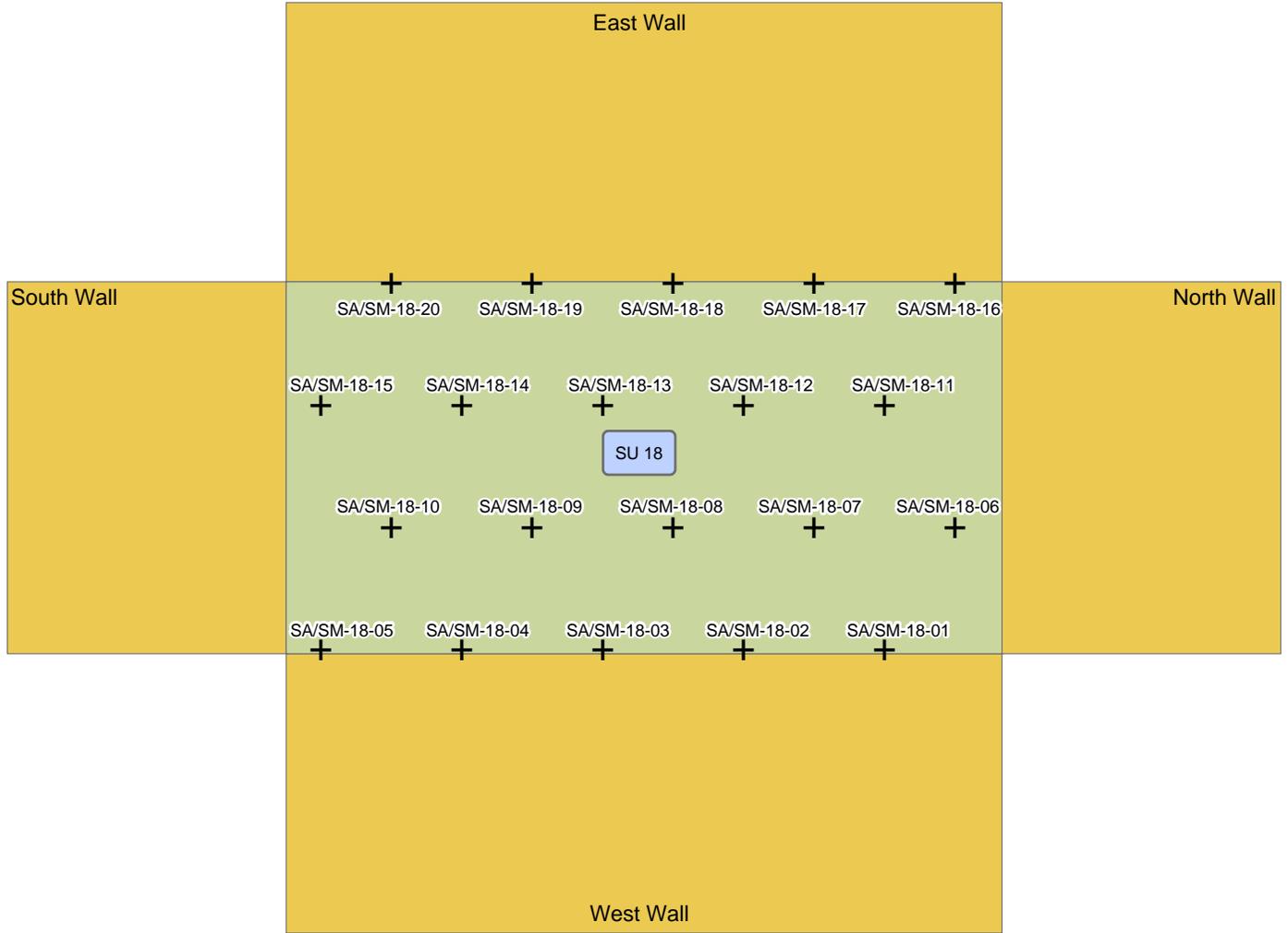
Date: Jan 2008

Scale



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**Building BRL 12
Interior Floor and Wall
Survey Unit
Sample Locations**



- +

Systematic Sample Location

Interior Ceiling

SA

Surface Alpha Measurement

Interior Wall

SM

Smear Sample

SU 18

Survey Unit Class 2

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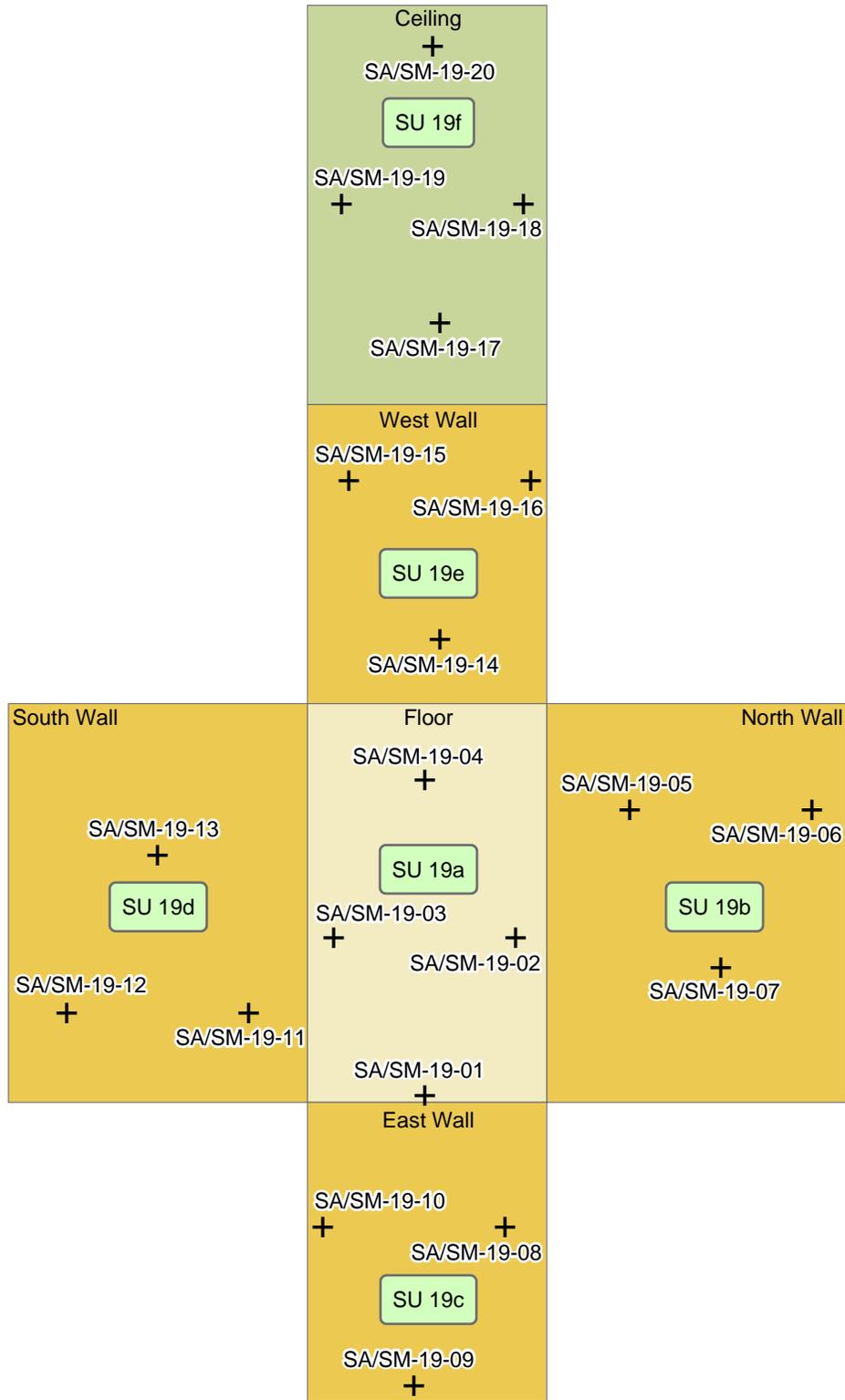


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 Scale

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**Building BRL 12
 Interior Ceiling
 Survey Unit
 Sample Locations**



- +** Systematic Sample Location
- SA** Surface Alpha Measurement
- SM** Smear Sample

- Interior Ceiling
- Interior Floor
- Interior Wall

SU 19a Survey Unit Class 1

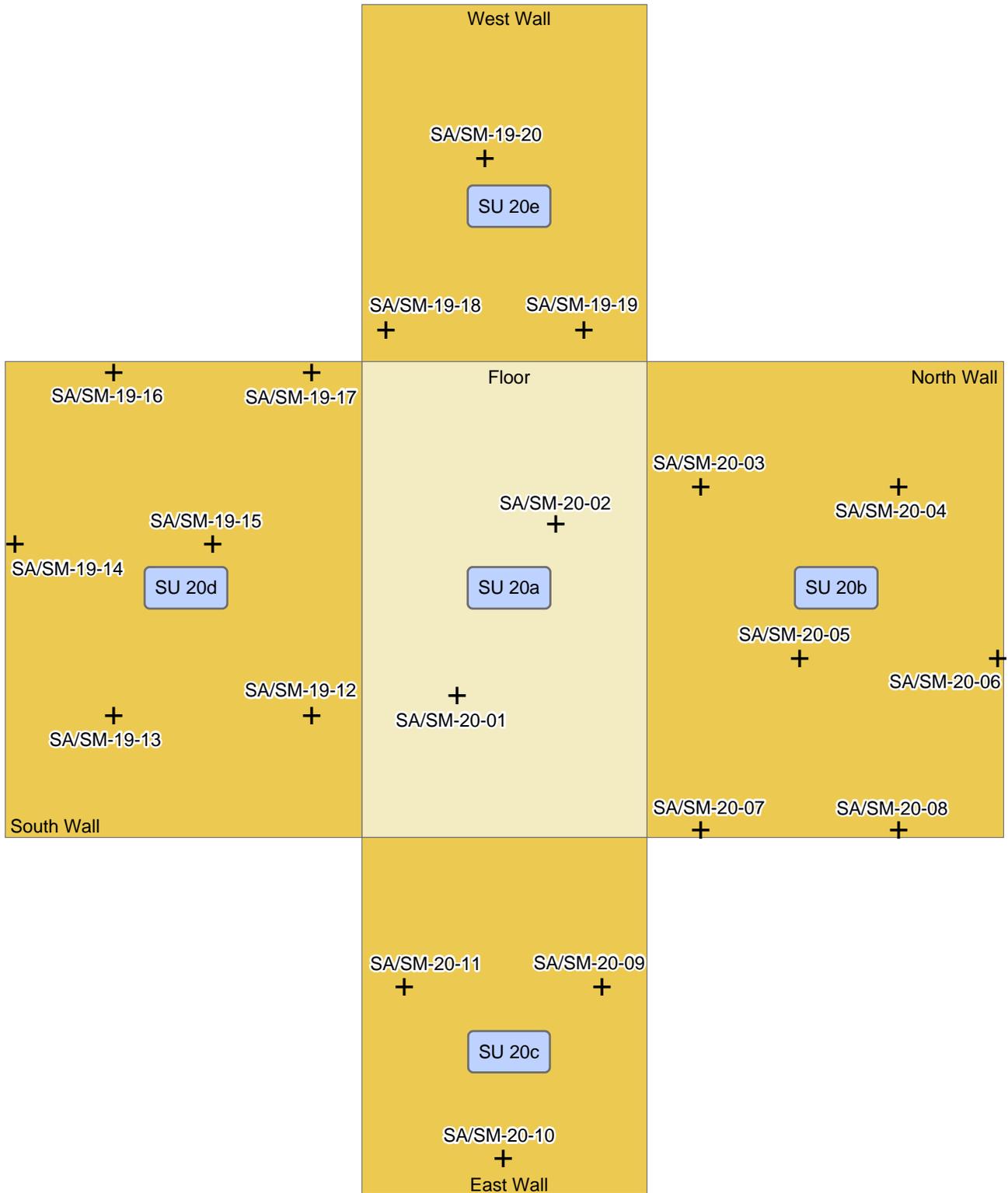
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Scale
0 1.5 3 6 Feet

Aberdeen Proving Ground Maryland
**North Vault Interior
Survey Unit
Sample Locations**



- +** Systematic Sample Location
- SA** Surface Alpha Measurement
- SM** Smear Sample

- Interior Floor
- Interior Wall
- Survey Unit Class 2

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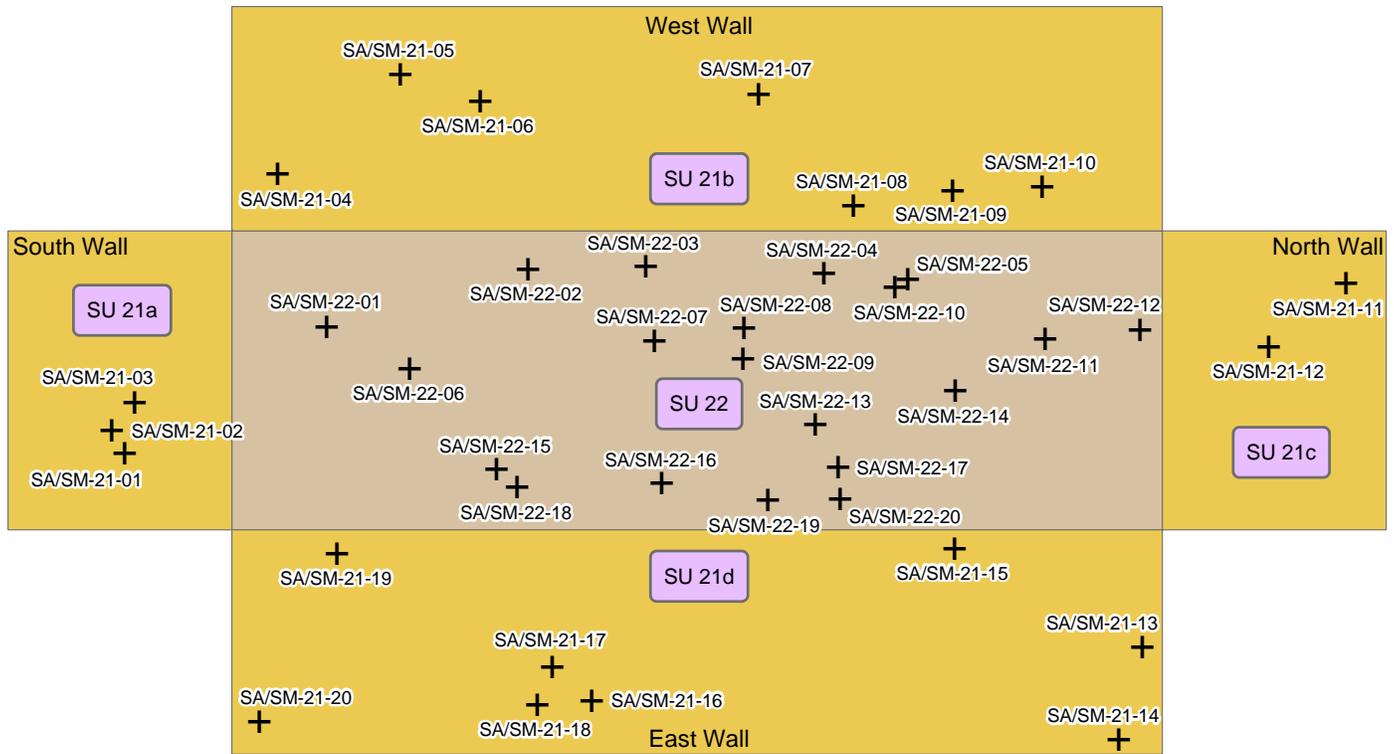


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Scale
0 1 2 4 Feet

Aberdeen Proving Ground Maryland

South Vault Interior Survey Unit Sample Locations



- +** Systematic Sample Location
- SA** Surface Alpha Measurement
- SM** Smear Sample
- Exterior Roof
- Exterior Wall
- Survey Unit Class 3

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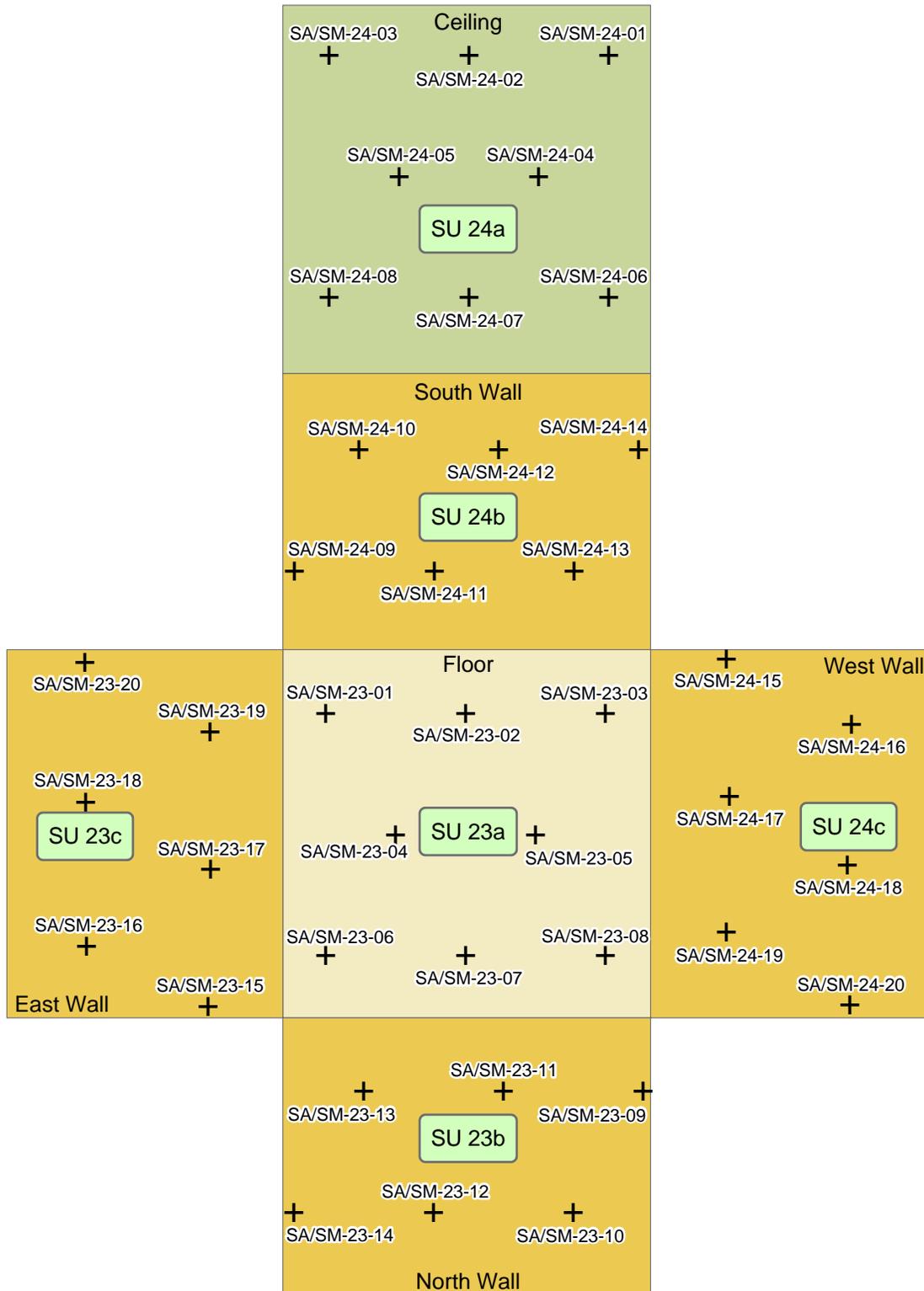


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Building BRL 12
Exterior
Survey Unit
Sample Locations



	<p>+ Systematic Sample Location</p> <p>SA Surface Alpha Measurement</p> <p>SM Smear Sample</p>	<p> Interior Ceiling</p> <p> Interior Floor</p> <p> Interior Wall</p>	<p> Survey Unit Class 1</p>
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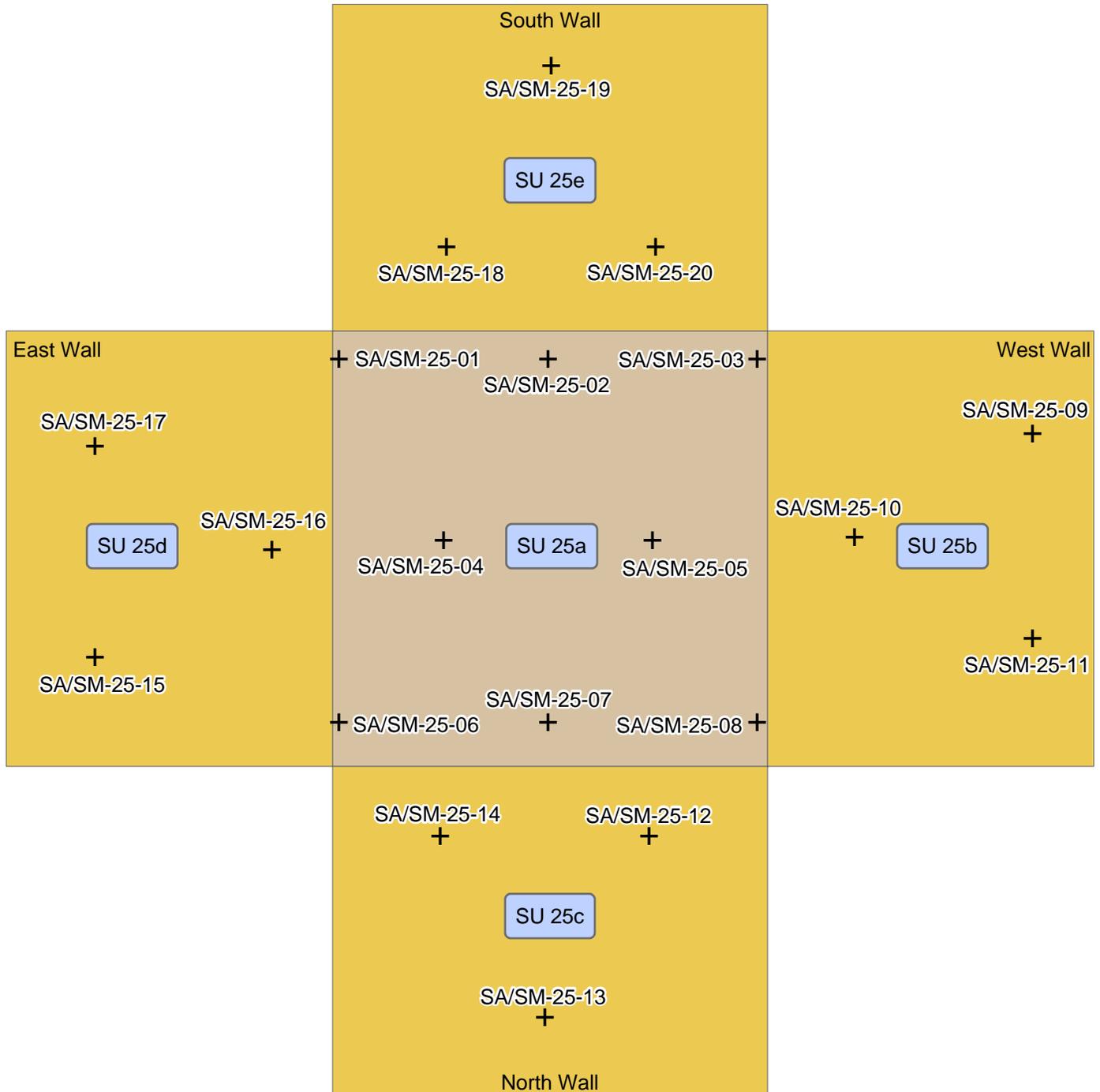
Scale

0 1.5 3 6 Feet

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Freestanding Vault Interior Survey Unit Sample Locations



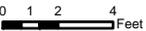
- +** Systematic Sample Location
- SA** Surface Alpha Measurement
- SM** Smear Sample

-  Exterior Roof
-  Exterior Wall
-  Survey Unit Class 2

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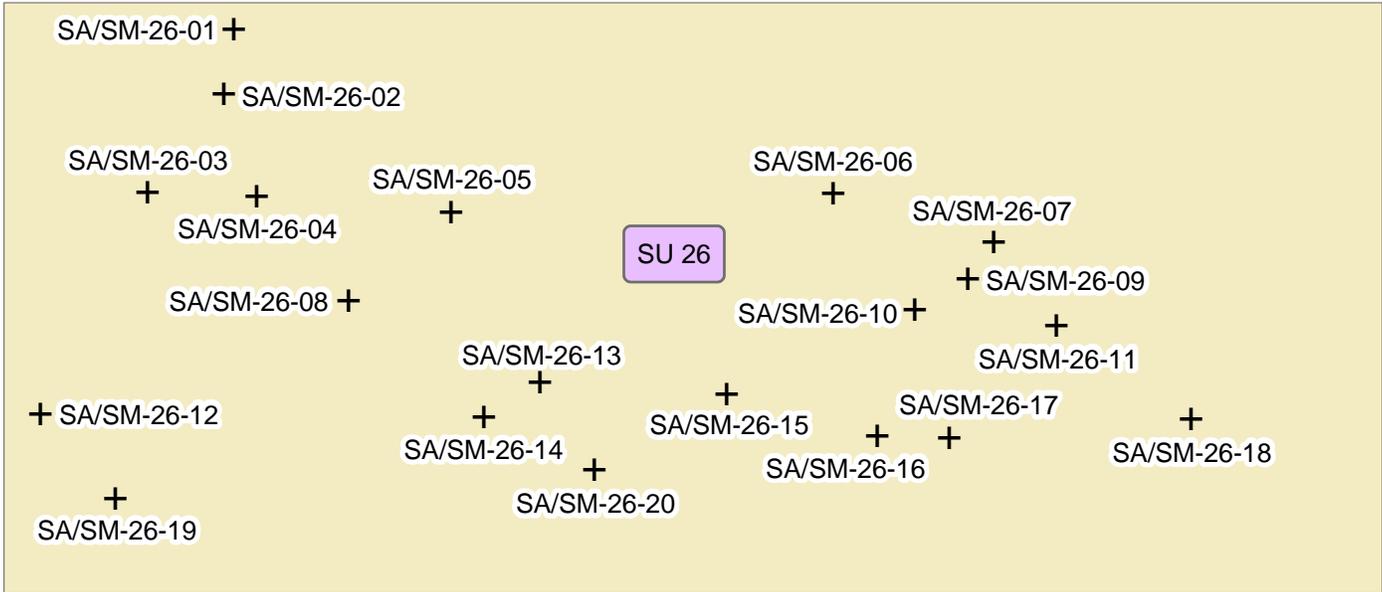


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Scale


Aberdeen Proving Ground Maryland

**Freestanding Vault
Exterior Surfaces
Survey Unit
Sample Locations**



- + Systematic Sample Location
- SA Surface Alpha Measurement
- SM Smear Sample



Interior Floor



Survey Unit Class 3

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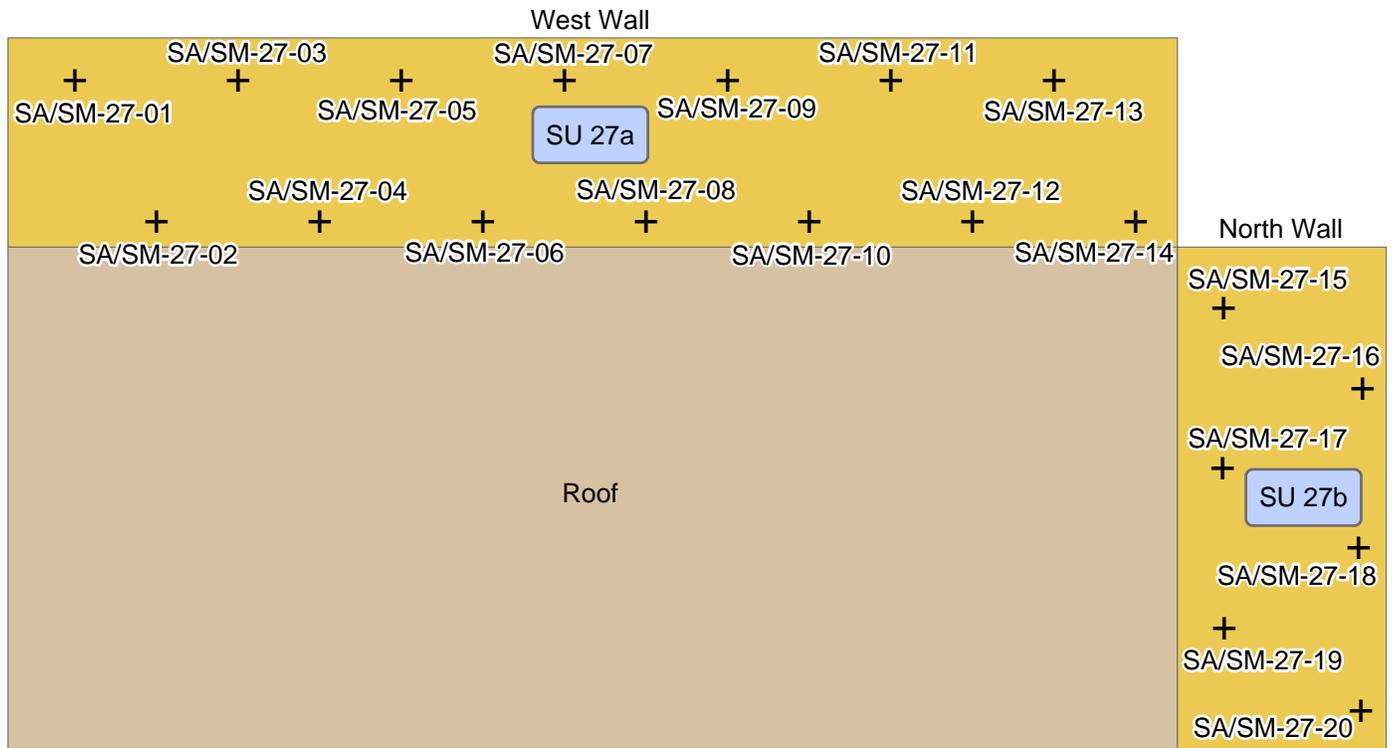
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**Building 1103B
Interior Floor
Survey Unit
Sample Locations**





- + Systematic Sample Location
- SA Surface Alpha Measurement
- SM Smear Sample
- Exterior Roof
- Exterior Wall
- SU 27a Survey Unit Class 2

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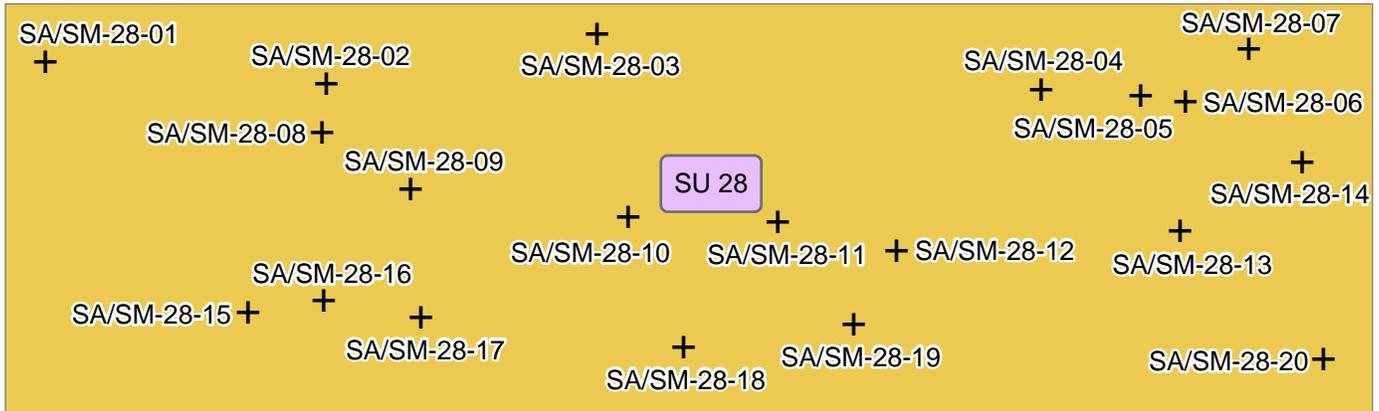
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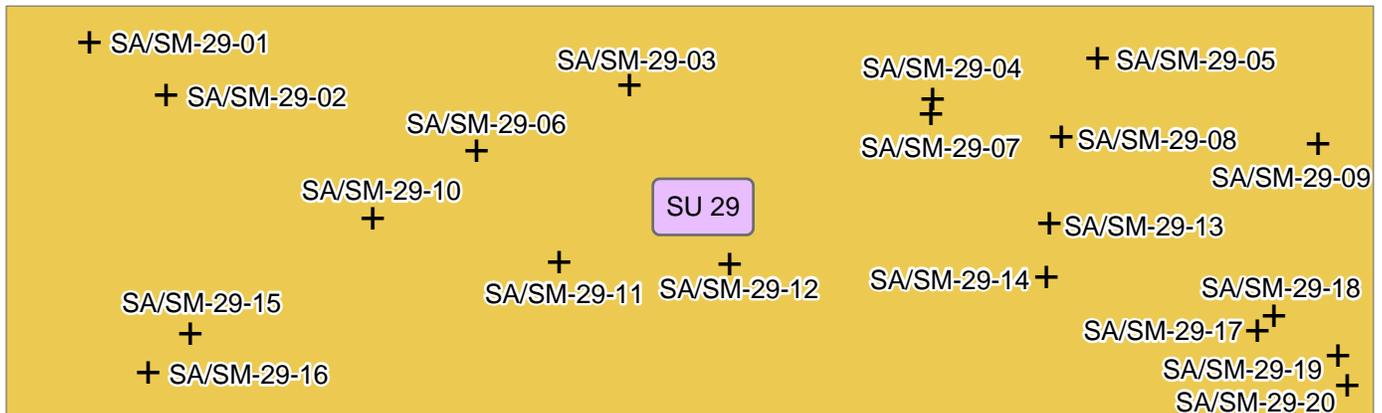


**Building 1103B
Exterior Wall
Survey Unit
Sample Locations**

Building 1100E
East Wall



Building 1100F
East Wall



- +** Systematic Sample Location
- SA** Surface Alpha Measurement
- SM** Smear Sample
-  Exterior Wall
-  Survey Unit Class 3

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Scale
0 1 2 4 Feet

Aberdeen Proving Ground Maryland
**Building 1100E and 1100F
Exterior East Wall
Survey Unit
Sample Locations**

APPENDIX B

FIELD INSTRUMENT DETECTION SENSITIVITY

FIELD INSTRUMENTATION DETECTION SENSITIVITY

Introduction

This appendix describes the detection sensitivities for field instrumentation used during the final status survey (FSS) of the Building 1103A Area of the U.S. Army Research Laboratory (ARL) located at Aberdeen Proving Ground (APG) in Aberdeen, Maryland. This includes instruments used for gamma walkover surveys (GWS) of land areas, and instruments used for detection of contamination on building and/or structure surfaces through surface activity scans and direct measurements of total and removable surface contamination.

Radionuclides of concern (ROC) known to be present in the area are limited to depleted uranium (DU) isotopes (i.e., uranium-234 [^{234}U], uranium-235 [^{235}U], and uranium-238 [^{238}U]) and their short-lived decay progeny. DU composition is based on the isotopic uranium weight ratios routinely used for shipments of DU waste from APG (Barg, 1995). The activity fractions are calculated from the weight ratios and specific activities of each uranium isotope. The resulting composition consists of ^{234}U , ^{235}U , and ^{238}U activity fractions of 0.084, 0.012, and 0.904, respectively. This composition is similar to the 0.190, 0.021, 0.790 average activity fractions measured in three DU soil samples described in the Argonne National Laboratory (ANL) report *Derived Uranium Guideline for the Depleted Uranium Study Area of the Transonic Range, Aberdeen Proving Ground, Maryland* (ANL, 1999).

The parent radionuclides in the two radioactive decay chains associated with DU, ^{238}U and ^{235}U , emit alpha particles. The daughter products in both chains decay by emission of alpha or beta particles, some with accompanying emission of gamma rays. The decay schemes for both are very well documented, and this knowledge is used in the design of the FSS and selection of appropriate survey instruments and analysis methods.

As presented in the following sections, the GWS minimum detectable concentration (MDC) for DU plus progeny in soil, using a 3"x3" sodium iodide (NaI) scintillation detector, is 32.9 picocuries per gram (pCi/g). The instrument scan minimum detectable count rate (MDCR), integrated or static measurement MDC, and the MDC for smear analysis are also presented in the following sections.

Gamma Walkover Survey Detection Sensitivity

The GWS will be performed using a Ludlum 44-20 3-in.x 3-in. NaI scintillation detector or equivalent detector. The GWS is accomplished by walking at a speed of approximately 1.5 feet per second (0.5 meters per second) with the detector at a height of approximately 2 to 3 in. above the ground surface. Results are recorded in units of counts per minute (cpm). The determination of NaI detection sensitivity (i.e., MDC in soil) for DU is provided below. This evaluation assumes the contaminant is present in the upper 15 centimeters (cm) layer of soil with an area of 56 cm for modeling and calculation purposes.

The methodology used to determine the NaI scintillation detector scan MDC is based on the Nuclear Regulatory Commission (NRC) document, *NUREG-1507: Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions*, dated December 1997. Factors included in this analysis are the surveyor scan efficiency, index of sensitivity, natural background of the surveyed area, scan rate, detector-to-source geometry, areal extent of the hot spot, and energy and yield of gamma emissions.

The computer code *Microshield* was used to model the presence of a normalized 1 pCi/g of total DU with its 50-year decay progeny in soil with the further assumption that the activity is uniformly distributed to a depth of 15 cm and spread over a disk shaped area having a diameter of 56 cm. The non-contaminated soil cover has zero thickness (i.e., contamination is at the surface), and there is a 0.051-cm aluminum shield simulating the cover of the NaI detector to complete the model source term. The dose point is centered over the contaminated disk of soil. This model is consistent with the *NUREG-1507* methodology and provides for the calculation of a count rate-to-exposure rate ratio in terms of counts per minute (cpm) to microroentgens per hour ($\mu\text{R/hr}$). Additional details and discussion describing the *NUREG-1507* analysis methodology are described in that publication.

Fluence Rate to Exposure Rate (unitless)

The fluence rate to exposure rate (FRER) may be approximated by:

$$\text{FRER} \sim (1 \mu\text{R/hr}) / (E_\gamma) (\mu_{\text{en}}/\rho)_{\text{air}}$$

Where:

$$E_\gamma = \text{energy of the gamma photon of concern, keV}$$
$$(\mu_{\text{en}}/\rho)_{\text{air}} = \text{the mass energy absorption coefficient for air, cm}^2/\text{g}$$

The FRER over a gamma energy range of 40 keV to 2 MeV is provided in Table 1.

TABLE 1: FLUENCE TO EXPOSURE RATE (FRER)

Energy _γ , keV	(μ _{en} /ρ) _{air} , cm ² /g	FRER
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

Probability of Interaction Through Detector End for a Given Energy

The probability, P, of a gamma ray interaction in the NaI scintillation crystal entering through the end of the crystal is given by:

$$\text{Probability (P)} = 1 - e^{-(\mu/\rho)_{\text{NaI}}(X)(\rho_{\text{NaI}})}$$

Where:

- (μ/ρ)_{NaI} = the mass attenuation coefficient for NaI
- X = the thickness through the bottom edge (end facing the soil) of the 3”x3” NaI crystal, 7.6cm
- ρ = the density of the NaI crystal, 3.67 g/cm³

The probability of interaction in the NaI detector over the same energy range is provided in Table 2.

TABLE 2: PROBABILITY OF INTERACTION (P)

Energy _γ , keV	(μ/ρ) _{NaI} , cm ² /g	P
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
60	6.62	1.00
80	3.12	1.00
100	1.72	1.00
150	0.625	1.00
200	0.334	1.00
300	0.167	0.99
400	0.117	0.96
500	0.0955	0.93
600	0.0826	0.90
800	0.0676	0.85
1,000	0.0586	0.80
1,500	0.0469	0.73
2,000	0.0413	0.68

Relative Detector Response

The relative detector response (RDR) by energy is determined by multiplying the FRER by the probability (P) of an interaction and is given by:

$$RDR = FRER \times P$$

The RDR for a NaI detector over the same energy range is provided in Table 3.

TABLE 3: RELATIVE DETECTOR RESPONSE (RDR)

Energy, keV	FRER	P	RDR
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1866
300	0.1157	0.99	0.1146
400	0.0845	0.96	0.0812
500	0.0673	0.93	0.0626
600	0.0563	0.90	0.0507
800	0.0433	0.85	0.0367
1,000	0.0357	0.80	0.0287
1,500	0.0261	0.73	0.0191
2,000	0.0214	0.68	0.0146

Determination of CPM per μ R/HR as a Function of Energy

The equivalent FRER, P, and RDR may be calculated for a NaI scintillation detector at the Cs-137 energy of 662 keV. Manufacturers of this equipment typically provide an instrument response in terms of cpm and μ R/hr at the Cs-137 energy level. This point allows determination of the cpm per μ R/hr and, ultimately, the activity concentration and minimum detection sensitivity in terms of pCi/g.

Based on measured counts in a known field it is estimated that a typical Ludlum Model 44-20 NaI response is 2,700 cpm/ μ R/hr. Using the same methodology as shown in the tables above, the FRER, P, and RDR can be calculated. The mass energy absorption coefficient for air and the mass attenuation coefficient for NaI are interpolated from tables in the *Radiological Health Handbook, Revised Edition*, dated January 1970, pages 139 and 140. These values are provided for Cs-137 in Table 4.

TABLE 4: FRER, P, AND RDR FOR CS-137 GAMMA ENERGY (BA-137M)

Energy _γ , keV	FRER	(μ _{en} /ρ) _{air} , cm ² /g	(μ/ρ) _{NaI} , cm ² /g	P	RDR
662	0.0514	0.0294	0.0780	0.89	0.0455

The detector response (in terms of cpm) to a different energy is based on the ratio of the RDR at that energy to the known Cs-137 energy RDR, as shown in the following equation:

$$\begin{aligned} \text{cpm}/\mu\text{R}/\text{hr}, E_i &= (\text{cpm}_{\text{Cs-137}}) \times (\text{RDR}_{E_i}) / (\text{RDR}_{\text{Cs-137}}) \\ &= (2,700) \times (\text{RDR}_{E_i}) / (\text{RDR}_{\text{Cs-137}}) \end{aligned}$$

The NaI count rate over the same gamma energy range presented previously is provided in Table 5.

Table 5: Count Rate (E_i) in cpm/μR/hr

Energy _γ , keV	RDR _{E_i}	NaI Detector, E _i , cpm per μR/hr
15	0.0517	3064
20	0.0969	5745
30	0.2268	13445
40	0.3906	23161
50	0.5208	30881
60	0.5708	33842
80	0.5297	31404
100	0.4329	25667
150	0.2656	15748
200	0.1866	11061
300	0.1146	6797
400	0.0812	4816
500	0.0626	3714
600	0.0507	3005
662	0.0455	2700
800	0.0367	2175
1,000	0.0287	17404
1,500	0.0191	1131
2,000	0.0146	867

Finally, the count rate to exposure rate ratio for the DU isotopes and progeny gamma emissions and the contribution to the total exposure rate are determined using the output of the *Microshield* runs and the count rate to exposure rate ratios from Table 5. The weighted cpm/ μ R/hr over the same energy range in previous tables is presented in Table 6.

TABLE 6: WEIGHTED COUNT RATE TO EXPOSURE RATE IN CPM/ μ R/HR

keV	MicroShield Exposure Rate With Buildup (μ R/hr)	Count Rate to Exposure Rate (cpm/ μ R/hr)	Weighted Count Rate to Exposure Rate (cpm/ μ R/hr)
15	7.662E-09	3064	0
20	6.224E-11	5745	0
30	4.751E*06	13445	8
40	8.301E-09	23161	0
50	7.223E-07	30881	3
60	3.724E-04	33842	1545
80	5.073E-05	31404	195
100	1.656E-03	25667	5212
150	1.272E-04	15748	246
200	6.157E-04	11061	835
300	1.432E-05	6797	12
400	1.608E-05	4816	9
500	2.927E-05	3714	13
600	1.416E-04	3005	52
800	1.023E-03	2175	273
1,000	3.968E-03	1704	829
1,500	1.162E-04	1131	16
2,000	1.873E-05	867	2
Total	8.155E-03		9252

Scan MDC Value

The scan MDC is calculated using the *NUREG-1507* methodology, where the average number of background counts in a one second interval, b_i , is cpm/60.

For the Ludlum 3'' x 3'' NaI scintillation detector and a background count rate of 27,000 cpm, the calculated background counts in a one second interval is:

$$b_i = (27,000 \text{ cpm}) / (60 \text{ sec/min}) = 450 \text{ counts}$$

The minimum detectable count rate (MDCR) is:

$$\text{MDCR} = (d') \times (b_i)^{0.5} \times (60 \text{ sec/min})$$

Where:

$$d' = 1.38 \text{ from } NUREG-1507 \text{ Table 6.1, which represents the rate of detection at a 95\% true positive proportion with a false positive proportion of 60\%.$$

The resulting MDCR is:

$$\text{MDCR} = (1.38) \times (450 \text{ counts/sec})^{0.5} \times (60 \text{ sec/min}) = 1,756 \text{ cpm}$$

The MDCR for the surveyor is represented as follows:

$$\text{MDCR}_{\text{surveyor}} = \text{MDCR} / (p)^{0.5}$$

Where:

$$P = \text{surveyor efficiency, equal to 0.75 to 0.5 as given by } NUREG-1507 \text{ (0.5 is selected as a conservative choice).}$$

The resulting surveyor MDCR is:

$$\text{MDCR}_{\text{surveyor}} = 1,756 / 0.707 = 2,484 \text{ cpm}$$

The minimum detectable exposure rate (MDER) for the surveyor, obtained from the $\text{MDCR}_{\text{surveyor}}$ divided by the Table 6 weighted count rate to exposure rate value of 9,252 cpm/ $\mu\text{R/hr}$ for DU and progeny, is:

$$\text{MDER} = (2,484 \text{ cpm}) / (9,252 \text{ cpm } / \mu\text{R/hr}) = 0.2685 \mu\text{R/hr}$$

The scan MDC is then equal to the ratio of the MDER in the field to the exposure rate determined for the normalized 1 pCi/g concentration of total DU, and is represented as follows:

$$\text{Scan MDC} = (\text{Normalized DU}_{\text{Total Conc}}) \times (\text{Exposure Rate MDCR}_{\text{Surveyor}}) / (\text{Exposure Rate}_{\text{normalized DU conc}})$$

The resulting scan MDC for the outdoor GWS is:

$$\text{Scan MDC} = (1 \text{ pCi/g}) \times (0.2685 \mu\text{R/hr}) / (8.155\text{E-}03 \mu\text{R/hr}) = \mathbf{32.9 \text{ pCi/g}}$$

Building and/or Structure Surface Activity Measurements

As indicated in the work plan, building and/or structure surfaces will be surveyed using direct surface scan and static measurement techniques. Smears will also be obtained and analyzed to determine the amount of removable contamination present on a surface. Surveys will be performed in accordance with standard operating procedures.

Surface scans will be performed using instruments capable of measuring the beta emissions from the DU radionuclides. Since many of the interior building surfaces within the scope of this FSS are known to be contaminated, the scan survey will attempt to determine the distribution of contaminants, as well as identify areas of contamination significantly higher than other areas (hot spots). The results of the beta scan surveys will then be used to identify locations for collection of biased integrated or static alpha total surface activity measurements and collection of smears to determine the removable contamination fraction in these areas. Because many of the interior surfaces are known to be contaminated with DU, the postulated hot spot area for performance of scan surveys is 1 square meter (m^2).

For the purpose of building surface and/or structure FSS, a hot spot is defined as any area exhibiting greater than two times the instrument minimum detectable count rate (MDCR). Following completion of the beta scan surveys, integrated or static alpha measurements may be performed at systematic and/or biased locations, including hot spot areas identified through surface beta scans. Smears may also be obtained at these locations to determine the removable fraction of contamination present on the surface. Only the results of the integrated or static alpha measurements will be compared to the screening limits presented in the work plan.

Beta surface scans may be performed using a Ludlum Model 43-37 floor monitor (582 cm^2) gas proportional detector, Ludlum Model 43-68 hand-held gas proportional detector (126 cm^2), or equivalent instrumentation. Integrated or static surface activity measurements may be performed using the Ludlum Model 43-37 floor monitor, Ludlum Model 43-68 gas proportional detector, Ludlum Model 43-89 ZnS scintillation detector (126 cm^2), or equivalent instrumentation. Smears may be analyzed using a Ludlum Model 2929 scaler coupled to a Ludlum Model 43-10-1 scintillation detector. The following sections discuss the detection sensitivity for each of these instruments used for FSS surveys.

Beta Scan Minimum Detectable Count Rate

The detection sensitivity derived for instruments used to perform beta scans focuses on the information provided directly from the measurement and available to the surveyor for decisions regarding survey performance. Therefore, the beta scan sensitivity is derived in terms of the measurement MDCR. The MDCR is determined for the Ludlum Model 43-37 floor monitor and the Ludlum Model 43-68 gas proportional detector, using *MARSSIM* Equations 6-8 and 6-9.

The observed background count (b') is defined as the number of background counts observed within the observation interval (i). The equation used for calculating b' is as follows:

$$b' = (\text{BCPM}) * (i) * (1 \text{ min}/60 \text{ sec}) = \text{counts/interval}$$

Where:

BCPM = instrument or reference area background count rate (cpm)

i = observation interval (seconds)

The minimum detectable number of net source counts in the interval is given by s_i . Therefore, for an ideal observer, the number of source counts required for a specified level of performance can be arrived at by multiplying the square root of the number of background counts by the detectability value associated with the desired performance (d'), as shown below:

$$s_i = d\sqrt{b'} \quad \text{MARSSIM Equation 6-8}$$

The MDCR is defined as the increase above background recognizable during a survey in a given period of time. The variable, d , is defined as the index of sensitivity and is dependent on the selected decision errors for Type I (alpha) and Type II (beta) errors. A true positive error ($1-\beta$) of 95% and a false positive error (alpha) of 60% may be selected to be consistent with NUREG 1507. The value of 1.38 was obtained from *NUREG 1507*, Table 6.1 (*MARSSIM* Table 6.5).

$$\text{MDCR (cpm)} = s_i \times (60/i) \quad \text{MARSSIM Equation 6-9}$$

The measurement interval (i) for both the Ludlum Model 43-37 and Ludlum Model 43-68 is one per second.

Ludlum Model 43-68

The background count rate for the Ludlum Model 43-68 reported by the manufacturer is 300 cpm (consistent with a typical concrete background count rate for this instrument).

$$b' = (300 \text{ cpm}) * (1) * (1 \text{ min}/60 \text{ sec}) = 5 \text{ counts in the 1 second observation interval}$$

Using $d = 1.38$:

$$s_i = 1.38\sqrt{5}$$

$$s_i = 3.1$$

Thus, the Ludlum Model 43-68 beta scan MDCR is:

$$\text{MDCR (cpm)} = 3.1 \times (60/1) = 185 \text{ cpm (above background)}$$

The beta scan action level for identifying a hot spot would therefore be:

$$\begin{aligned}\text{Scan Action Level (MDCR)} &= \text{MDCR} \times 2 \\ &= 370 \text{ cpm above background}\end{aligned}$$

For simplicity and to aid in surveyor decisions, this value is rounded to **400 cpm above background**.

Ludlum Model 43-37

The beta scan MDCR for the Ludlum Model 43-37 floor monitor is same manner as the Ludlum Model 43-68 except the background is adjusted to account for the significant increase in detector area. This is accomplished simply by multiplying the Ludlum Model 43-68 background by the ratio of the Ludlum Model 43-37 detector area (582 cm²) to the Ludlum Model 43-68 detector area (126 cm²) or 4.6.

$$\text{Ludlum Model 43-37 BCPM} = 300 \times 4.6 = 1386 \text{ cpm}$$

Using this background count rate, the values and formulas from the previous section, the Ludlum Model 43-37 floor monitor beta scan MDCR is 397 cpm above background. Rounding for simplicity and ease, the MDCR is approximately 400 cpm above background, resulting in a beta scan action level for the Ludlum Model 43-37 of **800 cpm above background**.

Integrated (Static) Alpha Surface Activity Measurements

Integrated direct measurements (i.e., static measurements) of surface alpha contamination will be performed to compare contaminant concentrations at discrete sampling locations to the screening limit presented in the work plan.

Integrated alpha activity measurements will be performed using a Ludlum Model 43-37 gas proportional detector, Ludlum Model 43-68 gas proportional detector, Ludlum Model 43-89 handheld scintillation detector, or equivalent. Although the background count rates are slightly different, the parameters and static measurement requirements are very similar for the Ludlum Model 43-68 and Ludlum Model 43-89 detectors.

Since the background and gross (or sample) count times are the same for all three detectors, the following equation is used to determine instrument MDC:

$$\text{MDC (dpm/100cm}^2) = \frac{3 + 4.65 \sqrt{(R_b)}}{\frac{[DA]}{100} [\epsilon_i][\epsilon_s]} \quad \text{MARSSIM Equation 6-7}$$

Where:

- ϵ_i = instrument efficiency (cpm/dpm)
- ϵ_s = surface efficiency (unitless)
- R_b = background count rate (cpm)
- DA = detector area (cm²)

For the purpose of this evaluation, instrument efficiency values (ϵ_i) were obtained from *NUREG 1507*, Table 4.4. Surface efficiency values (ϵ_s) were obtained from *NUREG 1507*, Table 5.5, for a sealed concrete surface with distributed alpha emitting radioactive source.

When using large area detectors, such as the detector associated with the Ludlum Model 43-37, it is typically not appropriate to account for detector area corrections. This is because the area of contamination is assumed to be much smaller than the detector area, on the order of 100 cm². However, since it is known that many interior surfaces are contaminated, and the postulated hot spot is much greater than the Ludlum Model 43-37 detector area, this correction is necessary and appropriate.

The integrated or static measurement MDC and assumptions used for each of the detectors are presented in Table 7. The MDC was determined using the above equation.

TABLE 7: INTEGRATED/STATIC MEASUREMENT MDC AND ASSUMPTIONS

Ludlum Model No.	Count Time (min)	Bkg Count Time (min)	Detector Area (cm ²)	ϵ_i (cpm/dpm)	ϵ_s	α Bkg (cpm)	α Static MDC (dpm/100 cm ²)
43-37	1	1	582	0.349	0.473	10	18
43-68	1	1	126	0.349	0.473	5	64
43-89	1	1	126	0.259	0.428	3	79

min = minutes

cpm = counts per minute

bkg = background

cm² = square centimeters

dpm = disintegrations per minute

Removable Contamination (Smear) Analysis MDC

Smear samples will be collected at biased building surface locations, as appropriate, to quantify transferable/removable surface alpha contamination. Samples of removable surface contamination are typically obtained by wiping a surface area of 100 cm² using a cloth or paper disc or other suitable media. These samples (smears) will be analyzed using a Ludlum 2929 scaler coupled to a Ludlum Model 43-10-1 scintillation detector. Since the background and gross (sample) count times for this instrument are typically different when analyzing smears for alpha emitting contamination, the following equation is used to determine the measurement MDC:

$$\text{Smear MDC (dpm/100 cm}^2\text{)} = \frac{3 + 3.29 \sqrt{(R_b)(T_s)(1 + \frac{T_s}{T_b})}}{(T_s) (\epsilon_i)}$$

NUREG 1507, Equation 3-11

Where:

- ϵ_i = instrument efficiency (cpm/dpm)
- R_b = background count rate (cpm)
- T_b = background count time (minutes)
- T_s = sample count time (minutes)

The smear analysis MDC and assumptions are presented in Table 8.

TABLE 8: SMEAR ANALYSIS MDC AND ASSUMPTIONS

Ludlum Model No.	Count Time (min)	Bkg Count Time (min)	Probe Area (cm ²)	α Efficiency (cpm/dpm)	α Bkg (cpm)	α Static MDC (dpm/100 cm ²)
2929	4*	20	Smear	0.33	0.8	7

min = minutes

cm² = square centimeters

cpm = counts per minute

dpm = disintegrations per minute

* Actual sample count time may be determined based on actual measured alpha background count rate and detector specific alpha efficiency. Background and sample count times may be adjusted to maintain a target MDC not greater than 10 dpm/100 cm² or 10% of the screening limit presented in the work plan.

Summary

GWS sensitivity parameters, beta surface scan MDCRs, and static measurement and smear analysis MDCs have been calculated for each instrument to be used during the FSS. Calculation of MDCs for each instrument ensures that direct measurements are performed using radiation survey instrumentation sufficient to evaluate radiological conditions in accordance with the requirements of the work plan. Due to the potential variations of conditions in the field, parameters such as static measurement and smear count times may be adjusted onsite with the permission of the project Health Physicist.