FINAL STATUS SURVEY PLAN

U.S. Army Watervliet Arsenal
Watervliet, NY

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LIST OF ACRONYMS AND ABBREVIATIONS

bkg	background
CFR	Code of Federal Regulations
cm	centimeter(s)
cm^2	square centimeter(s)
cpm	count(s) per minute
DCGL	Derived Concentration Guideline Level
$DCGL_{EMC}$	Derived Concentration Guideline Level used for elevated measurement comparison
$DCGL_w$	Derived Concentration Guideline Level used for nonparametric statistical test
dpm	disintegration(s) per minute
DQO	Data Quality Objective
DU	Depleted Uranium
FSS	Final Status Survey
FSSP	Final Status Survey Plan
H_a	alternative hypothesis
H_0	null hypothesis
HP	Health Physicist
in.	inch(es)
LBGR	Lower Bound of the Gray Region
m	meter(s)
m^2	square meter(s)
m/s	meter(s) per second
MARSSIM	Multi-Agency Radiological Survey and Site Investigation Manual
MDC	Minimum Detectable Concentration
MDCR	Minimum Detectable Count Rate
min	minute(s)
mrem/yr	millirem(s) per year
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
QA	Quality Assurance
QC	Quality Control
RDR	Relative Detector Response
ROC	Radionuclide of Concern
sec	second(s)
SOP	Standard Operating Procedure
SU	Survey Unit
TEDE	Total Effective Dose Equivalent
^{99}Tc	technetium-99
^{230}Th	thorium-230
^{234}Th	thorium-234
^{234}U	uranium-234
^{235}U	uranium-235
^{238}U	uranium-238
WRS	Wilcoxon Rank Sum

1.0 INTRODUCTION

This *Final Status Survey Plan (FSSP)* has been prepared by SIA Solutions, LLC. (SIA), under contract to the U.S. Army Joint Munitions Command (JMC), to support the decommissioning of the source material license at Watervliet Arsenal (WVA). This FSSP addresses the applicable radiological surveys, sampling, and data analysis necessary to demonstrate that the laboratory in Building 115 and the storage area in Building 119 are suitable for unrestricted release. These areas are under the control of WVA and are subject to the requirements of its U.S. Nuclear Regulatory Commission (NRC) license (No. STB-1554). Depleted uranium (DU) is the contaminant of concern.

The proposed derived concentration guideline level ($DCGL_W$) for building surfaces is taken from existing NRC guidance. Implementation of this FSSP will provide the data necessary to demonstrate compliance with the DCGL. Specifically, when the DCGL is applied to the final status survey (FSS) and the data obtained indicates that the requirements of this survey plan have been satisfied, the requirements in Title 10 of the Code of Federal Regulations (CFR) Part 20.1402 for unrestricted release will be achieved (NRC, 2006).

2.0 SITE INFORMATION

The Watervliet Arsenal (WVA) is an arsenal of the United States Army located in Watervliet, New York. It is located along the Hudson River, just a few miles north of the state capital of Albany, NY. It is the oldest continuously active arsenal in the United States, and today produces much of the artillery for the army, as well as gun tubes for cannons, mortars, and tanks. It has been a National Historic Landmark since 1966.

The arsenal was founded in 1813 to support the War of 1812 and was designated as the Watervliet Arsenal in 1817. It occupies 142 acres (57 hectares) of land, approximately 8 miles (13 km) north of Albany, New York. The location is adjacent to the Hudson River. The site contains manufacturing, administrative offices and storage areas. It also houses the Army's Benét Laboratories, which is the Army's premier research and design facility for large caliber weapons. The Watervliet Arsenal is the Army's primary gun-tube maker.

Watervliet's products include tank cannon, artillery cannon, battleship guns, marine drives, scissor bridges, and rocket motors. This 72-building arsenal encompasses over 1.2 million square feet of manufacturing space and employs almost 2,000 personnel.

2.1 Site Activities

WVA was licensed for possession of DU for a variety of purposes. Initially, DU billets were extruded in order to test extrusion methods and billet properties, during and after extrusion. A “hydrostatic” extrusion method was one of those tested. Also, experiments were conducted on heat treating DU billets.

Later, DU projectiles, weighing up to 15 pounds, underwent metallurgical testing. The studies were designed to determine physical properties of the projectiles. Gun tubes that had fired DU projectiles were also sent to WVA for metallurgical testing. The impact of residual DU on the inside of the gun tubes was studied.

In recent years, the only DU possessed by WVA was residual DU on gun tubes and other surfaces (e.g., floors and benchtops).

2.2 Site Description

Only two indoor areas were used in the handling of licensed material (DU). These are described below.

2.2.1 Building 115

Building 115 houses the machine shop used for the handling and analysis of DU projectiles and gun tubes contaminated with DU. The room numbers for the lab are Rooms 138 and 138A. (See Figure 2-1.) The entry area to both rooms is inside the door to Room 138. This area was set up as an access control point, with step-off pads and associated supplies. Room 138 contains lab benches; one lab bench contains and sink and drain. Room 138A contains a drip pan containing a small amount of machine oil. This will be removed and disposed of prior to the survey. Both rooms have an acoustic tile ceiling and Room 138 has a disconnected ceiling duct. The walls are concrete block, except for steel plate walls in 138A. The tile floors in both rooms were removed as part of an asbestos abatement program. Debris from the abatement will be disposed of as mixed waste (asbestos and radioactive). There are no floor drains.

2.2.2 Building 119

Building 119 was built in the 1800's as a storage bunker. The interior has been subdivided using concrete blocks. (See Figure 2-2.) A small, central room (Room 2, approximately 12' x 12') was used for storage of licensed material. There are floor drains in the building, but none in Room 2. There is nothing permanently installed in the room.

2.3 Previous Investigation

In 2019, SIA performed a scoping survey of potentially impacted areas in these buildings. Results of the surface contamination surveys are presented in the *HISTORICAL SITE ASSESSMENT AND SCOPING SURVEY* (SIA, 2019). Surface contamination was detected on floors in both buildings and on one benchtop in Room 138. The contamination was confined to several, small "hot spots" which will be remediated[1] before the final status survey is conducted.

[1] SIA plans to use a decontamination technique involving DeconGel. The solid waste generated will be disposed of at a licensed facility.

3.0 FINAL STATUS SURVEY REQUIREMENTS

A survey will be conducted in each survey unit (SU) identified inside the two buildings. This 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 both buildings are 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 another U.S. Army facility (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.

3.2 Derived Concentration Guideline Level

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 $DCGL_w$ 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 by each of the applicable isotopes 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.

$$DCGL_w = 1/\left\{\left(\frac{f1}{DCGL1}\right) + \left(\frac{f2}{DCGL2}\right) + \left(\frac{f3}{DCGL3}\right)\right\}$$

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	

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. Accordingly, the removable alpha activity action level during this FSS is 10 dpm/100 cm^2.

3.3 Area Classification Based on Contamination Potential

Based on the Historical Site Assessment (SIA, 2019), impacted areas of Buildings 115 and 119 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 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, often contiguous to Class 1 areas, that have a potential for radioactive contamination but at levels less than the $DCGL_W$.

Class 3: Buildings that are expected to contain little or no residual contamination based on site operating history or previous radiological surveys.

3.4 Identification of Survey Units

All impacted indoor areas 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. The SUs for this FSS are identified in Table 3-3 and shown in Figure 3-1.

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

m^2 = square meters

Table 3-3: WVA Survey Units

Area	Survey Unit	MARSSIM Classification
Bldg. 115, Room 138 & 138A, excluding entry area	1	1
Room 138 entry area	2	2
Hallways leading to Room 138	3	3
Bldg. 119, Room 2	4	1
Room 2 entry area	5	2
Areas adjacent to Room 2 and entry area	6	3

3.5 Background Reference Areas and Materials

Construction material-specific background measurements will be performed in areas of similar construction but without a history of radioactive material use. These material-specific background activity values will then be used to correct direct surface activity measurements for the contribution due to background and natural radioactivity in these materials. Material-specific background surface material count rates will be subtracted from survey count rates prior to converting the data to units of dpm/100 cm^2 for preliminary comparison with the $DCGL_W$.

The reference areas to be used are the hallways and office outside of Room 138 in Bldg. 115, and the fan room and exterior of Bldg. 119. Materials of interest are tile and concrete floors, block wall, stone wall, steel wall, and composite countertop.

3.6 Survey Design

Surface contamination will be assessed first by scanning, and then by collecting the required number of systematic alpha surface activity measurements within each SU. Scanning is designed to detect small areas of elevated alpha activity. Systematic counts, on the other hand, will be fixed counts at pre-determined locations. Instrumentation planned for these surveys is discussed in Section 4.0

Scan coverage planned for the FSS is given in Table 3-4. The survey will achieve or exceed the proposed coverage.

Table 3-4: Proposed FSS Scan Coverage

Class	Structures
1	100% floors and lower walls
2	50 to 100% floors
3	10 to 25% floors

Systematic Measurements

Systematic measurements will be made in each survey unit. The same detectors will be used to take one minute, fixed alpha readings at each location. The following sections describe the basis for and derivation of the minimum required measurements for each SU.

To determine the minimum number of measurements, the relative shift is first determined. The relative shift describes the relationship of site residual radionuclide concentrations to the $DCGL_w$ and is calculated using the following equation:

$$\Delta/\sigma = \frac{(DCGL_w - LBGR)}{\sigma}$$

Where:

$DCGL_w$ = 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 (NRC, 2000). The statistical test (WRS test) is discussed in Section 6.2.

For both buildings, the $DCGL_W$ for surface alpha radioactivity is 100 dpm/100 cm^2. The LBGR is estimated as 50 dpm/100 cm^2. Using the alpha data collected during the scoping survey as a rough guide, a standard deviation of 6 dpm/100 cm^2 is estimated (not calculated). Using these values and the above equation, the relative shift is 8.3. The corresponding number of systematic direct measurement locations, as calculated by MARSSIM Formula 5-2, is 11. Increasing by 20%, as recommended by MARSSIM, gives a minimum 13 measurement locations per SU.

<u>Determining Measurement/Sampling Locations</u>

Measurement and sampling locations will be established in a random-start/systematic fashion for Class 1 and Class 2 SUs, and 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:

$$0.866 \times L$$

Preliminary sampling grids are presented in Appendix B for the survey units identified. Sample locations were determined using Visual Sample Plan software.

3.7 Integrated Survey Strategy

Survey data collected for room surfaces consists of surface activity scans and direct, systematic measurements for alpha surface activity. Smears samples, although not used in the final data quality assessment, will be collected from each scan or systematic location that exceeds background. Additional biased measurements and samples will be obtained, as necessary, from locations where scans indicate the potential for elevated activity.

The recommended surface scan coverage of accessible survey unit areas, shown in Table 3-4, will be met or exceeded. FSS direct measurements to quantify total alpha activity on structure surfaces will be performed at pre-determined random-start/systematic or random locations, as applicable. Additional biased direct alpha and smear measurements will be performed at locations of elevated activity identified during the scan survey. Direct alpha measurements will be performed using gas proportional detectors coupled to ratemeter scalers.

Direct and removable surface activity data will be converted to units of dpm/100 cm^2 for comparison to the removable alpha activity limit. Specific FSS survey and sampling requirements for the various types of SUs are discussed in the following paragraphs.

<u>Class 1 SUs</u>

Class 1 areas include floors and concrete and steel walls. Surface activity scans will be performed over 100 percent of the accessible surface areas. At least 13 systematic direct alpha measurements will be performed in each of these SUs. Additionally, smears will be obtained at biased locations, depending on the surveyor's judgement (example: ceiling vent in Room 138). Additional biased direct alpha measurements will be obtained, if necessary, based on the results of the surface activity scans.

<u>Class 2 SUs</u>

Class 2 areas include portions of Room 138 and portions of Bldg. 119. Surface activity scans will be performed over 50 to 100 percent of the accessible surface areas. At least 13 systematic direct alpha measurements will be performed in each of these SUs. Additionally, smears will be obtained at biased locations, depending on the surveyor's judgement.

Additional biased direct alpha measurements will be obtained, if necessary, based on the results of the surface activity scans.

Class 3 SUs

Class 3 areas include unimpacted portions of Bldgs. 115 and 119. Surface activity scans will be performed over at least 10 percent of the accessible surface area in each SU at locations of greatest contamination potential. At least 13 random direct alpha measurements will be collected in each of the SUs.

4.0 SURVEY INSTRUMENTATION AND TECHNIQUES

This section describes the instrumentation and methodology that will be used for direct radiation measurement and smear survey collection, during the FSS of Buildings 115 and 119. The MDC and MDCR required for the building surface activity scans, integrated alpha surface activity measurements 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

Floor, lower wall, and workbench surfaces will be surveyed for radioactivity using direct surface scan techniques. Surveys will be performed as described in the previous sections and in accordance with the FSS contractor's standard operating procedures.

4.1.1 Ludlum Model 43-37-1

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. Scans will be performed on floor surfaces and walls using a Ludlum Model 43-37-1 gas proportional detector (with an active area of 609 cm^2), or equivalent. The scan rate for the Ludlum Model 43-37-1 will not exceed six inches per second as an upper bound scan rate, with a measurement interval of one observation per second (1/sec). The Ludlum Model 43-37-1 scan sensitivity is discussed in Appendix A.

Scans will be performed by moving the active area of the detector over the surface of interest, with the active area of the detector close to the surface. During the scan survey in any SU, if the surveyor observes a one alpha count, he will pause for a calculated "pause interval[1]" to wait for additional counts. If those are detected, the area will be identified as a potential location for additional biased static measurements.

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

[1] See Appendix A for discussion.

43-68 handheld gas proportional detector (with an active area of 100 cm^2), or equivalent. The detector's scan sensitivity is discussed in Appendix A.

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 or disposed in accordance with facility waste management procedures. One-minute integrated alpha activity measurements will be performed using the Ludlum Model 43-37-1 gas proportional detector (operating in alpha mode only), or equivalent. The Ludlum Model 43-68 handheld gas proportional detector will require a three-minute count to obtain the desired sensitivity. The *a priori* detector sensitivities and relevant assumptions are presented in Table 4-1 and discussed further in Appendix A.

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

Table 4-1: Integrated Alpha Measurement Sensitivity Assumptions

Model No.	Count Time (min)	Bkg. Count Time (min)	Probe Area (cm^2)	Total Alpha Efficiency[1] (cpm/dpm)	Alpha Background (cpm)	Alpha Static MDC (dpm/100 cm^2)
43-37-1	1	1	609	0.05	9	56
43-68	3	10	100	0.05	3	92

Note 1. Product of surface efficiency (0.25) and instrument efficiencies.

4.3 Smear Sample Collection and Analysis

Smear samples will be collected at biased measurement locations to quantify transferable surface alpha radioactivity. Smear samples will be 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 site conditions. 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 4-2.

Table 4-2: 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)
LMI 2929	4	20	100 cm^2 Smear	0.33	0.8	7

5.0 SURVEY QUALITY ASSURANCE/QUALITY CONTROL

Activities associated with this work plan will be performed in accordance with written operating procedures and 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 manufacturer's 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 will be maintained in the project file. Calibration certificates for each instrument will be included in an appendix to the FSS Report.

Alpha/Beta Detectors and Smear Counter

Alpha/beta detectors (e.g., Ludlum Models 43-68, 43-37) 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 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 ten minute count, with the source removed. The acceptance criteria for these instrument response checks will be plus and minus three standard deviations (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 unusual readings.

6.0 DATA EVALUATION AND COMPLIANCE DEMONSTRATION

The data generated during the survey 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 $DCGL_W$ established for this site, as described below.

6.1 Data Review and Investigation Thresholds

The 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 areas, 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. 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 DCGL

The objective is to evaluate the mean survey unit concentrations 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 described in the following sections.

As discussed in Section 3.2, a DCGL for surface activity has been developed for evaluation of the survey data. The DCGL addresses the mean activity concentration over a wide area (i.e., the $DCGL_W$), and also provides 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.

Preliminary Evaluation

To begin, each static measurement is compared to the guideline ($DCGL_W$). If all values from the random or random start/systematic locations for a survey unit are less than the guideline, the SU satisfies the criterion and no further evaluation is necessary.

Next, the average surface activity will be calculated for each survey unit. 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 Wilcoxon Rank Sum (WRS) test will be performed.

The WRS test is a two-sample, non-parametric procedure that can be used to evaluate compliance when the measurements taken are not radionuclide specific. The WRS test is a two-sample test to compare means between concentrations measured in reference background materials versus the same parameter measured in survey unit materials.

The WRS test involves the following steps:

1. List each of the SU measurements and reference area measurements.
2. Add the $DCGL_W$ to each reference area measurement.
3. Rank all the listed measurements from low to high.
4. Determine the Critical Value per MARSSIM Table I.4 (NRC, 2000) for the appropriate sample size and decision level.
5. Sum the ranks of the reference area measurements (only) and compare the sum to the critical value.

If this sum is less than the critical value, the null hypothesis is not rejected, and the SU does not meet the established criterion; investigation, remediation, reclassification, and/or re-survey should be performed, as appropriate. If the sum is greater than the critical value, an elevated measurement comparison is next.

Elevated Measurement Comparison

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 measurements may exceed the $DCGL_W$, yet the null hypothesis may still be rejected. Therefore, both the statistically based and biased readings exceeding the $DCGL_W$ must be compared with a $DCGL_{EMC}$, defined as the $DCGL_W$ times the Area Factor. This criterion corresponds with the size of a given area of elevated activity

Area factors, obtained from MARSSIM Table 5.7 (NRC, 2000), are provided in Table 6-1. These will be applied to this survey, unless site-specific factors can be generated. If no measurement exceeds the $DCGL_W$, an area factor will not be needed.

Table 6-1: 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 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] 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 this survey will be compiled into a detailed report. Unless significant contamination is discovered, the report will provide all applicable data and documentation necessary to demonstrate Buildings 115 and 119 are suitable for unrestricted release in accordance with 10 CFR 20, Subpart E.

8.0 REFERENCES

Barg, 1995. *Specific Manufacturing Capability Program, Depleted Uranium Constituents and Decay Heating.* Lockheed Idaho presentation. October 3, 1995.

NRC, 1998. *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions.* NUREG-1507. U.S. Nuclear Regulatory Commission. June 1998.

NRC, 1999. *Residual Radioactive Contamination from Decommissioning, Parameter Analysis.* NUREG-CR-5512, Volume 3. U.S. Nuclear Regulatory Commission. October 1999.

NRC, 2000. *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM),* NUREG-1575. U.S. Nuclear Regulatory Commission, U.S. Department of Defense, U.S. Environmental Protection Agency, and U.S. Department of Energy. August 2000.

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

SIA, 2019. *Historical Site Assessment and Scoping Survey*, SIA Solutions, LLC, 2019.

FIGURES

FIGURE 2-1: BUILDING 115 FLOORPLAN

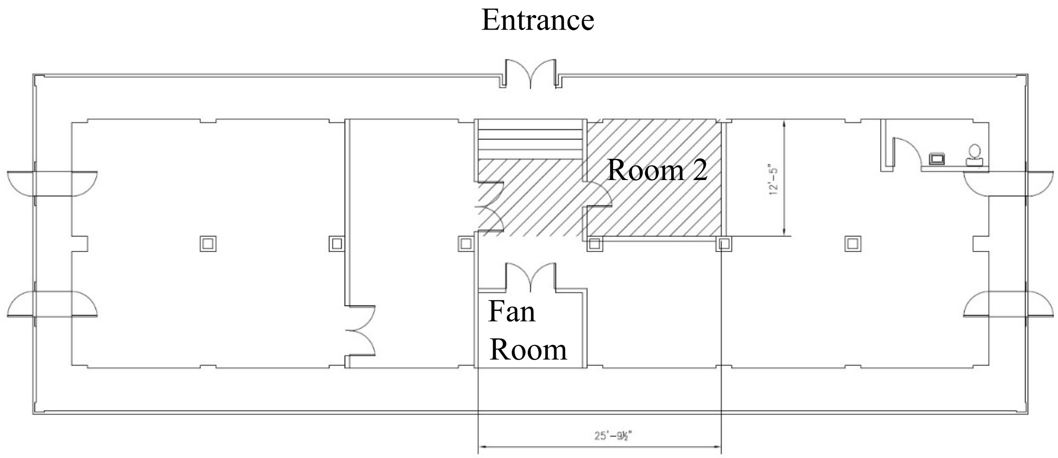


FIGURE 2-2: BUILDING 119 FLOOR PLAN

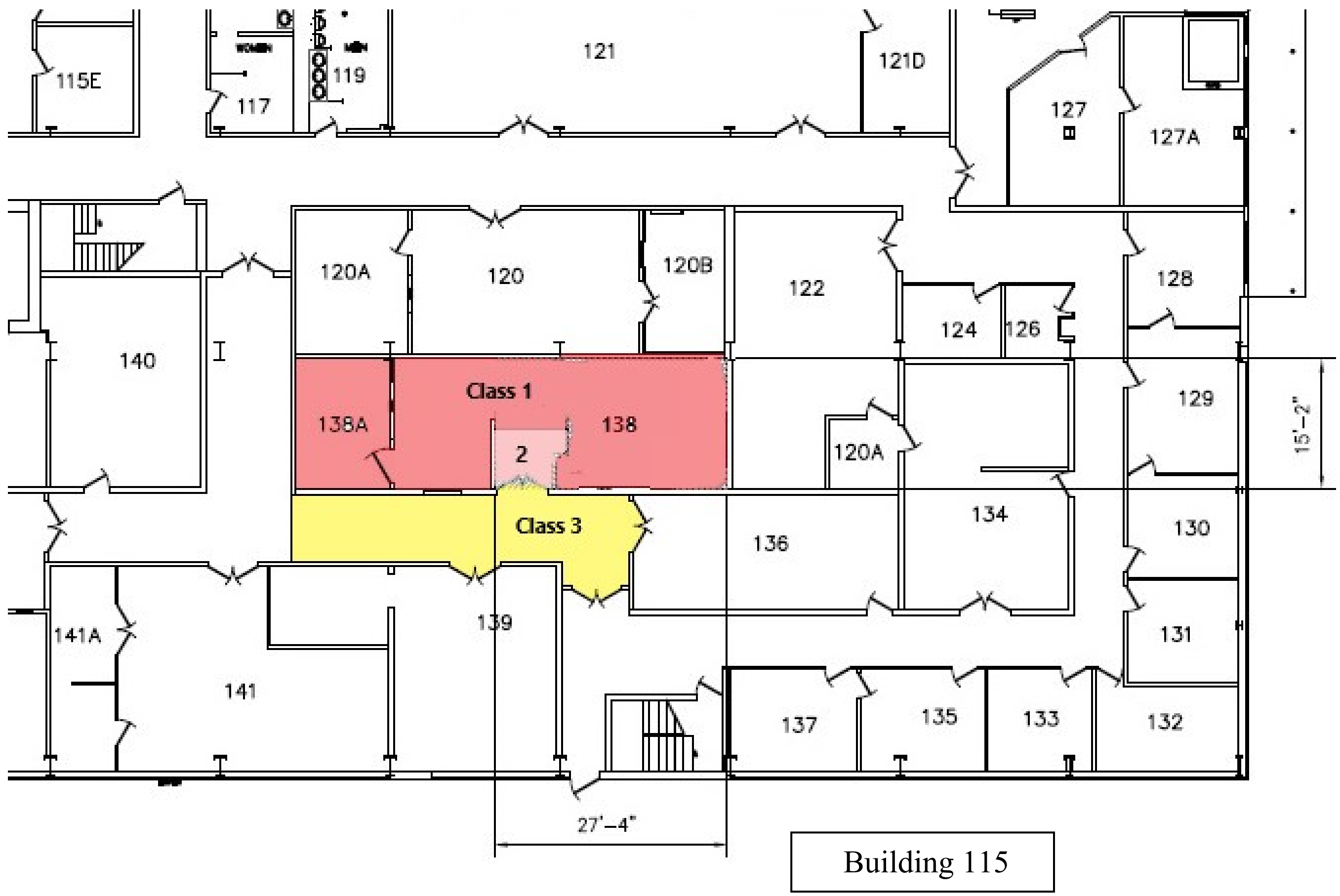


FIGURE 3-1: SURVEY UNITS

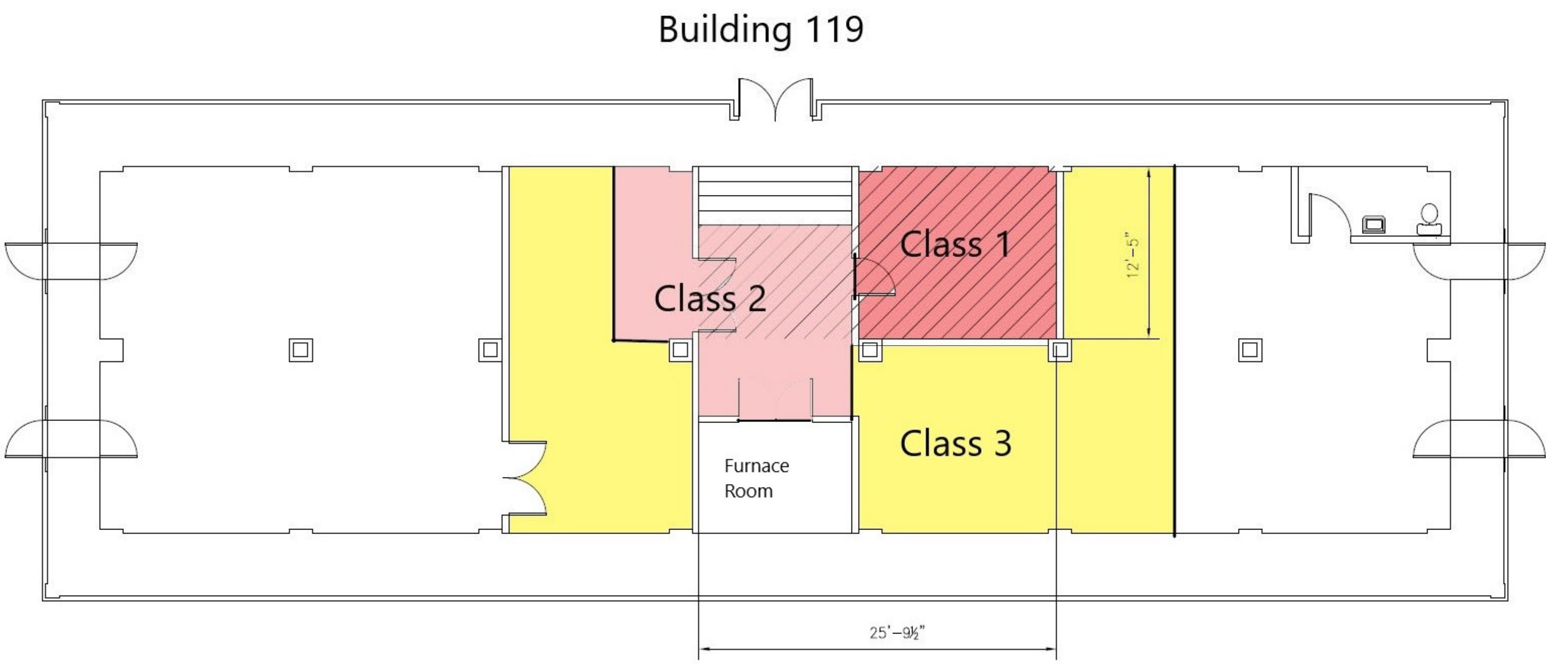


FIGURE 3-1: SURVEY UNITS (Cont'd.)

APPENDIX A

FIELD INSTRUMENT DETECTION SENSITIVITY

FIELD INSTRUMENTATION DETECTION SENSITIVITY

Introduction

This appendix describes the *a priori* detection sensitivities for field instrumentation to be used during the final status survey (FSS) of Buildings 115 and 119 of the U.S. Army Watervliet Arsenal (WVA) located in Watervliet, New York. This includes instruments used for detection of contamination on building 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. 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.

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.

The *a priori* instrument scan sensitivities, integrated or static measurement MDC, and the MDC for smear analysis are presented in the following sections.

Building and/or Structure Surface Activity Measurements

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

Surface scans will be performed using instruments capable of measuring the alpha emissions from the DU radionuclides.

For the purpose of building surface scans, a "hot spot" is defined as any area exhibiting greater than the instrument minimum detectable count rate (MDCR). Following completion of the scan surveys, static measurements will be performed at any "hot spot" areas identified through surface scans. Smears may also be obtained at these locations to determine the removable fraction of contamination present on the surface.

Finally, systematic static alpha measurements will be performed per MARSSIM guidance. The results of the integrated or static alpha measurements will be compared to the release limit presented in the survey plan.

Scanning Sensitivity

Scanning for alpha emitters differs significantly from scanning for beta and gamma emitters in that the expected background response of most alpha detectors is very close to zero. The following sections cover scanning for alpha emitters. Since the time a contaminated area is under the probe varies and the background count rate of some alpha instruments is less than 1 cpm, it is not reasonable to determine a fixed MDC for scanning. Instead, it is more practical to determine the probability of detecting an area of contamination at a predetermined DCGL for given scan rates.

For alpha survey instrumentation with backgrounds ranging from less than 1 to 3 cpm, a single count provides a surveyor sufficient cause to stop and investigate further. Assuming this to be true, the probability of detecting given levels of alpha surface contamination can be calculated by use of Poisson statistics. Given a known scan rate and a surface contamination release limit, the probability of detecting a single count while passing over the contaminated area is given by:

$$P(n \geq 1) = 1 - e^{-\frac{GEd}{60v}}$$

Where:

$P(n \geq 1)$	=	probability of observing a single count
G	=	contamination activity [disintegrations per minute (dpm)]
E	=	detector efficiency (4π)
d	=	width of detector in direction of scan [centimeters (cm)]
v	=	scan speed [centimeters per second (cm/s)]

Once a count is recorded and the guideline level of contamination is suspected, the surveyor should stop and wait until the probability of getting another count is at least 90 percent. This time interval can be calculated by:

$$t = \frac{13{,}800}{CAE}$$

Where:

t	=	time period for static count(s)
C	=	contamination guideline (dpm/100 cm^2)
A	=	physical probe area (cm^2)
E	=	detector efficiency (4π)

This discussion applies to the Ludlum Model 43-68 detector, whose alpha background is about 3 cpm. The "pause" interval discussed above calculates to about seven seconds for this detector.

The larger (>500 cm^2) gas proportional detectors have background count rates on the order of 5 to 10 cpm, and a single count will not cause a surveyor to investigate further. A counting period long enough to establish that a single count indicates an elevated contamination level would be prohibitively inefficient. For these types of instruments, the surveyor usually will need to get at least two counts while passing over the source area before stopping for further investigation. Assuming this to be a valid assumption, the probability of getting two or more counts can be calculated by:

$$P(n \geq 2) = 1 - \left[1 + \frac{(GE+B)t}{60}\right]\left[e^{\frac{-(GE+B)t}{60}}\right]$$

Where:

$P(n \geq 2)$	=	probability of getting two or more counts during the time interval t
t	=	time interval (s)
G	=	contamination activity (dpm)
E	=	detector efficiency (4π)
B	=	background count rate (cpm)

This applies to the Ludlum Model 43-37-1 detector, whose alpha background is about 9 cpm. Assuming a one second time interval, the probability of seeing two counts while scanning over a 100cm^2 area at the $DCGL_W$ is 54%. We can proceed with the confidence that it is greater than 50%.

Systematic (Static) Alpha Surface Activity Measurements

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

Integrated alpha activity measurements will be performed using Ludlum 43-37-1 or 43-68 gas filled proportional detectors. The following equation is used to determine instrument MDC:

$$\text{MDC (dpm/100cm}^2\text{)} = \frac{3 + 4.65\sqrt{(R_b)}}{\frac{[DA]}{100}[\varepsilon_i][\varepsilon_s]}$$ *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 (cm^2)

This assumes one minute count times for sample and background counts. For the purpose of this evaluation, instrument efficiency value (ε_i) was obtained from the manufacturer. The currently accepted default value for surface efficiency (ε_s) is used. Parameters and results are given in the following table:

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	R_b (cpm)	α Static MDC (dpm/100 cm^2)
43-37-1	1	1	609	0.2	0.25	9	56
43-68	3	10	100	0.2	0.25	3	92*

* Calculated using Equation 3-11 from NUREG-1507 (see below)

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 cm^2 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:

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

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 the following table.

SMEAR ANALYSIS MDC AND ASSUMPTIONS

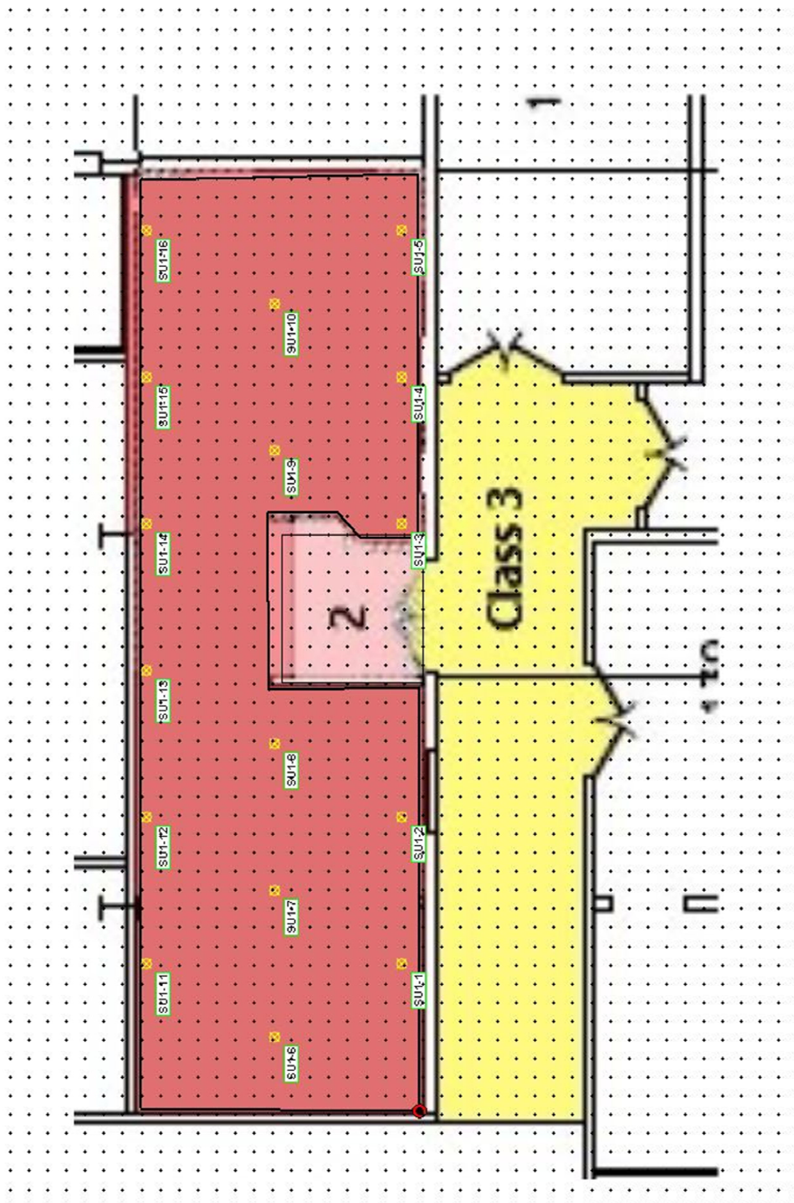
Ludlum Model No.	Count Time (min)	Bkg Count Time (min)	Probe Area (cm^2)	α Efficiency (cpm/dpm)	α Bkg (cpm)	α Static MDC (dpm/smear)
2929	4	20	Smear	0.33	0.8	7

APPENDIX B

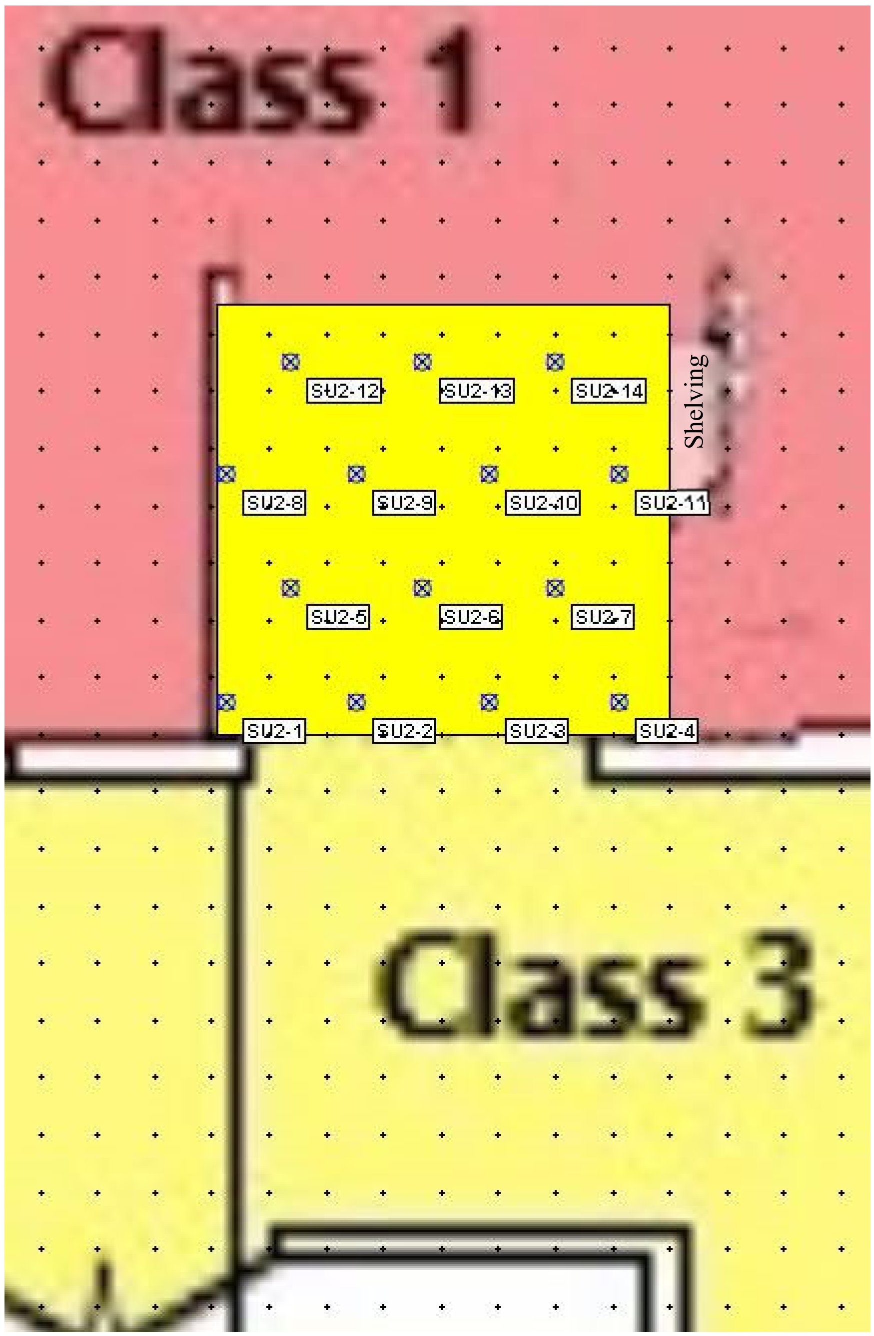
PRELIMINARY SAMPLING GRIDS

Notes: Survey Unit sizes are subject to change, based on survey results. Sample locations were determined using Visual Sample Plan software. Background grids (dots) are on one foot intervals.

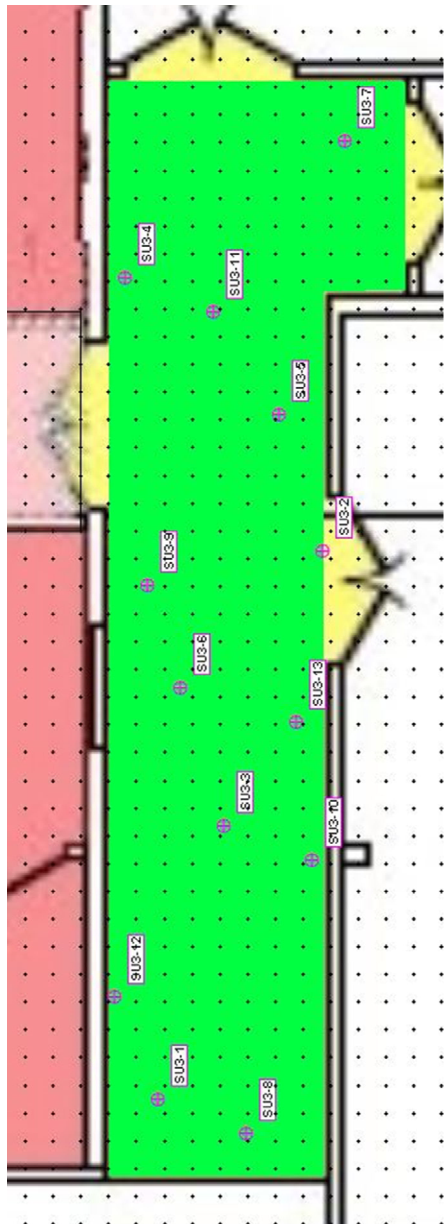
SU-1. Bldg. 115, Class 1 Area



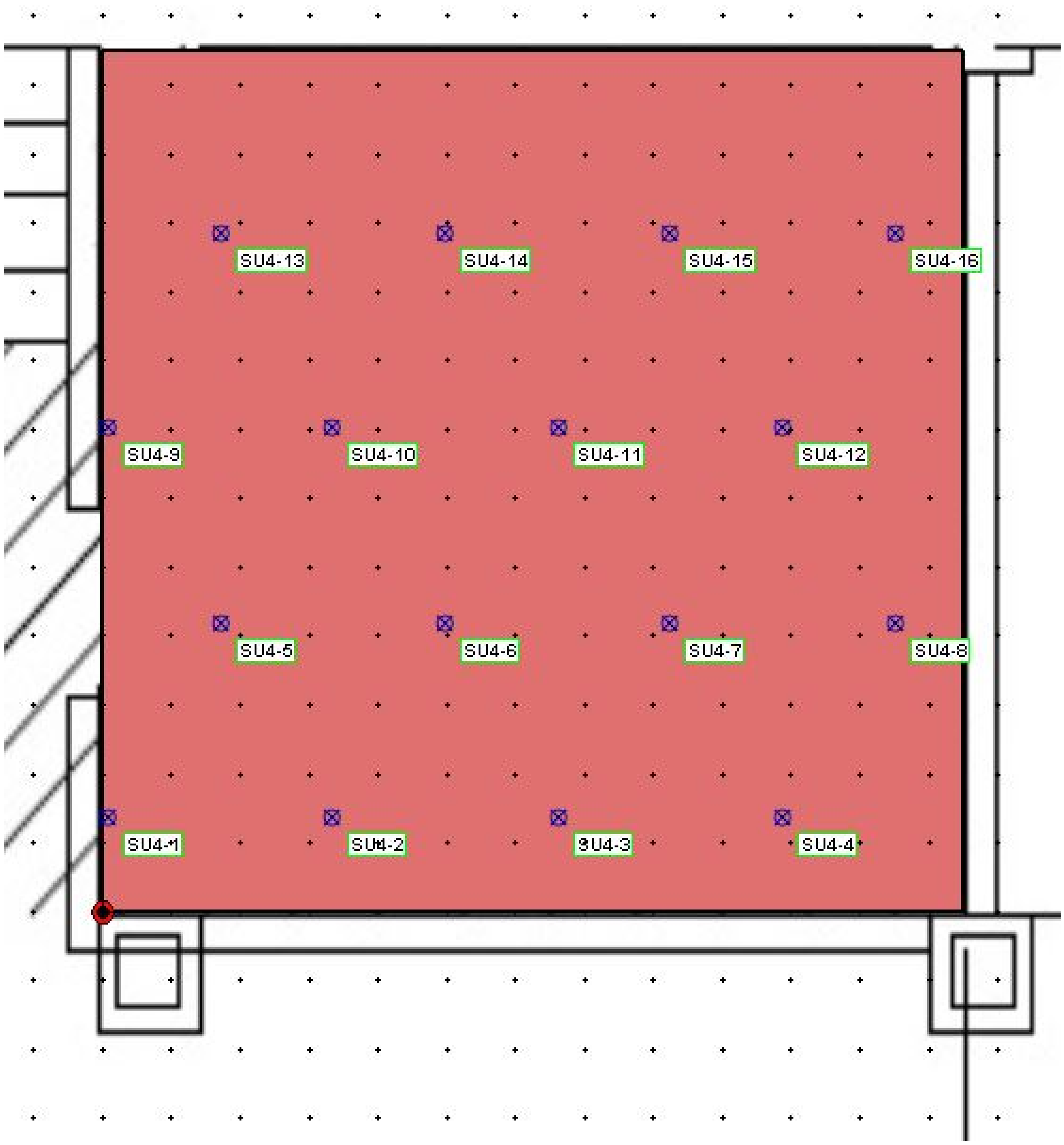
SU-2. Bldg. 115, Class 2 Area



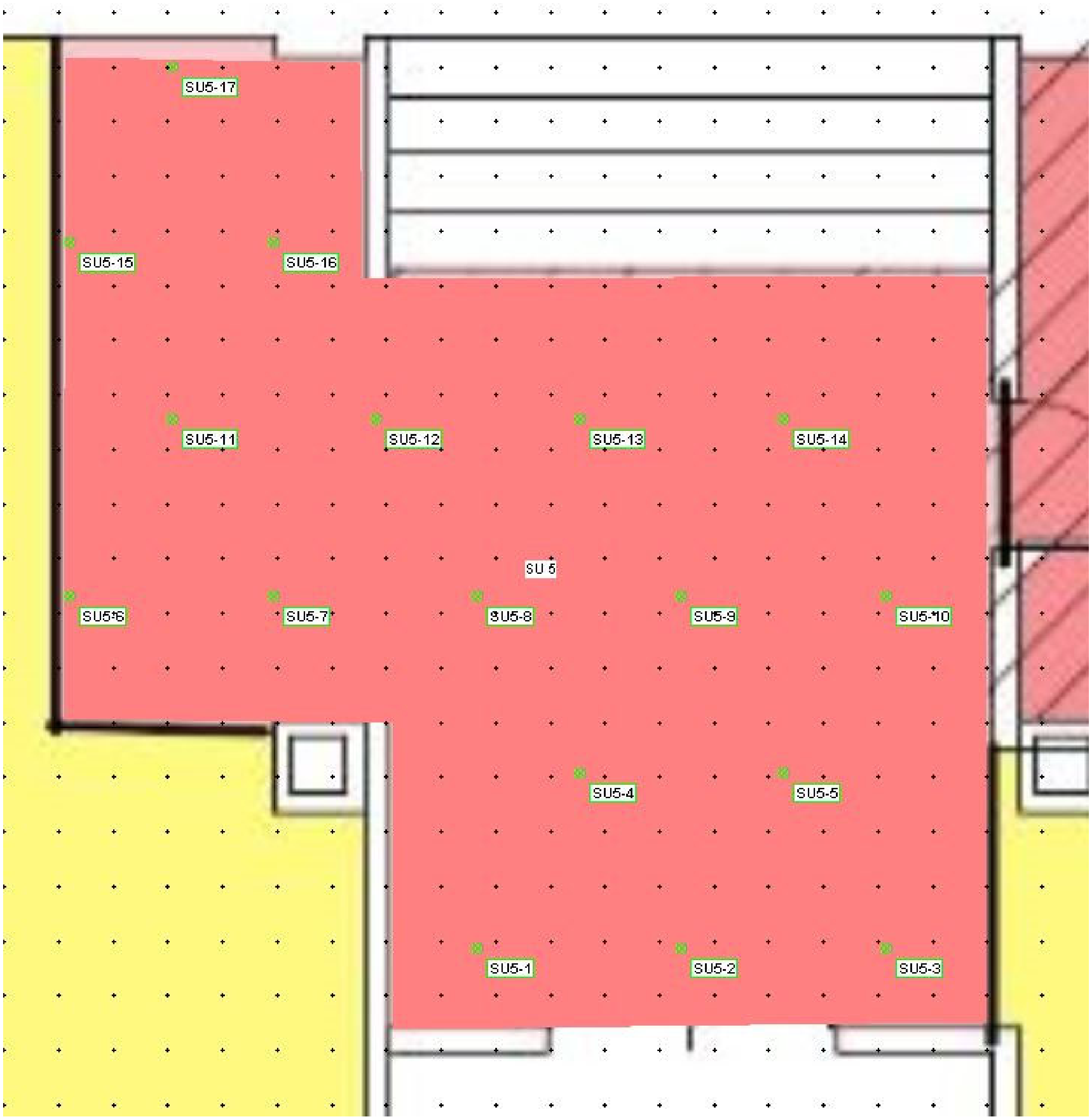
SU-3. Bldg. 115, Class 3 Area



SU-4. Bldg. 119, Class 1 Area



SU-5. Bldg. 119, Class 2 Area



SU-6. Bldg. 119, Class 3 Area