FINAL STATUS SURVEY PLAN

Building 3214 and Vermont Court Housing
Naval Station Great Lakes
Great Lakes, Illinois

Navy Control Number 2006-009
Contract No. DAAA09-02-D-0024/30

Prepared for:

Department of the Army
Headquarters, Joint Munitions Command
Rock Island, IL

Prepared by:

CABRERA SERVICES
RADIOLOGICAL · ENVIRONMENTAL · REMEDIATION

103 E. Mt Royal Ave, Suite 2B
Baltimore, MD 21202

Cabrera Project No. 03-3040.30

April 2007

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

LIST OF ACRONYMS AND ABBREVIATIONS

α	alpha
β	beta
σ	sigma or standard deviation
Δ	delta
%	percent
AEC	Atomic Energy Commission
ALARA	As Low as Reasonably Achievable
CABRERA	Cabrera Services, Inc.
cm	centimeter
cm^2	square centimeter
COC	chain of custody
CTA	center tank area
CY	cubic yard(s)
DCGL	derived concentration guideline level
$DCGL_w$	derived concentration guideline level used for non-parametric statistical test
DOT	Department of Transportation
dpm	disintegrations per minute
DQO	data quality objectives
EMC	elevated measurement comparison
FSM	Field Site Manager
FSS	final status survey
H_a	alternate hypothesis
H_0	null hypothesis
ID	identification
JMC	Joint Munitions Command
LBGR	lower bound of the gray region
m	meter
m^2	square meter
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	minimum detectable concentration
μR/h	microrem per hour
NAVSEADET	Naval Sea Systems Command Detachment
NFA	north fence area
NIST	National Institute of Standards and Technology
NRC	United States Nuclear Regulatory Commission
pCi/g	picocuries per gram
P_r	probability
PE	Project Engineer
PM	Project Manager
PPV	Public Private Venture
QA	quality assurance
QC	quality control
RA	recreation area
RASO	Radiological Affairs Support Office
RCOC	radiological contaminant of concern
S+	test statistic
Site	Naval Station Great Lakes
SOP	standard operating procedure
SU	survey unit
^{230}Th	thorium-230
^{232}Th	thorium-232
U.S.	United States

EXECUTIVE SUMMARY

Cabrera Services, Inc. (CABRERA) is under contract to the United States (U.S.) Army Joint Munitions Command (JMC) to perform a Final Status Survey (FSS) of Building 3214 (the woodshop) and residential structures on Vermont Court within the Public Private Venture (PPV) area at the Naval Station Great Lakes (hereafter referred to as the Site) in Great Lakes, Illinois. The goal is to release the buildings for unrestricted use following U.S. Nuclear Regulatory Commission (NRC) guidance presented in this FSS Plan.

On July 12, 1974, the U.S. Atomic Energy Commission (AEC) granted a license (License No. SMC-12078179) to Engelhard Minerals & Chemicals Corporation, authorizing “Repackaging of monazite sands in Department of Transportation (DOT) approved containers” at the Site. The former AEC license indicated that 1,826,153 pounds of monazite sand containing 9.226 percent (%) thorium oxide was held at the Site prior to shipment offsite in 1974.

In order to determine the scope of the FSS, a historical review of licensed radioactive material storage at the Site was performed to determine if structures were impacted as a result. This review identified seven potentially impacted structures, which include Building 3214 (the woodshop) and six residential structures on Vermont Court. The residential structures include 5 duplexes (Buildings 4236, 4237, 4238, 4239, and 4241) and 1 triplex (Building 4240), with a total of thirteen separate residential areas. Because of the low potential for residual radioactivity on structure surfaces, Building 3214 and each of the thirteen residential areas have been designated as Class 3 survey units (SUs) in accordance with *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) (NRC, 2000) guidance.

Concentrations of residual radioactive contamination on surfaces in each SU will be determined through surface scans to identify the presence of radioactivity, direct surface radioactivity measurements, and removable radioactivity measurements. If direct measurements for surface activity or removable surface activity in a SU do not exceed 50 % of the derived concentration guideline level (DCGL), and the statistical test for the SU passes, the SU will be determined acceptable for unrestricted release.

1.0 INTRODUCTION

Cabrera Services, Inc. (CABRERA) is under contract to the United States (U.S.) Army Joint Munitions Command (JMC) to perform a Final Status Survey (FSS) of Building 3214 (the woodshop) and the Vermont Court housing buildings located within the Public Private Venture (PPV) area at the Naval Station Great Lakes (hereafter referred to as the Site) in Great Lakes, Illinois. The goal is to release the buildings for unrestricted use following U.S. Nuclear Regulatory Commission (NRC) guidance presented in this FSS Plan.

1.1 Facility and Site Information

1.1.1 Facility Location and Description

The Site is located within the Naval Station in Great Lakes, Illinois. The portions of the Site included in this FSS are shown in Figure 1-1. On July 12, 1974, the U.S. Atomic Energy Commission (AEC) granted a license (License No. SMC-12078179) to Engelhard Minerals & Chemicals Corporation, authorizing "Repackaging of monazite sands in Department of Transportation (DOT) approved containers." These operations were confined to the following locations: Savannah Army Depot, Savannah, Illinois; Army Ammunitions Plant, Ravenna, Ohio; and U.S. Navy Administrative Command, Supply Depot (currently referred to as Naval Station Great Lakes), Great Lakes, Illinois. The former AEC license indicated that 1,826,153 pounds of monazite sand containing 9.226 percent (%) thorium oxide was held at the Site prior to shipment offsite. Records indicate the monazite sand was shipped from the Site to W.R. Grace & Company in Chattanooga, Tennessee in 1974.

Monazite is a rare earth phosphate containing a variety of rare earth oxides particularly cerium and thorium oxide. Thorium has wide industrial applications and has been mined as monazite sand since the 1930's. Monazite typically contains 5 to 7 % radioactive thorium and 0.1 to 0.3 % natural uranium. Radionuclides in the natural thorium decay series dominate.

The NRC conducted an inspection of the Tank Farm Number 5 area on January 19, 2000 and found several locations of elevated gamma activity on the north side of the warehouse foundation near the northern Site boundary. Surface dose rates of 80 microrem per hour (μR/h) were observed along the northern boundary of the North Fence Area (NFA). CABRERA was contracted by the Navy to assess the area and on March 8, 2000, identified locations of elevated gamma activity. Sample analysis indicated the elevated radioactivity was due to the presence of thorium-232 (^{232}Th), the primary radiological contaminant of concern (RCOC) in monazite sand. The previous Site survey and remediation areas are shown in Figure 1-2, which also shows the location of Building 3214.

In the form of a PPV, Forest City LLC is conducting renovation and development of the Forrestal Village housing area adjacent to the Site, which includes the Vermont Court housing units. These housing units consist of 5 duplexes (Buildings 4236, 4237, 4238, 4239, and 4241) and 1 triplex (Building 4240). The Vermont Court structures and Building 3214 are shown in Figure 1-1.

FIGURE 1-1: SITE MAP

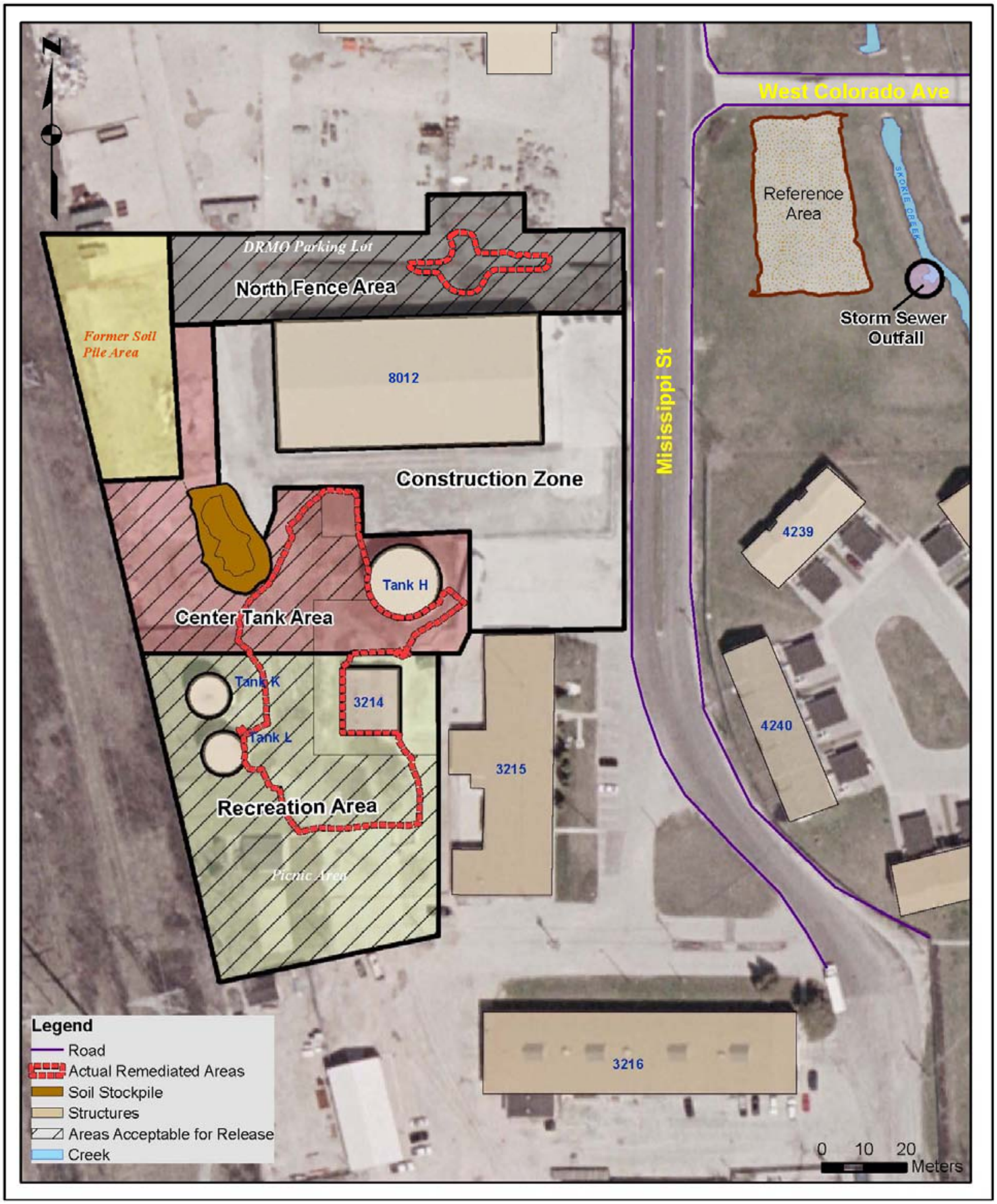

FIGURE 1-2: PREVIOUS SITE SURVEY AREA

Due to the close proximity of Building 3214 and the Vermont Court residential structures to the former monazite sand storage area and elevated radioactivity in soil has been identified near some of these residential structures, survey units (SUs) have been designated as Class 3 in accordance with *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) (NRC, 2000) guidance. This is appropriate due to the low potential for residual radioactive contamination on structure surfaces.

1.2 Previous Radiological Studies

Characterization and remediation of radiological contamination at the former monazite sand storage area has been performed in multiple phases since the discovery of contamination in 2000. The derived concentration guideline level used for the non-parametric statistical test ($DCGL_W$) for ^{232}Th, established by the Naval Sea Systems Command Detachment (NAVSEADET) Radiological Affairs Support Office (RASO), was determined to be 1.0 picocurie per gram (pCi/g) above background for ^{232}Th (and decay products) in surface soil (CABRERA, 2006b). This $DCGL_w$ value has been used for determination of survey, sampling, and remediation requirements. As a result, approximately 4,885 cubic yards (CY) of soil have been excavated from the Site, of which 1,730 CY have been released for re-use. Although the maximum ^{232}Th soil sample concentration was 120 pCi/g, the majority of soil removed was based on soil samples with concentrations slightly in excess of the $DCGL_w$ (CABRERA, 2006).

To support the renovation and development effort, radiological surveys of six PPV areas, identified as 3A, 3B, 3C, 3D, 3E and 3F, were performed by CABRERA in August, 2006 (CABRERA, 2006a). The primary purpose of this survey was to confirm locations of suspected elevated radioactivity in soil identified in previous surveys (MACTEC, 2006). Although most of the six PPV areas are in the general vicinity of Vermont Court, PPV area 3A is in the immediate vicinity of Building 4240 on Vermont Court.

In January 2007, CABRERA performed additional soil sampling and analysis in the six PPV areas to determine if the elevated radioactivity was due to the presence of licensed material (monazite sand) in soil (CABRERA, 2007). The result of this effort concluded that the elevated soil radioactivity in PPV areas 3A, 3B, 3C and 3F was most likely due to the presence of monazite sand. However, the report concluded that elevated radioactivity in PPV areas 3D and 3E was not due to the presence of licensed radioactive material. Therefore, the PPV areas of concern are limited to 3A, 3B, 3C and 3F. These PPV areas, Vermont Court housing structures, and Building 3214, are shown in Figure 1-3.

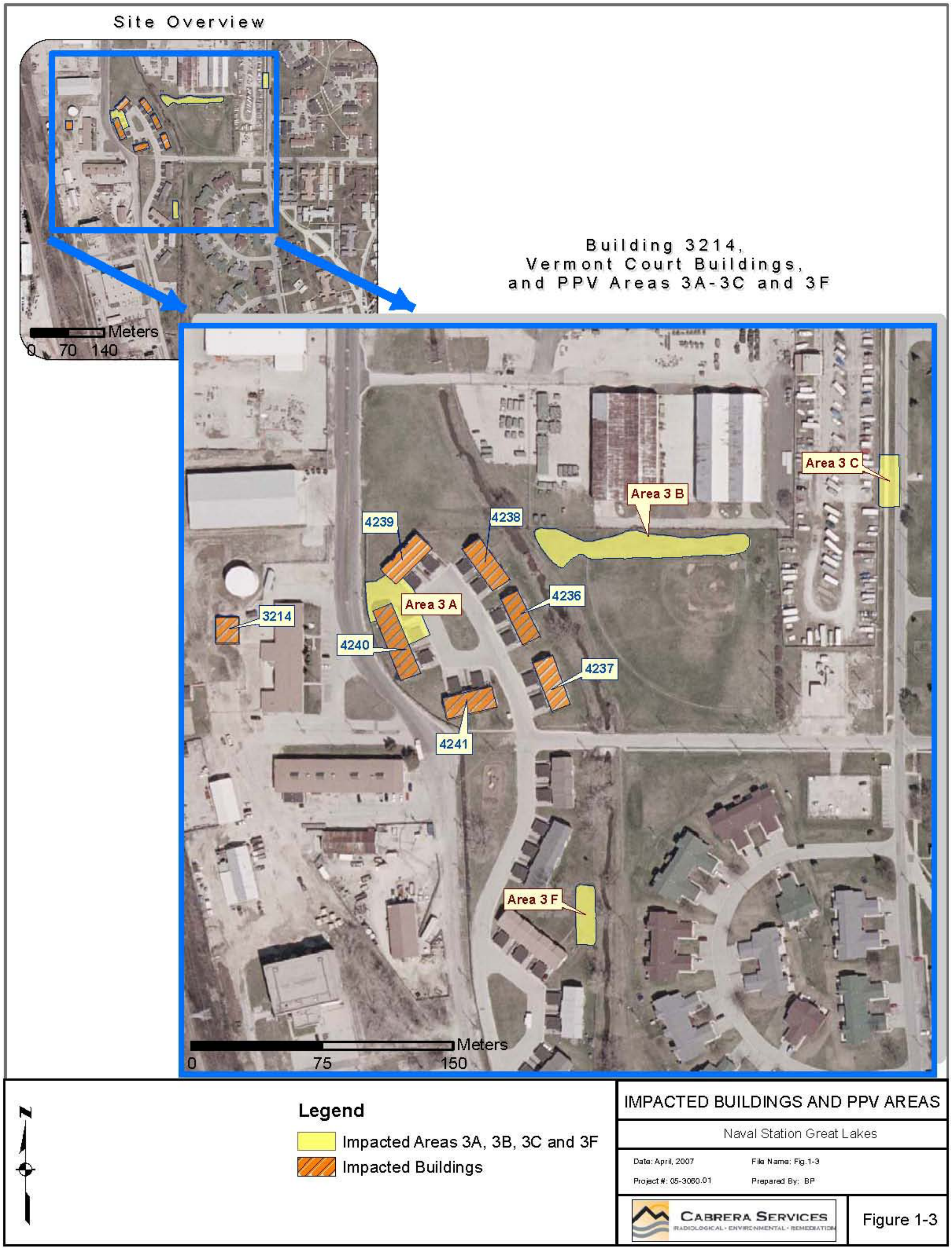

FIGURE 1-3: PPV IMPACTED AREAS AND BUILDING 3214

1.3 Radiological Contaminant of Concern

The RCOC at the Site is ^{232}Th. Soil sample analytical results from previous survey efforts (CABRERA, 2006b) confirmed the presence of ^{232}Th in secular equilibrium with its progeny. There is no evidence that any chemical or physical processes were performed at the Site that would have altered the assumed equilibrium of ^{232}Th and radioactive decay progeny.

2.0 DATA QUALITY OBJECTIVES

Data Quality Objectives (DQOs) are qualitative and quantitative statements that establish a systematic procedure for defining the criteria by which data collection design is satisfied in order to make determinations regarding remediated properties. Use of the DQO process ensures the type, quantity, and quality of data used in decision-making and will be appropriate for the intended application. A scientific approach, i.e., hypothesis testing, is used to determine appropriate DQOs. In this approach, the data obtained through the DQO process is used to select between one condition, the null hypothesis (H_0), and an alternate condition, alternate hypothesis (H_a). This process assumes H_0 is true unless significant evidence is provided through the DQO process to reject H_0 and accept H_a.

For this FSS, H_0 and H_a are stated as follows:

H_0 – Survey data does not demonstrate the release criteria have been satisfied for a Class 3 SU

H_a – Survey data does demonstrate the release criteria have been satisfied for a Class 3 SU.

Therefore, to reject H_0 and accept H_a, the DQO process must provide significant evidence to support the decision, while minimizing or optimizing decision errors.

Note: In the above hypothesis testing approach, acceptance of H_0 does not necessarily mean the SU is not acceptable for unrestricted release. Rather, the conclusion may be the SU was inappropriately determined to be Class 3 in lieu of Class 1 or Class 2. As a result, follow-up action may require reclassification of the SU, with survey design and performance appropriate for hypothesis testing based on the new classification.

The DQOs for this FSS include:

- Identifying the problem;
- Defining the data necessary for achieving the end use decisions;
- Determining the appropriate method of data collection; and
- Specifying the level of decision errors acceptable for establishing the quantity and quality of data needed to support the project decisions.

2.1 Step 1: State the Problem

2.1.1 Problem Description

Monazite was previously stored at the Site and residual contamination has been found during site investigations. The objective of these FSS activities is to obtain data of sufficient quality and quantity to support unrestricted release of Building 3214 and the Vermont Court housing units.

2.1.2 Planning Team Members

FSS planning is being performed by a team of CABRERA personnel, with input and direction from the JMC and the NAVSEADET RASO.

2.1.3 Primary Decision Maker

The ultimate decision regarding Site disposition will rest with the NRC. JMC and NAVSEADET RASO will work with the NRC in support of activities required to complete the FSS of Building 3214 and Vermont Court housing with the goal of releasing these structures for unrestricted use.

2.1.4 Available Resources

Sufficient resources are available through the combined staff of JMC, NAVSEADET RASO, CABRERA, and CABRERA subcontractors, to perform and complete all work required in order execute the requirements in this FSS Plan.

2.2 Step 2: Identify the Decision

2.2.1 Principal Study Question

Do the concentrations of the RCOC in the designated structures exceed applicable levels for unrestricted release established for Class 3 SUs (Building 3214 and each of the 13 dwellings among Buildings 4236, 4237, 4238, 4239, and 4240)?

2.2.2 Decision Statement

The following statement assumes that RCOC concentrations exceed release levels for Class 3 SUs. If RCOC concentrations inside the designated structures do not exceed the release criteria, H_0 will be rejected and H_a accepted, indicating the structures are suitable for unrestricted release.

- Determine whether SU RCOC concentrations inside the structures exceed background concentrations by more than the applicable release criteria.

2.3 Step 3: Identify Inputs to the Decision

This section lists the data needed, describes the sources of that data, and discusses the means of obtaining the required data. The primary parameters of interest are natural thorium and associated decay progeny in secular equilibrium. Concentrations of residual radioactive contamination due to licensed material on SU structure surfaces must be determined in order to resolve applicable decision statements. This information will be used to determine if a SU is suitable for unrestricted release or requires further evaluation and/or remediation. Obtaining this data will facilitate cost effective decision-making regarding the project's direction and duration.

Concentrations of residual radioactive contamination on surfaces in the SUs will be determined by means of:

- Surface scans to identify the presence of radioactivity;
- Direct surface radioactivity measurements; and
- Removable radioactivity measurements

2.4 Step 4: Define the Study Boundaries

2.4.1 Population of Interest:

The population of interest for the Site is the concentration of the RCOC and associated progeny on building surfaces. Constraints on data collection include inaccessible areas. In these instances, decisions may be made based on data collected from the accessible areas within the SU.

2.4.2 Spacial Boundaries:

The area of interest is limited to floor surfaces and walls up to two meters (m) from the floor surface within Building 3214 and the Vermont Court housing units.

2.4.3 Temporal Boundaries:

The NRC surface radioactivity screening value for the RCOC will serve as the basis for the DCGL used for the chosen non-parametric statistical test ($DCGL_W$). These values are based on risks to an average member of the critical group (the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity) over a 1,000-year period following the study. Data collection and analysis should be performed as soon as practical, as decisions regarding future property use are contingent upon the results of the FSS.

2.4.4 Decision Scale:

Decisions will be made for the entire SU regarding whether or not it meets the criteria for unrestricted release.

2.5 Step 5: State the Decision Rules

The decision rules for this FSS are:

- If direct measurements for surface activity or removable surface activity in a SU exceeds 50 % of the DCGL in Table 3-1, or the statistical test for the SU fails, H_0 will be accepted, the SU will be reclassified as Class 1 or Class 2, and an appropriately designed MARSSIM (NRC, 2000) survey required; or
- If direct measurements for surface activity or removable surface activity in a SU do not exceed 50 % of the DCGL in Table 3-1, and the statistical test for the SU passes, H_0 will be rejected and the SU will be determined acceptable for unrestricted release.

2.6 Step 6: Define Acceptable Decision Errors

MARSSIM (NRC, 2000), Appendix D, provides a discussion of decision errors. This discussion includes the concept that acceptable error rates must be balanced between the need to make appropriate decisions and the financial costs of achieving high degrees of certainty.

Errors can be made when making site remediation decisions. The use of statistical methods allows for controlling the probability of making decision errors. When designing a statistical test, acceptable error rates for incorrectly determining that a site meets or does not meet the applicable release criteria must be specified. In determining these error rates, consideration should be given to the number of sample data points that are necessary to achieve them. Lower error rates require more measurements, but result in statistical tests of greater power and higher levels of confidence in the decisions. In setting error rates, it is important to balance the consequences of making a decision error against the cost of achieving greater certainty.

Acceptability decisions are often made based on acceptance criteria. If the mean and median concentrations of a contaminant are less than the associated acceptance criteria, for example, then the results can usually be accepted. In cases where data results are not so clear, statistically based decisions are necessary. Statistical acceptability decisions, however, are always subject to error. Two possible error types are associated with such decisions.

The first type of decision error, called a Type I error, occurs when the H_0 is rejected when it is actually true. The probability of a Type I error is usually denoted by alpha (α). The maximum Type I error rate is 0.05.

The second type of decision error, called a Type II error, occurs when H_0 is not rejected when it is actually false. The probability of a Type II error is usually denoted by beta (β). The power of a statistical test is defined as the probability of rejecting the H_0 when it is false. It is numerically equal to 1-β where β is the Type II error rate. Potential consequences of Type II errors include unnecessary remediation expense and project delays.

For the purposes of this FSS, the acceptable error rate for both Type I and Type II errors is 5 % (i.e., $\alpha = \beta = 0.05$).

3.0 SURVEY DESIGN AND METHODOLOGY

CABRERA will conduct a FSS of the interior surfaces of Building 3214 and the Vermont Court housing units as described below. The objective of the FSS will be to release these structures for unrestricted use.

3.1 Determine Impacted and Non-Impacted Areas

In order to determine the scope of the FSS, a historical review of licensed radioactive material usage at the Site was performed. The purpose of the review was to:

1) Identify radionuclides potentially present, and which rooms/areas were used or were potentially contaminated;
2) Identify areas that were previously released; and
3) Identify and quantify actual areas of contamination.

This information was then used to determine if certain areas were impacted by radionuclide storage. Specific areas covered under this FSS Plan are Building 3214 and each of the 13 dwellings at the Vermont Court Buildings, which includes 5 duplexes (Buildings 4236, 4237, 4238, 4239, and 4241) and 1 triplex (Building 4240).

3.2 Area Classification Based on Contamination Potential

Impacted areas were then classified based on contamination potential in accordance with MARSSIM (NRC, 2000). Namely,

Class 1: The area had been contaminated above the release criteria, and it is possible to find radioactivity above the DCGL.

Class 2: The area had radioactive material use, but it is unlikely to have radioactivity above the DCGL.

Class 3: The area had some use of radioactive material, but it is very unlikely to have radioactivity greater than a fraction of the release criteria.

3.3 Statistical Tests

3.3.1 Sign Test

The Sign test is designed to detect uniform failure of remedial action throughout a SU. It draws direct comparisons between SU data and the chosen release criteria, i.e., DCGL. The H_0 is assumed to be true unless the statistical test indicates that it should be rejected in favor of the alternative. The H_0 states that the probability of a measurement less than the DCGL is less than one-half, i.e., the 50th percentile (or median) is greater than the DCGL. With this in mind, SUs may meet the release criteria even though some measurements may be greater than some reference area measurements. The result of the hypothesis test determines whether or not the SU as a whole meets the release criteria.

If all of the sample results are less than the DCGL then the Sign test statistical evaluation is not required.

3.3.2 Application of Sign Test for Multiple Surfaces

NUREG-1505 (NRC, 1998) states; "…the Sign test may be more appropriate when there are many different materials within what would otherwise logically be a single SU. As indicated at the beginning of this chapter in NUREG-1505 (Chapter 12), to divide such a SU into separate parts, each requiring its own reference area is not only impractical, but may be inconsistent with the dose models used to determine the DCGLs." This section further states, "Fortunately, there is a third option - to use the Sign test with paired observations. Each measurement in the SU is paired with an observation on a suitable reference material. The Sign test is then performed on the difference. The tradeoff is the higher variability of the differences compared to a single measurement."

Representative background values to be used in the paired observations will be collected in non-impacted areas of the buildings on similar building materials. The selection and measurement of the background reference areas will be done prior to the execution of the fieldwork so they can be applied directly. A minimum of five (5) 1-minute fixed-point measurements will be collected with the average used for subtraction from each systematic measurement location prior to evaluation using the Sign test.

3.3.3 Performing the Sign Test

The Sign test is applied as outlined in the following five steps from Section 8.3.2 of the MARSSIM (NRC, 2000). Each measurement will have the appropriate background reading subtracted and the difference would be subject to the Sign test, outlined in the steps below:

Step 1: List the SU measurements, X_i, $i = 1, 2, 3, \ldots N$.

Step 2: Subtract each measurement, X_i, from the DCGL to obtain the differences: $D_i = DCGL - X_i$, $i = 1, 2, 3, \ldots N$.

Step 3: Discard each difference that is exactly zero and reduce the sample size, N, by the number of such zero measurements.

Step 4: Count the number of positive differences. The result is the test statistic (S+). Note that a positive difference corresponds to a measurement below the DCGL and contributes evidence that the SU meets the release criterion.

Step 5: Large values of S+ indicate that the H_0 (that the SU exceeds the release criterion) is false. The value of S+ is compared to the critical values in MARSSIM (NRC, 2000) Appendix I, Table I.3. If S+ is greater than the critical value, *k*, the H_0 is rejected.

3.4 Elevated Measurement Comparison

The elevated measurement comparison (EMC) is not applicable for FSS measurements in Class 3 SUs. If surface contamination is identified above the designated thresholds, the SU will be reclassified as Class 1 or Class 2 and this FSS Plan revised to address the applicable survey design.

3.5 Survey Unit Breakdown

Building 3214 and the Vermont Court housing units (Buildings 4236 through 4241) have been identified as potentially impacted because of their proximity to the former monazite sand storage area. To address these structures, fourteen (14) Class 3 SUs have been identified:

1) Building 3214
2) Building 4236 Unit 1
3) Building 4236 Unit 2
4) Building 4237 Unit 1

5) Building 4237 Unit 2
6) Building 4238 Unit 1
7) Building 4238 Unit 2
8) Building 4239 Unit 1
9) Building 4239 Unit 2
10) Building 4240 Unit 1
11) Building 4240 Unit 2
12) Building 4240 Unit 3
13) Building 4241 Unit 1
14) Building 4241 Unit 2

3.6 Survey Unit Coverage

The minimum SU coverage for the interior structure surface Class 3 SUs in Building 3214 and the Vermont Court housing units is provided below:

- Perform a minimum 10 % scan survey of accessible floor and lower wall surfaces;
- Collect fixed-point measurements at random locations in sufficient numbers to satisfy the statistical test (Sign test);
- Collect biased fixed-point surface activity measurements at locations of potential elevated surface activity identified during the scan survey; and
- Perform a removable contamination survey at each random and biased fixed-point surface activity measurement location.

Note: There are no size limits for a Class 3 SU.

3.7 Release Criteria

3.7.1 Surface Activity DCGLs

The NRC surface activity screening value for ^{232}Th (with decay progeny in secular equilibrium) has been designated as the DCGL for this FSS as shown in Table 3-1.

TABLE 3-1: SURFACE ACTIVITY DCGLS

Parameter	DCGL[1]	Removable DCGL[2]	Reference
^{232}Th (building surfaces)	224 dpm/100 cm^2	22 dpm/100 cm^2	DCGLs based on total alpha emissions for ^{232}Th plus progeny using NUREG/CR-5512, Volume 3, Table 5.19, with a P_{crit} of 0.90 (NRC, 1999).

1. Measured at 1 centimeter (cm) from the surface (disintegrations per minute [dpm] per square centimeter [cm^2])
2. Screening value assumes removable surface contamination of 10 %

3.8 Sampling Requirements

3.8.1 Relative Shift

The relative shift describes the relationship of site residual radionuclide concentrations to the DCGL and is calculated using the following equation, found in Section 5.5.2.2 of MARSSIM (NRC, 2000):

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

where:

σ = An estimate of the standard deviation of the concentration of residual radioactivity in the SU (which includes real spatial variability in the concentration as well as the precision of the measurement system). σ is estimated as approximately 0.3 times the DCGL.

Δ = The width of the gray region, i.e., DCGL minus LBGR

DCGL = The derived concentration guideline level (i.e., release limit)

LBGR = Concentration at the lower bound of the gray region. The LBGR effectively becomes the survey action level. For conservatism, the LBGR is set to 0.5 times the DCGL for this FSS.

3.8.2 Number of Sampling Points

Section 2.6 of this FSS Plan establishes the acceptable decision errors, i.e., $\alpha=\beta=0.05$. Based on these decision errors and the relative shift, the minimum number of measurement locations in each SU was calculated using MARSSIM (NRC, 2000) Equation 5-2. This calculation includes the MARSSIM recommended 20 % additional samples to protect against the possibility of lost or unusable data.

Table 3-2 shows the MARSSIM-based statistical parameters used in the calculation of the number of samples per SU.

TABLE 3-2: SUMMARY OF MARSSIM DESIGN PARAMETERS

MARSSIM Parameter	Value
σ (dpm/100 cm^2)	67
DCGL (dpm/100 cm^2)	224
LGBR (dpm/100 cm^2)	112
Relative Shift (Δ/σ)	1.7
Probability P_r[1]	0.95
Number of data points required[2]	**17**

1. Obtained from MARSSIM (NRC, 2000), Table 5.4
2. Includes 20 % coverage as recommended by MARSSIM.

3.8.3 Survey Unit Measurement Locations

Measurement locations in Class 3 SUs and reference areas are selected at random. These locations are determined by multiplying the east-west (Y) and the north-south (X) dimensions of each SU by a randomly generated number between 0 and 1 for each dimension. For consistency, the southwest corner of each SU will be the origin. Sample locations will be calculated using a computer program to determine random numbers and plot data point locations on a survey map. To facilitate field measurements, the calculated coordinates will be rounded to the nearest whole number of meters.

3.9 Background Surface Activity Measurements

Determination of background is an important aspect in performance of radiological surveys. Since 'net' residual contamination values, or the difference between a sample count rate and background, are used to assert whether a particular SU satisfies the criteria for unrestricted release, application of background values is crucial to proper decision-making. Therefore, background measurements should be performed in non-impacted areas on building surfaces expected during the FSS. The selection and measurement of the background reference areas should be done before the execution of the FSS in a particular SU.

Integrated (or fixed) surface activity measurements should consider two factors that contribute to background.

1) The first is the background contribution due to cosmic sources and sources of radioactivity near the SU, but not directly from the surface of interest. To address this component, one surface activity measurement is performed in the SU in a shielded configuration. This is completed by performing an integrated measurement (typically 1-minute integration time) with a piece of wood or similar material between the detector face and the surface of interest.

2) The second component of background results from the activity measured due to the natural radioactivity present in the material of interest. This is addressed by selecting reference areas of similar material types (concrete, wood, gypsum, asphalt, etc.) and performing a set of integrated measurements for each type of material. This is first performed by completing a shielded measurement on the reference area material as discussed in the previous paragraph. The shielding is then removed and a second or total background measurement is conducted directly on the reference area material. The background due to the material of interest is then the total background measurement result minus the shielded measurement result.

Using this information, net SU fixed surface activity, which is compared to the surface activity DCGL, equals:

Gross unshielded SU measurement – shielded SU measurement – net material background

4.0 FIELD ACTIVITIES

Field FSS activities should be performed within the SUs identified in Section 3.5.

4.1 Radiological Samples and Measurements

The surface activity DCGLs in Table 3-1 are based on total alpha emissions from natural thorium; therefore, surface scans, integrated measurements and analysis of samples for removable surface activity will focus on alpha surveys. Alpha scan, integrated measurement and smear analysis procedures and minimum detectable concentrations (MDCs) are presented in Appendix A.

4.1.1 Building 3214

Building 3214 is located 12 m south of Tank H, which is located in the center tank area (CTA) within the Site. The building is a one-room rectangular building with a concrete floor and walls. It is approximately 15 m by 12.5 m. Building 3214 is designated as a single Class 3 SU.

Accessible lower surfaces (floors and lower walls) will be scanned for gross alpha activity. Scans shall be performed at locations of highest contamination potential (biased) and shall cover a minimum of 10 % of the accessible surface area.

Direct integrated alpha measurements will be performed at 17 random locations. Smear samples will be collected at each direct measurement location and analyzed on-site for removable alpha radioactivity.

4.1.2 Vermont Court Buildings 4236, 4237, 4238, 4239, and 4241 (Two Units Each)

Vermont Court buildings 4236, 4237, 4238, 4239, and 4241 are duplexes located within the PPV area adjacent to the Site within a cul-de-sac. Each duplex contains two units that mirror each other. Each unit contains two bedrooms, a bathroom, a kitchen, and a living room and is approximately 15 m by 12 m. Each unit is designated as a single Class 3 SU for a total of 10 SUs in buildings 4236, 4237, 4238, 4239, and 4241.

Accessible lower surfaces (floors and lower walls) will be scanned for gross alpha activity. Scans shall be performed at locations of highest contamination potential (biased) and shall cover a minimum of 10 % of the accessible surface area. Scans will not be performed on floor coverings, i.e., carpet, and they will be removed before FSS activities begin, as necessary.

Direct integrated alpha measurements will be performed at 17 random locations. Smear samples will be collected at each direct measurement location and analyzed on-site for removable alpha radioactivity.

4.1.3 Vermont Court Building 4240 (Three Units)

The Vermont Court building 4240 is a triplex located within the PPV area adjacent to the Site within a cul-de-sac. The triplex contains three units that have approximately the same layout. Each unit contains two bedrooms, a bathroom, a kitchen, and a living room and is approximately 15 m by 12 m. Each unit is to be surveyed as a single Class 3 SU for a total of 3 SUs in building 4240.

Accessible lower surfaces (floors and lower walls) will be scanned for gross alpha activity. Scans shall be performed at locations of highest contamination potential (biased) and shall cover a minimum of 10 % of the accessible surface area. Scans will not be performed on floor coverings, i.e., carpet, and they will be removed from the area of interest, as necessary, before survey activities begin.

Direct integrated alpha measurements will be performed at 17 random locations. Smear samples will be collected at each direct measurement location and analyzed on-site for removable alpha radioactivity.

5.0 SAMPLING APPARATUS AND FIELD INSTRUMENTATION

The purpose of this section is to describe survey instruments and methodologies that shall be used for surveys implemented during site radiological investigations. Specific measurement/sampling frequencies and approaches are discussed in Section 4.0.

Surface scans, integrated direct measurements and surface smears should be performed to measure surface radioactivity concentrations of the site RCOC. These measurements should be based on alpha emissions. Smears should be analyzed on-site. Surveys will be performed in accordance with CABRERA Standard Operating Procedures (SOPs). Relevant field SOPs for this FSS effort are listed in Table 5-1.

TABLE 5-1: RELEVANT CABRERA FIELD STANDARD OPERATING PROCEDURES

Number	Procedure Topic
AP-005	ALARA
OP-001	Radiological Surveys
OP-004	Unconditional Release of Materials from Radiological Control Areas
OP-009	Use and Control Radioactive Check Sources
OP-020	Operation of Contamination Survey Meters
OP-021	Alpha -Beta Counting Instrumentation

5.1 Direct Radiation Measurements

Building and/or structural surfaces should be scanned for total alpha activity. Static or integrated measurements shall also be performed at Class 3 random and biased locations. If possible, and equipped, beta measurements should also be obtained, as necessary.

Building and/or structural surface scans and integrated measurements should be performed on floors and walls, as possible. These floor surface measurements may be performed using a Ludlum Model 43-37 floor monitor (active area of 582 square centimeters [cm^2]), or equivalent detector. A Ludlum Model 43-68 gas proportional detector (active area of 126 cm^2), or equivalent detector, should also be used to perform measurements on lower walls. The 43-37 detector should be coupled to a Ludlum 2360 Alpha/Beta data logger, or equivalent data logger, and the 43-68 detector should be coupled to a Ludlum 2224 Alpha/Beta data logger, or equivalent data logger. The 43-37 and 43-68 should be calibrated to measure both alpha and beta surface activity (i.e., dual channel analysis).

To adequately determine the potential for radioactive contamination on scanned surfaces, the background contribution should first be determined. This is completed by selecting a reference area similar in characteristics to the SU. For buildings and/or structural surfaces, approximately 10 one square meter (m^2) areas are selected for scanning. The scan is completed in each of these areas, recording the highest scan measurement value for each. This value is then used to subtract from the SU scans.

Appendix A contains RCOC MDC calculations and related information.

5.1.1 Integrated Surface Radioactivity Measurements

For integrated measurements, an instrument is held in a stationary position for a set period of time to obtain an integrated measurement at a systematic or biased location.

Integrated surface radioactivity measurements will be performed at systematic or biased locations. A Ludlum 43-68 or 43-37 probe, or equivalent, with a Ludlum 2224 or 2360 data logger, or equivalent, for alpha and beta activity shall be used to perform integrated alpha and/or beta measurements.

Background measurements will be performed on each material type encountered during survey activities, as described in Section 3.9. Integrated measurements are then performed in the applicable SU. The final result is determined by subtracting the shielded measurement result and the material background. This result is then compared to the SU DCGL.

Biased surface activity measurements should be considered at elevated scan locations and/or at the following locations:

- Cracks in floors or walls;
- Corners of floors and walls;
- Openings in floors or walls such as drains and ducts; and
- Additional areas where contamination would be expected to accumulate.

5.2 Smear Sample Collection and Analysis

Smear samples will be collected to quantify removable surface alpha radioactivity at locations of biased and systematic integrated measurements. Smear samples will be collected over approximately 100 cm^2 and analyzed for alpha radioactivity using a Ludlum model 2929 dual scaler, or equivalent instrument. Smear locations and results should be recorded on proper survey forms.

Smears may require decay (i.e., radon progeny decay) prior to counting under certain conditions. Smears that must be counted immediately will be recounted after at least 24 hours of decay time if radon activity becomes a problem.

Smear sample count times shall be determined daily, with a minimum detectable concentration not exceeding the removable surface activity DCGL presented in Table 3-1.

6.0 SURVEY QUALITY ASSURANCE/QUALITY CONTROL

Activities shall be performed in accordance with CABRERA SOPs (referenced in Table 5-1) in order to ensure consistent, repeatable results. Topics covered in project procedures and protocols may include proper use of instrumentation, Quality Control (QC) requirements, equipment limitation, etc. Implementation of Quality Assurance (QA) measures for this work plan are described in this section.

6.1 Instrumentation Requirements

The Project Engineer (PE) is responsible for determining the instrumentation required to complete the survey requirements specified in this FSS Plan. Only instrumentation approved by the PE will be used to collect radiological data. The PE is responsible for ensuring individuals are appropriately trained to use project instrumentation and other equipment, and that instrumentation meets the required detection sensitivities. Instrumentation shall be operated in accordance with either a written procedure or manufacturers' manual. The procedure and/or manual will provide guidance to field personnel on the proper use and limitations of the instrument.

6.1.1 Radiation Detection Instrument Calibration and Field Checks

Instruments used during the survey should have current calibration/maintenance records kept on-site for review and inspection. The records should include, at a minimum, the following:

- Name of the equipment;
- Equipment identification (model and serial number);
- Manufacturer;
- Date of calibration; and
- Calibration due date.

Instrumentation shall be maintained and calibrated to manufacturers' specifications to ensure the instruments have the required traceability, sensitivity, accuracy, and precision. Instruments shall be calibrated using National Institute of Standards and Technology (NIST) traceable sources. Instruments should be operationally checked daily (QC, or source checks) to ensure they respond in a consistent manner when exposed to known radiation sources. Records of daily source checks should be maintained and filed in the project file, along with control charts associated with each instrument. The following subsections describe initial setup and daily QC checks performed on each type of radiation detection instrument identified in Section 5.0.

(A) Alpha Measurement Instruments

Surface alpha activity scans and integrated measurements will be performed using a Ludlum 43-37, 43-68, or 43-89 detector coupled to an appropriate survey meter. The instruments shall be calibrated at least annually using NIST-traceable standards. QC source checks are performed daily, prior to instrument use, at a minimum. This typically consists of a 1-minute integrated count with an appropriate alpha emitting radioactive source, such as thorium–230 (^{230}Th). The acceptance criterion for this instrument response is within two and three-sigma of the mean response generated using ten initial source checks and ten measurements of background performed at the beginning of the project. A response check outside these criteria should be cause for evaluation of conditions (e.g., instrument operation, source/detector geometry), and the response check should be repeated once prior to field use of that instrument. Instruments that fail the second successive response check should be removed from service and corrective actions should be taken.

A QC source check should also be performed on the 43-37 and 43-68 after 3 to 4 hours of use in the field to ensure quality data are being collected throughout the day.

(B) Smear Counter

A Ludlum Model 2929 dual scaler or equivalent instrument will be used for on-site analysis of samples obtained to determine removable alpha surface radioactivity (smears). The instrument shall be calibrated at least annually using NIST-traceable standards.

QC source checks are performed daily, prior to instrument use, at a minimum, by comparing response to an appropriate alpha emitting radioactive source, such as ^{230}Th. Background measurements shall also be performed daily. This typically consists of a 1-minute count of the alpha source positioned in a reproducible geometry. Background measurements should be performed in an identical manner, however, with the source removed. Background count time shall be sufficient to achieve the desired MDC discussed in Appendix A.

The acceptance criteria for instrument response should be set to 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, but within the three-sigma criteria should be cause for a recount prior to further evaluation. A response check outside the two sigma range on the second count or the three-sigma range on the initial count should be cause for further evaluation prior to continued use. A response check outside the three-sigma range is cause for notification to the Field Site Manager (FSM) and the 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 should also be inspected for physical damage, battery voltage levels, current calibration and erroneous readings.

7.0 SAMPLE CHAIN OF CUSTODY/DOCUMENTATION

7.1 Field Log

Project data should be recorded in a Field Data Logbook (or other equivalent method of data record) and subsequently transferred to an electronic format. Field Data Logbook records should be sufficient to allow data transactions to be reconstructed after the project is completed. The CABRERA Project Manager (PM), or designee, is responsible to ensure logbook(s) entries are completed appropriately. The CABRERA designee should review the Project Logbook at least weekly and should report significant issues to the CABRERA PM.

Each survey team should maintain a logbook to document their field activities. The following information, at a minimum, should be recorded:

- Instrument (e.g., meter/detector) serial numbers;
- Names of field survey personnel;
- Identification of area surveyed, including material type, i.e., soil, wood floor, concrete, asphalt, etc., and any nearby structures or material that may affect the survey results;
- Description of large obstacles that limit accessibility to the areas to be surveyed;
- Notes regarding equipment performance (e.g., instrument malfunction, etc.); and
- Notes regarding any issue related to the survey and requiring documentation.

Field Data Logbooks shall be permanently bound and the pages shall be numbered. Pages may not be removed from logbooks under any circumstances. All entries are to be made in blue or black ink. Entries shall be legible, factual, detailed, and complete and shall be signed and dated by the individual(s) making the entries. If a mistake is made, the error shall be denoted by placing a single line through the erroneous entry and initialing the deletion. Under no circumstances shall any previously entered information be completely obliterated. Use of whiteout in data logbooks is not permitted for any reason.

7.1.1 Project Log Book

All significant events that occur during this FSS shall be documented and retained for future reference. While many types of project events have specific forms on which they are documented, many events occur on a routine basis during survey field activities that must be documented as they occur. Additionally, project data transactions must also be recorded as they occur. To provide a practical means of capturing this information, a project logbook should be initiated upon project commencement.

Significant project events, including data transactions involving project electronic data, shall be recorded in the Project Logbook. Data transactions are defined as any transfer, download, export, copy, differential correction, sort, or other manipulation performed on project electronic data. Project Logbook records shall be sufficient to allow data transactions to be reconstructed after the project is completed.

The FSM is responsible for maintaining the Project Logbook and shall review the Project Logbook at least daily to report significant issues.

The Project Logbook is considered a legal record and shall be permanently bound and the pages should be pre-numbered. Pages may not be removed from the logbook under any circumstances. Entries shall be legible, factual, detailed, and complete and shall be signed and dated by the individual(s) making the entries. All documentation shall be completed with waterproof ink. If a mistake is made, the individual making the entry shall place a single line through the erroneous entry and shall initial and date the deletion. Under no circumstances shall any previously entered information be completely obliterated. Use of whiteout in the Project Logbook is not permitted for any reason. Only one Project Logbook shall be maintained. If a Project Logbook is completely filled, another volume shall be initiated. In this case, each volume shall be sequentially numbered.

7.1.2 Project Electronic Data

Much of this survey may rely on data collected and stored electronically. Electronic data is subject to damage and/or loss if not properly protected. As such, all project electronic data should be downloaded from its collection device (e.g., laptop computers, data loggers, etc.) on at least a daily basis.

Data files shall be named according to a naming protocol designated by the FSM. No variations from this protocol shall occur without the prior concurrence of the FSM. During data download and transfer transactions, the applicable data file name(s) shall be included in project data logbook entries.

7.1.3 Sample Documentation

This section describes procedures for maintaining sample control through proper sample documentation. When samples are collected for radiological and chemical analysis, documentation such as sample labels, chain of custody (COC) forms (if they are to be sent offsite for analysis), and field logbooks shall be completed. The information presented in this section enables the maintenance of sample integrity from the time of the sample collection through transport to the laboratory.

7.1.4 Sample Labels and/or Tags

The sample labels and COCs, if required, shall be generated using an electronic database management system to more accurately and precisely manage the sample identification (ID) numbers, labeling, and COCs. Any biased sample labels may be handwritten and entered in the database afterwards.

7.1.5 Chain of Custody Records

A COC form shall be completed and shall accompany any sample being sent offsite. The following information shall be provided on the COC:

- Site name;
- Laboratory name and contact;
- Turnaround time-only if site-specific conditions require non-standard turnaround time);
- Sample ID, matrix, sample date, and collection time;
- Parameters, analytical methods, bottle type, bottle volume, sample type, and preservative; and
- Signed release on bottom of COC.

7.1.6 Receipt for Sample Forms

For samples shipped to an off-site laboratory, the analytical services laboratory shall analyze the condition of the samples upon receipt. This information shall be recorded on a form. The form shall include the date, client's name, cooler number, temperature of samples, etc. The laboratory sample custodian or manager shall sign and date the form. The form shall be returned to the Project Manager via facsimile or email within 24 hours of receiving the samples.

7.2 Field Records

Field analytical records shall include the following field data forms for recording the results/measurements and QA/QC checks for field surveys:

- Building and/or structure scans;
- Integrated, fixed measurement results;
- Smear analytical results;
- Radiological screening instrument QC checks; and
- Instrument calibrations.

8.0 REFERENCES

(CABRERA, 2006a) Letter Report, *Results from Gamma Walkover Surveys of the Public-Private Venture Housing Area, Naval Station Great Lakes, Great Lakes, IL, Project Number USN 2000-03 Phase V*, October 2006.

(CABRERA, 2006b) *Remediation and Final Status Survey Former Monazite Sand Storage Area, North Fence Area, Recreation Area, and Center Tank Area, Naval Station Great Lakes – Great Lakes, Illinois.*, June 2006.

(CABRERA, 2007) *Coal Ash Determination Sampling Report, Naval Station Great Lakes, Great Lakes, Illinois*, March 2007

(MACTEC, 2006) *Forrestal Village Phased-Approach Radiological Survey Report In Support of the Phase II Environmental Assessment, NAVSTA Great Lakes, Naval Region Midwest Family Housing Privatization*, MACTEC, February 2006.

(NRC, 1998) NUREG-1505, Rev.1, *A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys*, U.S. Nuclear Regulatory Commission, June 1998.

(NRC, 1999) NUREG/CR-5512, Volume 3 *Residual Radioactive Contamination from Decommissioning*, *Parameter Analysis*, *Draft Report for Comment*, U.S. Nuclear Regulatory Commission, October 1999.

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

APPENDIX A

FSS SURVEY INSTRUMENT SENSITIVITIES

FIELD INSTRUMENTATION DETECTION SENSITIVITY

This appendix describes the detection sensitivities for field instrumentation used during the FSS of Building 3214 and the Vermont Court housing units at the Naval Station Great Lakes. This includes instruments used for detection of contamination on building and/or structure surfaces through surface activity scans, direct measurements and smear analysis for transferable contamination.

The RCOC at the Naval Station Great Lakes, discussed in Section 1 of the FSS Plan, is natural thorium (^{232}Th with decay products in secular equilibrium). Since monazite sand was maintained and stored at the Site in its natural state, the thorium decay chain remained in secular equilibrium with the parent radionuclide, ^{232}Th.

The parent radionuclide in the natural thorium decay chain, ^{232}Th, decays by emission of alpha particles. The daughter products in this chain decay by emission of alpha or beta particles, some with accompanying emission of gamma rays. The decay scheme for natural thorium is very well documented, and this knowledge is used in the design of the FSS and selection of appropriate survey instruments and analysis methods.

Structure surface scan, integrated or static measurement and smear analysis minimum detectable concentrations (MDCs) are presented in the following sections.

Building Surface and/or Structure Surface Scan, Static Measurements and Smear Analysis Minimum Detectable Concentration

Building and/or structure surfaces will be surveyed for alpha contamination using direct surface scan and static measurement techniques. Surveys will be performed in accordance with CABRERA standard operating procedures. These surveys may be performed using a Ludlum Model 43-37 floor monitor, Ludlum Model 43-68 gas flow proportional detector, or Ludlum Model 43-89 ZnS scintillation detector. The alpha surface scan MDC for each of these detectors is provided in the following sections.

General Alpha Scan MDC Information

Scan MDCs for alpha emitters must be derived differently than scanning for beta and gamma emitters. *MARSSIM* contains formulas and probability concepts for alpha scans in Appendix J, which provides a complete derivation of the formulas used to determine the probability of observing a count when performing an alpha scan. Additional information on various material background, detector efficiencies, surface material effects, etc. may be found in NUREG-1507.

In general, when performing an alpha scan, once a count has been recorded and the surveyor stops, the surveyor should wait a sufficient period of time such that if the guideline level (or action level) of contamination is present, the probability of getting another count is at least 90 %. For low background areas (alpha background of 0 to 3 cpm), it is assumed that a single count is sufficient to cause a surveyor to stop and investigate. For higher background areas or when using larger area detectors resulting in a higher background count rate such as the Ludlum Model 43-37 floor monitor (alpha background up to 10 cpm), the surveyor will usually need to get at least 2 counts while passing over the source area before stopping for further investigation.

For the purpose of determining alpha scan MDCs, the source activity, G in the following equations, is assumed to be slightly less than 50 % of the natural thorium surface activity action level presented in the FSS Plan, Table 3-1, i.e., 100 dpm/100 cm^2.

The assumptions pertaining to scan speeds, background, efficiency, dwell times, etc. used in the evaluation of alpha scan MDCs (probability of detection) are provided in Table 1. The probabilities of detection calculated using the equations below are also presented in Table 1. These calculations indicate that the under the conditions presented in the assumptions, the design objective of 90 % probability is achieved when scanning surfaces contaminated to 100 dpm/100 cm^2 when using the indicated detectors.

TABLE 1: ALPHA SURFACE SCAN ASSUMPTIONS

Model No.	Probe Area (cm^2)	Probe Width (cm)	α Efficiency (cpm /dpm)	α Bkgrd (cpm)	Scan Speed (cm/sec)	Pause Time (sec)	P(n>=1)	P(n>=2)
43-37	582	15	0.15*	10	6	2.5	NA	0.91
43-89 & 43-68	126	9	0.15*	3	1	7.3	0.90	NA

cm = centimeters
cpm = counts per minute
sec = second
cm^2 = square centimeters
dpm = disintegrations per minute
cm/sec = centimeters per second

* Manufacturer's stated 4π alpha efficiencies for these detectors have a range of 15 to 20%. For this evaluation, 15% is chosen as a conservative approach.

Ludlum Model 43-37 Scan MDC

The Ludlum Model 43-37 gas proportional detector is a large area detector (active area of 582 cm^2) with a higher background count rate compared to smaller area detectors, such as the Ludlum Model 43-68 or Ludlum Model 43-89. Using *MARSSIM* Equation J-7, the probability of two or more alpha counts during the scan survey of a surface is determined as follows:

$$P(n \geq 2) = 1 - P(n = 0) - P(n = 1) \qquad \text{(\textit{MARSSIM} Equation J-7)}$$

$$= 1 - \left(e^{-A}\right) \times \left(1 + A\right)$$

$$\text{for } A = \frac{(GE + B)t}{60}$$

Where:

$P(n \geq 2)$ = Probability of getting 2 or more counts during the time interval t

$P(n = 0)$ = Probability of not getting any counts during the time interval t

$P(n = 1)$ = Probability of getting 1 count during the time interval t

G = Source activity (100 dpm/100 cm^2)

E = Detector efficiency (4π)

B = Background count rate (cpm)

t = Dwell time over source (seconds)

Scans will be performed by moving the active area of the detector over the surface of interest at or below the given scan speed in Table 1. If two or more counts occur over the indicated observation interval, a one-minute integrated or static measurement will be performed at that location prior to resuming the scan survey. For Class 3 survey units, if the result of the static measurement is in excess of 110 dpm/100 cm^2 (approximately 50 % of the DCGL), the area will be marked for further investigation.

Ludlum Model 43-89 and Ludlum Model 43-68 Scan MDC

If the Ludlum Model 43-89 alpha scintillation detector or Ludlum Model 43-68 gas proportional detector is used, then *MARSSIM* Equation J-5 and the assumptions listed in Table 1, with a probability of at least one count occurring while surveying an area of contamination equal to the 100 dpm/100 cm^2 surface scan action level $P(n \geq 1)$, will be implemented instead of *MARSSIM* Equation J-7. The Model 43-89 and Model 43-68 are similar in active area and efficiency. Scans are performed the same (scan speed and dwell time) for both detectors. Although, the background may be slightly different for the two detector types, for this evaluation, they are assumed to be the same.

Using *MARSSIM* Equation J-5 and the assumptions listed in Table 1 (scan speeds, background, efficiency, dwell times, etc), the probability that a single count is sufficient to cause a surveyor to stop and investigate further is derived as follows:

$$P(n \geq 1) = 1 - P(n = 0) = 1 - e^{-A} \qquad \text{(MARSSIM J-5)}$$

$$\text{for } A = \frac{GEd}{60v}$$

Where:

$P(n \geq 1)$ = Probability of getting 1 or more counts during the time interval t

$P(n = 0)$ = Probability of not getting any counts during the time interval t

G = Source activity (100 dpm/100 cm^2)

E = Detector efficiency (4π)

d = Width of the detector in the direction of scan (cm)

v = Scan speed (cm/s)

Alpha scans will be performed using the Ludlum Model 43-89 or Ludlum Model 43-68 detector by moving the active area of the detector over the surface of interest at the scan speed shown in Table 1. Whenever a count is detected during the scan, the detector will be held in place over the location where the count was detected for the indicated pause time (approximately 7-8 seconds). If a second count is detected over this location during the pause time, a one minute integrated count will be performed. For Class 3 survey units, if the result of the static measurement is in excess of 110 dpm/100 cm^2 (approximately 50 % of the DCGL), the area will be marked for further investigation.

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 DCGL presented in the FSS 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:

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

Where:

ε_i = instrument efficiency (cpm/dpm)

ε_s = surface efficiency (unitless)

R_b = background count rate (cpm)

DA = detector area (cm^2)

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 cm^2.

The integrated or static measurement MDC and assumptions used for each of the detectors are presented in Table 2. The MDC was determined using the above equation.

TABLE 2: 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	107
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
cm^2 = 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 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:

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

TABLE 3: 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 MDC (dpm/100 cm^2)
2929	4*	20	Smear	0.33	0.8	7

min = minutes
cpm = counts per minute
cm^2 = square centimeters
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 less than the removable contamination DCGL presented in the FSS Plan.

Summary

Scan, static measurement and smear analysis MDCs have been calculated for each instrument to be used during the FSS of Building 3214 and Vermont Court housing units. MDC calculations 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 FSS 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 Cabrera Project Health Physicist.