New World Environmental, Inc., d.b.a.

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FINAL STATUS SURVEY REPORT
BLDG. 5 MICHELSON LABORATORY, ROOM 1613

NAVAL AIR WARFARE CENTER WEAPONS DIVISION

CHINA LAKE, CA

For the:

U.S. ARMY JOINT MUNITIONS COMMAND

ROCK ISLAND, IL

November 16, 2007

Rev. 1

Prepared by:

New World Technology
448 Commerce Way
Livermore, California 94551

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Approvals Page

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Written by:	*Daniel M. Spicuzza* Daniel M. Spicuzza, Project Manager	Date:	11/16/2007
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ABBREVIATIONS AND ACRONYMS

ALARA	as low as reasonably achievable
ANS	American Nuclear Society
ANSI	American National Standards Institute
AOC	Areas of Concern
BLDG	building
C-14	carbon-14
CFR	Code of Federal Regulations
cpm	counts per minute
DAC	Derived Air Concentration
DCGLs	Derived Concentration Guideline Limits
D&D	Decontamination and Decommissioning
DOD	Department of Defense
DP	Decommissioning Plan
dpm/100 cm^2	disintegrations per 100 square centimeters
DQO	Data Quality Objectives
ε_i	instrument efficiency
ε_s	Surface Efficiency Factor
EPA	Environmental Protection Agency
ft	feet
ft^2	square feet
HASP	Health and Safety Plan
ISO	International Organization for Standardization
LLRW	Low Level Radioactive Waste
m	meter
m^2	square meter
MARSSIM	Multi Agency Radiation Survey & Site Investigation Manual
MDC	Minimum Detectable Concentration
MDCR	Minimal Detectable Count Rate
MOU	Memorandum of Understanding

MSDS	Material Safety Data Sheets
mrem/y	millirem per year
N/A	not applicable
NAWC	Naval Air Warfare Center, China Lake
NaI	Sodium iodide
NIST	National Institute of Standards and Technology
NRC	Nuclear Regulatory Commission
NRMP	Navy Radioactive Materials Permit
NWT	New World Technology
OSHA	Occupational Safety and Health Administration
PEcoS	Pacific Eco Solutions
PM	Project Manager
PPE	personal protective equipment
QA	Quality Assurance
QC	Quality Control
RASO	Naval Sea Systems Command Detachment, Radiological Affairs Support Office
RWP	Radiation Work Permit
SOPs	Standard Operating Procedures
TEDE	Total Effective Dose Equivalent
Th-232	thorium-232
TLD	thermoluminescent dosimeter
μR/h	micro roentgens per hour
WRS	Wilcoxon Rank Sum Test
y	year

RECORD OF REVISIONS

Revision Number	Description	Date
0	Draft Final Status Survey Report, China Lake Building 5, Room 1613	9/27/2007
1	Final Status Survey Report, China Lake Building 5, Room 1613	11/16/2007

1.0 EXECUTIVE SUMMARY

New World Environmental, Inc. doing business as New World Technology (NWT) was contracted by the U.S. Army Joint Munitions Command (AFSC) to perform decommissioning activities and perform final status surveys in Bldg. 5, Michelson Lab Room 1613 located at the Naval Air Warfare Center (NAWC), in China Lake, CA.

The USN Radiological Affairs Support Office (RASO) had requested a decontamination effort and a Final Status Survey effort for the Navy Facility at Bldg. 5, Michelson Laboratory, Room 1613, China Lake, CA. The nuclides of concern were carbon-14 (C-14) and thorium-232 (Th-232). Room 1613 is approximately 18 feet by 30 feet by 15 feet to 20 feet high. The C-14 work area was confined to a corner of Room 1613 which contained a table, a bench counter containing a sink, and an adjoining bench counter, a fume hood and table. Th-232 oxide powder and uranium dioxide were also stored in the room and presumable used. The entire room was considered an impacted area.

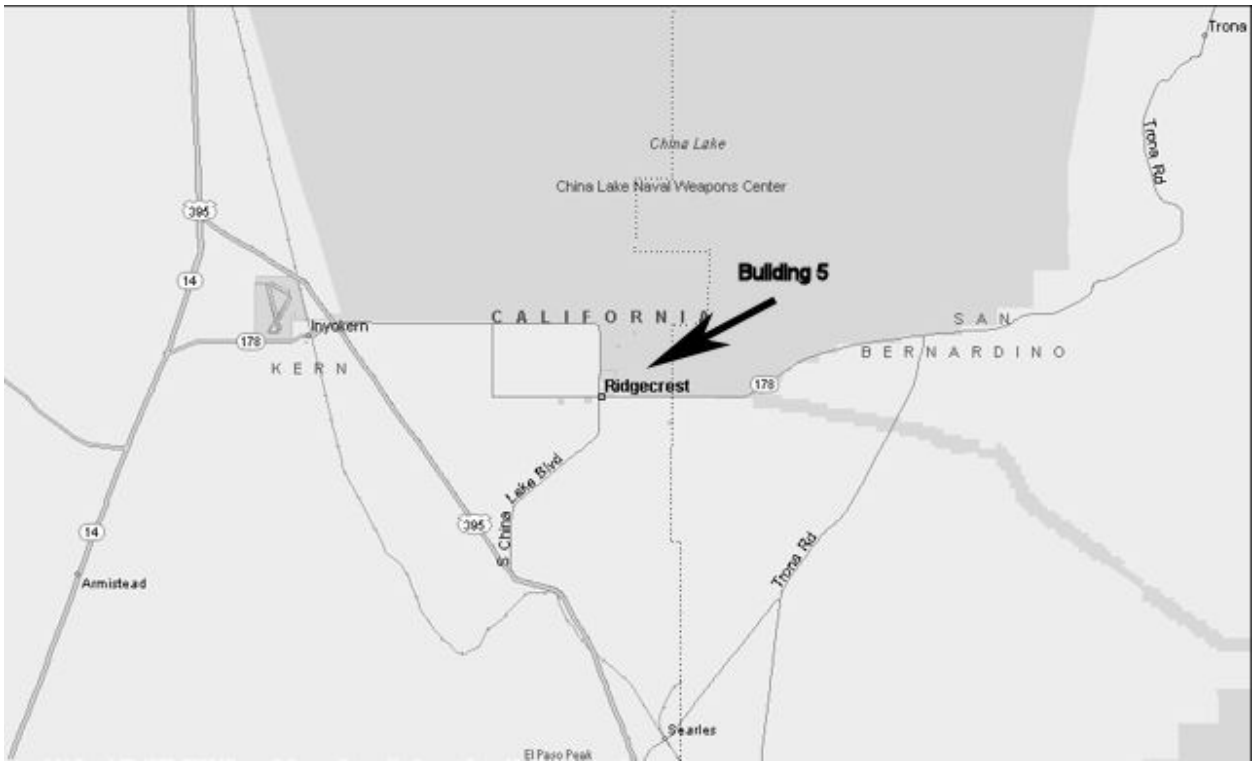
NWT's survey work was completed during the period of 17 September, 2007 to 21 September, 2007. The areas included the floor, lower wall, upper wall, and ceiling areas of Room 1613 in Building 5.

The surveys detailed in this report confirm that the radiological conditions were met for unrestricted release of Room 1613 in Building 5. Room 1613 in Building 5 was surveyed and met the requirements for unrestricted reuse based on the Derived Concentration Guideline Limits (DCGLs) of 450 dpm/100 cm^2 gross alpha, and 3.7 x 10^6 dpm/100 cm^2 gross beta, as they are to remain intact and used in the future. The gross alpha release limit was calculated using DandD Version 2.1, the resuspension factor recommended by NUREG 1720 (NRC 2002), and the assumption of secular equilibrium of the progeny. The C-14 release limit was a published screening value. These limits will ensure that no TEDE to future workers in the room will exceed 25 mrem/y.

Equipment and materials were released to the limits specified in "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses, By-product, Source, or Special Nuclear Materials, (NRC 1987)."

A map showing NAWC China Lake and the approximate location of Building 5 is presented in Figure 1.

Figure 1 NAWC China Lake Map



2.0 PROJECT BACKGROUND INFORMATION

The purpose of these tasks was to perform surveys in accordance with MARSSIM guidelines for unrestricted release of Room 1613 in Building 5. This report describes the steps that were followed and the results of the surveys necessary to provide for the release of this area.

2.1 Licenses, Permits, and Authorized Activities

Naval Radioactive Materials Permit No. 04-68307-W1NP was issued August 7, 2003 to the Naval Air Warfare Center Weapons Division at China Lake and authorized the use of Carbon-14 for preparation of radio-labeled derivatives of an energetic material for analysis by offsite laboratories

All work that was performed and detailed in this report was performed under NWT's California State Radioactive Materials License 5363-01. A Memorandum of Understanding (MOU) was issued on September 17, 2007 between Navy and NWT outlining the applicability and responsibilities of each organization as it applied to the scope of work and license implementation.

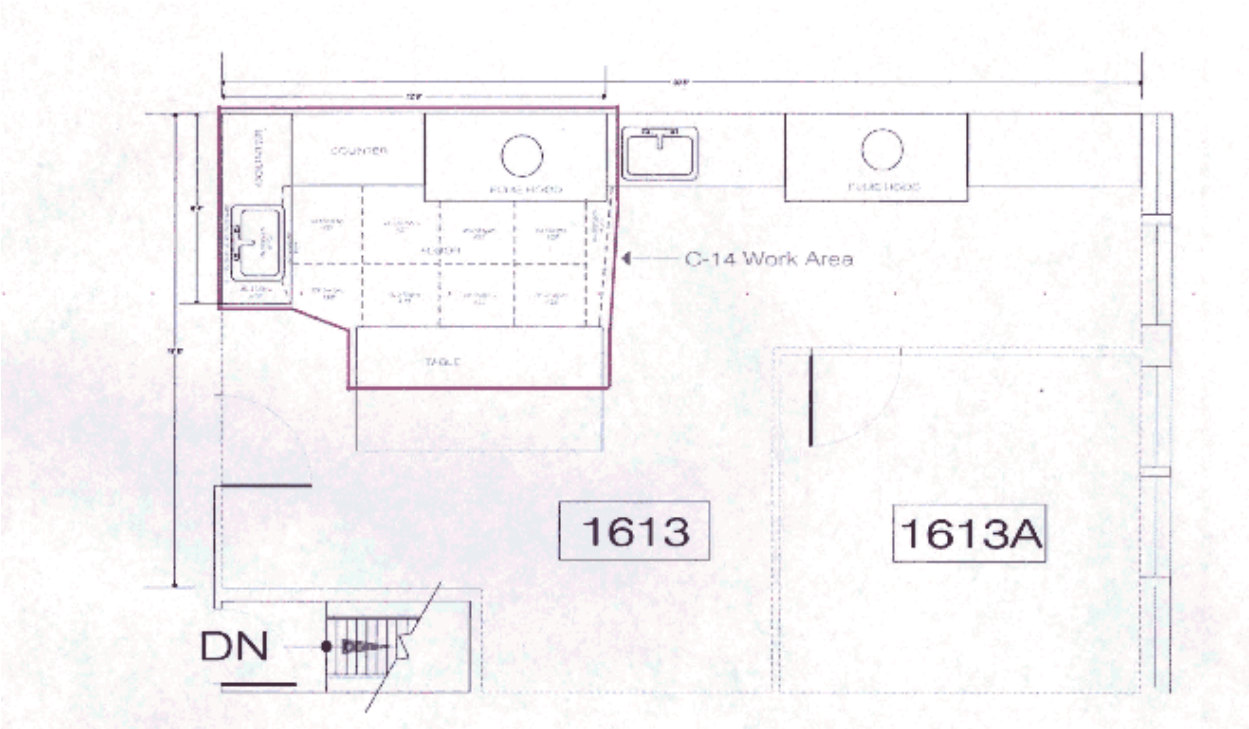
A copy of the MOU is presented in this report in Appendix A.

2.2 Facilities and Equipment

Naval Air Weapons Station China Lake (NAWC) is a 1.1 million acre (1735 square mile) military reservation in the upper Mojave Desert of south central California. It is approximately 150 miles northeast of Los Angeles at the boundaries of Inyo, Kern and San Bernardino counties. NAWC China Lake consists of two separate ranges, the North Range and South Range, connected by a narrow diagonal corridor. The North Range is where most major research, development and testing facilities are located.

The carbon-14 work area was confined to a corner of Room 1613 with dimensions of approximately 10 feet by 13 feet. The work area contained a table, a bench counter containing a sink, an adjoining bench counter, a fume hood, and a table. Room 1613 is approximately 18 feet by 30 feet by 15 feet high in the carbon-14 work area to 20 feet high on the opposite side of the room. Figure 2 presents a layout of Room 1613 in Building 5.

Figure 2 Building 5 Room 1613 Layout Diagram



2.3 Facility Radiological History Information

The preparation of radio-labeled derivatives of an energetic material was performed in Building 5 Michelson laboratory, Room 1613. The carbon-14 work area was confined to a corner of Room 1613 with dimensions of approximately 10 feet by 13 feet.

Bottles of thorium-232 oxide powder (15 grams) and uranium dioxide (100 grams) were stored in the room and were presumably used. One researcher is known to have used thorium in his research in the building, but the exact room is not known. These amounts of source material are unlicensed and readily available from chemical supply houses. The RSO estimated he had removed 50 to 100 similar bottles from the Michelson Laboratory building.

3.0 RADIOLOGICAL CONTROL REQUIREMENTS

3.1 Radiation Work Permit

A Radiation Work Permit (RWP) was prepared and specified the activities to be performed and all radiological safety requirements for the work including protective clothing, dosimetry requirements and expected radiation and contamination levels. All personnel assigned to site work were required to read, understand and sign the RWP prior to beginning work.

The RWP was also used as an information document for industrial safety. Hazards other than radiological were included in the RWP so proper protection was taken for all possible hazards.

A copy of the completed RWP is presented in Appendix B of this report.

3.2 Personnel Monitoring and Dosimetry

Even though the likelihood that personnel would receive any external or internal exposure was very minimal, NWT administrative policies require the use of external dosimetry on any field project that has the potential for exposure to radioactive material. The Project Manager was responsible for ensuring that all NWT personnel assigned to perform the surveys were appropriately monitored for exposure to ionizing radiation. Each individual working at the site wore the dosimetry devices as specified in the RWP, a thermoluminescent dosimeter (TLD). The issuance of monitoring devices was documented on a Badge Issue Log.

3.3 Official Exposure Determination and Project Dose Estimate

The vendor TLD report showed that no personnel received any detectable whole body exposure of < 10 millirem, which is the detection threshold of the TLDs. Personnel were sent a hard copy record (NRC Form 5) of their exposure.

4.0 SITE PREPARATION, EQUIPMENT AND PERSONNEL

4.1 Accessibility

Access to the active work areas was limited to only those personnel performing work in the areas.

4.2 Office Space, Restroom Facilities and Electrical Power

Existing facility space and restroom facilities located in Building 5 were utilized by the survey crew during work activities. There was existing electrical power available in the work areas where it was needed.

4.3 Personnel

Project personnel and their responsibilities consisted of the following:

Project Manager – Responsible for the overall operations and safety of the project team.

Senior Waste Broker – Responsible for properly packaging, marking and labeling waste containers, and preparing shipping paperwork required to transport the waste to an approved treatment/disposal site.

Health Physics Technicians - Performed surveys and sampling operations.

All NWT personnel were trained and experienced at the tasks to be performed.

4.4 Training

Initial project training included, but was not limited to:

- Site-Specific Health and Safety Plan
- Decommissioning Plan
- Fall Protection

- Event Reporting
- Operation of radiological survey instrumentation

5.0 PLANNING PHASE OF FINAL STATUS SURVEYS

5.1 Radionuclides of Concern

Based on historical information from the work performed in Room 1613 of Building 5, carbon-14 and thorium-232 are the radionuclides of concern. Therefore, the residual surface activity release limits were determined for these radionuclides of potential concern.

5.2 Materials and Equipment Surface Activity Derived Concentration Guideline Limits (DCGLs) for Radionuclides of Concern

The surface activity DCGLs are stated in the "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses, By-product, Source, or Special Nuclear Materials, (NRC 1987)." Table 1 shows the DCGLs for materials and equipment.

Table 1 Surface Activity DCGLs for Materials and Equipment

Radionuclide	Removable in dpm/100cm^2	Average [2] in dpm/100cm^2	Maximum [3] in dpm/100cm^2	Radiations Emitted
C-14	1,000	5,000	15,000	β
Th-232	200	1,000	3,000	α

1. Measurements of average contamination should not exceed 1 m^2 in area
2. The maximum contamination level applies to an area of not more than 100 cm^2

5.3 Building/Structure Surface Activity Derived Concentration Guideline Limits (DCGLs) for Radionuclides of Concern

5.3.1 Gross Alpha DCGL

The specified DCGL (RASO, Morris) for structure surfaces which will be considered acceptable for unrestricted use is 450 dpm/100 cm^2, alpha, based on the suspected presence of Th-232. The following discussion explains how the limit was derived.

Using DandD Version 2.1 and inputting a unit concentration produces a dose of 4.73 mrem. Dividing this dose into 25 mrem/year calculates to 5.3 dpm/100 cm^2 of Th-232 (for an infinite area) as the DCGL. This procedure is recommended in NUREG 1757.

NUREG 1720 "Re-evaluation of the Indoor Resuspension Factor for the Screening Analysis of the Building Occupancy Scenario for NRC's License Termination Rule" recommends a resuspension factor of 1×10^{-6} vice 1.42×10^{-5} that is used in DandD 2.1. Consequently $(1 \times 10^{-6})/(1.42 \times 10^{-5}) = 14.2$ which is the factor of adjustment for the resuspension factor. The adjustment uses the ratio of the default resuspension factor at the 90th percentile from DandD 2.1 compared to the resuspension factor recommended by NUREG 1720 for the 90th percentile. This is the only adjustment to the default screening values used by DandD2.1.

Since the exposure for thorium results almost entirely from inhalation, the adjusted DCGL is 5.3 dpm/100 cm^2 x 14.2. The adjusted DCGL is 75 dpm/100 cm^2 of Th-232.

The progeny are all presumed to be in secular equilibrium. In secular equilibrium there are six alphas emitted for every disintegration of Th-232. Consequently, the gross alpha limit then becomes 75 dpm/100 cm^2 x 6 = 450 dpm/100 cm^2 for building surfaces after readjusting the resuspension factor.

5.3.2 Gross Beta DCGL

The generic screening limit for carbon-14 of 3.7×10^6 dpm/100 cm^2 from Appendix B, NUREG 1757, Volume 1, Revision 1 will be used as the DCGL for releasing the area for unrestricted use.

Table 2 shows the Building/Structure Surface activity DCGLs.

Table 2 Building/Structure Surface Activity DCGLs

Radionuclide	DCGL in dpm/100cm^2
C-14	3.7 x10^6
Th-232	450

6.0 IMPLEMENTATION PHASE OF FINAL STATUS SURVEYS

6.1 Objective of Final Status Surveys

The objective of the final status survey was to demonstrate that residual radioactivity levels meet the release criterion. In demonstrating the objective is met, the null hypothesis (Ho) that residual contamination exceeds the release criterion is tested; the alternative hypothesis (Ha) is that residual contamination meets the release criterion.

6.2 Background Reference Area Radiation Levels

Site background reference areas were chosen that had similar characteristics as the survey unit or piece of equipment being evaluated. Background reference areas were selected from non-impacted areas, but were not limited to natural areas undisturbed by human activities. The reference areas selected were not part of the survey unit being evaluated.

Unaffected areas in and just outside of Room 1608 of Building 5 were selected as the reference (background) areas due to the different types of building surfaces and equipment encountered in Room 1613.

The site background count rate levels were established for the final status surveys by obtaining sixteen, 2-minute static readings with each instrument used, taken on contact with con floor tile, metal walls, counter tops, and ceiling tile surfaces for alpha-beta surveys from areas unlikely to be affected by the residual radioactive materials that could be present at the different survey areas. The average value for these readings was used as the area/equipment background radiation levels.

Figure 3 presents the location of the background reference area for Room 1613 survey.

Table 3 presents a summary of the background reference area readings. The survey data is presented in this report in Appendix C.

Figure 3 Building 5 Background Reference Area

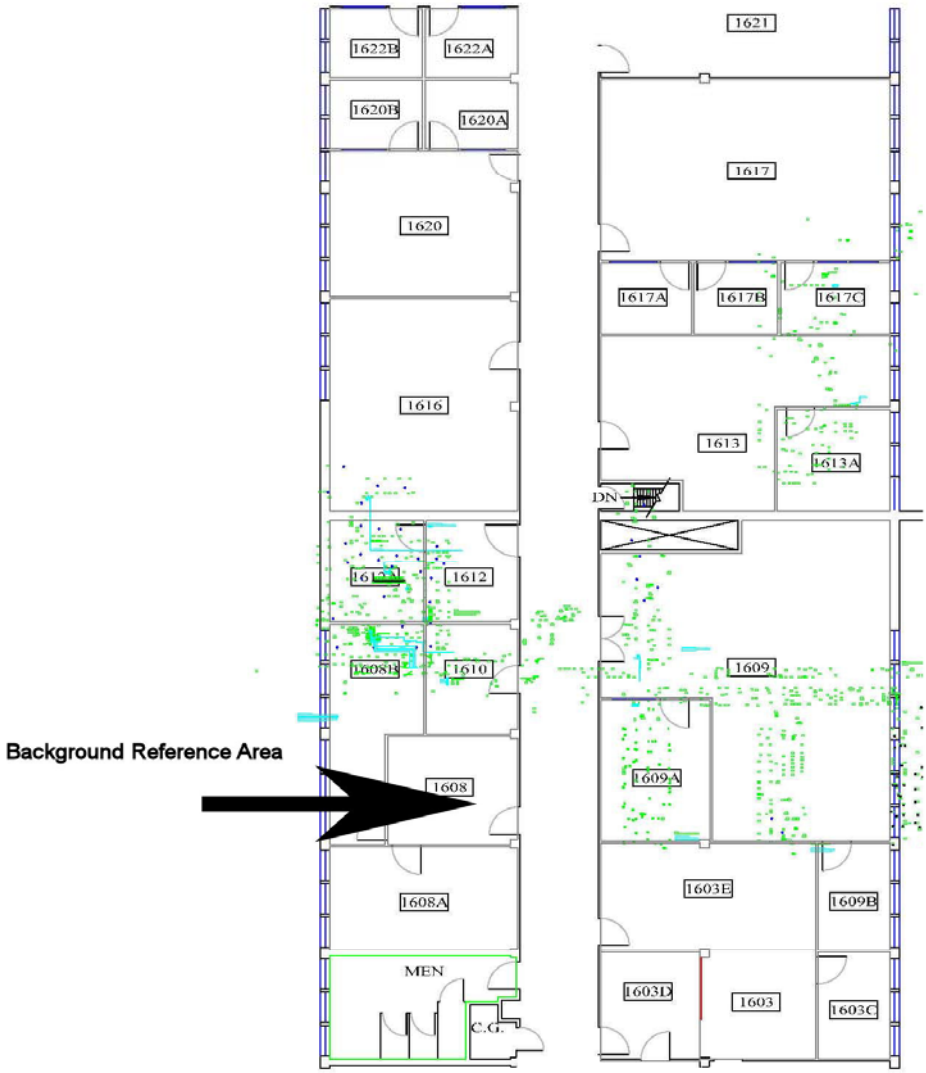


Table 3 Background Reference Area Survey Summary Table

Surface Type	Average Gross Alpha Results in dpm/100cm^2	Average Gross Beta Results in dpm/100cm^2
Floor Tile	28	3,588
Metal Walls	52	3,977
Counter Tops	25	2,856
Ceiling Tile	63	8,644

6.3 Area Classifications

For the purposes of establishing the sampling and measurement frequency and pattern, Room 1613 was divided into impacted areas with one of three following classifications:

Class 1 Areas: Areas that have, or had prior to remediation, a potential for radioactive contamination (based on site operational history) or known contamination (based on previous radiation surveys) above the release limits. Examples of Class 1 areas include:

- site areas previously subjected to remedial actions
- locations where leaks or spills are known (or suspected) to have occurred
- radioactive material storage areas
- areas with contaminants in discrete solid pieces of material or high specific activity

*Class 2 Area*s: Areas that have, or had prior to remediation, a potential for radioactive contamination or known contamination but are not expected to exceed the building residual surface activity release limits provided in Tables 1 and 2. To justify changing the classification from Class 1 to Class 2, there should be measurement data that provides a high degree of confidence that no individual measurement would exceed the release limits. Other justifications for reclassifying an area, as Class 2 may be appropriate, based on site-specific considerations. Examples of areas that might be classified as Class 2 include:

- locations where radioactive materials were present in an unsealed form
- areas downwind from the main areas of concern (AOC)

- areas handling radioactive materials
- areas on the perimeter of former contamination control areas

*Class 3 Area*s: Any impacted areas that are not expected to contain any residual radioactivity, or are expected to contain levels of residual radioactivity at a small fraction of the release limits, based on site operating history and previous radiation surveys. Examples of areas that might be classified as Class 3 include buffer zones around Class 1 or Class 2 areas and areas with very low potential for residual contamination but insufficient information to justify a non-impacted classification.

Based upon process knowledge, the operational history, and routine surveys and inspections performed the floor and lower wall areas (up to 6 feet) of Room 1613 were classified as *Class1* areas. The upper wall (above 6 feet) and ceiling/overhead areas of Room 1613 were classified as *Class 2* areas.

6.4 Survey Units

Table 4 below presents the classifications and number of survey units of the areas where radiological surveys are to be performed during this effort.

Table 4 Survey Unit Summary Table

Area/Location	MARSSIM Classification	Total Surface Area (Square meters/Square feet)	Radionuclide(s) of Concern	Number of Survey Units
Room 1613 Floor	Class 1	~ 44.4/478.5	See Section 5.1	1
Room 1613 Lower Walls Up to 6 Feet	Class 1	~ 57.6/621	See Section 5.1	1
Room 1613Upper Walls Above 6 Feet	Class 2	~ 86.5/931.5	See Section 5.1	1
Room 1613 Ceiling/Overhead	Class 2	~44.4/478.5	See Section 5.1	1

Survey units are limited in size based on classification, exposure pathway modeling assumptions, and site-specific conditions. MARSSIM (Rev. 1, August 2000) recommends areas for survey units according to the following:

Classification	Suggested Area
Class 1 Building Surfaces	up to 100 m^2/1076 ft^2 floor area
Class 2 Building Surfaces	100 m^2/1076 ft^2 to 1,000 m^2/10,763 ft^2
Class 3 Building Surfaces	no limit

6.5 Reference Grids

A reference coordinate system was laid out for each survey unit. A square grid system was used for the Final Status Surveys in Room 1613. The length, L, of a side of the square grid is determined by the total number of samples or measurements to be taken. The length of the square determined the distance between direct measurements (MARSSIM, 2000). The length or spacing of the grids was calculated for the survey unit using the following equation:

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

Where,

L = length of squares grids (ft);

A = surface area of the survey unit (ft^2); and

N = statistically calculated number of samples.

The length of the measurement/sampling intervals for each of the survey units is presented in Table 5 below.

Table 5 Survey Unit Data Table

Survey Unit	Survey Unit Size in m^2/ft^2	MARSSIM Class	Number of Direct Measurements	Length of Grid Pattern in Meters/Feet
Room 1613 Floor	~ 44.4/478.5	1	18	1.7/5.5
Room 1613 Lower Walls Up to 6 Feet	~ 57.6/621	1	18	1.8/6
Room 1613 Upper Walls Above 6 Feet	~ 86.5/931.5	2	18	1.8/6
Room 1613 Ceiling/Overhead	~44.4/478.5	2	18	1.7/5.5

Diagrams showing the layouts of the area survey units are presented in Figure 4 through Figure 7 below.

Figure 4 Room 1613 Floor Survey Unit Layout

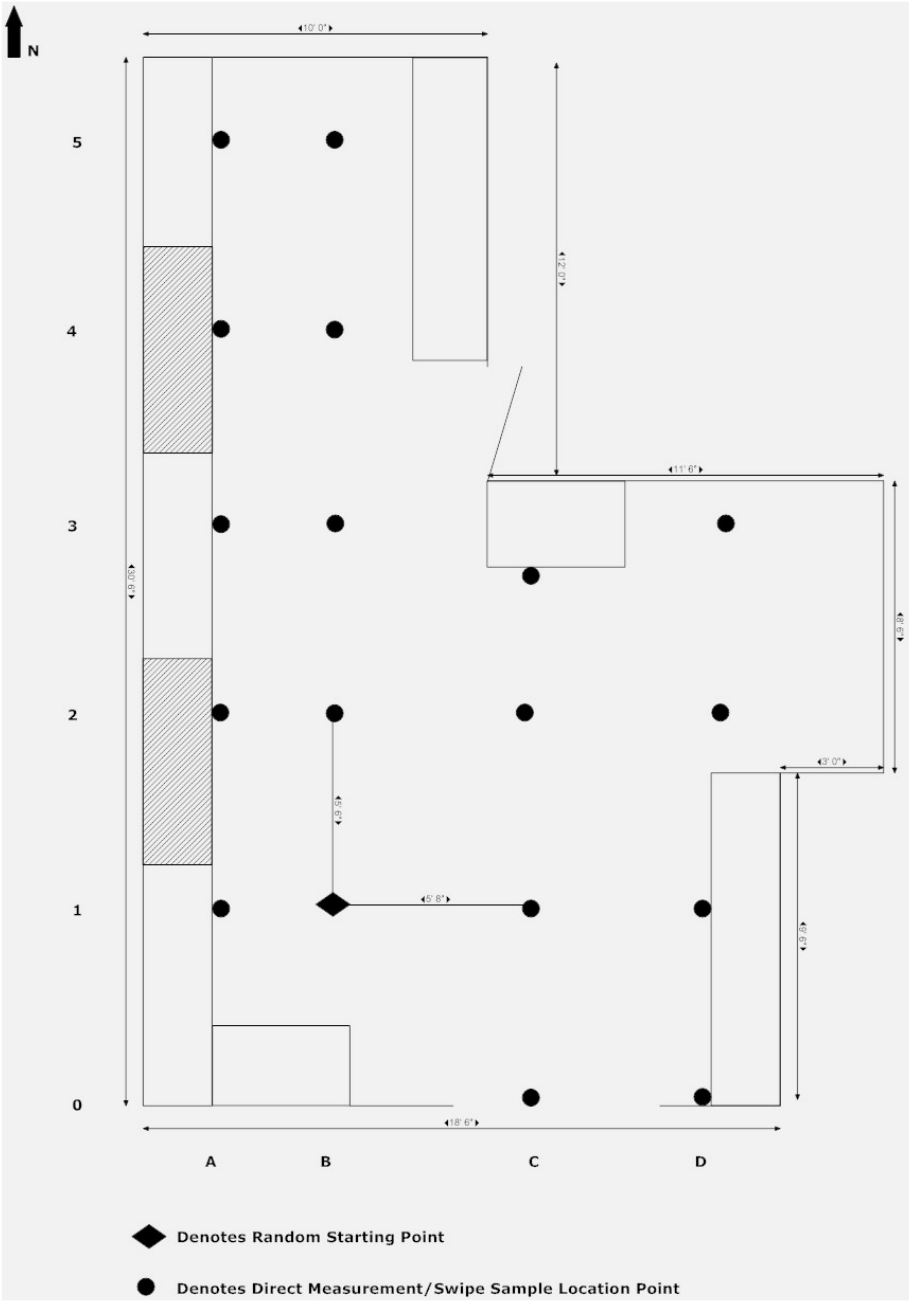


Figure 5 Room 1613 Lower Wall Survey Unit Layout

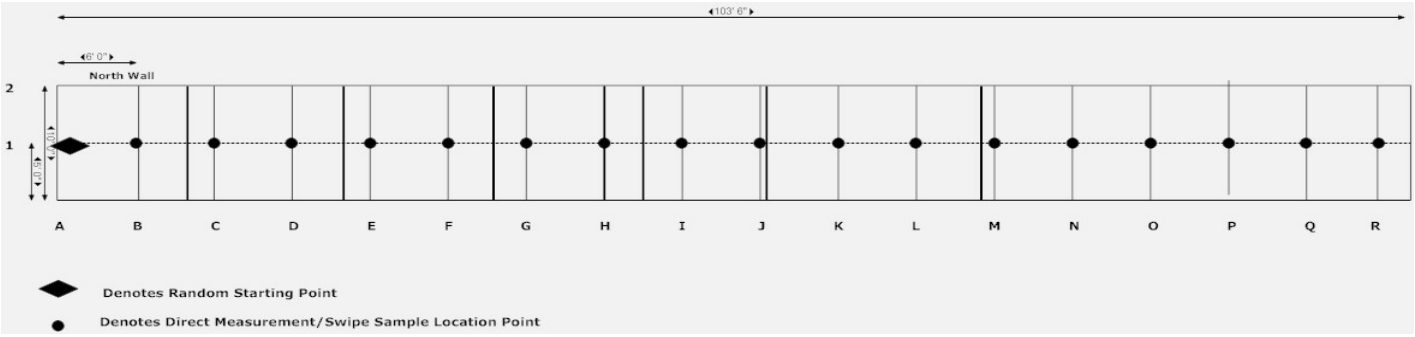


Figure 6 Room 1613 Upper Wall Survey Unit Layout

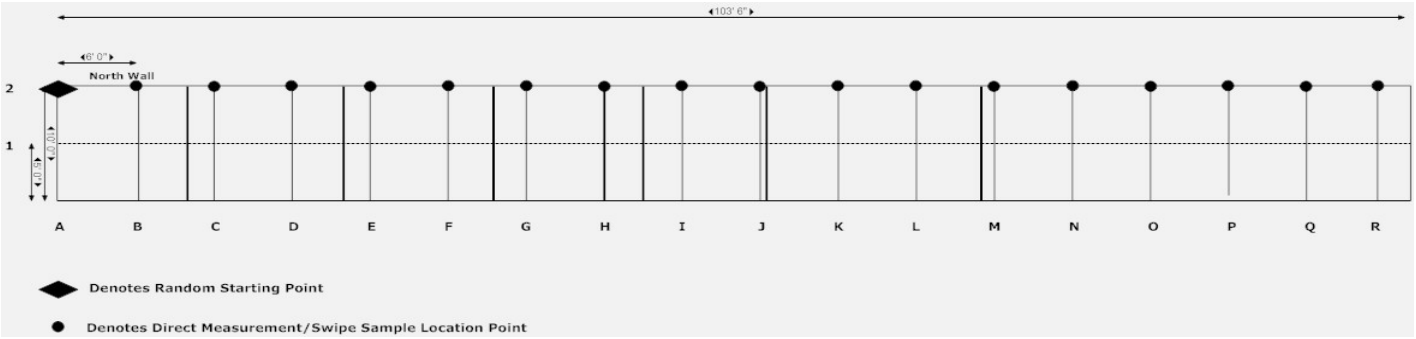
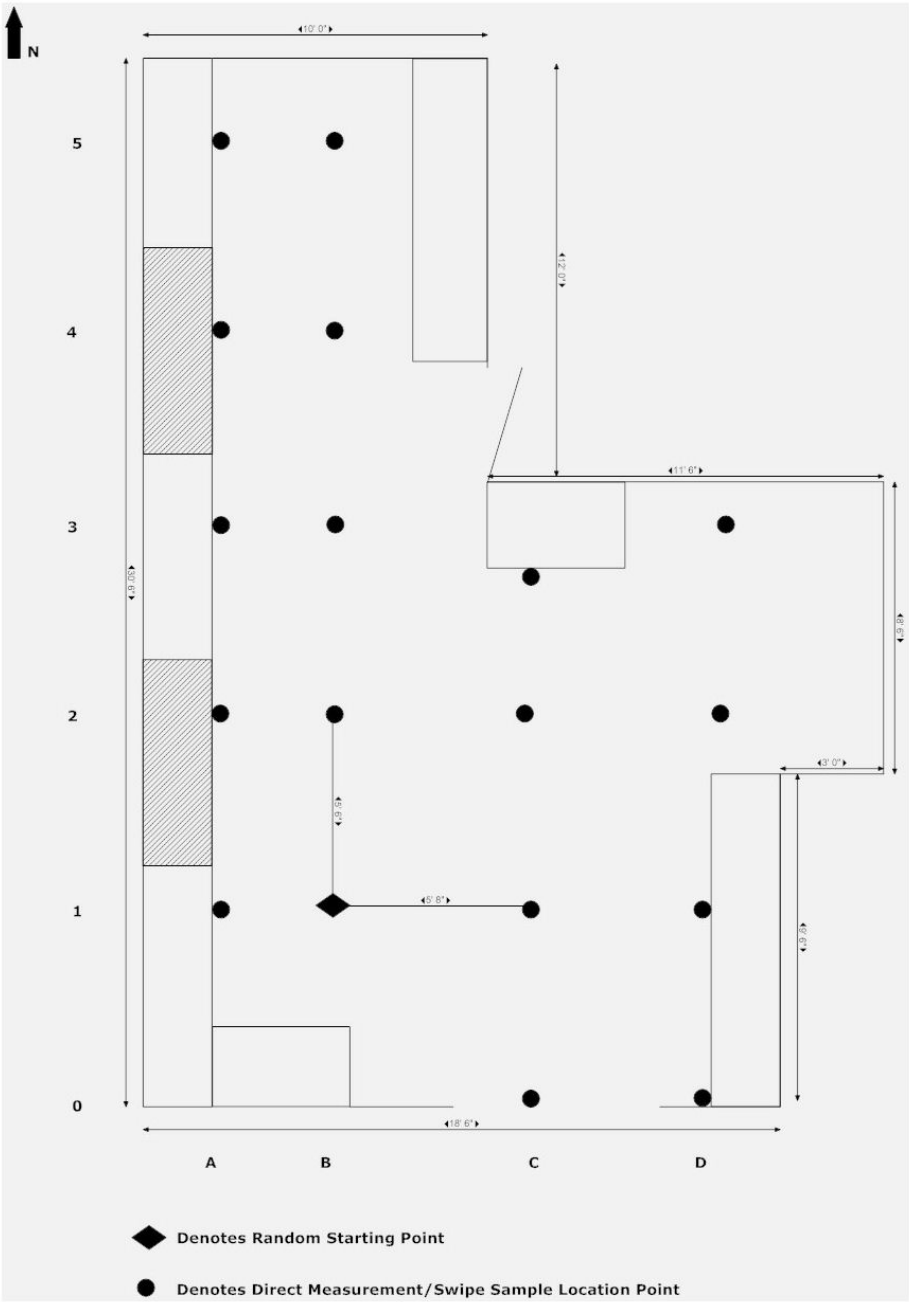


Figure 7 Room 1613 Overhead/Ceiling Survey Unit Layout



6.6 Systematic and Biased Sampling

Both systematic and biased sampling was employed in Room 1613. The alpha-beta scan surveys covered 100% of the Class 1 areas, and 50% of the Class 2 areas. The systematic sampling pattern starting point for a survey unit was randomly placed. However, in addition to these systematic samples, other samples (2-minute alpha-beta direct measurements) were taken where the potential for contamination would be the greatest on the equipment and areas that were surveyed in Room 1613. 2-minute alpha-beta direct measurements throughout the entire survey units at systematic locations were also performed.

6.7 Survey Instrumentation

6.7.1 Instrumentation Selection

Instruments were selected that are suitable for the physical and environmental conditions at the site. The instruments and measurement methods selected were able to detect the radionuclides of concern or radiation types of interest, and are, in relation to the survey or analytical technique, capable of measuring levels that were equal to or less than the release limits.

6.7.2 Instruments for the Scan and Direct Measurement Surveys for Alpha and Beta Surface Activity

Surface scan surveys for alpha and beta radiation were conducted with Ludlum Model 43-68 and Model 43-37 alpha-beta gas proportional probes and Ludlum Model 2360 data loggers. The probes had 0.8 mg/cm^2 thick Mylar windows. The detector was moved over the surface being surveyed at a rate of ½" per second. The detector was held within ¼" of the surface being surveyed. Direct measurements were conducted with the detector on contact with the surface for a period of 2 minutes. Audible indicators were used during the surveys.

6.7.3 Gross Beta-Gamma-Alpha Loose Surface Contamination Surveys

Loose surface contamination surveys for alpha and beta/gamma emitters were performed using cloth smears.

The swipe survey was performed by wiping over an area of 100 cm^2 (~ 4" by 4") with a cloth smear, and applying moderate pressure.

The smears were analyzed with a Ludlum Model-2929 Dual Channel Scaler utilizing a phoswich detector.

6.8 Detection Sensitivity—Static and Scan Minimum Detectable Concentration (MDC), Gross Alpha-Gross Beta Surveys

6.8.1 Determination of Instrument Efficiency (ε_I) for Alpha and Beta Surface Activity Measurements

The instrument efficiency (ε_I) was determined during calibration and is defined as the ratio between the net count rate (in counts per minute (cpm)) of the instrument and the surface emission rate of the calibration source for a specified geometry. The surface emission rate is the 2π particle fluence that is affected by both the attenuation and backscatter of the radiation emitted from the calibration source. Equation 1 was used to calculate the instrument efficiency in counts per particle, although efficiency is typically reported as having no units.

Equation 1

$$\varepsilon_i = \frac{R_{S+B} - R_B}{q_{2\Pi}\left(W_A / S_A\right)}$$

Where,

R_{S+B} = the gross count rate of the calibration measurement (cpm)

R_B = the background count rate in cpm

$q_{2\pi}$ = surface emission rate of the calibration source (NIST traceable)

W_A = Active Area of the detector window (cm^2)

S_A = Area of the source (cm^2)

The instrument efficiency is determined during calibration by obtaining static counts with the detector over a calibration source that has a National Institute of Standards and Technology (NIST) traceable surface emission rate. The 2π particle fluence rate is corrected for decay, attenuation and scatter, then; the surface emission rate of the source must be corrected for the area subtended by the probe. Factors that can also affect the instruments efficiency are discussed below:

<u>Calibration Sources:</u> The calibration sources selected emit alpha or beta radiation with energies similar to those expected from the contaminant in the field, i.e., similar to the expected radionuclide(s) of concern.

<u>Source Geometry Factors:</u> The instrument efficiency was determined with a calibration source equal to or greater than the area of the probe.

Source-to-Detector Distance: The detector was calibrated at a source-to-detector distance that is the same as the detector-to-surface distance used in the field.

Window Density Thickness: The detector was calibrated with a probe window density thickness that is the same as the probe window density thickness used in the field.

6.8.2 Static MDC

The static MDC is the level of radioactivity, on a surface, that is practically detectable by the overall measurement process. The conventional equation, Equation 2, was used to calculate the instrument MDC in dpm per 100 cm^2 when the background and sample are counted for the same time intervals.

Equation 2

$$MDC = \frac{3 + 4.65\sqrt{C_B * T_B}}{\varepsilon_i \varepsilon_s \frac{W_A}{100\ cm^2} T_B}$$

where;

C_B = background count rate (cpm)

T_B = background counting time (min)

ε_ι = instrument efficiency (count per particle)

ε_s = contaminated surface efficiency (particle per disintegration)

W_A= area of the detector window (cm^2)

If the background and sample are counted for different time intervals, Equation 3 is used to calculate the MDC in dpm per 100 cm^2.

Equation 3

$$MDC = \frac{3 + 3.29\sqrt{R_B T_{S+B}\left(1 + \frac{T_{S+B}}{T_B}\right)}}{\varepsilon_i \varepsilon_s \frac{W_A}{100\ cm^2} T_{S+B}}$$

where;

R_B = background count rate (cpm)

T_B = background counting time (min)

T_{S+B} = sample counting time (min)

ε_ι = the instrument efficiency (count per particle)

ε_s = the contaminated surface efficiency (particle per disintegration)

W_A = the area of the detector window (cm^2)

6.8.3 Surface Efficiency (ε_s) for Surface Activity Measurements

The surface efficiency term in Equation 2 is used to determine the 4π total efficiency for a particular surface and condition. Suitable values are based on the radiation and radiation energy, and are primarily impacted by the backscatter and self-absorption characteristics of the surface on which the contamination exists in the field. Backscatter is most affected by the energy of the radiation and the density of the surface material. Self-absorption characteristics or attenuation are also a function of the radiation's energy and surface condition. Surfaces typically encountered in the field include concrete, wood, dry wall, plaster, carpet, and metal. Surface conditions include both physical effects, such as scabbled concrete, and the effect of surface coatings, i.e., dust, paint, rust, water, and oil.

In the absence of experimentally determined surface efficiencies, ISO-7503-1 and NUREG 1507, provide conservative recommendations for surface efficiencies. ISO-7503-1, recommends a surface efficiency of 0.5 for maximum beta energies exceeding 0.5 MeV, and to use a surface efficiency of 0.25 for beta energies between 0.15 and 0.4 MeV and for alpha emitters (ISO, 1998), (NRC, 1997). NUREG-1507 provides surface efficiencies based on studies performed primarily at ORISE. In general, NUREG-1507 indicates that the ISO rule-of-thumb for surface efficiencies is conservative, particularly for beta-emitting radionuclides with end-point energies between 0.25 MeV and 0.4 MeV.

The surface condition in Room 1613 was floor tile that was slightly covered with dust. The surface efficiency for alpha emitters (Th-232) used in accordance with ISO-7503-1 was 0.25 and for beta emitters (C-14) was 0.25.

6.8.4 Probe Area Correction Factor for Surface Activity Measurements

In Equation 2, W_A is the size of the "active" area of the detector window. If the area of the detector window (cm^2) does not equal 100 cm^2, it is necessary to convert the detector response to units of dpm per 100 cm^2.

6.8.5 Scanning Minimal Detectable Count Rate, (MDCR)

The minimum detectable number of net source counts in the scan interval, for an ideal observer, can be arrived at by multiplying the square root of the number of background counts (in the scan interval) by the detectability value associated with the desired performance (as reflected in *d'*) as shown in Equation 4.

Equation 4

$$MDCR = d'\sqrt{b_i} \times 60/i$$

where,

d' = index of sensitivity (α and β error) – MARSSIM Table 6.5

b_i = number of background counts in scan time interval (count)

i = scan or observation interval (s) (time that a typical source remains under the probe during the scan)

6.8.6 Determination of MDCR and Use of Surveyor Efficiency

The $MDCR_{Surveyor}$ was calculated as shown in Equation 5.

Equation 5

$$MDCR_{Surveyor} = \frac{MDCR}{\sqrt{p}}$$

6.8.7 Scan MDC

The scan MDC is determined from the minimum detectable count rate (MDCR) by applying conversion factors that account for detector and surface characteristics and surveyor efficiency. As discussed below, the MDCR accounts for the background level, performance criteria (d'), and observation interval. The observation interval during scanning is the actual time that the detector can respond to the contamination source. This interval depends on the scan speed, detector size in the direction of the scan, and area of elevated activity, which is assumed to be 100 cm^2 in size.

The scan MDC for structure surfaces was calculated using Equation 6.

Equation 6

$$Scan\ MDC = \frac{MDCR}{\sqrt{p}\ \varepsilon_i \varepsilon_s \frac{W_A}{100\ cm^2}}$$

Where;

MDCR = discussed in Section 7.8.5

p = surveyor efficiency factor

ε_ι = instrument efficiency (count per particle)

ε_s = contaminated surface efficiency (particles per disintegration)

W_A = area of the detector window (cm^2)

6.8.8 Alpha Scan MDCs for Building and Structure Surfaces (126cm^2 probe)

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. Surveying surfaces that are dirty, non-planar, or weathered can significantly affect the detection efficiency and therefore bias the expected MDC for the scan. The use of reasonable detection efficiency values instead of optimistic values has been incorporated.

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 <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 summation 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 was calculated using Equation 7 below.

Equation 7

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

Where

P(n≥1)	=	probability of observing a single count
G	=	contamination activity (dpm)
E	=	detector efficiency (4π)
d	=	width of detector in direction of scan (cm)
v	=	scan speed (cm/s)

Once a count is recorded and the guideline level of contamination is present the surveyor should stop and wait until the probability of getting another count is at least 90%. This time interval was calculated using Equation 8 below.

Equation 8

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

Where

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

6.8.9 Alpha Scan MDCs for Building and Structure Surfaces (582cm^2 probe)

The larger (582cm^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 2 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 was calculated using Equation 9 below.

Equation 9

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

Where

P(n≥2)	=	probability of getting 2 or more counts during the time interval *t*
t	=	d/v, dwell time over source (s)
G	=	contamination activity (dpm)
E	=	detector efficiency (4π)
B	=	background count rate (cpm)

6.8.10 Scan MDC (Alpha)

Using the following equation (Abelquist, 2001), one can calculate the activity of a 100 cm^2 "hot spot" with a 90 % probability of detection using Equation 10 below.

Equation 10

$$\alpha\ scanMDC = \frac{[-\ln(1 - P(n \geq 1))]60}{t\varepsilon_i\varepsilon_s}$$

Where

t	=	dwell time over source (seconds)
ε_i	=	Instrument efficiency (counts per particle)
ε_s	=	contaminated surface efficiency (particles per disintegration)

Table 6 below presents a summary of the instrumentation used during the performance of the surveys.

Table 6 Instrumentation for NWT Radiological Surveys

	Alpha Measurements			Beta Measurements		
Areas Surveyed	Floor	Ceiling/Walls	Equipment/Counter Tops	Floor	Ceiling/Walls	Equipment/Counter Tops
Instrument Model	Ludlum 2360	Ludlum 2360	Ludlum 2360	Ludlum 2360	Ludlum 2360	Ludlum 2360
Instrument Serial No.	225305	227415	227399	225305	227415	227399
Instrument Detector	Gas Proportional 43-37	Gas Proportional 43-68	Gas Proportional 43-68	Gas Proportional 43-37	Gas Proportional 43-68	Gas Proportional 43-68
Probe Serial No.	PR147628	PR147404	PR178075	PR147628	PR147404	PR178075
Calibration Source	Th-230 100 cm^2	Th-230 100 cm^2	Th-230 100 cm^2	C-14 100 cm^2	C-14 100 cm^2	C-14 100 cm^2
Probe Window Thickness mg/cm^2	0.8	0.8	0.8	0.8	0.8	0.8
Probe Size in cm^2	582	126	126	582	126	126
Instrument Efficiency (ε_i)	0.27	0.36	0.36	0.22	0.19	0.27
Instrument Background (CPM)	11	7/6 [1]	3.7/2.9 [2]	1148	512/236 [1]	265/242 [2]
Static Count Time (Minutes)	2	2	2	2	2	2
Surface Efficiency (ε_s)	0.25	0.25	0.25	0.25	0.25	0.25
Total Efficiency (4π) (ε_t)	.067	,09	.09	.055	.05	.067
Radionuclides of Concern	Th-232	Th-232	Th-232	C-14	C-14	C-14
Static MDC in $dpm/100cm^2$	32	90/83 [1]	69/62 [2]	353	1282/877 [1]	649/621 [2]
Scan Observation Interval (Seconds)	10	7	7	10	7	7
Scan Probability % Alpha Measurements	99	99/99 [1]	99/99 [2]	N/A	N/A	N/A
Scan MDC in $dpm/100cm^2$ Beta Measurements	N/A	N/A	N/A	1203	4341/2948 [1]	2609/2493 [2]
Scan MDC in $dpm/100cm^2$ @ 90% Probability Alpha Measurements	205	219/219 [1]	219/219 [2]	N/A	N/A	N/A
Gross DCGL	450	450	1000	3.7×10^6	3.7×10^6	5000
Data Points Required Per Survey Unit	16	16	16	16	16	16
Data Points Per Survey Unit	18	18	18	18	18	18
Statistical Test	WRS	WRS	WRS	WRS	WRS	WRS

[1] Values are: Ceiling/Walls
[2] Values are: Equipment(Metal)/Counter Tops

6.9 Statistical Considerations

6.9.1 Demonstration of Compliance

When determining compliance with remediation goals, the survey unit is examined. One measurement does not determine compliance. Rather, the site data are examined statistically. The three compliance tests are summarized in Table 7 below. They include:

- Compare the largest site measurement to the smallest background measurement.
- Compare the average site measurement to the average background measurement.
- Use the Wilcoxon Rank Sum test (MARSSIM, 2000) to determine if the site data (less background) exceed the surface contamination release limits.

Table 7 Statistical Comparisons with Release Limits

Survey Result	Conclusion
Difference between the largest survey measurement and the smallest background reference area measurement is less than the surface contamination release limits.	Site meets release criterion.
Difference of survey unit and background reference area average is greater than the surface contamination release limits.	Site does not meet release criterion.
Difference between any survey unit measurement and any background reference area measurement greater than the surface contamination release limits and the difference of survey unit average and background reference area average is less than the surface contamination release limits.	Site meets release criterion if Wilcoxon Rank Sum test rejects the hypothesis that the survey unit exceeds the release criterion.

6.9.2 Null Hypothesis

Using the MARSSIM methodology, the null hypothesis is stated as "the residual activity in the survey unit exceeds the release criteria" (Rev. 1, August 2000). Thus, in order to pass the survey unit (that is, release the area), the null hypothesis must be rejected

6.9.3 Confidence Levels

The Final Status Survey was designed to limit Type I and Type II errors to 5%. It is important to minimize the chances that area grids exceeding the release limits will be missed (Type I) and area grids meeting the release limits will be rejected as too high (Type II). The probability of either of these occurring is set at a maximum of 5%. The Critical Value for the Wilcoxon Rank Sum Test is calculated from these probability values and from the number of samples/measurements taken.

6.9.4 Wilcoxon Rank Sum Test

Since gross alpha-beta measurements and not radionuclide specific measurements were performed as part of this Final Status Survey, Chapter 8, Subsection 8.2.3 of MARSSIM suggests use of the Wilcoxon Rank Sum Test to test the statistical null hypothesis instead of the Sign Test.

The WRS test is a two-sample test that compares the distribution of a set of measurements in a survey unit to that of a set of measurements in a reference area. The test is performed by first adding the value of the release limits to each measurement in the reference area. The combined set of survey unit data and adjusted reference area data are listed, or ranked, in increasing numerical order. If the ranks of the adjusted reference site measurements are significantly higher than the ranks of the survey unit measurements, the survey unit demonstrates compliance with the release criterion. The advantage of this nonparametric test is that it does not assume the data are normally or log-normally distributed. The WRS test also allows for "less than" measurements to be present in the reference area and the survey units.

For this case, the release limit value is added to each of background reference area measurement results that were obtained in the background reference area to obtain the adjusted reference area measurement Z_i.

The *m* adjusted reference sample measurements, Z_i, from the reference area and the *n* sample measurements, Y_i, from the survey unit are pooled and ranked in order of increasing size from 1 to N, where N = *m*+*n*. For this case N=34.

If several measurements are tied *(i.e.*, have the same value), they are all assigned the average rank of that group of tied measurements.

If there are *t* "less than" values, they are all given the average of the ranks from 1 to *t*.

Therefore, they are all assigned the rank t(t+1)/(2t) = (t+1)/2, which is the average of the first *t* integers. If there is more than one detection limit, all observations below the largest detection limit should be treated as "less than" values.

The ranks of the adjusted measurements from the background reference area are then summed, W_r.

Since the sum of the first N integers is N(N+1)/2, one can equivalently sum the ranks of the measurements from the survey unit, W_s, and compute $W_r = N(N+1)/2 - W_s$.

Compare W_r with the critical value given in Table I.4 found in Appendix I of MARSSIM for the appropriate values of n, m, and α. If W_r is greater than the critical value, the hypothesis that the survey unit exceeds the release criterion is rejected.

If the test shows that the first group is larger than the second, then the release criteria is not met.

6.9.5 Direct Measurement/Swipe Sampling Frequency

It is assumed that there will be no radioactive contamination in the background reference area. The MARSSIM guidelines were used and a 95 percent confidence level for detecting radioactivity above the investigation level will be assumed. Using the Wilcoxon Rank Sum Test, a release limit of 450 dpm/100cm^2 gross alpha, a LBGR value of 225 dpm/100cm^2 (one half of the release limit value), and a Standard Deviation value of 135 dpm/100cm^2 (conservative estimate of 30% of the release limit value) with a false negative (β) error rate of 5 percent, and a false positive error (α) rate of 5 percent, the number of survey/sampling data points can then be calculated.

The initial step in determining the number of data points is to calculate the relative shift, Δ/σ = (Release Limit Value-LBGR)/σ, from the release limit value, the lower bound of the gray region (LBGR), and the standard deviation of the contaminant in the survey unit, σ. Values of the relative shift that are less than one will result in a large number of measurements needed to demonstrate compliance.

The calculated value of the relative shift is 1.67.

The corresponding value of P_r from Table 5.4 in Chapter 5 of MARSSIM is 0.871014.

The number of direct measurement sample data points (N/2) can then be obtained directly from Table 5.3 in Chapter 5 of MARSSIM. For $\alpha = 0.05$, $\beta = 0.05$ and Δ/σ = 1.67, a value of 16 is obtained for N/2. The table value has already been increased by 20% to account for missing or unusable data and uncertainty in the calculated value of N/2.

The Critical Value is 308

Note: In order to maintain the proper spacing interval, the number of direct measurement sample data points for the survey units in Room 1613 was increased to 18 resulting in Critical Value of 328.

7.0 QUALITY ASSURANCE

7.1 Equipment

The instruments and systems were calibrated on an annual frequency using the manufacturer's calibration protocol to National Institute of Standards and Technology (NIST) traceable sources. Copies of the instrument calibration data in presented in Appendix D of this report.

The survey instruments were source checked each day prior to the start of the survey activities and at the end of survey activities each day to verify proper operation of detectors and detection systems. Copies of the instrument daily response check data is presented in Appendix E of this report.

7.2 Quality Control Samples

Paired duplicates of 10 % of the swipe samples were collected and counted on site. The results of the QC duplicate samples were compared to each other. A maximum deviation of ± 20% was the satisfactory objective of the comparison of the samples.

7.3 Data Management

Data was maintained in the on-site office. Back up copies of data were made routinely and maintained on the computer and/or copier provided. Further, back up copies of survey and sample results were routinely made to CDs or other electronic media.

8.0 SURVEY PROCEDURES AND MEASUREMENT DATA INTERPRETATION

8.1 Surface Activity Measurements

Measurements to quantify surface activity levels represent the fundamental compliance measurements for buildings and structures. ISO-7503, NUREG-1507, and ASTM were used as technical guidance to ensure the accurate measurement of surface activity.

Equation 11 was used to document and calculate the surface activity in dpm per 100 cm^2.

Equation 11

$$A_S = \frac{R_{S+B} - R_B}{\varepsilon_i \varepsilon_s \frac{W_A}{100\, cm^2}}$$

Where;

A_S = total surface activity (dpm/100 cm^2)

R_{S+B} = the gross count rate of the measurement in cpm,

R_B = the background count rate in cpm

ε_ι = the instrument efficiency (counts per particle)

ε_s = the contaminated surface efficiency (particles per disintegration)

W_A = the area of the detector window (cm^2)

This equation has two efficiency terms, which account for differences between the conditions under which the detector is calibrated, and conditions under which the detector is used in the field. The instrument efficiency (ε_i) is discussed in Section 6.8.1, and is determined under ideal conditions in the laboratory. The surface efficiency, is discussed in Section 6.8.3, and is used to determine the 4π total efficiency for a particular surface and condition.

8.2 Removable Activity Measurements

Equation 12 was used to calculate the removable surface activity in units of dpm per 100 cm^2.

Equation 12

$$A_S = \frac{R_{S+B} - R_B}{\varepsilon_i \varepsilon_s}$$

Where:

A_S = removable surface activity (dpm/100 cm^2)
R_{S+B} = the gross count rate of the measurement in cpm
R_B = the background count rate in cpm
ε_i = the instrument efficiency
ε_s = the contaminated surface efficiency

This equation has two efficiency terms, which account for differences between the conditions under which the detector is calibrated, and conditions under which the swipe is used in the field. The instrument efficiency (ε_i), as discussed in Section 6.8.1, is determined under ideal conditions in the laboratory. The surface efficiency, discussed in Section 6.8.3, is used to determine the total efficiency for a particular surface and condition. Assuming most of the daughters for Th-232 were in equilibrium, the surface efficiency used for the swipe samples for gross alpha activity was 0.25, and for gross beta activity was 0.25.

8.3 Data Assessment

Basic statistical quantities were calculated for the data in order to identify patterns, relationships and any type anomaly.

The Project Manager reviewed data at the end of each phase of the survey to determine the validity of the results and adequate coverage of the survey areas.

9.0 DECONTAMINATION/WASTE DISPOSAL

9.1 Decontamination of Fume Hood

During performance of scoping surveys in the fume hood that was used for the C-14 experiments, up to ~ 28,000 dpm/100cm^2 loose surface beta contamination was discovered in the area between the fume hood back inner and outer panels. The fume hood was dismantled and decontaminated by wiping of the surfaces with rags dampened in a solution of Simple Green ®. The waste generated from the decontamination effort was packaged into a 55-gallon drum for disposal.

Post decontamination survey results of the fume hood indicated no activity above background levels of radiation.

9.2 Packaging/Transportation of Waste Materials

The waste materials were packaged into two 55-gallon drums (15 cubic feet total). A radiological survey was performed on the exterior surfaces of the drums. The survey consisted of a loose surface contamination survey and exposure rate survey. The survey indicated acceptable results.

The drums were weighed (Drum #1, 97 lbs, and Drum #2, 87 lbs.) onsite. All shipping manifests and appropriate shipping documentation was completed by a JMC approved broker prior to the drums leaving the China Lake facility. The drums were loaded onto an enclosed van truck and transported to the Perma-Fix Northwest waste treatment facility located in Richland, WA for processing and eventual disposal at the Hanford waste disposal facility located in Hanford, WA. The shipment complied with JMC and DOT shipping procedures.

Copies of the waste manifests and appropriate shipping documentation are included in this report in Appendix F.

NOTE: It should be noted that during sorting of the waste materials two zip lock bags of kitty litter with rubber gloves and absorbent wipes were discovered that emanated a very strong acidic odor. The material was segregated from the rest of the waste and placed into a white plastic bucket with lid and stored inside of Room 1613 for future disposition. The approximate volume of this material is one half gallon.

10.0 SURVEY ANALYSIS AND RESULTS

The survey design always makes use of the statistical tests in helping to assure that the number of sampling points and the instrument measurement sensitivities are adequate, but not excessive, for the decision made. Radiological survey data were obtained in units of cpm and activity that have no intrinsic meaning to the release limits. Data was converted to dpm/100cm^2 to evaluate results with the release limits and to help identify which statistical tests would prove to be the best in interpreting data.

The statistical model used to interpret the data for Room 1613 was the WRS test. The WRS test is designed to test a hypothesis about the data results of a population distribution. It is most often used to test the hypothesis about a population median and often involves the use of matched pairs, for example, before and after data, in which case it tests for a median difference of zero. The WRS test does not require the assumption that the population is normally distributed. This test is a nonparametric test that may be of use when it is only necessary (or possible) to know if observed differences between two conditions are significant. The WRS test is structured to denote change in magnitude, as opposed to any attempt at quantitative measurement.

There are two types of decision errors that can be made when performing the statistical tests described in this report. The first type of decision error, called a Type I error, occurs when the null hypothesis is rejected when it is actually true. A Type I error is sometimes called a "false positive." The probability of a Type I error is usually denoted by α. The Type I error rate is often referred to as the significance level or size of the test.

The second type of decision error, called a Type II error, occurs when the null hypothesis is not rejected when it is actually false. A Type II error is sometimes called a "false negative." The probability of a Type II error is usually denoted by β . The *power* of a statistical test is defined as the probability of rejecting the null hypotheses when it is false. It is numerically equal to $1-\beta$, where β is the Type II error rate.

This survey was designed to limit Type I and Type II errors to 5%. It is important to minimize the chances of concluding that a survey unit meets the release limits (reject the null hypothesis) when it actually exceeds the limits (Type I Error) and concluding that a survey unit exceeds the release limit (accept the null hypothesis) when it actually meets the limit (Type II Error). The probability of either of these occurring was set at a maximum of 5 percent.

10.1 Room 1613

10.1.1 Alpha/Beta Scan Surveys of Survey Units (Floor/Walls, Ceiling), Analysis and Results

No elevated areas of activity distinguishable above background levels were detected during the scan surveys.

10.1.2 Fixed Alpha Measurements of Survey Units (Floor/Walls/Ceiling), Analysis and Results

This final status survey was implemented in accordance with MARSSIM guidelines. One complete set of alpha measurements were conducted in the appropriate reference (background) areas and in each of the survey units. The alpha survey data was converted to units of dpm per 100 cm^2 so the results could be compared directly to the release criteria. Table 6 presents a summary of the instruments used to evaluate alpha surface activities and the efficiencies used to convert instrument readings to DCGL units. Table 6 also provides a summary of instrument sensitivities, the release criteria, and the number of samples taken in the survey units. The gross alpha release criterion for the radionuclides of concern was 450 dpm per 100 cm^2. The WRS test was used, since some of the radionuclides of concern are present in background, and gross activity measurements were performed to evaluate if the residual radioactivity levels in the survey units meet the release criterion and to test the null hypothesis (H_o) or alternative hypothesis (H_a) (see Section 6.9.2).

Alpha results are provided in Appendix G. The mean (average) alpha levels for all of the survey units are less than the release criteria. The WRS test also demonstrates that the concentration of alpha radioactivity is less than the release criteria in all of the survey units.

The H_o is rejected for all of the survey units as the survey unit means (average) are less than the gross alpha release criteria, and there was no evidence of small areas of elevated activity.

Table 8 through Table 11 present summaries of the WRS test for the survey units.

Table 8 Room 1613 Floor Survey Unit Gross Alpha WRS Test Summary Table

DCGL = 450 dpm/100 cm^2 Gross Alpha

Survey Point	DATA dpm/100 cm^2	AREA	ADJUSTED DATA	RANKS	REFERENCE AREA RANKS
1	29.3	R	479.3	28	28
2	30.5	R	480.5	30.5	30.5
3	31.8	R	481.8	32	32
4	38.2	R	488.2	34	34
5	28.0	R	478.0	25	25
6	28.0	R	478.0	25	25
7	25.5	R	475.5	23	23
8	36.9	R	486.9	33	33
9	28.0	R	478.0	25	25
10	22.9	R	472.9	21.5	21.5
11	29.3	R	479.3	28	28
12	22.9	R	472.9	21.5	21.5
13	30.5	R	480.5	30.5	30.5
14	29.3	R	479.3	28	28
15	21.6	R	471.6	20	20
16	19.1	R	469.1	19	19
A1	15.3	S	15.3	3.5	0
A2	17.8	S	17.8	11.5	0
A3	17.8	S	17.8	11.5	0
A4	16.5	S	16.5	6.5	0
A5	17.8	S	17.8	11.5	0
B1	12.7	S	12.7	1	0
B2	20.4	S	20.4	16.5	0
B3	15.3	S	15.3	3.5	0
B4	16.5	S	16.5	6.5	0
B5	17.8	S	17.8	11.5	0
C0	16.5	S	16.5	6.5	0
C1	16.5	S	16.5	6.5	0
C2	14.0	S	14.0	2	0
C3	20.4	S	20.4	16.5	0
D0	20.4	S	20.4	16.5	0
D1	17.8	S	17.8	11.5	0
D2	20.4	S	20.4	16.5	0
D3	17.8	S	17.8	11.5	0
			SUM	595	424
			W_r =		424
			Critical Value =		328

Reject the null hypothesis - the survey unit meets the release criterion.

S-Survey Unit
R-Background Reference Area

Table 9 Room 1613 Lower Wall Survey Unit Gross Alpha WRS Test Summary Table

DCGL = 450 dpm/100 cm^2 Gross Alpha

Survey Point	DATA dpm/100 cm^2	AREA	ADJUSTED DATA	RANKS	REFERENCE AREA RANKS
1	61.1	R	511.1	31	31
2	48.0	R	498.0	23	23
3	48.0	R	498.0	23	23
4	61.1	R	511.1	31	31
5	43.6	R	493.6	20	20
6	21.8	R	471.8	19	19
7	61.1	R	511.1	31	31
8	61.1	R	511.1	31	31
9	65.4	R	515.4	34	34
10	48.0	R	498.0	23	23
11	56.7	R	506.7	28	28
12	52.3	R	502.3	26.5	26.5
13	48.0	R	498.0	23	23
14	61.1	R	511.1	31	31
15	52.3	R	502.3	26.5	26.5
16	48.0	R	498.0	23	23
A1	87.2	S	87.2	18	0
B1	39.2	S	39.2	2	0
C1	43.6	S	43.6	5	0
D1	74.1	S	74.1	15.5	0
E1	82.9	S	82.9	17	0
F1	52.3	S	52.3	8.5	0
G1	43.6	S	43.6	5	0
H1	52.3	S	52.3	8.5	0
I1	43.6	S	43.6	5	0
J1	65.4	S	65.4	12	0
K1	56.7	S	56.7	10	0
L1	48.0	S	48.0	7	0
M1	74.1	S	74.1	15.5	0
N1	69.8	S	69.8	13.5	0
O1	39.2	S	39.2	2	0
P1	61.1	S	61.1	11	0
Q1	39.2	S	39.2	2	0
R1	69.8	S	69.8	13.5	0
			SUM	595	424
			W_r =		424
			Critical Value =		328

Reject the null hypothesis - the survey unit meets the release criterion.

S-Survey Unit
R-Background Reference Area

Table 10 Room 1613 Upper Wall Survey Unit Gross Alpha WRS Test Summary Table

DCGL = 450 dpm/100 cm^2 Gross Alpha

Survey Point	DATA dpm/100 cm^2	AREA	ADJUSTED DATA	RANKS	REFERENCE AREA RANKS
1	61.1	R	511.1	31	31
2	48.0	R	498.0	23	23
3	48.0	R	498.0	23	23
4	61.1	R	511.1	31	31
5	43.6	R	493.6	20	20
6	21.8	R	471.8	19	19
7	61.1	R	511.1	31	31
8	61.1	R	511.1	31	31
9	65.4	R	515.4	34	34
10	48.0	R	498.0	23	23
11	56.7	R	506.7	28	28
12	52.3	R	502.3	26.5	26.5
13	48.0	R	498.0	23	23
14	61.1	R	511.1	31	31
15	52.3	R	502.3	26.5	26.5
16	48.0	R	498.0	23	23
A2	52.3	S	52.3	6.5	0
B2	61.1	S	61.1	13.5	0
C2	82.9	S	82.9	16	0
D2	52.3	S	52.3	6.5	0
E2	48.0	S	48.0	3	0
F2	61.1	S	61.1	13.5	0
G2	34.9	S	34.9	1	0
H2	43.6	S	43.6	2	0
I2	52.3	S	52.3	6.5	0
J2	52.3	S	52.3	6.5	0
K2	56.7	S	56.7	11	0
L2	87.2	S	87.2	17.5	0
M2	69.8	S	69.8	15	0
N2	56.7	S	56.7	11	0
O2	52.3	S	52.3	6.5	0
P2	87.2	S	87.2	17.5	0
Q2	52.3	S	52.3	6.5	0
R2	56.7	S	56.7	11	0
			SUM	595	424
			W_r =		424
			Critical Value =		328

Reject the null hypothesis - the survey unit meets the release criterion.

S-Survey Unit
R-Background Reference Area

Table 11 Room 1613 Ceiling Survey Unit Gross Alpha WRS Test Summary Table

DCGL = 450 dpm/100 cm^2 Gross Alpha

Survey Point	DATA dpm/100 cm^2	AREA	ADJUSTED DATA	RANKS	REFERENCE AREA RANKS
1	61.1	R	511.1	25.5	25.5
2	69.8	R	519.8	32	32
3	65.4	R	515.4	30	30
4	56.7	R	506.7	21.5	21.5
5	52.3	R	502.3	19.5	19.5
6	56.7	R	506.7	21.5	21.5
7	61.1	R	511.1	25.5	25.5
8	61.1	R	511.1	25.5	25.5
9	78.5	R	528.5	33.5	33.5
10	61.1	R	511.1	25.5	25.5
11	65.4	R	515.4	30	30
12	78.5	R	528.5	33.5	33.5
13	61.1	R	511.1	25.5	25.5
14	52.3	R	502.3	19.5	19.5
15	65.4	R	515.4	30	30
16	61.1	R	511.1	25.5	25.5
A1	65.4	S	65.4	11	0
A2	39.2	S	39.2	1	0
A3	65.4	S	65.4	11	0
A4	87.2	S	87.2	17	0
A5	65.4	S	65.4	11	0
B1	65.4	S	65.4	11	0
B2	95.9	S	95.9	18	0
B3	61.1	S	61.1	5	0
B4	65.4	S	65.4	11	0
B5	61.1	S	61.1	5	0
C0	43.6	S	43.6	2	0
C1	65.4	S	65.4	11	0
C2	61.1	S	61.1	5	0
C3	52.3	S	52.3	3	0
D0	65.4	S	65.4	11	0
D1	74.1	S	74.1	16	0
D2	65.4	S	65.4	11	0
D3	65.4	S	65.4	11	0
			SUM	595	424
			W_r =		424
			Critical Value =		328

Reject the null hypothesis - the survey unit meets the release criterion.

S-Survey Unit
R-Background Reference Area

10.1.3 Fixed Beta Measurements of Survey Units (Floor/Wall/Ceiling), Analysis and Results

This final status survey was implemented in accordance with MARSSIM guidelines. One complete set of beta measurements were conducted in the appropriate reference (background) areas and in each of the survey units. The beta survey data was converted to units of dpm per 100 cm^2 so the results could be compared directly to the release criteria. Table 6 presents a summary of the instruments used to evaluate beta surface activities and the efficiencies used to convert instrument readings to DCGL units. Table 6 also provides a summary of instrument sensitivities, the release criteria, and the number of samples taken in the survey units. The gross beta release criterion for the radionuclides of concern was 3.7×10^6 dpm per 100 cm^2. The WRS test was used, since some of the radionuclides of concern are present in background, and gross activity measurements were performed to evaluate if the residual radioactivity levels in the survey units meet the release criterion and to test the null hypothesis (H_o) or alternative hypothesis (H_a) (see Section 6.9.2).

Beta results are provided in Appendix G. The mean (average) beta levels for all of the survey units are less than the release criteria. The WRS test also demonstrates that the concentration of beta radioactivity is less than the release criteria in all of the survey units.

The H_o is rejected for all of the survey units as the survey unit means (average) are less than the gross beta release criteria, and there was no evidence of small areas of elevated activity.

Table 12 through Table 15 present summaries of the WRS tests for the survey units.

Table 12 Room 1613 Floor Survey Unit Gross Beta WRS Test Summary Table

DCGL = 3.70E+06 dpm/100 cm^2 Gross Beta

Survey Point	DATA dpm/100 cm^2	AREA	ADJUSTED DATA	RANKS	REFERENCE AREA RANKS
1	3552.0	R	3703552.0	23	23
2	3720.7	R	3703720.7	34	34
3	3547.3	R	3703547.3	21	21
4	3641.0	R	3703641.0	31	31
5	3500.5	R	3703500.5	19	19
6	3556.7	R	3703556.7	24	24
7	3592.6	R	3703592.6	30	30
8	3548.9	R	3703548.9	22	22
9	3573.9	R	3703573.9	26	26
10	3578.6	R	3703578.6	29	29
11	3687.9	R	3703687.9	33	33
12	3575.4	R	3703575.4	27	27
13	3577.0	R	3703577.0	28	28
14	3656.7	R	3703656.7	32	32
15	3528.6	R	3703528.6	20	20
16	3567.6	R	3703567.6	25	25
A1	3655.1	S	3655.1	8	0
A2	3581.7	S	3581.7	2	0
A3	3658.2	S	3658.2	9	0
A4	3680.1	S	3680.1	13	0
A5	3628.6	S	3628.6	5	0
B1	3659.8	S	3659.8	10	0
B2	3691.0	S	3691.0	15	0
B3	3616.1	S	3616.1	4	0
B4	3606.7	S	3606.7	3	0
B5	3673.9	S	3673.9	12	0
C0	3753.5	S	3753.5	18	0
C1	3645.7	S	3645.7	7	0
C2	3689.5	S	3689.5	14	0
C3	3564.5	S	3564.5	1	0
D0	3637.9	S	3637.9	6	0
D1	3737.9	S	3737.9	17	0
D2	3670.7	S	3670.7	11	0
D3	3719.2	S	3719.2	16	0
			SUM	595	424
			W_r =		424
			Critical Value =		328

Reject the null hypothesis - the survey unit meets the release criterion.

S-Survey Unit
R-Background Reference Area

Table 13 Room 1613 Lower Wall Survey Unit Gross Beta WRS Test Summary Table

DCGL = 3.70E+06 dpm/100 cm^2 Gross Beta

Survey Point	DATA dpm/100 cm^2	AREA	ADJUSTED DATA	RANKS	REFERENCE AREA RANKS
1	3968.3	R	3703968.3	28	28
2	4170.9	R	3704170.9	33	33
3	3951.4	R	3703951.4	26	26
4	3816.3	R	3703816.3	23.5	23.5
5	3807.8	R	3703807.8	22	22
6	3740.3	R	3703740.3	19	19
7	4103.3	R	3704103.3	29	29
8	3774.1	R	3703774.1	20	20
9	3790.9	R	3703790.9	21	21
10	3816.3	R	3703816.3	23.5	23.5
11	4145.6	R	3704145.6	30	30
12	4154.0	R	3704154.0	31	31
13	4162.4	R	3704162.4	32	32
14	3959.8	R	3703959.8	27	27
15	3934.5	R	3703934.5	25	25
16	4314.4	R	3704314.4	34	34
A1	4458.0	S	4458.0	6	0
B1	5057.4	S	5057.4	18	0
C1	4913.9	S	4913.9	17	0
D1	4170.9	S	4170.9	1	0
E1	4280.6	S	4280.6	3	0
F1	4897.0	S	4897.0	16	0
G1	4483.3	S	4483.3	7	0
H1	4728.1	S	4728.1	13.5	0
I1	4609.9	S	4609.9	10	0
J1	4660.6	S	4660.6	11	0
K1	4728.1	S	4728.1	13.5	0
L1	4702.8	S	4702.8	12	0
M1	4593.0	S	4593.0	9	0
N1	4550.8	S	4550.8	8	0
O1	4854.8	S	4854.8	15	0
P1	4213.1	S	4213.1	2	0
Q1	4415.7	S	4415.7	5	0
R1	4407.3	S	4407.3	4	0
			SUM	595	424
			W_r =		424
			Critical Value =		328

Reject the null hypothesis - the survey unit meets the release criterion.

S-Survey Unit
R-Background Reference Area

Table 14 Room 1613 Upper Wall Gross Beta WRS Test Summary Table

DCGL = 3.70E+06 dpm/100 cm^2 Gross Beta

Survey Point	DATA dpm/100 cm^2	AREA	ADJUSTED DATA	RANKS	REFERENCE AREA RANKS
1	3968.3	R	3703968.3	28	28
2	4170.9	R	3704170.9	33	33
3	3951.4	R	3703951.4	26	26
4	3816.3	R	3703816.3	23.5	23.5
5	3807.8	R	3703807.8	22	22
6	3740.3	R	3703740.3	19	19
7	4103.3	R	3704103.3	29	29
8	3774.1	R	3703774.1	20	20
9	3790.9	R	3703790.9	21	21
10	3816.3	R	3703816.3	23.5	23.5
11	4145.6	R	3704145.6	30	30
12	4154.0	R	3704154.0	31	31
13	4162.4	R	3704162.4	32	32
14	3959.8	R	3703959.8	27	27
15	3934.5	R	3703934.5	25	25
16	4314.4	R	3704314.4	34	34
A2	4821.0	S	4821.0	10	0
B2	5488.0	S	5488.0	16	0
C2	6383.0	S	6383.0	18	0
D2	4804.1	S	4804.1	9	0
E2	4246.9	S	4246.9	2	0
F2	4863.2	S	4863.2	12	0
G2	5808.8	S	5808.8	17	0
H2	4694.4	S	4694.4	8	0
I2	4559.3	S	4559.3	5	0
J2	4491.7	S	4491.7	3	0
K2	5065.9	S	5065.9	14.5	0
L2	4947.7	S	4947.7	13	0
M2	4601.5	S	4601.5	7	0
N2	4593.0	S	4593.0	6	0
O2	4145.6	S	4145.6	1	0
P2	5065.9	S	5065.9	14.5	0
Q2	4517.1	S	4517.1	4	0
R2	4854.8	S	4854.8	11	0
			SUM	595	424
			W_{r} =		424
			Critical Value =		328

Reject the null hypothesis - the survey unit meets the release criterion.

S-Survey Unit
R-Background Reference Area

Table 15 Room 1613 Ceiling Survey Unit Gross Beta WRS Test Summary Table

DCGL = 3.70E+06 dpm/100 cm^2 Gross Beta

Survey Point	DATA dpm/100 cm^2	AREA	ADJUSTED DATA	RANKS	REFERENCE AREA RANKS
1	8384.0	R	3708384.0	19	19
2	8637.3	R	3708637.3	26	26
3	8713.3	R	3708713.3	30	30
4	8671.1	R	3708671.1	28	28
5	8460.0	R	3708460.0	21	21
6	8578.2	R	3708578.2	24	24
7	8612.0	R	3708612.0	25	25
8	8536.0	R	3708536.0	22	22
9	8400.9	R	3708400.9	20	20
10	8831.5	R	3708831.5	32	32
11	8730.2	R	3708730.2	31	31
12	8654.2	R	3708654.2	27	27
13	8552.9	R	3708552.9	23	23
14	8679.5	R	3708679.5	29	29
15	8983.5	R	3708983.5	34	34
16	8873.7	R	3708873.7	33	33
A1	9110.1	S	9110.1	15	0
A2	9253.6	S	9253.6	18	0
A3	8569.7	S	8569.7	6	0
A4	9169.2	S	9169.2	16.5	0
A5	9084.8	S	9084.8	13.5	0
B1	9034.1	S	9034.1	12	0
B2	8671.1	S	8671.1	8	0
B3	8367.1	S	8367.1	2	0
B4	9025.7	S	9025.7	11	0
B5	8654.2	S	8654.2	7	0
C0	8333.3	S	8333.3	1	0
C1	9169.2	S	9169.2	16.5	0
C2	8493.8	S	8493.8	5	0
C3	8434.7	S	8434.7	3	0
D0	9017.2	S	9017.2	10	0
D1	9084.8	S	9084.8	13.5	0
D2	8823.0	S	8823.0	9	0
D3	8460.0	S	8460.0	4	0
			SUM	595	424
			W_r =		424
			Critical Value =		328

Reject the null hypothesis - the survey unit meets the release criterion.

S-Survey Unit
R-Background Reference Area

10.1.4 Swipe Measurements for Removable Gross Alpha/Beta Activity

Swipe samples were conducted in all of the survey units to identify removable alpha and beta contamination activity. Each swipe covered an area of 100 cm^2. Although swipe measurements cannot be used to quantify the total surface activity, swipe measurements can indicate the presence of loose surface activity and its removable fraction. As a rule, if the removable fraction of the total surface activity is 10%, the loose surface alpha and beta levels should not exceed approximately 10% of the release criteria.

Appendix H provides the swipe results. All of the swipe measurement results were less than the minimum detectable activity (MDA) of the counting system.

10.2 Room 1613 Lab Cabinets/Drawers/Shelves/Counter Tops Surveys

10.2.1 Alpha/Beta Scan Surveys of Lab Cabinets/Drawers/Shelves/Counter Tops, Analysis and Results

No elevated areas of activity distinguishable above background levels were detected during the scan surveys.

10.2.2 Fixed Alpha Measurements of Lab Cabinets/Drawer/Shelves/Counter Tops, Analysis and Results

Release surveys were performed on the cabinets, drawers, shelves, and counter tops that were located in Room 1613. 2-minute direct measurements were taken on each item and compared directly to the release limit. The alpha survey data was converted to units of dpm per 100 cm^2 so the results could be compared directly to the release criteria. Table 6 presents a summary of the instruments used to evaluate alpha surface activities and the efficiencies used to convert instrument readings to DCGL units. Table 6 also provides a summary of instrument sensitivities and the release criteria. The gross alpha release criterion for the radionuclide of concern was 1,000 dpm per 100 cm^2. All of the survey results were less than the release criteria.

Alpha results are provided in Appendix I.

Table 16 presents a summary of the surveys of the cabinets/drawers/shelves, and counter tops.

Appendix M presents pictures of the cabinets/drawers/shelves, and counter tops.

10.2.3 Fixed Beta Measurements of Lab Cabinets/Drawers/Shelves/Counter Tops, Analysis and Results

Release surveys were performed on the cabinets, drawers, shelves, and counter tops that were located Room 1613. 2-minute direct measurements were taken on each piece of equipment and compared directly to the release limit. The beta survey data was converted to units of dpm per 100 cm^2 so the results could be compared directly to the release criteria. Table 6 presents a summary of the instruments used to evaluate beta surface activities and the efficiencies used to convert instrument readings to DCGL units. Table 6 also provides a summary of instrument sensitivities and the release criteria. The gross beta release criterion for the radionuclide of concern was 5,000 dpm per 100 cm^2. All of the survey results were less than the release criteria.

Beta results are provided in Appendix I.

Table 16 presents a summary of the surveys of the cabinets/drawers/shelves, and counter tops.

Appendix M presents pictures of the cabinets/drawers/shelves, and counter tops.

10.2.4 Swipe Measurements for Removable Gross Alpha/Beta Activity

Swipe samples were conducted on all of the cabinets/drawers/shelves/counter tops to identify removable alpha and beta activity. Each swipe covered an area of 100 cm^2. Although swipe measurements cannot be used to quantify the total surface activity, swipe measurements can indicate the presence of loose surface activity and its removable fraction. As a rule, if the removable fraction of the total surface activity is 10%, the loose surface alpha and beta levels should not exceed approximately 10% of the release criteria.

Appendix J provides the swipe results. All of the swipe measurement results were less than the minimum detectable activity (MDA) of the counting system.

Table 16 presents a summary of the surveys of the cabinets/drawers/shelves, and counter tops.

Appendix M presents pictures of the cabinets/drawers/shelves, and counter tops.

Table 16 Room 1613 Lab Cabinet/Drawers/Shelves/Counter Tops Survey Summary Table

Area/Location	Maximum Net Fixed Alpha Results in dpm/100cm^2	Maximum Net Fixed Beta Results in dpm/100cm^2	Maximum Net Removable Alpha Results in dpm/100cm^2	Maximum Net Removable Beta Results in dpm/100cm^2
Cabinets	11	167	4.5	41
Drawers	19	127	4.5	46
Shelves	-10	395	4.6	40
Counter Tops	23	926	0	256

10.3 Room 1613 Lab Fume Hood/Vent Ducts/Sink Drains Surveys

10.3.1 Alpha/Beta Scan Surveys of Lab Fume Hood/Vent Duct/Sink Drains, Analysis and Results

No elevated areas of activity distinguishable above background levels were detected during the scan surveys.

10.3.2 Fixed Alpha Measurements of Lab Fume Hood/Vent Ducts, Analysis and Results

Release surveys were performed on the fume hood, vent ducts, and sink drains that were located in Room 1613. 2-minute direct measurements were taken on each piece of equipment and compared directly to the release limit. The alpha survey data was converted to units of dpm per 100 cm^2 so the results could be compared directly to the release criteria. Table 6 presents a summary of the instruments used to evaluate alpha surface activities and the efficiencies used to convert instrument readings to DCGL units. Table 6 also provides a summary of instrument sensitivities and the release criteria. The gross alpha release criterion for the radionuclides of concern was 1,000 dpm per 100 cm^2. All of the survey results were less than the release criteria.

Alpha results are provided in Appendix K.

Table 17 presents a summary of the surveys of the fume hood, vent ducts, and sink drains.

Appendix M presents pictures of the fume hoods, vent ducts, and sink drains.

10.3.3 Fixed Beta Measurements of Lab Fume Hood/Vent Duct/Sink Drains, Analysis and Results

Release surveys were performed on the fume hoods, vent ducts, and sink drains that were located in Room 1613. 2-minute direct measurements were taken on each piece of equipment and compared directly to the release limit. The beta survey data was converted to units of dpm per 100 cm^2 so the results could be compared directly to the release criteria. Table 6 presents a summary of the instruments used to evaluate beta surface activities and the efficiencies used to convert instrument readings to DCGL units. Table 6 also provides a summary of instrument sensitivities and the release criteria. The gross beta release criterion for the radionuclide of concern was 5,000 dpm per 100 cm^2. All of the survey results were less than the release criteria.

Beta results are provided in Appendix K.

Table 17 presents a summary of the surveys of the fume hood, vent ducts, and sink drains.

Appendix M presents pictures of the fume hoods, vent ducts, and sink drains.

10.3.4 Swipe Measurements for Removable Gross Alpha/Beta Activity

Swipe samples were conducted on all of the fume hood/vent ducts/sink drains to identify removable alpha and beta activity. Each swipe covered an area of 100 cm2. Although swipe measurements cannot be used to quantify the total surface activity, swipe measurements can indicate the presence of loose surface activity and its removable fraction. As a rule, if the removable fraction of the total surface activity is 10%, the loose surface alpha and beta levels should not exceed approximately 10% of the release criteria.

Appendix L provides the swipe results. All of the swipe measurement results were less than the minimum detectable activity (MDA) of the counting system.

Table 17 presents a summary of the surveys of the fume hoods, vent ducts, and sink drains.

Appendix M presents pictures of the fume hoods, vent ducts, and sink drains.

Table 17 Room 1613 Lab Fume Hood/Vent Ducts/Sink Drains Survey Summary Table

Area/Location	Maximum Net Fixed Alpha Results in dpm/100cm^2	Maximum Net Fixed Beta Results in dpm/100cm^2	Maximum Net Removable Alpha Results in dpm/100cm^2	Maximum Net Removable Beta Results in dpm/100cm^2
Fume Hoods	35	429	-0.9	36
Vent Ducts	51	429	10	25
Sink Drains	14	679	-2.6	352

11.0 CONCLUSION

Statistical tests were used to determine if the residual radioactivity levels in the survey units of Room 1613 in Building 5 met the release criterion or did not exceed natural background radiation levels. The survey and sampling data both show that the residual radioactivity in Room 1613 in Building 5 is less than the release criteria, and is similar to the background levels of radioactivity for a similarly constructed room, and that there is no evidence of small areas of elevated activity. In addition, equipment/items located in Room 1613 of Building 5 that were surveyed were also less than the release criteria and should be considered as released for unrestricted reuse.

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