New World Technology

FINAL REPORT

PICATINNY ARSENAL
RADIOLOGICAL REMEDIATION/RELEASE SURVEYS AND SAMPLING PROJECT

Project No. USA 99-109

Revision 4
September 27, 2006

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NEW WORLD TECHNOLOGY

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Approvals,

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Bill Haney
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ACRONYMS AND ABBREVIATIONS

α	Alpha
AFSC	U.S. Army Field Support Command
AOC	Areas of concern
ALARA	As Low As Reasonably Achievable
ARDEC	Armaments Research, Development & Engineering Center
β	Beta
B	Background counts
Ba^{133}	Barium-133
bgs	below grade surface
b_i	Background counts in counting interval
Bi^{214}	Bismiuth-214
Bkg	background
cal	Calibration
cm	Centimeter
cm^2	square centimeter
cpm	counts per minute
C^{14}	Carbon-14
Cs^{137}	Cesium-137
Co^{60}	Cobalt-60
DAC	Derived Air Concentration
DCGL	Derived Concentration Guideline Limit
$DCGL_W$	Derived Concentration Guideline Limit (Weighted)
$DCGL_{EMC}$	Derived Concentration Guideline Limit (Elevated Measurement Comparison)
DOT	Department Of Transportation
dpm	disintegrations per minute
$dpm/100cm^2$	disintegrations per minute per 100 square centimeters
DQO's	Data Quality Objectives
DU	Depleted Uranium
eff	Efficiency
ε_i	Instrument efficiency
ε_s	Surface efficiency factor
F	Relative fraction
FOP	Field Operating Procedures
FSS	Final Status Survey
Ft	Feet
Ft^2	Square feet
g	Gram
H_o	Null Hypothesis
H^3	Hydrogen-3 (Tritium)
inst	Instrument
IAW	In Accordance with
ISO	International Organization for Standardization
LBGR	lower bound of gray region
LLD	Lower Level of Detection
LSC	Liquid Scintillation Counting
m	Meters
m^2	Square meter
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual

MDA	Minimum Detectable Activity
MDC	Minimum Detectable Concentration
MDCR	Minimum Detectable Count Rate
mCi	Millicurie
mm	Millimeter
mrem	Millirem
mrem/yr	Millirem per year
N/A	Not applicable
NaI	Sodium iodide
NIST	National Institute of Standards and Technology
NMSS	Nuclear Regulatory Commission Office of Nuclear Material Safety and Safeguards
Np^{237}	Neptunium-237
NRC	Nuclear Regulatory Commission
NUREG	Nuclear Regulatory Guide
NWT	New World Technology, Inc.
ORISE	Oak Ridge Institute for Science and Education
Pb^{214}	Lead-214
pCi	Picocurie
ppm	parts per million
Pu^{238}	Plutonium-238
Pu^{239}	Plutonium-239
NWT	New World Technology
OSC	Operations Support Command
Ra^{226}	Radium-226
Δ/σ	Relative shift
RESRAD	Residual radioactivity
RPO	Radiation Protection Officer
RWP	Radiation Work Permit
σ	Standard deviation
S_i	minimum detectable number of net source counts in the counting interval
Sign P	the estimated probability that a random measurement from the survey unit will be less than the DCGL when the survey unit median is actually at the LBGR
S/N	Serial Number
SOP	Standing Operating Procedure
Sr^{90}	Strontium-90
t	Count time
$Tc^{99`}$	Technetium-99
TCLP	Toxicity Characteristic Leaching Procedure
TEDE	total effective dose equivalent
Th-nat	Natural Thorium
Th^{230}	Thorium-230
Th^{232}	Thorium-232
Type I Error	False negative error
Type II Error	False positive error
U^{234}	Uanium-234
U^{235}	Uranium-235
U^{238}	Uranium-238 (Depleted Uranium)
USAEHA	United States Army Environmental Hygiene Agency
USACHPPM	US Army Center for Health Promotion Preventive Medicine
USA	U.S. Army
μR/hr	microroentgen per hour
μCi	microcurie
ZnS(Ag)	Silver activated zinc sulfide

$Z_{1-\alpha}$	percentile represented by selected value of $\alpha = 0.05$
$Z_{1-\beta}$	percentile represented by selected value of $\beta = 0.05$

1.0 INTRODUCTION

New World Technology (NWT) was contracted by the U.S. Army Operations Support Command (OSC) to perform characterization and Final Status Surveys, license termination surveys, as well as remediation and removal of contaminated items at the Armaments Research, Development & Engineering Center (ARDEC), Picatinny Arsenal, NJ. This included:

- Closeout survey to support license termination for Bunker 3030.
- Closeout survey for the following: Magazine 3018, Bldg. 167 (basement, 1st floor and fenced area behind Bldg 167).
- Characterization surveys for the Gorge Area (slug butts and detonation pit area).
- Remediation, waste disposal, and closeout of contaminated items in Bldg. 315.
- Characterization surveys of the Dog Pound Area.

The work was performed by NWT personnel in October/November of 2001 and June of 2002.

Site activities were performed under reciprocity with the Nuclear Regulatory Commission (NRC) or equivalent agreement state regulatory agency under NWT's California Radioactive Materials License # 5363-01.

A copy of NWT's Radioactive Material License and associated reciprocity documentation are provided in Volume 1, Appendix A of this report.

2.0 PROJECT SCOPE/PURPOSE

The objectives of the project are summarized in Table 1 below:

Table 1 Project Summary Table

AREA	SCOPE
Bunker 3030	Final Status Survey
Magazine 3018	Final Status Survey
Building 315	Remediation of salt fog chamber, contaminated ductwork, and plugged drain. Radiological investigation of plugged drain line with loose surface contamination survey.
Building 167 and Grounds (Fenced in Area, Perimeter ,and Area across Kibler Road)	Remediation and Final Status Surveys of Building 167 Interior, and Fenced In Area Behind Building 167
Dog Pound Area	Characterization Surveys and Sampling
Gorge Area	Characterization Surveys and Sampling of Slug Butt (#1222G) and Detonation Pit Areas Scoping Survey of Slug Butt (#1242A)

3.0 BACKGROUND INFORMATION

3.1 BUNKER 3030

Bunker 3030 may have contained Uranium-238 and Uranium-235, Cesium-137, Tritium and other possible radionuclides as contaminates. Picatinny Arsenal personnel wanted this area to be released for unrestricted use. The area was once used to store radioactive munitions, an irradiator, and special nuclear material. This bunker is to be determined to be free of radioactive contamination and released for unrestricted use, and demonstrate compliance with the license termination criteria as set by the NRC. This bunker was used for radioactive waste storage in the late 1970's.

Items of note:

- The bunker has housed uranium-238 (U-238), uranium-235 (U-235), and depleted uranium (DU).

- The U-235 was stored in 3 drums. The drums were surveyed quarterly. None of the wipe test samples indicated removable radioactive contamination which exceeded the minimum detectable activity (MDA).

- A special NRC Type B license (number SUB-348 covering DU and thorium) was used to store DU in this facility. This license will remain valid after the Final Status Survey.

- The NRC license SNM-561 covering storage of the special nuclear material (U235, Np237, Pu238, and Pu-239) will be terminated once this facility is determined to be able to be released for unrestricted use.

- A lead shielded irradiator contained Cs-137 (The NRC Radiography license 29-00047-06 covers the Co-60 and Cs-137 sources). The irradiator was surveyed quarterly for leakage. No wipe test samples indicated removable radioactive contamination which exceeded the MDA.

- Fluid contaminated with H-3 was stored here. The fluid was contained in a 5-gallon pail which has been shipped off-post for disposal. This material was covered under the NRC license 29-0047-02. This license will not be terminated.

- Liquid scintillation (LS) wipe test samples performed by a Health Physicist from the Radiation Protection Office did not indicate any removable contamination above the minimal detectable activity (MDA).

- The dimensions of this survey unit are: 4.0 m x 6.0 m x 3.0 m.

3.2 MAGAZINE 3018

Magazine 3018 may have contained residual contamination from the following radionuclides: C-14, Th-232, U-238, DU, and H-3. Secondary explosives without primers or fuses were currently stored in this magazine and were removed at the time of the Final Status Survey.

Items of note:

- Explosives were stored here that were tagged with C-14.

- This material was licensed under the NRC Broadscope License Number 29-00047-02 for radionuclides with atomic numbers from 3-83.

- This magazine at one time housed the following radionuclides: Th-232, U-238, DU, and H-3.
- Liquid scintillation (LS) wipe test samples conducted by a Health Physicist from the Radiation Protection Office at Picatinny Arsenal did not indicate any removable contamination above the minimal detectable activity (MDA).
- Secondary main charge explosives without primers or fuses were stored in this magazine and were removed at the time of the Final Status Survey.
- The dimensions of this survey unit are: 4.0 m x 6.0 m x 3.0 m.

3.3 BUILDING 315

Building 315 housed a salt fog chamber, contaminated ductwork and a plugged drain. These items required decontamination or disposal. ARDEC requested the following items and areas prepared for free release:

- Salt Fog Chamber. This instrument was used for corrosion studies of DU munitions. This item was believed to be contaminated with DU. ARDEC wanted this device to be shipped off site for disposal. The MSDS for this device (sodium chloride) was available. There was no previous pre-release survey information available for the salt fog chamber. The dimensions of this survey unit were 1.5 m x 1.2 m x 1.2 m.
- Contaminated Duct. This 6" diameter duct extended approximately 5' from the ceiling into the room. ARDEC requested that the duct be removed near the ceiling and the remaining piece capped off to contain any potential contamination. This item was believed to be contaminated with DU. There was no previous survey information available for the duct. The dimensions of this survey unit were 0.15 m diameter cylinder x 1.5 m length.
- Plugged Drain. Previously, a drain that had been tiled over was discovered when the tile above it was cracked. ARDEC wanted the area decontaminated or the drain and tile removed for disposal as deemed appropriate. This item was believed to be contaminated with DU. the dimensions of this survey unit was calculated to be a 0.15 m diameter cylindrical pipe and 0.3 m x 0.3 m tile. It was not known how far the contamination extended into the drain or if it was merely located on the surface.

3.4 BUILDING 167 INTERIOR

The entire building (basement and ground floor) was to be surveyed and released for unrestricted use.

Items of note:

- The first floor of this building contained the hot lab, semi-hot lab and the 250-Curie Cesium-137 Gamma Irradiator as seen in the enclosed building 167 generalized first floor plan (Figure 1) and proposed sample location and enclosed layout depicting the hot lab, semi-hot lab and proposed location for the 250-Curie Cesium-137 Gamma Irradiator (Figure 2). The basement was a radioactive material storage area for sealed and unsealed sources.

- The estimated dimensions were: Basement at 10.0 m x 10.0 m x 2 m; and first floor at 10.5 m x 10.5 m x 3 m.

- Based on the following document, *CHPPM Historical Records Review, Volume 2, No. 27-MH-7799-98, Work Plan, Part 1, Relative Risk Site Evaluation No. 38-EH-5690-97, 22 Jun – 2 Jul 97*, the potential radioisotopes used inside of Building 167 could have included alpha, beta and gamma radiation emitters.

- Isotopic analysis of soil outside the building indicated that Barium-133 (Ba-133) could have been involved.

- As evidenced by the prior liquid wastes collected, and based upon gamma spectroscopy results of water samples, the following radioisotopes could have been used inside of Building 167:

Tritium (H-3)	Radium-228 (Ra-228)
Strontium-90 (Sr-90)	Cesium-137 (Cs-137)
Radium-226 (Ra-226)	Carbon-14 (C-14)
Thorium-232 (Th-232)	

NOTE: Based on historical survey files, the minimal presence of radionuclides such as barium-133, chlorine-36, europium 152-154, iodine-129, iron-59, lead-219, phosphorous-32, nickel-63, ruthenium 103, cerium 144, scandium-46, silver-110, cobalt-60, sodium-22, sulfur-35, thallium-204, and zirconium-95 not mentioned above, would have a very minimal affect on the results of the final status surveys performed.

Figure 3 presents a map of the room numbers designated for the surveys.

Figure 1 Building 167 First Floor Layout (During Operations)

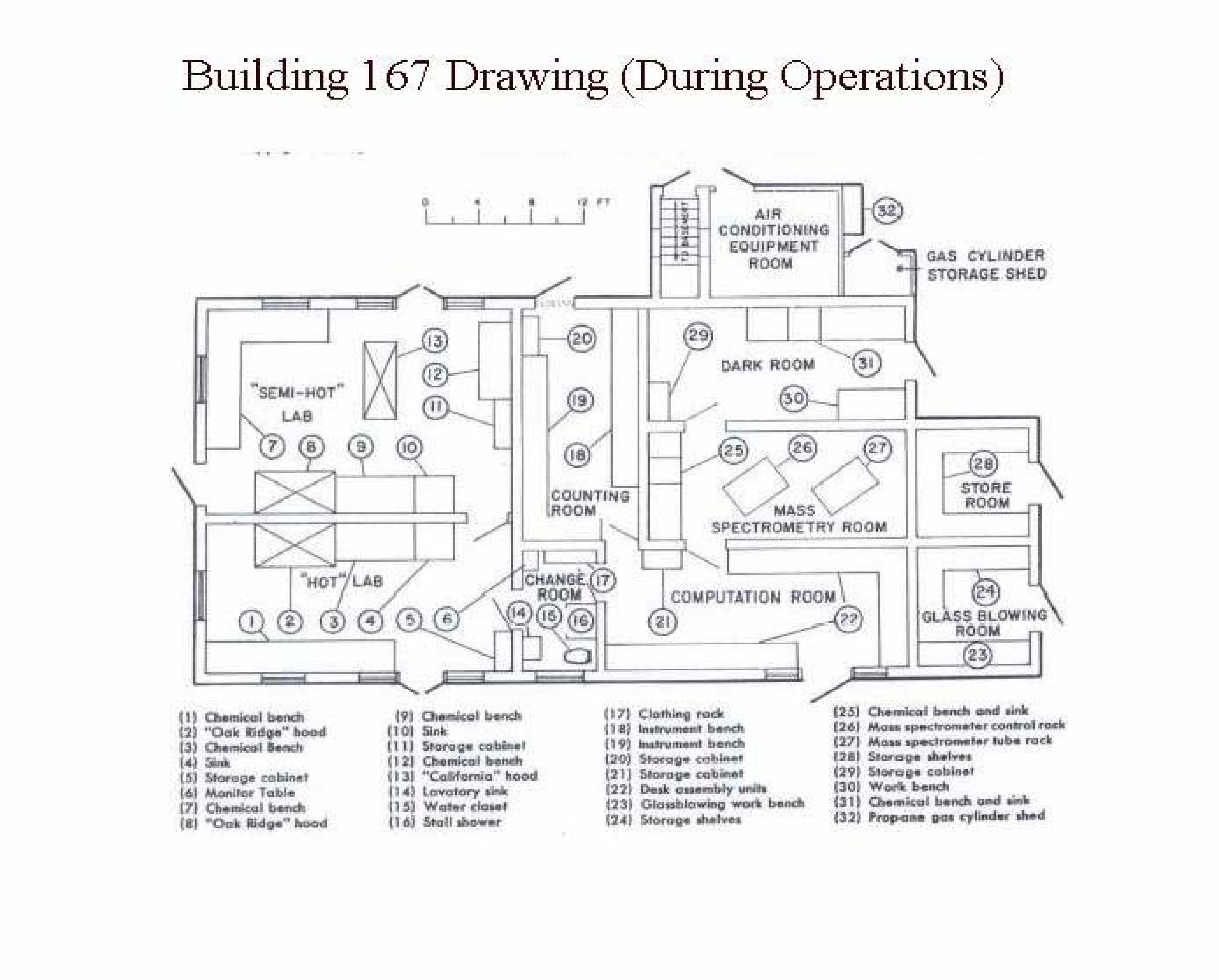


Figure 2 Building 167 Proposed Location of Cs-137 Gamma Irradiator

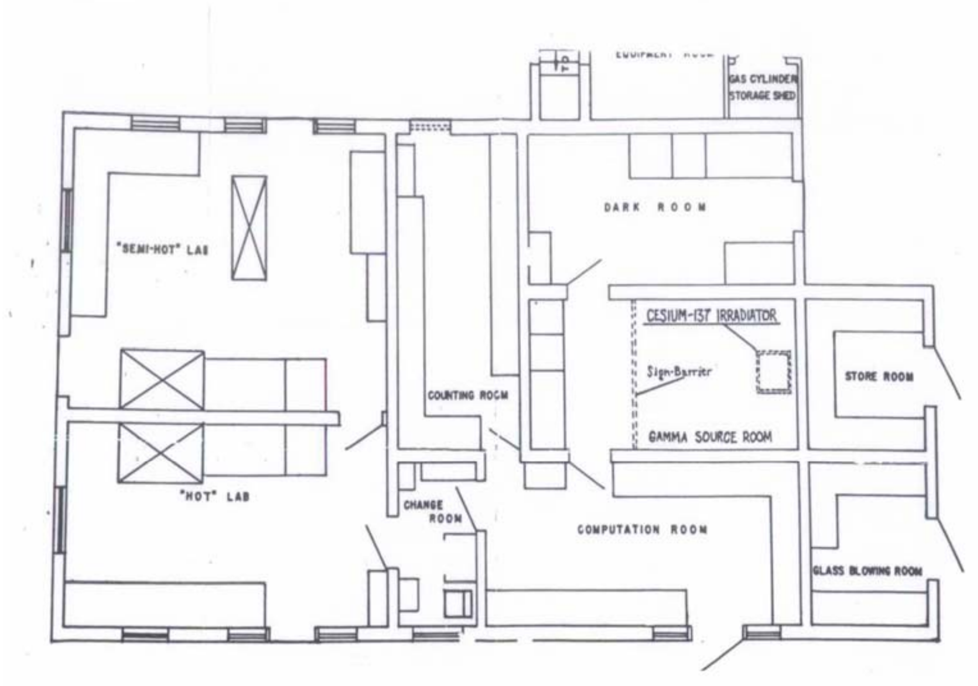
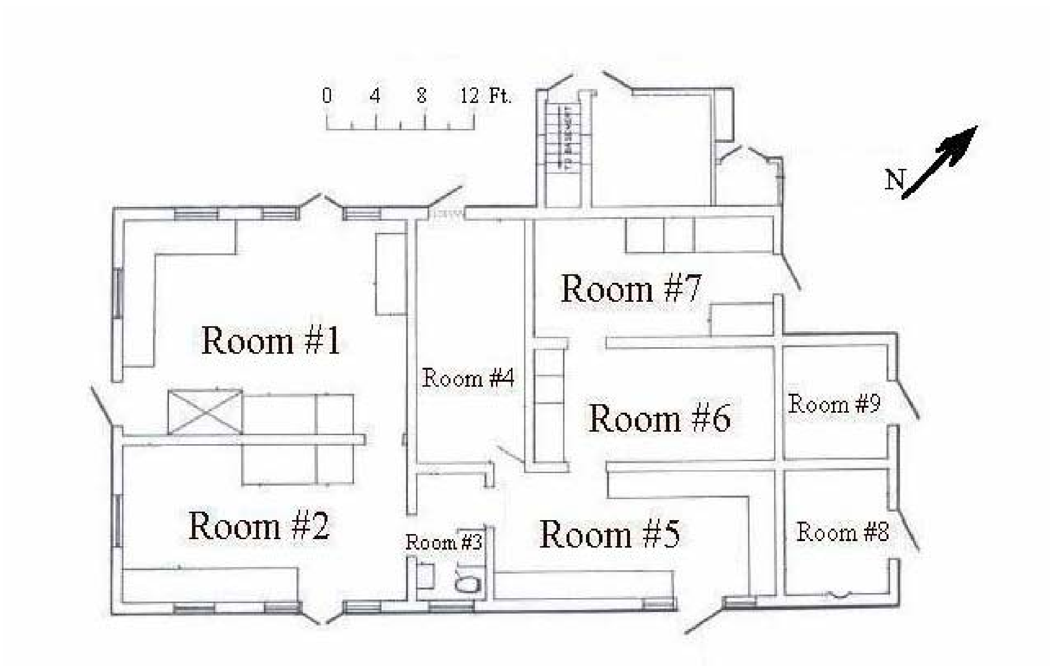


Figure 3 Building 167 Room Number Designations



3.5 BUILDING 167 EXTERIOR GROUNDS (IMMEDIATELY ADJACENT TO BUILDING 166 SOUTHEAST WALL)

This area was contaminated with Barium-133.

Items of note:

- The U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) conducted surveys on the fenced-in area adjacent to the building (*USACHPPM Report 27-MH-5690-97*). This area was contaminated with Barium-133 (Ba-133). The highest concentration was 246 ± 2 picocuries per gram (pCi/g). The report also stated that the migration pathway factor was "confined" due to the localized nature of the contamination which has been limited to approximately 2 cubic meters (m^3) over a 20 year period.

- This area was located adjacent to the southeast wall of Building 166 behind Building 167.

- The dimensions of this survey unit are 3 m x 2 m.

3.6 BUILDING 167 EXTERIOR GROUNDS (ACROSS KIBLER RD)

USACHPPM conducted a Historical Records Review (*USACHPPM Volume 2, No. 27-MH-7799-98*). That report states that there was a caged area that was used to store radioactive wastes generated from Building 167. This area (Figure 4) was across Kibler Rd. from Building 167 on the southeastern side of the building. The existence of the site was determined from photographic evidence in an archived technical journal article. In the background of the photograph (Figure 5), Building 172 can be seen.

ARDEC personnel requested that this area be surveyed and sampled.

The dimensions of this survey unit are 20 m x 40 m, and 10 m x 10 m.

Figure 4 Area Across Kibler Road

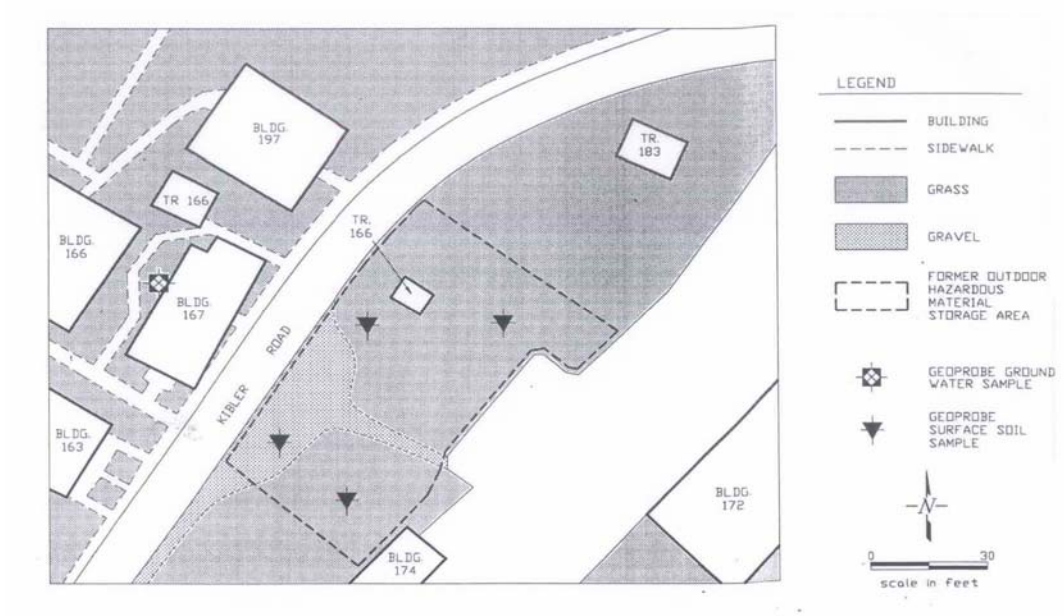
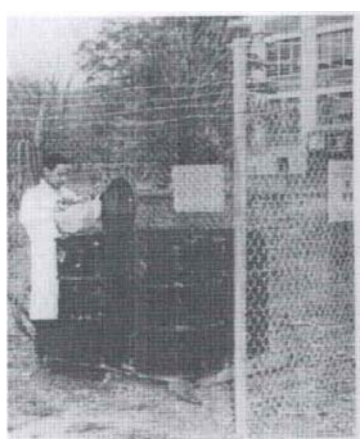


Figure 5 Picture of Area across Kibler Road



3.7 BUILDING 167 EXTERIOR GROUNDS (AROUND ENTIRE PERIMETER OF BUILDING)

ARDEC personnel requested that this area be surveyed and sampled.

The dimensions of this survey unit are: 10 m x 40 m, and 10 m x 10 m.

3.8 DOG POUND AREA

The Dog Pound Area had the highest concentration of contamination due to the presence of natural thorium (Th-232) from the coal clinkers that had been stored there. It was discovered to be contaminated during a 1997 USACHPPM survey (*USACHPPM Report No. 27-MH-5690-97*).

Items of note:

- The area was contaminated with coal “clinkers”. The USACHPPM did not find any contamination levels of radioactive materials that posed a health hazard to the general public.
- Other than the USACHPPM report, there was no other survey information available for this area. Elevated readings of 30 microroentgens per hour (μR/hr) were found during the 1997 USACHPPM survey at 1 m from the surface. The highest concentration of contamination was 13.0 pCi/g from natural thorium in the coal clinkers.
- ARDEC personnel requested this area be surveyed and sampled for unrestricted release to demonstrate compliance with the license termination criteria set by the NRC.
- This area was cleared of brush and weeds by Picatinny Arsenal personnel prior to the survey being conducted. Precautions were taken to avoid tick infestation.
- There was no physical evidence of the presence of the coal clinkers prior to NWT’s surveys in this area.
- The approximate dimensions of this survey unit were 80 m x 10 m.

3.9 GORGE AREA

The detonation pit in the gorge area was used to detonate a limited number of mines containing small quantities of DU. NWT coordinated with the personnel at Picatinny Arsenal so that all pertinent standing operating procedures (SOPs) dealing with unexploded ordnance (UXO) were adhered to and ARDEC was represented by the appropriate personnel. NWT had certified EOD technician coverage for all work in this area.

Items of note:

- The Open Detonation Pit was used for detonation of munitions and as a demilitarization area. It was used to detonate a limited number of mines containing small quantities of DU. A USACHPPM survey done of the area

(*USACHPPM Report No. 27-43-EQ86-93*) detected no concentrations of DU exceeding the MDA.

- Other than the USACHPPM Report there was no other previous survey information for the open detonation pit.
- The sand in the detonation pit tested above the TCLP limit for lead. It will not be disposed of until DU results are obtained and screening values demonstrate compliance with the license termination criteria set by the NRC for free release for unrestricted use.
- ARDEC personnel requested this area be surveyed and sampled for unrestricted release to demonstrate compliance with the license termination criteria set by the NRC.
- NWT EOD/UXO certified personnel coordinated their sweeps with ARDEC EOD/UXO experts for removal of any identified UXO.
- The dimensions of this survey unit were 40 m x 60 m, and 10 m x 60 m.

3.10 SLUG BUTTS

3.10.1 Slug Butt on Hill Near Detonation Pit Area (Slug Butt # 1222G)

This area was used as a catch box for 30, 50 caliber, and 40mm rounds. No 120mm or 105mm rounds have ever been fired into this catch box.

Items of note:

- No ARDEC personnel can remember any DU rounds being shot into the slug butt.
- No other survey information existed for the slug butt.
- The approximate dimensions for this survey unit are: 6 m x 6 m x 6 m deep.
- NWT coordinated activities with the proper personnel at Picatinny Arsenal so that all pertinent standing operating procedures (SOPs) dealing with explosives and unexploded ordnance (UXO) was adhered to and that the appropriate personnel represented ARDEC. NWT provided certified EOD/UXO technician coverage for all work in this area.

3.10.2 Slug Butt On Hill In Wooded Area (Slug Butt # 1242A)

No background formation was available at the time of the survey on the use of this slug butt.

Items of note:

- ARDEC personnel requested a scoping survey be performed on the interior ground surfaces of the slug butt.
- No ARDEC personnel can remember any DU rounds being shot into the slug butt.
- No other survey information existed for the slug butt.
- The approximate dimensions for this survey unit were: 4.2 m x 2 m x 9 m deep.

3.11 CERTIFIED OFFSITE LABORATORIES

NWT chose Severn Trent Laboratories of Earth City, MO and Paragon Analytics of Fort Collins, CO as their offsite laboratories. These laboratories were chosen because they are participants in the National Environmental Laboratory Accreditation Program (NELAP) and are of national reputation.

These laboratories are also certified by the State of New Jersey to perform the analytical work that was required during the project.

The laboratories certifications and associated paperwork are provided in Volume 1, Appendix B of this report.

3.12 SITE CONDITIONS AT TIME OF FINAL STATUS SURVEYS

3.12.1 Building 315 Corrosion Test Lab, Restroom

Building 315 was occupied with personnel when the Salt Fog Chamber and ventilation ductwork was removed.

3.12.2 Magazine 3018

Magazine 3018 contained secondary main charge explosives without primers. These items were removed at the time of the Final Status Survey.

3.12.3 Bunker 3030

Bunker 3030 contained shelving and miscellaneous items. These items were surveyed for free release and removed at the time of the Final Status Survey with the exception of the five steel plates found to be contaminated. Those steel plates were placed into the B-25 box that was shipped to the Environmental Management & Controls, Inc. (EMC)

Facility located in Turlock, California, a licensed and permitted waste reduction facility, for processing and eventual disposal at Envirocare Inc. of Utah.

3.12.4 Building 167 Ground Floor

The floor surfaces of the ground floor of Building 167 was littered with lead paint chips and cracked asbestos floor tiles and could not be surveyed during NWT's first site visit in October/November of 2001. The Final Status Surveys were completed in June of 2002 after the area had been cleared of the lead paint chips and the cracked asbestos floor tiles which had been bagged and temporarily stored in Building 167 for ultimate disposal until the extent of radiological contaminants could be determined to demonstrate compliance with the unrestricted release criteria developed by the NRC.

3.12.5 Building 167 Basement

The basement area of Building 167 was contaminated with friable asbestos insulation. No surveys were performed in the basement area of Building 167 during NWT's first site visit in October/November of 2001.

During NWT's second site visit in June of 2002 the asbestos had been removed from the basement floor and pipes. The basement floor was flooded with rainwater following a heavy thunderstorm. The water was pumped from the basement into two lined 55-gallon drums and the floor dried with fans prior to conducting the Final Status Surveys.

4.0 REMEDIATION/DECONTAMINATION ACTIVITIES

4.1 WASTE PROFILE SAMPLES

NWT personnel performed a site visit in September of 2001 to collect waste profile samples from the following areas:

- Dog Pound Area Soils
- Outside Area Soils Behind Building 167 (Directly Adjacent to Building 166 Southern Wall)
- Building 315 Salt Fog Chamber and Miscellaneous Bags of Dry Activated Waste

The samples were composited from the three areas.

The samples were sent to an offsite laboratory for analysis by gross alpha, gross beta, gamma spectroscopy, and TCLP analysis.

The laboratory data reports of the waste profile samples are provided in Volume 1, Appendix C this report. Appendix C does not contain any cross-reference to locations due to the fact that the samples from the various areas were composited.

4.2 BUILDING 167 FINAL STATUS SURVEY SUPPORT SAMPLES

Samples described in Sections 9.16, 9.17, 9.19, and 9.20 of this report, were obtained in June of 2002 in support of the Final Status Surveys of Building 167.

4.3 PREREQUISITES

Once office spaces, instrumentation, and equipment were mobilized and set up, dosimeters (TLD's) were issued to on site personnel to monitor external whole body radiation exposure.

TACOM/ARDEC personnel generated Radiation Work Permits (RWP's), which specified the activities to be performed, and all radiological safety requirements for the work. The RWP's also designated personal protective equipment (PPE) requirements for the specific tasks to be performed. All personnel assigned to the site work were required to read and understand the requirements prior to beginning work. Copies of the RWP's are provided in Volume 1, Appendix D of this report.

4.4 DAILY TAILGATE SAFETY MEETINGS

Daily tailgate safety meetings were held prior to work each day to discuss the planned activities for that day and address any safety/radiological concerns involved in that work. All NWT personnel attended these meetings. Copies of the safety meetings are archived at the NWT corporate office in Livermore, CA and are available for review upon request.

4.5 REMEDIATION/REMOVAL OF CONTAMINATED ITEMS FROM BUILDING 315

The electricity to the salt fog chamber was de-energized and all air and water connections were disconnected prior to removal of the salt fog chamber from the room inside of Building 315. Approximately 80 gallons of water was drained from the inside of the outer closed loop chamber of the salt fog chamber prior to its removal from the room inside Building 315. This water was collected into 55-gallon drums and then evaporated during the course of the project using drum heaters.

Loose items that were located inside of the salt fog chamber were placed inside of it, and secured using a plywood board to cover the opening at the top of the chamber. The plywood was then secured to the salt fog chamber with banding material.

The 6" vent duct was removed to above the penetration in the ceiling using hand tools. The ends of the removed vent duct were sealed to prevent the spread of contamination. The remaining portion of vent duct was also sealed to contain any contamination that may be present.

The salt fog chamber, removed vent duct, and five 40-gallon bags of trash were then removed from Building 315 and placed into a B-25 box for eventual shipment to Environmental Management & Controls, Inc. (EMC) Facility located in Turlock, California, a licensed and permitted waste reduction facility.

4.6 RADIOLOGICAL LOOSE SURFACE CONTAMINATION SURVEY OF ROOM #2, BUILDING 315

Following removal of the salt fog chamber, a loose surface contamination survey was performed inside of the room where the salt fog chamber was located. Results of the loose surface contaminations survey indicated no alpha/beta activity above Minimum Detectable Activity (MDA) levels i.e. 13 dpm/100cm^2 α, 110 dpm/100cm^2 $\beta\gamma$.

Gross alpha/beta counting of the swipes was performed using a Ludlum Model-2929 dual channel scaler.

Results of the loose surface contamination survey are provided in Volume 1, Appendix E of this report.

4.7 RADIOLOGICAL INVESTIGATION/SURVEY OF PLUGGED DRAIN LINE IN BUILDING 315

An investigation was conducted on the plugged drain line inside of the foyer leading into the restroom of Building 315. A cleanout cap along with surrounding broken pieces of tile were covered and taped to the floor with a labeled square piece of aluminum was present. Several attempts to remove the cleanout cap were made after the duct tape and aluminum square were removed. They were unsuccessful. A radiological survey was then performed on the exterior surface of the cleanout cap. No detectable activity above background radiation levels were found using a Ludlum Model-3 survey instrument with an attached Ludlum Model 44-9 thin window GM pancake detector.

Since radioactive material was not present during the time of NWT's survey it is assumed that the elevated readings, found at the time of the survey/monitoring performed by ARDEC personnel, were due to an aberrant hot particle that had somehow dislodged from the tile around the cleanout cap and adhered to the duct tape which was disposed of as radioactive waste.

4.8 REMOVAL OF CONTAMINATED ITEMS IN BUNKER 3030

While performing the release surveys of the miscellaneous items located inside Bunker 3030, five steel plates with holes in them were discovered to be contaminated up to levels of approximately 20,000 Net CPM. The survey was performed with a Ludlum Model-3 rate meter with an attached Model 44-9 thin window pancake GM detector. The five steel plates were placed into a B-25 box for disposal (See Section 3.12.2).

4.9 REMEDIATION OF CONTAMINATED SOIL BEHIND BUILDING 167

The Ba-133 contaminated soil was removed using hand shovels. The soil was then placed into the B-25 box (that contained the removed salt fog chamber) that was staged immediately adjacent to the work area. Approximately 13.5 cubic feet of soil was removed from this area.

Following removal of the contaminated soil, a 100% gamma surface scan survey was performed to determine if further soil removal was required.

The area was divided into six, 1-meter by 1-meter grids. A 100% gamma scan survey was then performed in each of the grids using a Ludlum Model 44-10 2" by 2" NaI detector coupled to a Ludlum Model 2350-1 Data Logger. The survey was performed by moving the detector in a serpentine pattern at a rate of approximately 1 foot per second with the detector within 4 inches of the surface being surveyed.

The highest reading in each grid was recorded on the appropriate survey form. The highest reading detected in any of the grids was 18,000 CPM. The results of the gamma scan surveys are provided in Volume 1, Appendix F of this report.

One soil sample was then obtained from each of the $1m^2$ grids and sent to an offsite laboratory for analysis by gamma spectroscopy for Ba-133. The highest soil concentration found in any of the grids was 6.0 pCi/g. The remaining samples were below 1.0 pCi/g. The results of the soil samples are provided in Volume 1, Appendix F of this report. Figure 6 and Figure 7 present maps of the grids and soil sample locations.

Figure 6 Area Behind Bldg. 167 Grid Layout

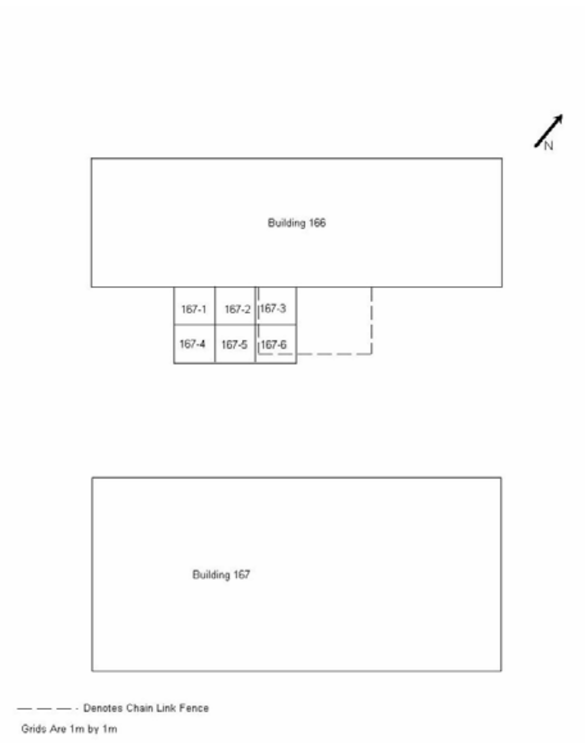
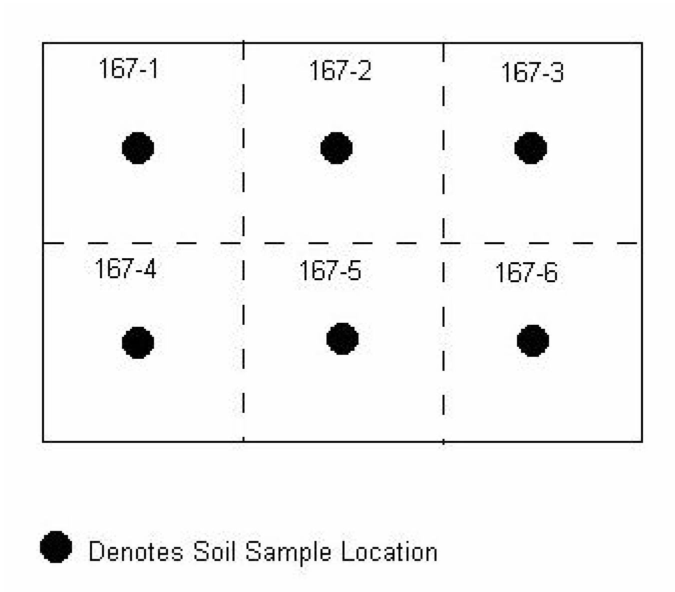


Figure 7 Area Behind Bldg. 167 Soil Sample Location



4.10 WASTE PACKAGING AND DISPOSAL

The waste volume of 96 cubic feet of material was packaged into one B-25 box during the course of the project. The B-25 box was surveyed, weighed, labeled and manifested in accordance with DOT regulations. A NWT OSC approved waste broker shipped the B-25 box to Environmental Management & Controls, Inc. (EMC) Facility located in Turlock, California, a licensed and permitted waste reduction facility, for processing and eventual disposal at Envirocare Inc. of Utah. Copies of the bill of lading and waste manifest for the B-25 box are provided in Volume 1, Appendix G of this report.

5.0 FINAL STATUS SURVEY/SAMPLING OBJECTIVE

5.1 SURVEY/SAMPLING OBJECTIVE

The purpose of the Final Status Survey and sampling effort was to provide data and documentation to demonstrate that the various buildings and areas surveyed were in compliance with the Nuclear Regulatory Commission established license termination criteria for the unrestricted use of Building 167 and grounds, Magazine 3018, Bunker 3030, and the characterization of the Dog Pound Area and the Gorge (Detonation Pit and Slug Butts).

5.2 CALCULATION OF DERIVED CONCENTRATION GUIDELINE LIMITS (DCGL'S) USING RESRAD-BUILD VERSION 3.2.2 AND RESRAD VERSION 6.3 DOSE MODELING CODES

5.2.1 Objective

The surface contamination release limits and the soil contamination release limits were selected to comply with the dose-based release criteria of 15-mrem/yr total effective dose equivalent (TEDE) and/or ALARA. The RESRAD-Build Version 3.22 and RESRAD Version 6.3 dose modeling codes were used to establish the DCGL's for building surfaces and soil on the project.

5.2.2 Qualification of the Site for Use of Screening Analysis in Accordance with the Requirements in Appendix H of NUREG-1757 Volume 2

The following describes the physical site and source-term conditions of the sites that qualify the sites for use of the screening approach to develop DCGL’s for building surfaces and soil:

Building Surface Residual Radioactivity:

- Based upon survey results, the residual radioactivity in Building 167, Bunker-3030, and Magazine-3018 surfaces (e.g., walls, floors, ceilings) is surficial and non-volumetric.
- Based upon survey results of Building 167, Bunker-3030, and Magazine-3018, there is no loose residual radioactivity that exceeds 10 percent of the total surface activity.
- The screening criteria was not applied to surfaces such as buried structures (e.g., drainage or sewer pipes) or equipment within any of the buildings.

Surface Soil Residual Radioactivity:

- Based upon survey and sampling results the residual radioactivity is contained in the top layer of the surface soil [e.g., approximately 15 cm (6 inches)].
- Based upon the geological makeup of the area and sample results the unsaturated zone and the ground water are free of residual radioactivity.
- The vertical saturated hydraulic conductivity at the specific site is greater than the infiltration rate.

Radionuclides of Potential Concern

Based on historical data and survey records the radionuclides of concern are carbon-14, tritium, cesium-137, neptunium-237, plutonium-238, plutonium-239, radium-226, strontium-90, thorium-232, uranium-235, and uranium-238. The RESRAD Build Version 3.22 calculations were based on these eleven radionuclides of potential concern. The RESRAD Version 6.22 calculations were based on barium-133 as the radionuclide of potential concern.

DCGL, Area Factor and $DCGL_{EMC}$ Value Determinations for Building Surfaces

The DCGL values were based on protecting future building occupants from a radiological target dose of 15 mrem/year Total Effective Dose Equivalent (TEDE). DCGL determinations were completed using the RESRAD-BUILD Version 3.22 model developed by Argonne National Laboratory to evaluate doses from exposure to radioactively contaminated buildings.

The $DCGL_{EMC}$ was calculated based on the grid area between direct measurement locations. The largest spacing interval in any of the survey units was 2 meters, which results in a grid area of 4 m^2. This value was used as the size of the area of contamination instead of the default value of 36 m^2 when calculating the $DCGL_{EMC}$ and area factors for each of the radionuclides of concern. The area factors were then computed by taking the ratio of the dose per unit concentration calculated by RESRAD Build Version 3.22 for the default 36 m^2 to that calculated for the 4 m^2 area. Therefore, if the guideline limit concentration for residual radioactivity distributed over 36 m^2 is multiplied by the area factor, the resulting concentration distributed over the specified smaller area results in the same average dose.

The primary assumptions used in the DCGL calculations were:

- Residual contamination covers the entire floor;
- The residual contamination is present on the floor, and is not shielded;
- An adult occupies the building 12-hours per day, 7-days per week, 52 weeks per year; and;
- The building occupant remains at a position one meter above the center of the floor in the center of the room while occupying the building.

The RESRAD-BUILD model input parameters, including site specific, literature, and default parameters are provided in Table 2.

All of the exposure pathways available in RESRAD-BUILD 3.22 were assumed open. The external exposure pathways were:

- Radiation from source;[1]
- Air submersion; and,

- Radiation from re-deposited material.[2]

[1] The radiation from the source is external exposure received directly from the source.

[2] The radiation from re-deposited material is external exposure received from radioactive dust particles deposited onto surfaces.

The internal exposure pathways were:

- Inhalation of radon progeny;
- Inhalation of airborne radioactive dust;
- Ingestion of deposited material; and,[1]
- Ingestion of removable radioactivity (direct ingestion of the source material)[2].

[1] Ingestion of deposited material is the ingestion of radioactive dust particulates deposited onto surfaces.

[2] Ingestion of removable activity is the ingestion of loose material directly from the volume source in the room containing the radionuclide.

Uncertainty Evaluation

RESRAD-BUILD Version 3.22 is a validated model that provides conservative dose estimations for most buildings. The potential Building 167, Magazine 3018, and Bunker 3030 contamination, building characteristics, and forecasted future use of these buildings are well within the predicted capabilities of RESRAD-BUILD 3.22.

Default values were used in the model.

Room height and room area default values were used. The default parameter values for source area, source/receptor geometry, receptor inhalation rate, source direct ingestion rate, and fraction of source released to air were used.

Default values, such as the indoor time fraction, air exchange rate, removable fraction of source, and time until source is completely eroded and removed, were used.

Because a validated model and conservative parameter values were used, the calculated DCGLs will likely result in actual doses to future building occupants well below the target doses.

DCGL, Area Factor, and $DCGL_{EMC}$ Calculation Results

The DCGL, Area Factor, and $DCGL_{EMC}$ results are summarized for each radionuclide in Table 3. The modeling results indicate that peak year doses occurred in the first year for all of the radionuclides. The RESRAD-BUILD Version 3.22 model inputs and outputs are presented in this report in Volume 3, Appendix JJ.

Table 2 RESRAD-BUILD INPUT PARAMETERS [a]

Parameter	Value
Number of sources	1
Number of receptors	1
Exposure duration (days)	365
Indoor time fraction	0.5[b]
Receptor location on x axis (meters)	6.0[c]
Receptor location on y axis (meters)	6.0[c]
Receptor location on z axis (meters)	1.0[c]
Fraction of time receptor spends at receptor location	1
Receptor inhalation rate (cubic meters / day)	18.0
Receptor ingestion rate of deposited dust (square meters / hour)	1.0E-4
Density of source shielding material (grams / cubic centimeters)	2.4
Thickness of source shielding material (centimeters)	0
Shielding material description	Concrete
Room air exchange rate (1 / hour)	0.8
Room height	2.5
Room area (square meters)	36
Particle deposition velocity (meters / second)	0.01
Particle resuspension rate (1 / seconds)	5.0E-7
Source location on x axis (meters)	6[d]
Source location on y axis (meters)	6[d]
Source location on z axis (meters)	0[d]
Source area (square meters)	36[e]
Source direction	Z[e]
Source direct ingestion rate (1 / hour)	0
Fraction of source released to air	0.1
Removable fraction of source	0.5
Time until source is completely eroded and removed (day)	365
Radon release fraction	0.1

Notes

a RESRAD-BUILD general default parameter unless otherwise specified.
b Fraction of time inside buildings based on 12 hour workday, 7 days per week, 52 weeks per year.
c Receptor located one meter above center of floor based on origin in center of room at floor level
d Sources were located on floor, in center of room based on origin in center of floor.
d Source areas were assumed equal to entire floor.
e Direction of line perpendicular to the exposed area of the source (straight up in direction of ceiling).

Table 3 RESRAD-BUILD Version 3.22 Calculation Summary Table

Radionuclide	DCGL in dpm/100cm^2	Resulting TEDE in mrem/year	$DCGL_{EMC}$ in dpm/100cm^2	Resulting TEDE in mrem/year	Area Factor
H^3	140,000,000 β	14	1,300,000,000 β	15	9.3
C^{14}	4,700,000 β	15	41,000,000 β	15	8.7
Cs^{137}	40,000 β	14	160,000 β	14	4.0
Np^{237}	64 α	15	580 α	15	9.1
Th^{232}	61 α	15	550 α	14	9.0
Pu^{238}	90 α	15	800 α	15	8.9
Pu^{239}	82 α	15	730 α	15	8.9
Ra^{226}	2,400 α	15	17,000 α	15	7.1
Sr^{90}	20,000 β	14	180,000 β	14	9.0
U^{235}	280 α	15	2600 α	15	9.3
U^{238}	290 α	14	2500 α	14	8.6

Surface contamination DCGLs apply to the total of fixed plus removable surface activity. For cases where the surface contamination is due entirely to one radionuclide, the DCGL for that radionuclide is used for comparison to the measurement data.

For situations where multiple radionuclides with their own DCGLs are present, a gross activity DCGL can be developed. This approach enables field measurement of gross activity, rather than determination of individual radionuclide activity, for comparison to the DCGL. The gross activity DCGL for surfaces with multiple radionuclides is calculated as follows:

1. Determine the relative fraction (f) of the total activity contributed by the radionuclide
2. Obtain the DCGL for each radionuclide present
3. Substitute the values of f and DCGL in the following equation:

$$\text{Gross Activity DCGL} = \frac{1}{\frac{f^1}{DCGL_1} + \frac{f^2}{DCGL_2} + \frac{f^3}{DCGL_3} + \frac{f^4}{DCGL_4} + \frac{f^5}{DCGL_5}}$$

For the purposes of the Final Status Surveys, the above equation was applied to the alpha emitting radionuclides. For the beta-gamma emitting radionuclides the most restrictive DCGL (20,000 dpm/100cm^2 for Sr-90) was employed.

The following equation was used for determining the alpha emitting radionuclides DCGL:

$$\frac{1}{\frac{.14285}{64_{\text{Np-237}}}+\frac{.14285}{61_{Th-232}}+\frac{.14285}{90_{Pu-238}}+\frac{.14285}{82_{Pu-239}}+\frac{.14285}{2400_{Ra-226}}+\frac{.14285}{280_{U-235}}+\frac{.14285}{290_{U-238}}} = 111 \text{ dpm/100cm}^2$$

NOTE: Since no site specific data was available on specific radionuclide concentrations, each of the alpha emitting radionuclides was assumed to be distributed in equal percentages.

DCGL Value Determinations for Ba-133 In Soil

The DCGL values were based on protecting future residents from a radiological target dose of 15 mrem/year Total Effective Dose Equivalent (TEDE). The DCGL calculations were completed using the RESRAD Version 6.3 model developed by Argonne National Laboratory to evaluate doses from exposure to radioactively open land areas. The primary assumptions used in the DCGL calculations were:

- The residual contamination zone covers the entire ground surface (6 m^2) in the area of concern;
- 48 pCi/g of Ba-133 was used as the input soil concentration value;
- The residual contamination is present in the top 15-centimeter of the surface, and is not shielded (thickness of contaminated zone);
- A density of 1.5 g/cm^3 was used as the input value for the density of the contaminated zone;
- The receptor is located in the center of the contaminated zone.

The open exposure pathways available in RESRAD-6.3 were:

- External gamma;

- Inhalation (without radon);
- Soil ingestion;
- Plant ingestion,
- Meat ingestion,
- Milk ingestion;
- Aquatic foods,
- Drinking water;

The suppressed exposure pathways available in RESRAD-6.3 were:

- Radon

The key parameters used in the “Resident Farmer” scenario are provided in Table 4.

Table 4 KEY PARAMETERS USED IN THE RESIDENT FARMER SCENARIO

Parameter	Unit	Resident Farmer
Exposure duration	yr	30
Inhalation rate[a]	m^3/yr	8,400
Fraction of time indoors[b]	-[c]	0.50
Fraction of time outdoors[d]	-	0.25
Contaminated fractions of food	-	
Plant food	-	0.5
Milk	-	1.0
Meat	-	1.0
Aquatic food	-	0.5
Soil Ingestion[e]	g/yr	36.5
Drinking water intake [f]	L/yr	510

[a] RESRAD assumes an average inhalation rate of 8,400 m^3/yr for the suburban resident scenarios.

[b] RESRAD assumes that the suburban resident spend 50% of their time inside on the contaminated site.

[c] A hyphen indicates that the parameter is dimensionless.

[d] RESRAD assumes that the suburban resident spend 25% of their time outside on the contaminated site.

[e] RESRAD uses 36.5 g/yr as the soil ingestion rate. The actual resident soil ingestion rate is corrected by the occupancy factor, which is the sum of the time spent on site (time fraction inside + time fraction outside). The average value suggested in the EPA *Exposure Factor Handbook* (EPA, 1997) is 50 mg/d.

[f] RESRAD considers water ingestion only for the rural resident, and the ingestion rate is 510 L/yr. The EPA also considers water ingestion for the suburban resident and industrial worker; the EPA *Exposure Factor Handbook* (EPA 1997) recommends an average drinking water intake of 1.4 L/d.

DCGL Calculation Results

The DCGL calculation results are summarized for Ba-133 in Table 5. The modeling results indicate that peak year doses occurred in the first year for Ba-133. The RESRAD Version 6.3 model inputs and outputs are presented in this report in Volume 3, Appendix JJ of this report.

Table 5 RESRAD-Version 6.3 Calculation Summary Table

Radionuclide	DCGL in pCi/g	Resulting TEDE in mrem/year
Ba^{133}	48	14.7

The modeling code calculations are presented in Volume 3, Appendix JJ of this report.

Sensitivity Analysis

A sensitivity analysis was run with a multiplier/divisor of 2.0 for the following input parameters which had the largest affect on the calculated dose:

- Area of contaminated zone
- Thickness of contaminated zone
- External gamma shielding factor
- Outdoor time fraction
- Livestock intake of soil

Table 6 below provides a summary of the sensitivity analysis.

Table 6 Sensitivity Analysis Results Summary

Input Parameter	Calculated Dose in mrem/year
Thickness of Contaminated Zone	
0.3 meters	16.6
0.15 meters	14.8
0.075 meters	9.2
Area of Contaminated Zone	
12 meters	14.8
6 meters	14.8
3 meters	14.8
Outdoor Time Fraction	
0.5	21.0
0.25	14.8
0.125	11.8
External Gamma Shielding Factor	
1.0	18.5
0.7	14.8
0.49	12.2
Livestock Intake of Soil	
1.0 kg/day	14.8
0.5 kg/day	14.8
0.25 kg/day	14.8

The graphical results of the sensitivity analyses runs are presented in Volume 3, Appendix JJ of this report.

5.2.3 Building Surfaces and Structures

The DCGL's for building surfaces and structures and the modeling code from which the DCGL's were derived from are presented in Table 7 below.

Table 7 Building Surfaces/Structures DCGLs

Radionuclide	DCGL in DPM/100cm^2 for Building Surfaces	Modeling Code
H^3	140,000,000 β	RESRAD Build 3.22
C^{14}	4,700,000 β	RESRAD Build 3.22
Cs^{137}	40,000 β	RESRAD Build 3.22
Np^{237}	64 α	RESRAD Build 3.22
Th^{232}	61 α	RESRAD Build 3.22
Pu^{238}	90 α	RESRAD Build 3.22
Pu^{239}	82 α	RESRAD Build 3.22
Ra^{226}	2,400 α	RESRAD Build 3.22
Sr^{90}	20,000 β	RESRAD Build 3.22
U^{235}	280 α	RESRAD Build 3.22
U^{238}	290 α	RESRAD Build 3.22

5.2.4 Equipment and Tools

For equipment and tools the limits specified in: "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Materials (NRC 1993), Office of Nuclear Material Safety and Safeguards (NMSS)" were applied.

5.2.5 Soil

The DCGL's for soil concentrations and the modeling code from which the DCGL's were derived from are presented in Table 8 below.

Table 8 Soil Concentration DCGL's

Radionuclide	DCGL in pCi/g for Soil Concentrations	Reference Document
Ba^{133} in Soil	48	RESRAD 6.3
Th^{232} in Soil	1.1	Federal Register, Dated December 7, 1999 (Volume 64, Number 234)
Depleted Uranium in Soil U^{238}	0.5	Federal Register, Dated December 7, 1999 (Volume 64, Number 234)

6.0 RADIOLOGICAL SURVEY METHODS AND INSTRUMENTATION

6.1 RADIOLOGICAL SURVEY METHODS

6.1.1 Scanning Of Land Areas

Land area surfaces were scanned for gamma emitting radionuclides to identify the presence of elevated direct radiation that might indicate residual gross activity or hot spots. 2" by 2" NaI detectors coupled to data loggers were used during this type of survey. The distance between the detector and the surface being measured was less than 4 inches. Scanning rates did not exceed 1 foot per second while moving the detector back and forth in a serpentine pattern. Audible indicators were used to detect changes in instrument count rate. The intensity of the coverage of the scanning survey depended on the classification of the survey unit.

6.1.2 Scanning Of Building Surfaces/Structures

Prior to conducting any fixed measurements, surfaces were scanned for alpha-beta-gamma emitting radionuclides to identify the presence of elevated direct radiation that might indicate residual gross activity or hot spots. Large area gas proportional detectors coupled to rate meters/scalers were used during this type of survey. The distance between the detector and the surface measured was less than 1 cm. Scanning rates did not exceed 1/2 detector width per second and audible indicators were used to detect changes in instrument count rate. The intensity of the coverage of the scanning survey depended on the classification (See Sections 8.2 and 8.3) of the survey unit.

6.1.3 Scanning Minimum Detectable Concentration (MDC)

For scanning the building surfaces for beta and alpha emitters, the scanning minimum detectable concentration (MDC_{scan}) was determined. The MDC_{scan} was determined in the field using site-specific background values. The scanning technique initially considers the sensitivity of the technique and background radiation levels. The initial value is calculated using the following equation:

$$S_i = d'\sqrt{b_i}$$

Where:

s_i = minimum detectable number of net source counts in the interval

d '= recommended value of sensitivity of 3.28 , that is for 95% detection of a concentration equal to MDC_{scan} with a 5% false-positive rate

b_i = number of background counts in counting interval

The s_i is then used to calculate the minimum detectable count rate (MDCR) using the following equation:

$$MDCR = S_i(60/i)$$

Where:

MDCR = minimum detectable count rate

S_i = minimum detectable number of net source counts in the interval; and

i = counting interval (scan interval).

The MDCR is then used to calculate the MDC_{scan} using the following equation:

$$MDC_{Scan} = \frac{MDCR}{\sqrt{p}\,\varepsilon_i \varepsilon_s \frac{probe\ area\ in\ cm^2}{100 cm^2}}$$

Where:

MDC_{scan} = scanning MDC (dpm/100 cm^2)

MDCR = minimum detectable count rate

p = surveyor efficiency

ε_i = instrument efficiency (counts per particle)

ε_s = the contaminated surface efficiency (particles per disintegration)

The calculated MDCR and scan MDC for the instrumentation used is provided along with the data for each of the surveys in the appropriate appendices of this report.

The background reference areas survey data in presented in Volume 1, Appendix I of this report.

6.1.4 Direct Measurement Minimum Detectable Concentration

The minimum detectable concentration (MDC) was determined for each instrument and technique used during the Final Status Surveys. For an integrated measurement over a preset time, the MDC can be obtained from the equation below.

$$MDC = \frac{3 + 4.65\sqrt{B * T}}{\varepsilon_i * \varepsilon_s * T * \frac{\text{Probe Area Size in cm}^2}{100}}$$

Where:

B = background counts (cpm)

ε_i = instrument efficiency (counts per particle)

ε_s = the contaminated surface efficiency (particles per disintegration)

T = count time (minutes)

The calculated Direct Measurement MDC for the instrumentation used is provided along with the data for each of the surveys in the appropriate appendices of this report.

6.1.5 Surface Efficiency (ε_s) for Surface Activity Measurements

The surface efficiency term used above 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. 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 conditions in Bunker 3030, Magazine 3018, and Building 167 were concrete that was slightly covered with dust. Some of the radionuclides of concern occur naturally in concrete and produce a wide range of beta energies. The surface efficiency used in accordance with ISO-7503-1 was 0.25 for beta emitters and 0.25 for alpha emitters.

6.1.6 Weighted Total Efficiencies

Weighted total efficiencies were not used to determine instrument efficiencies due to the fact that the sources used to determine instrument efficiencies provided a conservative estimate of the instrument efficiency.

The NIST traceable sources that were used to determine the instrument efficiencies were:

Beta Efficiency: Tc-99
Alpha Efficiency: Th-230

Table 9 below provides a summary and comparison of the radionuclides of concern, sources used to determine instrument efficiency, and the decay energy levels of the alpha and beta particles of the radionuclides of concern and the NIST traceable check sources.

Table 9 Radionuclide Check Source Summary Table[1]

Alpha Emitting Radionuclides of Concern	**Average Energy (Mev)**	**Yield %**
Np-237	4.78	47%
Th-232	4.01	77%
Pu-238	5.49	71%
Pu-239	5.15	73%
Ra-226	4.78	94%
U-235	4.39	55%
U-238	4.19	77%
Total Average:	**4.68**	N/A
Th-230 Check Source	**4.68**	76%
Beta Emitting Radionuclides of Concern	**Average Energy (Mev)**	**Yield %**
C-14	0.049	100%
Sr-90	0.195	100%
Cs-137	0.156	94%
Total Average:	**0.133**	99%
Tc-99 Check Source	**0.084**	99%

1 Source of information was "The Health Physics and Radiological Health Handbook", 1984 Nucleon Lectern Associates

6.1.7 Exposure Rate Measurements

Exposure rate measurements were obtained as part of the Final Status Surveys. Readings were taken at a distance of one meter from the surface of concern.

6.1.8 Removable Contamination Measurements

Smears were used to obtain measurements of removable contamination. Smears for removable surface activity were obtained by wiping an area of approximately 100 cm^2. Loose surface contamination surveys of alpha and beta emitters were performed using cloth smears.

Loose surface contamination surveys for H-3 and C-14 were performed using paper smears.

6.2 RADIOLOGICAL SURVEY INSTRUMENTATION

6.2.1 Surface Scans of Land Areas

Ludlum Model 44-10 2” by 2” NaI scintillation detectors coupled to Ludlum Model 2350-1 Data Loggers were used for the surface scan surveys that were performed.

6.2.2 Surface Scans/Direct Measurements of Building Surfaces/Structures

Ludlum Model 43-37 (582 cm^2) and Ludlum Model 43-68 (126 cm^2) large area gas proportional detectors coupled to count rate/scaler meters were used for the surface scans and direct measurements that were performed during the Final Status Surveys.

6.2.3 Exposure Rate Measurements

Exposure rate surveys were performed using Ludlum Instruments Model-19 micro-R meters (1" by 1" NaI detector) or equivalent.

6.2.4 Removable Contamination Measurements

Loose surface contamination surveys for alpha and beta emitters were performed using cloth smears and analyzed with a Ludlum Model-2929 Dual Channel Scaler with an attached Model 43-10-1 ZnS (Ag) phoswich detector.

Loose surface contamination surveys for H-3 and C-14 were performed using paper smears and analyzed by a liquid scintillation counter (LSC) located at Picatinny Arsenal’s laboratory in Building 320.

6.2.5 Instrument Calibration and Daily Performance Checks

All instruments were calibrated a minimum of once every 12 months, using NIST-traceable standards. Performance and background checks were performed and documented at least once per shift on instrument use.

Copies of the instrument calibration documentation and daily performance checks are provided in Volume 1, Appendix H of this report.

Table 10 below presents a summary of the instruments that were used during the Final Status Surveys and the Minimum Detectable Activity (MDA) or Minimum Detectable Count Rate (MDCR) for each instrument.

Table 10 Instrumentation for Radiological Surveys

Type of Measurement/Technique	Instrumentation Detector	Meter	Background	Eff. %	Detection Sensitivity
Surface Scans-alpha/beta/gamma (Floor & Walls)	Large Area gas Prop. Ludlum Model 43-37 (582 cm^2)	Ludlum Model-2224 Scaler/Ratemeter	1000-1200 CPM $\beta\gamma$ 2-10 CPM α	~12 β ~6 α See Note 1	~ 1000 dpm/100cm^2 $\beta\gamma$ ~ 145 dpm/100cm^2 α
Surface Scans-alpha/beta/gamma (Floor & Walls)	Large Area gas Prop. Ludlum Model 43-68 (126 cm^2)	Ludlum Model-2224 Scaler/Ratemeter	300-400 CPM $\beta\gamma$ 2-10 CPM α	~12 β ~6 α See Note 1	~ 2,500 dpm/100cm^2 $\beta\gamma$ ~ 450 dpm/100cm^2 α
Exposure Rates	NaI Scintillation Micro R Meter Ludlum Model-19	(Same as detector)	8-12 μR/hr γ	N/A	2 μR/hr γ
Gross alpha/beta/gamma on Swipe Samples	Ludlum Model-2929 Dual Channel Scaler	Ludlum Model 43-10-1 ZnS Scintillation Detector	0.1-1.0 CPM α 50-75 CPM $\beta\gamma$	~32 α ~20 $\beta\gamma$	~ 15 dpm/100cm^2 α ~ 120 dpm/100cm^2 $\beta\gamma$
Surface Scans Open Land Areas-Gamma	NaI 2” x 2” Scintillation Ludlum Model 44-10	Ludlum Model-2350-1 Data Logger	8000 to12000 CPM γ	N/A	56 pCi/gram DU 1.8 pCi/gram Th-232 2.8 pCi/gram Ra-226
Direct Measurements Static Reading (3-Minute)	Large Area Gas Prop. Ludlum Model 43-37 (582 cm^2)	Ludlum Model-2224 Scaler/Ratemeter	1000-1200 CPM $\beta\gamma$ 2-10 CPM α	~12 β ~6 α See Note 1	~ 150 dpm/100cm^2 $\beta\gamma$ ~ 25 dpm/100cm^2 α
Direct Measurements Static Reading (3-Minute)	Large Area Gas Prop. Ludlum Model 43-68 (126 cm^2)	Ludlum Model-2224 Scaler/Ratemeter	300-400 CPM $\beta\gamma$ 2-10 CPM α	~12 β ~6 α See Note 1	~ 340 dpm/100cm^2 $\beta\gamma$ ~ 80 dpm/100cm^2 α
Low Energy Beta Emitters on Swipe Samples	Beckman Model LS6500	N/A	~ 19 CPM β	~ 60 β	~ 36 dpm/100 cm^2 β

Note 1: Efficiencies are expressed as total efficiencies, which are calculated by: (Instrument Efficiency) x (Surface Efficiency Factor)

7.0 CHARACTERIZATION SURVEYS

7.1 DOG POUND AREA

The dog pound area was divided into eight 10-meter by 10-meter grids. A map presenting the grid layout for the dog pound area is provided in Volume 1, Appendix J of this report.

Each grid was 100% gamma scan surveyed using 2” by 2” NaI detectors coupled to data loggers. The results of the gamma scan surveys are provided in Volume 1, Appendix J of this report.

10 surface soil samples were collected at biased locations from within each of the survey grids. The samples were sent to an offsite laboratory for analysis by gamma spectroscopy for Th-232.

The results of the samples ranged between 1.53 pCi/g to 8.7 pCi/g for Th-232 and do not demonstrate compliance with the termination criteria established by the Nuclear Regulatory Commission for screening values for soil. The sample locations and results are provided in Volume 1, Appendix J of this report.

7.2 BUILDING 167 GROUND AREAS

7.2.1 Across From Kibler Road

The area across from Building 167 was divided into nine10-meter by 10-meter grids. Each grid was 100% gamma scan surveyed using 2" by 2" NaI detectors coupled to data loggers. The results of the gamma scan surveys are provided in Volume 1, Appendix K of this report.

A surface soil sample (within 15 cm) was collected at biased locations from within each of the survey grids (9 total samples). The samples were sent to the offsite laboratory for analysis by gamma spectroscopy. The results of the samples demonstrate compliance with the screening values established by the Nuclear Regulatory Commission for soil and is free of radioactive contamination. The sample locations and results are provided in Volume 1, Appendix K of this report.

7.2.2 Around Entire Perimeter of Building 167

The entire perimeter of Building 167 was divided into seven different survey grids. The survey grids varied in size but none of them exceeded 100 square meters. Each grid was 100% gamma scan surveyed using 2" by 2" NaI detectors coupled to data loggers.

One surface soil sample (within 15 cm) was collected at biased locations from each of the survey grids for a total of 7 samples. The samples were sent to the offsite laboratory for analysis by gamma spectroscopy. The results of the samples demonstrate compliance with the screening values established by the Nuclear Regulatory Commission for soil and is free of radioactive contamination. The results of the gamma scan surveys are provided in Volume 1, Appendix L of this report.

7.3 GORGE AREA

7.3.1 Detonation Pit Area

The detonation pit in the gorge area was divided into thirty 10-meter by 10-meter grids. Each grid was 100% gamma scan surveyed using 2" by 2" NaI detectors coupled to data loggers. The results of the gamma scan surveys are provided in Volume 1, Appendix M of this report.

25 surface and 10 subsurface soil samples (3 foot bgs) were collected at biased locations from within various survey grids. The samples were sent to the offsite laboratory for analysis by gamma spectroscopy for U-238 (depleted uranium).

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The results of the samples ranged between 0.5 and 60 pCi/g for U-238. In addition, two of the samples (G-24 and G-27) showed high levels of Bi-214 and Pb-214, suspected to be daughter products of Ra-226. These two samples were re-analyzed by gamma spectroscopy for Ra-226 and isotopic uranium analysis. The results of the gamma spectroscopy analysis indicated the presence of Bi-214 and Pb-214 at levels of 730 pCi/g in sample G-24, and 73 pCi/g (Bi-214) and 77 pCi/g (Pb-214) in sample G-27.

The results of the isotopic uranium analysis of sample G-24 were 1.48 pCi/g (U-238), 0.117 pCi/g (U-235), and 1.22 pCi/g (U-234). The results of the isotopic uranium analysis of sample G-27 were 0.98 pCi/g (U-238), 0.122 pCi/g (U-235), and 0.65 pCi/g (U-234).

The results of the samples do not demonstrate compliance with the screening values established by the Nuclear Regulatory Commission for soil.

The sample locations and results are provided in Volume 1, Appendix M of this report.

7.3.2 Soil Piles

There were two soil piles located in close proximity to the northwest of the detonation pit area. These soil piles were 100% gamma scan surveyed using 2” by 2” NaI detectors coupled to data loggers. The results of the gamma scan surveys are provided in Volume 2, Appendix N of this report.

A surface soil sample was collected at biased locations from each of the soil piles. The samples were sent to the offsite laboratory for analysis by gamma spectroscopy for U-238 (depleted uranium). The results of the samples ranged between 1.1 pCi/g and 5.5 pCi/g for U-238. The sample locations and results are provided in Volume 2, Appendix N of this report.

7.3.3 Slug Butt Areas

7.3.3.1 Slug Butt On Hill Near Detonation Pit Area (# 1222G)

The slug butt near the detonation pit area was divided into two 6-meter by 6-meter grids. Each grid was 100% gamma scan surveyed using 2” by 2” NaI detectors coupled to data loggers. No distinguishable activity above background radiation levels was detected during the surveys. The results of the gamma scan surveys are provided in Volume 2, Appendix O of this report.

10 surface soil samples were collected at biased locations from each of the two survey grids. The samples were sent to the offsite laboratory for analysis by gamma spectroscopy for U-238 (depleted uranium). The results of the samples ranged between –0.1 pCi/g and 1.19 pCi/g for U-238 and all were less than the specified MDC or less than the associated Total Propagated Uncertainty and demonstrate compliance with the screening values established by the Nuclear Regulatory Commission for soil. The sample locations and results are provided in Volume 2, Appendix O of this report.

7.3.3.1 Slug Butt On Hill In Wooded Area (# 1242A)

The inner ground surface of slug butt on the wooded area was 100% gamma scan surveyed using 2” by 2” NaI detectors coupled to data loggers. No distinguishable activity above background radiation levels was detected during the survey. The results of the gamma scan surveys are provided in Volume 2, Appendix O of this report.

8.0 FINAL STATUS SURVEYS (MAGAZINE 3018, BUNKER 3030, BUILDING 167)

The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) NUREG-1575, NUREG-1505, and NUREG-1507 were used as guidance in designing and conducting the final status surveys.

8.1 OBJECTIVE OF FINAL STATUS SURVEYS

The objective of final status surveys is to demonstrate that residual radioactivity levels meet the release criterion. In demonstrating the objective is met, the null hypothesis (H_o) is tested which states that: “the residual contamination exceeds the release criterion”; the alternative hypothesis (H_a) is that residual contamination demonstrates compliance with the criteria established by the Nuclear Regulatory Commission for release for unrestricted use.

8.2 AREA CLASSIFICATIONS

For the purposes of establishing the sampling and measurement frequency and pattern, the various site areas were divided into one of the 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 DCGL. Examples of Class 1 areas include:

    1) site areas previously subjected to remedial actions
    2) locations where leaks or spills are known (or suspected) to have occurred
    3) former burial or disposal sites
    4) material storage areas
    5) areas with contaminants in discrete solid pieces of material or high specific activity

- *Class 2 Areas*: Areas that have, or had prior to remediation, a potential for radioactive contamination or known contamination but are not expected to exceed the DCGL. 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 DCGL. 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:

1) locations where radioactive materials were present in an unsealed form
2) potentially contaminated transport routes
3) areas downwind from the main areas of concern (AOC)
4) areas handling radioactive materials
5) 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 DCGL, 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.

The classification of each area surveyed is presented along with the survey data in the corresponding appendixes in this report.

8.3 SURVEY UNITS

Table 11 below presents the classifications, number of survey units, and scan survey coverage frequency of the areas where the Final Status Surveys were performed during the project.

Table 11 Survey Unit Summary Table

Area/Location	MARSSIM Classification	Total Surface Area (Square Meters)	Number of Survey Units	Scan Survey Coverage Frequency
Bunker 3030 Floor And Walls Up To 2 Meters	Class 1	~ 64	1	100%
Magazine 3018 Floor And Walls Up To 2 Meters	Class 1	~ 64	1	100%
Building 167 Ground Floor Room #1 Floor/ And Walls Up To 4 Meters	Class 1/Class 2	48/112	1/1	100%/100%
Building 167 Ground Floor Room #2 Floor/ Walls Up To 4 Meters	Class 1/Class 2	32/96	1/1	100%/100%
Building 167 Ground Floor Room #3 Floor & Walls Up To 4 Meters	Class 1	56	1	100%
Building 167 Ground Floor Room #4 Floor/ Walls Up To 4 Meters	Class 1/Class 2	24/80	1/1	100%/100%
Building 167 Ground Floor Room #5 Floor/ Walls Up To 4 Meters	Class 1/Class 2	32/96	1/1	100%/100%
Building 167 Ground Floor Room #6 Floor/ Walls Up To 4 Meters	Class 1	24/80	1/1	100%/100%
Building 167 Ground Floor Room #7 Floor/ Walls Up To 4 Meters	Class 1/Class 2	24/80	1/1	100%/100%
Building 167 Ground Floor Room #8 Floor/ Walls Up To 4 Meters	Class 1/Class 1	16/36	1/1	100%
Building 167 Ground Floor Room #9 Floor/ Walls Up To 4 Meters	Class 1/Class 2	16/36	1/1	100%
Building 167 Basement Walls Up to 2 Meters	Class 2	192	1	100%
Building 167 Basement Floor	Class 1	288	3	100%

Survey units were limited in size based on classification, exposure pathway modeling assumptions, and site-specific conditions. MARSSIM recommends areas for survey units according to the following:

Classification	**Suggested Area**
Class 1 Structures	up to 100 m^2 floor area
Class 2 Structures	100 to 1,000 m^2
Class 3 Structures	no limit

The limitation on survey unit size for Class 1 areas ensures that each area is assigned an adequate number of data points.

8.4 AREA GRID MAPS

Grid maps are provided in this report preceding the survey data for each survey area in the corresponding appendix.

8.5 REFERENCE (BACKGROUND) AREAS

8.5.1 Outdoor Open Land Areas

A 10-meter by 10-meter grid was setup on the corner of 1st Street and 3rd Avenue southwest of Building 95 as a background reference area for outdoor open land areas. A 100% gamma scan survey was conducted in the reference grid using Ludlum Model 44-10 2" by 2" NaI scintillation detectors coupled to Ludlum Model 2350-1 Data Loggers. 10 surface samples (within 15 cm) were also obtained from random locations throughout the reference grid. The samples were sent to the offsite laboratory for gamma spectroscopy analysis. The results of the gamma scan survey, soil samples, and soil sample locations are provided in Volume 1, Appendix I of this report.

8.5.2 Indoor Building Surfaces

A room and hallway in Building 163 were selected as the reference (background) area. The reference area within Building 163 is similar in size to the rooms in Building 167, Magazine 3018, and Bunker 3030 with comparable concrete floor and walls. However, as the buildings were constructed in different years, there is a possibility that the concrete used to construct the survey units and reference area may be somewhat different. The results of the background surveys are provided in Volume 1, Appendix I of this report.

9.0 SUMMARY OF SURVEY FINDINGS

9.1 STATISTICAL CONSIDERATIONS

9.1.1 Demonstration of Compliance

When determining compliance with remediation goals, the entire site (survey unit) was examined. The site data was examined statistically. The three compliance tests are summarized in Table 12 below. They include:

- Compare the largest site measurement to the DCGL.
- Compare the average site measurement to the DCGL.
- Use the Sign Test (MARSSIM, Chapter 8) to determine if the site data exceed the DCGL.

Table 12 Statistical Comparisons with DCGL

Survey Result	**Conclusion**
All measurements less than the $DCGL_W$.	Survey unit meets release criterion.
Average greater than the $DCGL_W$.	Survey unit does not meet release criterion.
Any measurement greater than $DCGL_W$ and the average less than $DCGL_W$.	Conduct Sign Test and elevated measurement comparison.

9.1.2 Null Hypothesis

Using the MARSSIM methodology, the null hypothesis is stated as: "the residual activity in the survey unit exceeds the release criteria". Thus, in order to pass the survey unit (that is, meet the release criteria for the area), the null hypothesis must be rejected. The Sign Test was used on the survey data to test the null hypothesis.

9.1.3 Confidence Levels

The Final Status Survey is designed to limit Type I and Type II errors to 5%. It is important to minimize the chances that area grids exceeding the DCGL will be missed (Type I) and area grids meeting the DCGL 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 Sign Test are calculated from these probability values and from the number of samples/measurements taken.

9.1.4 Statistical Sign Test

The one-sample Sign Test is used if the contaminant is not present in background. The test is designed to demonstrate compliance with the release criterion when the radionuclides of interest are not present in background and the distribution of the data is not symmetric. The Sign Test is appropriate for this condition according to MARSSIM.

The Sign Test was used to compare site date to the DCGL. Significance is measured by confidence levels. To conduct the test, each of the site measurements is subtracted from the DCGL. If the result is positive, it is given a value of +1. If negative, it is given a value of -1. All the positive (+1) results are summed, and the total is compared to the Critical Value. If the sum exceeds the Critical Value, then the DCGL is met.

The Critical Value for the each survey unit is provided with the survey data for each survey unit.

9.1.5 Calculation of Number of Samples/Measurements (N)

An important factor in performing this test is the number of measurements taken. A minimum number must be taken. The minimum is calculated based on confidence limits, the general distribution of the contaminant at the site, the DCGL and other factors.

The number of 3-minute direct measurements to be obtained for the one sample Sign Test was calculated using the following formula:

$$N = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4(SignP - 0.5)^2} * 1.2$$

where,

N	=	number of samples;
1.2	=	multiplication factor to add 20% to the number of samples;
$Z_{1-\alpha}$	=	percentile represented by selected value of $\alpha = 0.05$;
$Z_{1-\beta}$	=	percentile represented by selected value of $\beta = 0.05$; and
Sign P	=	the estimated probability that a random measurement from the survey unit will be less than the DCGL when the survey unit median is actually at the LBGR.

The lower bound of the gray region (LBGR) value was selected as one half the DCGL value.

The initial step in determining the number of data points in the one-sample case is to calculate the relative shift, Δ/σ = (DCGL-LBGR)/σ, from the DCGL 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.

Sign P is the estimated probability that a random measurement from the survey unit will be less than the DCGL when the survey unit median is actually at the LBGR.

The Sign P is used to calculate the minimum number of data points necessary for the survey to meet the DQOs. The value of the relative shift calculated above is used to obtain the corresponding value of Sign P from Table 5.4 in Chapter 5 of MARSSIM.

The percentiles, $Z_{1-\alpha}$ and $Z_{1-\beta}$, represented by the selected decision error levels, α and ß, respectively are calculated from Table 5.2 in Chapter 5 of MARSSIM.

The value of the percentiles $Z_{1-\alpha}$ and $Z_{1-\beta}$ is 1.645.

Since no prior survey data was available, the standard deviation was calculated by obtaining 30 randomly selected (5 in each room) alpha direct measurements on the floor in Rooms # 1, # 2, # 4, # 5, # 6, and # 7 of Building 167 prior to conducting the final status surveys.

The results of the scoping survey are presented in Table 13 below.

Table 13 Scoping Survey Summary Table

	Results in dpm/100cm^2	Room #
	2.6	7
	18.5	7
	5.3	7
	2.6	7
	2.6	7
	23.8	1
	18.5	1
	5.3	1
	23.8	1
	2.6	1
	23.8	4
	33.2	4
	2.6	4
	31.8	4
	5.3	4
	18.5	5
	23.8	5
	7.9	5
	23.8	5
	2.6	5
	18.5	2
	5.3	2
	33.2	2
	2.6	2
	2.6	2
	18.5	6
	33.2	6
	33.2	6
	2.6	6
	33.2	6
Average:	**15.40**	
Standard Deviation:	**12.0**	

The calculated standard deviation was then used to calculate the relative shift:

$$78 - 39/12 = 3.25$$

The corresponding Sign P value was then obtained from Table 5.4 of MARSSIM.

SignP: 1.0

The number of samples/direct measurements (N) were then calculated by:

$$N = \frac{(1.645 + 1.645)^2}{4(1 - 0.5)^2} * 1.2 = 13$$

9.1.6 Determination of Number of Samples/Measurements for Small Areas of Elevated Activity

The statistical tests described above evaluate whether or not the residual radioactivity in an area exceeds the $DCGL_W$ for contamination conditions that are approximately uniform across the survey unit. In addition, there should be a reasonable level of assurance that any small areas of elevated residual radioactivity that could be significant relative to the $DCGL_{EMC}$ are not missed during the final status survey. The statistical tests introduced in the previous sections may not successfully detect small areas of elevated contamination. Instead, systematic direct measurements and sampling, in conjunction with surface scanning, are used to obtain adequate assurance that small areas of elevated radioactivity will still satisfy the release criterion or the $DCGL_{EMC}$. The procedure is applicable for all radionuclides, regardless of whether or not they are present in background, and is implemented for Class 1 survey units.

One method for determining values for the $DCGL_{EMC}$ is to modify the $DCGL_W$ using a correction factor that accounts for the difference in area and the resulting change in dose or risk. The area factor is the magnitude by which the concentration within the small area of elevated activity can exceed $DCGL_W$ while maintaining compliance with the release criterion.

The minimum detectable concentration (MDC) of the scan procedure needed to detect an area of elevated activity at the limit determined by the area factor is calculated as follows:

Scan MDC (required) = ($DCGL_W$) × (Area Factor)

The $DCGL_{EMC}$ is calculated based on the grid area. The largest spacing interval in any of the survey units is 2 meters, which results in a grid area of 4 m^2. Running RESRAD Build Version 3.21 modeling code and using Th-232 (most restrictive) as the radionuclide of concern and using 4 m^2 as the area of contamination, a contamination level of 500 dpm/100cm^2 the resulting TEDE is ~ 13.7 mrem/year which is below the target dose limit of 15 mrem/year TEDE.

The highest calculated gross alpha scan MDC was ~ 456 dpm/100cm^2 which is below 500 dpm/100cm^2. Therefore, the calculated number of samples/measurements in Section 9.1.5 are sufficient to show compliance using the elevated measurement comparison criteria.

The modeling code output data for the $DCGL_{EMC}$ calculations are presented in Volume 3, Appendix JJ of this report.

9.2 LOOSE SURFACE CONTAMINATION SURVEYS

9.2.1 Gross Alpha-Beta Activity

The results of the loose surface contamination surveys for all of the areas are provided in Volume 2, Appendix P of this report. The results of the surveys indicate that all of the smear samples were below the DCGL's.

9.2.2 Low Energy Beta Activity

The results of the loose surface contamination surveys for all of the areas are provided in Volume 2, Appendix Q of this report. The results of the surveys indicate that all of the smear samples were below the DCGL's.

9.3 MAGAZINE 3018

The results of the scan survey, and direct measurement survey for Magazine 3018 along with the statistical Sign-Test are provided in Volume 2, Appendix R of this report. In addition, histograms and posting plots are provided in Volume 3, Appendices KK and LL of this report respectively. Retrospective power curves are provided in Volume 3, Appendix MM of this report. The results of the survey indicate that the null hypothesis is rejected and that the survey unit demonstrates compliance with the criteria established by the Nuclear Regulatory Commission for release for unrestricted use.

9.4 BUNKER 3030

The results of the scan survey and direct measurement survey for Bunker 3030 along with the statistical Sign-Test are provided in Volume 2, Appendix S of this report. In addition, histograms and posting plots are provided in Volume 3, Appendices KK and LL of this report respectively. Retrospective power curves are provided in Volume 3, Appendix MM of this report. The results of the survey indicate that the null hypothesis is rejected and that the survey unit demonstrates compliance with the criteria established by the Nuclear Regulatory Commission for release for unrestricted use.

9.5 BUILDING 167 ROOM #1

The results of the scan surveys and direct measurement surveys for Room #1 along with the statistical Sign-Test are provided in this report in Volume 2, Appendix T. In addition, histograms and posting plots are provided in Volume 3, Appendices KK and LL respectively of this report. Retrospective power curves are provided in Volume 3, Appendix MM of this report. The results of the survey indicate that the null hypothesis is rejected and that the survey unit demonstrates compliance with the criteria established by the Nuclear Regulatory Commission for release for unrestricted use.

9.6 BUILDING 167 ROOM #2

The results of the scan surveys and direct measurement surveys for Room #2 along with the statistical Sign-Test are provided in Volume 2, Appendix U of this report. In addition, histograms and posting plots are provided in Volume 3, Appendices KK and LL respectively of this report. Retrospective power curves are provided in Volume 3, Appendix MM of this report. The results of the survey indicate that the null hypothesis is rejected and that the survey unit demonstrates compliance with the criteria established by the Nuclear Regulatory Commission for release for unrestricted use.

9.7 BUILDING 167 ROOM #3

The results of the scan surveys and direct measurement surveys for Room #3 along with the statistical Sign-Test are provided in Volume 2, Appendix V of this report. In addition, histograms and posting plots are provided in Volume 3, Appendices KK and LL of this report respectively. Retrospective power curves are provided in Volume 3, Appendix MM of this report. The results of the survey indicate that the null hypothesis is rejected and that the survey unit demonstrates compliance with the criteria established by the Nuclear Regulatory Commission for release for unrestricted use.

9.8 BUILDING 167 ROOM #4

The results of the scan surveys and direct measurement surveys for Room #4 along with the statistical Sign-Test are provided in this revised report in Volume 2, Appendix W. In addition, histograms and posting plots are provided in this report in Volume 3, Appendices KK and LL respectively. Retrospective power curves are provided in this report in Volume 3, Appendix MM. The results of the survey indicate that the null hypothesis is rejected and that the survey unit demonstrates compliance with the criteria established by the Nuclear Regulatory Commission for release for unrestricted use.

9.9 BUILDING 167 ROOM #5

The results of the scan surveys and direct measurement surveys for Room #5 along with the statistical Sign-Test are provided in Volume 2, Appendix X of this report. In addition, histograms and posting plots are provided in this report in Volume 3, Appendices KK and LL respectively. Retrospective power curves are provided in this report in Volume 3, Appendix MM. The results of the survey indicate that the null hypothesis is rejected and that the survey unit demonstrates compliance with the criteria established by the Nuclear Regulatory Commission for release for unrestricted use.

9.10 BUILDING 167 ROOM #6

The results of the scan surveys and direct measurement surveys for Room #6 along with the statistical Sign-Test are provided in Volume 2, Appendix Y of this report. In addition, histograms and posting plots are provided in this report in Volume 3, Appendices KK and LL respectively. Retrospective power curves are provided in this report in Volume 3, Appendix MM. The results of the survey indicate that the null hypothesis is rejected and that the survey unit demonstrates compliance with the criteria established by the Nuclear Regulatory Commission for release for unrestricted use.

9.11 BUILDING 167 ROOM #7

The results of the scan surveys and direct measurement surveys for Room #7 along with the statistical Sign-Test are provided in Volume 2, Appendix Z of this report. In addition, histograms and posting plots are provided in this report in Volume 3 Appendices KK and LL respectively. Retrospective power curves are provided in this report in Volume 3, Appendix MM. The results of the survey indicate that the null hypothesis is rejected and that the survey unit demonstrates compliance with the criteria established by the Nuclear Regulatory Commission for release for unrestricted use.

9.12 BUILDING 167 ROOM #8

The results of the scan surveys and direct measurement surveys for Room #8 along with the statistical Sign-Test are provided in Volume 3, Appendix AA of this report. In addition, histograms and posting plots are provided in this report in Volume 3, Appendices KK and LL respectively. Retrospective power curves are provided in this report in Volume 3, Appendix MM. One gross alpha reading was above the DCGL (88.9 dpm/100cm^2) but was below the $DCGL_{EMC}$. The results of the survey indicate that the null hypothesis is rejected and that the survey unit demonstrates compliance with the criteria established by the Nuclear Regulatory Commission for release for unrestricted use.

9.13 BUILDING 167 ROOM #9

The results of the scan surveys and direct measurement surveys for Room #9 along with the statistical Sign-Test are provided in Volume 3, Appendix BB of this report. In addition, histograms and posting plots are provided in this report in Volume 3, Appendices KK and LL respectively. Retrospective power curves are provided in this report in Volume 3, Appendix MM. The results of the survey indicate that the null hypothesis is rejected and that the survey unit demonstrates compliance with the criteria established by the Nuclear Regulatory Commission for release for unrestricted use.

9.14 BUILDING 167 BASEMENT

The results of the scan survey and direct measurement survey for the Building 167 Basement along with the statistical Sign-Test are provided in this report in Volume 3, Appendix CC. In addition, histograms and posting plots are provided in this report in Volume 3, Appendices KK and LL respectively. Retrospective power curves are provided in this report in Volume 3, Appendix MM. The results of the survey indicate that the null hypothesis is rejected and that the survey unit demonstrates compliance with the criteria established by the Nuclear Regulatory Commission for release for unrestricted use.

9.15 BUILDING 167 ASBESTOS BAG SAMPLES

There were a total of seventy five bags containing asbestos debris stored inside of Building 167 following asbestos abatement on the first floor and basement by other contractors prior to NWT's second site visit in June of 2002.

Each bag was given a unique identification number and composite (one sample each from five bags combined into one composite sample) samples were obtained of the materials inside of the bags. These samples were sent to an outside laboratory for analysis by gross alpha and gross beta analysis.

The results of the samples indicated that the materials inside of the bags are free of radioactive contamination. The bags can be disposed of at a state licensed and permitted asbestos disposal facility. A table, cross referencing where the samples were obtained and the laboratory data reports are provided in Volume 3, Appendix DD of this report.

9.16 BUILDING 167 PUMPED WATER SAMPLES

While performing the Final Status Surveys in the basement of Building 167, water flooded the basement during a heavy thunderstorm. The water was pumped to two 55-gallon drums so the basement area could be dried to facilitate the completion of the Final Status Survey. Approximately 70 gallons of water were pumped from the basement area into 55- gallon drums.

Samples were obtained of the water and sent to the offsite laboratory for analysis by gross alpha, gross beta, gamma spectroscopy, and TCLP analysis. The results of the samples indicated that the water is free of radioactive and hazardous contaminants. The laboratory data reports of the water samples are provided in Volume 3, Appendix EE of this report.

9.17 BUILDING 167 DRAIN TRAP AND MANHOLE SAMPLES

A sample was collected from the residual material located inside all of the drain traps located in the basement of Building 167. All of the drain traps led into a common drain header that exits the building in the southern corner of the basement.

The drain header exiting Building 167 drains into a manhole located outside and to the southwest of Building 167. The manhole is located approximately twenty-five feet from Building 167 near Building 163. A sample was collected from the residual material located inside the bottom of the manhole. The results of the drain trap and manhole sample analysis demonstrate compliance with the screening values presented in Table 14 (found in Reference 10, Federal Register, Dated December 7, 1999, Volume 64, Number 234, Pages 68395-668396, "Supplemental Information on the Implementation of the Final Rule on Radiological Criteria for License Termination") established by the Nuclear Regulatory Commission for soil and is free of radioactive contamination.

The results of the drain trap and manhole samples are provided in Volume 3, Appendix FF of this report.

Table 14 NRC Surface Soil Screening Values

Radionuclide	Surface Soil Screening Value in pCi/g
H-3	1.1 E-02
C-14	1.2 E+01
Na-22	4.3 E+00
S-35	2.7 E+02
Cl-36	3.6 E-01
Ca-45	5.7 E+01
Sc-46	1.5 E+01
Mn-54	1.5 E+01
Fe-55	1.0 E+04
Co-57	1.5 E+02
Co-60	3.8 E+00
Ni-59	5.5 E+03
Ni-63	2.1 E+03
Sr-90	1.7 E+00
Nb-94	5.8 E+00
Tc-99	1.9 E+01
I-129	5.0 E-01
Cs-134	5.7 E+00
Cs-137	1.1 E+01
Eu-152	8.7 E+00
Eu-154	8.0 E+00
Ir-192	4.1 E+01
Pb-210	9.0 E-01
Ra-226	7.0 E-01
Ra-226+C	6.0 E-01
Ac-227	5.0 E-01
Ac-227+C	5.0 E-01
Th-228	4.7 E+00
Th-228+C	4.7 E+00
Th-230	1.8 E+00
Th-230+C	6.0 E-01
Th-232	1.1 E+00
Th-232+C1	1.1 E+00
Pa-231	3.0 E-01
Pa-231+C	3.0 E-01
U-234	1.3 E+01
U-235	8.0 E+00
U-235+C	2.9 E-01
U-238	1.4 E+01
U-238+C	5.0 E-01
Pu-238	2.5 E+00
Pu-239	2.3 E+00
Pu-241	7.2 E+01
Am-241	2.1 E+00
Cm-242	1.6 E+02
Cm-243	3.2 E+00

9.18 BUILDING 167 BASEMENT CONTAMINATED CONCRETE SAMPLES

Two small areas (each approximately 1 ft^2 in area) of elevated activity were found during the scan survey of the basement floor area in. Area #1 was initially reading ~3,000 Net CPM β and ~ 50 Net CPM α. Area #2 was initially reading ~50,000 Net CPM β and ~ 300 Net CPM α. The readings were taken with a Ludlum Model-2224 scaler/ratemeter with an attached Ludlum Model 43-37 large area gas proportional detector. The areas were then decontaminated by scabbling the concrete surface. The removed material was collected from each area decontaminated and sent to the offsite laboratory for gamma spectroscopy analysis for radionuclide identification.

The results of the two samples indicated the presence of Pb-214 and Bi-214, daughter products of Ra-226. The area #1 sample result was 1.18 pCi/g and 1.15 pCi/g for Bi-214 and Pb-214 respectively. The area #2 sample result was 16.5 pCi/g and 17 pCi/g for Bi-214 and Pb-214 respectively. The results of the concrete samples are provided in Volume 3, Appendix GG of this report.

9.19 BUILDING 167 BASEMENT POST DECONTAMINATION CONCRETE SAMPLE

Following decontamination and resurvey of the two areas, a composite concrete sample (both areas combined into one sample) was collected from both areas and sent to the offsite laboratory for gamma spectroscopy analysis. The result of the sample was 0.41 pCi/g and 0.50 pCi/g for Bi-214 and Pb-214 respectively.

Resurveys of the decontaminated areas (2.6 net dpm/100cm^2 gross alpha, and 304 net dpm/100cm^2 gross beta) showed compliance with the DCGLs of 78 dpm/100cm^2 gross alpha, and 20,000 dpm/100cm^2 gross beta for building surfaces.

The result of the post decontamination concrete sample is provided in Volume 3, Appendix HH of this report.

9.20 BUILDING 167 BASEMENT SOIL SAMPLES

The floor in the basement of Building 167 was prepared for the Final Status Survey by pumping the water and drying the surface (See Section 9.16 above). The dirt on the floor surface was then swept up into a pile. A gamma scan was performed on the pile of dirt with a 2” by 2” NaI detector. No detectable activity above background radiation levels was found during this survey. A sample was then collected from the pile and sent to the offsite laboratory for gamma spectroscopy analysis. The result of the analysis indicated that the dirt demonstrates compliance with the screening values presented in Table 13 (found in Reference 10, Federal Register, Dated December 7, 1999, Volume 64, Number 234, Pages 68395-668396, “Supplemental Information on the Implementation of the Final Rule on Radiological Criteria for License Termination") established by the Nuclear Regulatory Commission for soil and is free of radioactive contamination

The northern corner of the basement floor had a section (approximately 5' by 5') that was not covered with concrete. A gamma scan was performed in this area with a 2" by 2" NaI detector. No detectable activity above background radiation levels was found during this survey. A surface soil sample was then collected and sent to the offsite laboratory for gamma spectroscopy analysis. The results of the analysis indicated that the soil demonstrates compliance with the license unrestricted use criteria established by the Nuclear Regulatory Commission and is free of radioactive contamination.

The results of the dirt pile and northern basement floor area samples are provided in Volume 3, Appendix II of this report.

10.0 SUMMARY

Based upon the survey data in this report, Magazine 3018, Bunker 3030, and Building 167 inside and outside ground areas demonstrates compliance with the criteria approved by the Nuclear Regulatory Commission for unrestricted use per the limits contained in the contamination tables of ARDEC's NRC Broad Scope and Source Material Licenses. The Dog Pound Area and Gorge Area do not demonstrate compliance with the unrestricted use criteria established by the Nuclear Regulatory Commission without further investigation. Unrestricted use of areas may be permissible with the requirement that their use will be in support of ARDEC's mission.

Unrestricted release and removal of the facilities from the license may be approved by the NRC taking site specific information into account in determining acceptable concentrations of residual radioactivity at the specific sites using appropriate dose models and exposure scenarios.

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4. USACHPPM Historical Records Review, Volume 2, No. 27-MH-7799-98.

5. U.S. Code of Federal Regulations, 10 CFR 20.

6. "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Materials (NRC 1993), Office of Nuclear Material Safety and Safeguards (NMSS)."

7. U.S. Nuclear Regulatory Commission, Draft Regulatory Guide DG-4006, August 1998, *Demonstrating Compliance With The Radiological Criteria For License Termination.*

8. U.S. Nuclear Regulatory Commission, Draft Regulatory Guide NUREG-1500, August 1994, *Working Draft Regulatory Guide on Release Criteria for Decommissioning.*

9. Federal Register, Dated November 18, 1998 (Volume 63, Number 222, Pages 64132-64134) "Supplemental Information on the Implementation of the Final Rule on Radiological Criteria for License Termination".

10. Federal Register, Dated December 7, 1999 (Volume 64, Number 234, Pages 68395-668396) "Supplemental Information on the Implementation of the Final Rule on Radiological Criteria for License Termination".

11. ISO-7503-1, International Organization for Standardization, (ISO), 1988. *Evaluation of Surface Contamination -Part 1 :Beta-emitters (Maximum Beta Energy Greater Than 0,15 MeV) and Alpha-emitters, 1st Edition*, 1 August 1988

12. New World Technology, *Field Operations Procedures*