FINAL

AREA 10 SAND PILES REMOVAL ACTION
FINAL STATUS SURVEY REPORT

Lake City Army Ammunition Plant
Independence, Missouri

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EXECUTIVE SUMMARY

Removal action and final status survey (FSS) activities have been completed for the Area 10 Sand Piles at Lake City Army Ammunition Plant (LCAAP), in accordance with the *Area 10 Sand Piles Action Memorandum (*CABRERA, 2008a*)*. The Area 10 Sand Piles contained spent bullet catcher sand from historic test firing and demilitarization activities conducted at the LCAAP firing range. Some of these activities involved munitions containing depleted uranium (DU), a licensed radioactive material. The purpose of the Area 10 removal action and FSS was to: 1) identify and remove DU and radioactively contaminated material from the site, and 2) demonstrate that the remaining soils are suitable for unrestricted release with respect to radioactivity, in accordance with Nuclear Regulatory Commission (NRC) requirements.

Field activities, which were conducted in 2008, consisted of gamma walkover surveys (GWS) and soil sampling and analysis consistent with FSS requirements specified in the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM; NRC, 2000). Site-specific activities were implemented as described in the *Area 10 Final Status Survey Plan,* which is presented as Appendix B of the *Area 10 Sand Piles Removal Action Work Plan* (CABRERA, 2008b). This *Final Status Survey Report* presents the results of release surveys for the Area 10 sand pile material and FSS of the underlying and adjacent soils.

A 100% GWS was conducted for each of 52 lifts of sand pile material, and 10 underlying soil Class 1 survey units (SUs). A 50% GWS was conducted for the single adjacent soil Class 2 SU. The GWS employed field instruments for the detection of low-energy radiation (FIDLERs), each equipped with a global positioning system (GPS). The GWS results were used to identify specific locations where surface radioactivity appeared to be elevated so that buried DU fragments and associated contaminated materials could be located and removed.

Systematic sand/soil samples were collected from each one-foot lift of sand pile material and from the top layer of underlying and adjacent soil using a triangular grid pattern to establish sample locations. In addition, biased soil samples were collected from locations of highest gamma response, as measured during the GWS. A total of 1,207 samples were collected; 1,040 from the sand pile material and 167 from the soil SUs.

Results of the sand pile material release surveys were used to determine whether specific SU lifts of sand were suitable for unrestricted release. Survey and sampling results demonstrated that approximately 95% of the sand pile waste (by weight) met the release criteria and was

disposed at a local Subtitle D industrial waste landfill. Sand and debris that did not meet the release criteria was separated from the main waste stream and set aside for disposal as special waste at a Subtitle C permitted landfill.

Results of the FSS indicate that the underlying and adjacent soil remaining at Area 10 following removal of the sand piles is suitable for unrestricted release, in accordance with NRC requirements set forth in 10 CFR 20.1402. Neither direct radiation measurements nor analytical data for the FSS samples indicate the presence of residual licensed radioactive materials at Area 10. In light of the information presented in this report, it is recommended that a license amendment be sought from the NRC to release Area 10 for unrestricted use with respect to radioactivity.

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ACRONYMS AND ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
^{241}AM	americium-241
CABRERA	Cabrera Services, Inc.
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
^{60}Co	cobalt-60
cf	cubic foot (feet)
COC	chain of custody
cpm	count(s) per minute
^{137}Cs	cesium-137
cy	cubic yard(s)
DCGL	Derived Concentration Guideline Level
DU	Depleted Uranium
EPA	Environmental Protection Agency
FIDLER	Field Instrument for the Detection of Low Energy Radiation
FSS	Final Status Survey
FSSP	Final Status Survey Plan
ft	foot (feet)
GIS	Geographic Information System
GM	Geiger-Mueller
GPS	Global Positioning System
GWS	Gamma Walkover Survey
HEPA	High-Efficiency Particulate Air
HP	Health Physics
HPGe	High-Purity Germanium
JMC	Joint Munitions Command
keV	kiloelectron volt(s)
LCAAP	Lake City Army Ammunition Plant
m^2	square meters
MARLAP	Multi-Agency Radiological Laboratory Analytical Protocols
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MC	Munitions Constituents
MD	Munitions Debris
MDC	Minimum Detectable Concentration
MEC	Munitions and Explosives of Concern
mrem/yr	millirem(s) per year
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
pCi/g	picoCurie(s) per gram
QAPP	Quality Assurance Project Plan
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
ROC	Radionuclide of Concern
SARA	Superfund Amendments and Reauthorization Act
σ	sigma
SU	Survey Unit
TEDE	Total Effective Dose Equivalent
^{234}Th	thorium-234
^{208}Tl	thallium-208
UXO	Unexploded Ordnance
^{234}U	uranium-234
^{235}U	uranium-235
^{238}U	uranium-238
Z_{Rep}	Z-Replicate

1.0 INTRODUCTION

Cabrera Services, Inc. (CABRERA) has performed a removal action and associated final status survey (FSS) activities within Area 10 at the Lake City Army Ammunition Plant (LCAAP) in Independence, Missouri. Activities were performed under contract to the U.S. Army Joint Munitions Command (JMC). The sand pile removal action at Area 10 was developed and conducted in accordance with the provisions of the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA), as amended by the *Superfund Amendments and Reauthorization Act* (SARA), and in accordance with the *Area 10 Sand Piles Action Memorandum* (CABRERA, 2008a).

This *Final Status Survey Report* summarizes the radiological survey and sampling results, documents the disposition of sand pile material, and demonstrates that the final (i.e., post-removal action) conditions at Area 10 meet the established radiological criteria for unrestricted release from NRC license requirements. Documentation of sampling results for non-radiological constituents, as well as processing, segregation, and other waste handling and disposal activities performed as part of the removal action are presented in the *Area 10 Sand Piles Removal Action Completion Report* (CABRERA, 2009).

1.1 Background

LCAAP is a Class II government-owned, contractor-operated, military industrial installation that manufactures and tests small arms ammunition for the U.S. Army. The 3,935-acre facility is located in Independence, Missouri, on the east side of the intersection of Highways 7 and 78. Area 10 is situated within the controlled perimeter of the active munitions firing range in the eastern uplands portion of the LCAAP installation, as shown in Figure 1-1.

The Area 10 removal action involved the removal, processing, and disposal of approximately 37,500 cubic yards (cy; equivalent to approximately 59,000 tons) of waste. This material consisted of spent bullet catcher sand; munitions and explosives of concern (MEC), which includes munitions constituents (MC) and potential unexploded ordnance (UXO); and munitions debris (MD) derived from historical munitions testing and demilitarization operations. Results of past investigations at the site have identified lead and DU as CERCLA contaminants of concern. MEC was addressed as a potential safety hazard.

1.2 Previous Site Activities

Over the past 15 years, Area 10 has been the subject of numerous investigations including: an extensive archives search to examine the history and use of DU at LCAAP; sampling and analysis events designed to characterize the nature and extent of contamination; and treatability studies designed to evaluate potential remediation techniques for DU and lead. In 1998, based on results of previous field investigations, the Army removed approximately 30,000 cubic feet (cf; equivalent to 1,100 cy) of material in which high concentrations of surface radioactivity were observed. This partial remediation of the sand piles was conducted as an NRC license decommissioning effort, in accordance with the *Area 10 Decommissioning Plan* (ATG, 1998). The remediation was not completed, however, due to the unexpected discovery of hazardous concentrations of leachable lead and radioactive UXO, neither of which the Army was prepared to address at the time.

In 2001, the NRC deferred its decommissioning oversight authority for Area 10 to the U.S. Environmental Protection Agency (EPA) in order to facilitate the remediation of both chemical and radiological contaminants without imposing dual regulation (NRC, 2001). The intent was that EPA would assume oversight responsibility for the remediation of Area 10 as part of its overall regulatory oversight authority at LCAAP under the *Federal Facilities Agreement* (FFA, 1989). The NRC retained responsibility for reviewing EPA's determination as to whether Area 10 had been successfully remediated, and for ensuring that the remediation complied with the NRC release criteria for unrestricted use, as specified in the Army's nuclear materials license (No. SUC-1380; NRC, 2004).

Since 2001, several field investigations have been performed at Area 10 under *CERCLA*. In 2004, additional characterization activities were conducted to evaluate contaminants of potential concern (COPCs) other than lead and DU that may have impacted the sand piles and surrounding media (*Area 10 Sand Piles Sampling and Analysis Report,* CABRERA, 2004). In 2005, a field treatability study was performed to generate design-level data for a full-scale removal action. The objectives of this study were to generate an inventory of UXO and munitions scrap (both radioactive and non-radioactive) and develop operating parameters for the full-scale treatment design for stabilization of lead (*Area 10 Sand Piles Field Treatability Study Report,* CABRERA, 2005a). To improve the general understanding of existing groundwater conditions at the site and verify the conceptual site model used for risk assessment purposes, a final groundwater sampling and analysis event was conducted in 2007

(*Technical Memorandum: Groundwater Sampling and Analysis Report for Area 10*, CABRERA, 2007).

Data from the field investigations were considered in the removal action design for Area 10. The results of studies conducted prior to 2005 were incorporated into the *Area 10 Sand Piles Engineering Evaluation/Cost Analysis* (EE/CA; CABRERA, 2005b), which presented the basis for the removal action by characterizing current site conditions and associated risks, evaluating potential removal action alternatives, and recommending a suitable removal action approach. Details of the recommended removal action were reviewed by EPA, MDNR, and NRC, and discussed at two separate public meetings. Upon achieving concurrence with the regulatory agencies and the LCAAP stakeholders, a slightly modified version of the removal action approach recommended in the EE/CA was formally documented and authorized by the Army in the *Area 10 Sand Piles Action Memorandum* (CABRERA, 2008a).

1.3 Radionuclide of Concern

The principal radionuclides of concern (ROCs) at Area 10 are the isotopes of uranium that comprise DU: uranium-234 (^{234}U), uranium-235 (^{235}U), and uranium-238 (^{238}U). Based on the U.S. Army Environmental Policy Institute's Technical Report, *Health and Environmental Consequences of Depleted Uranium Use in the Army* (Army, 1995), it is assumed that uranium isotopes were present in the DU at Area 10 in the following percent activities: 15.55% ^{234}U, 1.07% ^{235}U, and 83.38% ^{238}U. These published isotopic activity fractions are consistent with those previously observed at LCAAP in soil samples from the 600-Yard Bullet Catcher (15% ^{234}U, 1.9% ^{235}U, and 83.1% ^{238}U), DU Impact Areas (15% ^{234}U, 1.7% ^{235}U, and 83.4% ^{238}U), and Area 31 Waste Landfill (14.5% ^{234}U, 1.6% ^{235}U, and 83.8% ^{238}U).

1.4 Derived Concentration Guideline Level

As outlined in the *Area 10 Final Status Survey Plan (FSSP),* which is Appendix B of the *Area 10 Sand Piles Removal Action Work Plan* (CABRERA, 2008b), there were two components of the Derived Concentration Guideline Level (DCGL) for the Area 10 removal action: 1) the DCGL for the sand pile material, and 2) the DCGL for the residual underlying and adjacent soil.

1.4.1 Sand DCGL

The DCGL applicable to the disposition of sand pile waste was set at 8.4 picocuries per gram (pCi/g) for ^{238}U, based on detection and quantification of the surrogate radionuclide, thorium-234 (^{234}Th), via gamma spectroscopy. The DCGL determination is presented in the *Area 10 Sand Piles Action Memorandum (*CABRERA, 2008a*)*. This value corresponds to the EPA-specified total effective dose equivalent (TEDE) of 15 millirem per year (mrem/yr), and ensures that waste disposed in an off-site landfill does not result in a maximum dose rate to an exposed individual higher than that recommended by the EPA. The sand pile DCGL was derived by scaling down the NRC screening level (14 pCi/g) equivalent to 25 mrem/yr, per NUREG-1757, Volume 2 (NRC, 2003), to account for the lower EPA-recommended dose rate. Any ^{238}U result measured in the sand pile material (as inferred from the measured ^{234}Th activity concentration) that was greater than the DCGL of 8.4 pCi/g required further investigation, including delineating the area of elevated activity and exclusion of this volume of sand from consideration for off-site disposal at a Subtitle D facility.

1.4.2 Residual Soil DCGL

The DCGL applicable to residual underlying and adjacent soil corresponded to the NRC-established unrestricted release criterion of 35 pCi/g total uranium specified in the Army's Nuclear Materials License (No. SUC-1380; NRC, 2004). Assuming the activity percentages for DU presented in Section 1.3 of this report, this criterion equates to a ^{238}U soil concentration of 29.2 pCi/g. This soil DCGL (i.e., 35 pCi/g total uranium or 29.2 pCi/g ^{238}U) was used to evaluate individual soil samples from the Class 1 and Class 2 SUs following the removal of sand pile material. As with the sand samples, ^{238}U results were inferred from the measured ^{234}Th activity concentration in the soil samples.

2.0 SAND PILE REMEDIATION ACTIVITIES

The sand pile material was surveyed and sampled prior to excavation to identify and remove DU fragments and radioactively contaminated materials, and to verify compliance with the sand DCGL prior to off-site disposal. Investigation activities included GWS, as well as systematic and biased sampling. The overall investigative process was as follows:

- Initial (characterization) GWS to identify areas of elevated radioactivity. GWS data were mapped and evaluated graphically to identify specific areas for further investigation and/or remediation.
- Removal of DU fragments and contaminated material. Removals were conducted manually, at locations of elevated (i.e., greater than 12,000 counts per minute [cpm], as specified below) GWS count rates, using manual excavation techniques (e.g., shovel or trowel).
- Secondary (final status) GWS following fragment removal. Additional survey data was collected following the removal of material at each location to determine whether the remediation was successful in removing areas of elevated radioactivity
- Systematic sampling. Systematic sampling was conducted on a triangular grid to provide ^{234}Th concentration data and verify through analytical results that the remediation was successful prior to excavation of the one-foot lift.

2.1 Gamma Walkover Surveys

Consistent with *MARSSIM* (NRC, 2000) requirements for Class 1 areas, a GWS was conducted using FIDLERs over 100% of the surface area of the sand pile SUs prior to the release of each one-foot lift. A gross count rate of 12,000 cpm was empirically determined to be the lowest count rate at which DU fragments were potentially present in the top 12 inches of sand pile material. This flag value was used by technician crews to guide remediation efforts. GWS data were further evaluated using a Z-score calculation to identify potential hotspots. The purpose of the GWS was to detect the presence of DU projectiles and/or fragments in the sand piles and to identify any additional locations of elevated activity for the collection of biased samples. If DU fragments were detected and removed as a result of the first GWS, a second GWS was performed over the disturbed area to confirm that no further remediation was required. GWS reports containing a spatial depiction of field measurements for each of the 52 sand pile SUs are presented in Appendix A.

The GWS of the sand pile material was conducted using the instrumentation and methodology discussed in the *FSSP* (CABRERA, 2008b). The surveys were implemented in a manner that facilitated the real-time identification of areas exhibiting elevated radioactivity (i.e., through audible and visual meter response signals) so that DU and potentially impacted sand could be immediately recognized and addressed.

2.2 Sand Pile Sampling

Consistent with *MARSSIM* requirements for FSS, sampling and analysis was conducted at a statistically significant number of systematic locations in each SU lift to verify compliance with the applicable DCGL (see Section 1.4). The derivation of the minimum number of measurements required and the establishment of sample locations are presented in the *FSSP* (CABRERA, 2008b). A triangular sampling grid with a randomly generated starting point was established across each sand pile SU lift once the boundary of the individual SU was delineated. Sample location coordinates were determined using a Geographical Information System (GIS) program, and were placed in the field using a global positioning system (GPS) unit and measuring tape, as necessary.

Sample spacing within the triangular grid was approximately 11 meters. Samples of sand pile material were collected at each systematic location and analyzed according to the methodology presented in the *FSSP* (CABRERA, 2008b). All samples were analyzed in the CABRERA onsite gamma spectroscopy laboratory. A total of twenty (20) systematic samples were collected and analyzed from each sand pile SU lift. The GWS reports in Appendix A contain the analytical results for samples collected from each of the 52 sand pile SUs. Table 2-1 presents the summary statistics generated from these sample results.

2.3 Sand Pile Processing and Disposition

Upon completion of radiological survey, sampling, and removal activities across the surface of each sand pile SU, the top one-foot lift of material was excavated from the SU and temporarily stockpiled elsewhere within Area 10 to await further processing and final disposition. Survey, sampling, and removal activities were repeated for the newly exposed SU lift and for each subsequent underlying lift of material until the entire sand pile was removed.

The excavated material was processed through a mechanical screening plant for the removal of MEC. During the mechanical screening and processing of the sand pile material, additional monitoring was implemented as a conservative measure to ensure that the residual DU concentration was maintained as low as reasonably achievable (ALARA). The monitoring design included three stationary, alarm-enabled FIDLER detectors suspended above the conveyor belt and situated downstream of the screening plant to monitor the screened sand exiting the plant. The conveyor moved sand at a constant speed (i.e., between 0.5 and 2 meters per second) to a process stockpile to await stabilization and disposal. The depth of the screened sand conveyed below the detectors was between 1 and 4 inches, depending on the screen plant load rate and the conveyor speed. The goal of the detector system was to reliably detect a 40-gram fragment in the passing sand so that it could be retrieved from the screened sand. In practice, DU fragments as small as 5 grams were detected during this screening process due to redundancies in the detector design and more favorable operating geometry.

Non-radioactive sand exiting the screening plant was treated with Maectite® to stabilize the leachable lead and shipped off-site for disposal as industrial waste at a Subtitle D landfill in Johnson County, Kansas. Screened sand from the remediated portions of the sand piles (i.e., radioactively contaminated sand) was packaged and shipped as "Special Waste with Unimportant Quantities of Radioactivity," D008-Lead, for treatment and disposal at the U.S. Ecology Resource Conservation and Recovery Act (RCRA) Subtitle C permitted facility in Grand View, Idaho.

Table 2-1: Summary Statistics (^{234}Th) for Sand Pile Survey Units

Survey Unit	Number of Samples	Activity Concentration (pCi/g)				
		Average	Standard Deviation	Median	Minimum	Maximum
SU-01	20	0.79	0.42	0.70	0.22	1.58
SU-02	20	0.81	0.49	0.77	0.08	2.14
SU-03	20	0.81	0.46	0.83	-0.03	1.61
SU-04	20	0.68	0.32	0.73	0.08	1.24
SU-05	20	0.56	0.45	0.52	-0.52	1.58
SU-06	20	0.67	0.47	0.63	-0.14	1.48
SU-07	20	0.52	0.45	0.42	-0.21	1.55
SU-08	20	0.79	0.36	0.77	0.31	1.59
SU-09	20	0.67	0.44	0.67	-0.06	1.60
SU-10	20	0.78	0.52	0.82	-0.27	1.94
SU-11	20	0.60	0.73	0.46	-0.82	2.92
SU-12	20	0.67	0.61	0.58	-0.44	2.13
SU-13	20	0.48	0.37	0.48	-0.08	1.21
SU-14	20	0.53	0.50	0.46	-0.64	1.75
SU-15	20	0.65	0.53	0.61	-0.14	1.76
SU-16	20	0.69	0.58	0.78	-0.71	1.55
SU-17	20	0.70	0.67	0.70	-0.35	2.55
SU-18	20	0.68	0.52	0.63	-0.09	1.58
SU-19	20	0.71	0.52	0.52	0.07	2.08
SU-20	20	0.53	0.30	0.54	0.05	1.05
SU-21	20	0.73	0.51	0.62	-0.17	1.84
SU-22	20	0.56	0.40	0.56	-0.10	1.22
SU-23	20	0.64	0.40	0.64	-0.13	1.26
SU-24	20	0.61	0.45	0.51	-0.17	1.51
SU-25	20	0.53	0.30	0.54	0.05	1.05
SU-26	20	0.69	0.41	0.64	-0.01	1.84
SU-27	20	0.65	0.26	0.62	0.25	1.22
SU-28	20	0.86	1.67	0.69	0.19	2.97
SU-29	20	0.46	0.24	0.52	-0.18	0.73
SU-30	20	0.95	0.37	0.93	0.43	1.98
SU-31	20	0.62	0.35	0.52	0.07	1.54
SU-32	20	0.57	0.23	0.54	0.15	1.04
SU-33	20	0.87	0.28	0.86	0.29	1.65
SU-34	20	0.40	0.30	0.40	-0.56	0.76
SU-35	20	0.46	0.25	0.44	-0.05	1.02
SU-36	20	0.48	0.36	0.46	-0.59	1.11

Table 2-1: Summary Statistics (^{234}Th) for Sand Pile Survey Units (cont'd)

Survey Unit	Number of Samples	Activity Concentration (pCi/g)				
		Average	Standard Deviation	Median	Minimum	Maximum
SU-37	20	0.56	0.17	0.54	0.31	0.85
SU-38	20	0.55	0.32	0.48	0.08	1.43
SU-39	20	0.46	0.13	0.46	0.24	0.79
SU-40	20	0.63	0.33	0.64	0.05	1.23
SU-41	20	0.64	0.34	0.53	0.26	1.58
SU-42	20	0.58	0.25	0.57	-0.13	1.08
SU-43	20	0.51	0.24	0.50	-0.17	0.90
SU-44	20	0.48	0.22	0.50	-0.07	0.79
SU-45	20	0.56	0.27	0.57	-0.23	1.00
SU-46	20	0.68	0.53	0.59	-0.17	2.46
SU-47	20	0.54	0.20	0.52	-0.04	0.92
SU-48	20	0.66	0.26	0.64	0.09	1.31
SU-49	20	0.56	0.19	0.54	0.23	0.94
SU-50	20	0.48	0.44	0.43	-0.90	1.26
SU-51	20	0.50	0.41	0.53	-0.35	1.17
SU-52	20	0.63	0.43	0.47	-0.13	1.54

3.0 FINAL STATUS SURVEY ACTIVITIES

A FSS on the underlying/adjacent soils was conducted after the sand pile removal activities were complete. Survey and sampling activities were performed in accordance with the *FSSP* (CABRERA, 2008b), and were consistent with *MARSSIM* requirements for FSS. The underlying soil within the sand pile footprint was subdivided into 10 Class 1 SUs; while the soil immediately adjacent to the sand pile footprint (including an area approximately 5 meters wide surrounding the perimeter of the sand pile footprint, as well as the swale between the footprint and the downgradient pond) was designated as a Class 2 SU. Class 1 and 2 areas are defined as follows:

- Class 1: impacted areas that that have, or had prior to remediation, a potential for contamination or known contamination above the DCGL. *MARSSIM* allows areas of up to 2,000 square meters (m^2) for Class 1 SUs.

- Class 2: impacted areas that have, or had prior to remediation, concentrations of residual radioactivity that are not likely to exceed the DGCL. *MARSSIM* allows areas of up to 10,000 m^2 for Class 2 SUs.

The soil SU locations and boundaries are presented in Figure 3-1. The FSS of these soil SUs was designed to identify DU fragments located within the top 12 inches of soil.

3.1 Gamma Walkover Survey

Upon removal of the sand pile material from Area 10, a 100% GWS was performed in each of the ten Class 1 underlying soil SUs. In addition, a GWS was performed over a minimum of 50% of the adjacent soil Class 2 SU. The purpose of the GWS was to locate and remove any remaining DU projectiles or fragments following the removal of sand pile material, as well as to identify areas of elevated radioactivity for the collection of biased surface soil samples.

For the footprint soil, a gross count rate of 15,500 cpm was used as a flag value. This value was higher than that used for the sand pile material because higher background levels were observed in the native clay than in the sand. Initial set of GWS data were evaluated to identify the range of background levels using time-series graphs and Z-score calculations. The threshold value of 15,500 cpm represented the empirically-determined upper level of background, and its use was supported by the soil sampling results.

DU fragments that were detected during the GWS were removed manually, and additional GWS data were collected to confirm that no further remediation was required. FSS reports containing a spatial depiction of the final GWS data for each of the 11 soil SUs are presented in Appendix B. Figure 3-1 presents a compilation of the GWS results for all underlying and adjacent soil SUs.

3.2 Systematic Surface Soil Sampling

Fourteen (14) surface soil samples were collected in each of the 11 soil SUs. Sample locations were established based on a triangular grid pattern with a sample spacing of approximately 13 meters. The minimum number of systematic soil samples required in the soil SUs was derived in accordance with *MARSSIM*, as discussed in the *FSSP* (CABRERA, 2008b). The individual FSS reports in Appendix B present the onsite analytical results for each soil SU.

3.3 Biased Soil Sampling

Surface soil samples were collected at biased locations to investigate areas of elevated radioactivity based on GWS results. Biased samples were collected at locations exhibiting a Z-score of greater than three (i.e., where radioactivity measurements were greater than 3 standard deviations above the data set mean). In areas exhibiting multiple measurements with a Z-score of greater than three, the sample was collected at the location of highest activity within a horizontal radius of 10 feet (ft). Results of the biased sampling are included in the Appendix B FSS reports.

3.4 Onsite Gamma Spectroscopy Laboratory

The CABRERA onsite gamma spectroscopy laboratory consisted of an 8-ft x 28-ft portable office trailer split into two operating areas: 1) a gamma spectroscopy and health physics (HP) instrumentation count room; and 2) a sample preparation, packaging, and storage area. CABRERA performed onsite gamma spectroscopy sample analyses on all soil samples utilizing a high purity germanium (HPGe) detector. Prior to the performance of project sample analyses, the detector was calibrated using a mixed gamma standard traceable to the National Institute of Standards and Technology (NIST). The certificate of calibration for the NIST-traceable standard, along with the HPGe detector calibration information are included in Appendix C.

The gamma spectroscopy system was operated by a trained technician in accordance with CABRERA'S Standard Operating Procedures. The operator performed spectral analysis during each measurement, which encompassed the evaluation of spectra for problems such as peak shift, high dead-time and other potential inconsistencies in spectral structure. A qualified Health Physicist reviewed the integrity of the sample results for each sample prior to submittal of the final results for approval.

3.4.1 Onsite Sample Preparation Activities

All samples collected were delivered to the onsite lab for interim storage, processing and analysis, and packaging for off-site analysis. Samples were accompanied by a completed field Chain-Of-Custody (COC) form. This sample collection, preparation, and counting process was tracked throughout the project on the *Onsite Lab Sample Count Tracking Log*, provided in Appendix D.

Following sample collection and logging, soil samples were prepared for analysis by heating (to dryness) in a conventional oven. A pilot study was performed prior to collection of actual FSS samples, in accordance with Cabrera procedure OP-026, to determine an appropriate drying time in the oven. Soils were weighed and dried and reweighed until the percent moisture difference of less than 1% was observed. The corresponding drying time for the pilot samples was used for drying the FSS samples to ensure complete dryness without the need to perform sample-by-sample moisture measurements. .Once dry, the soil was ground to a consistent particle size to provide a homogeneous sample. Grinding operations were monitored using a low-volume air sampler to ensure that no airborne radioactive hazards were present in the sample preparation laboratory (see Appendix E for results). The completed sample was then packaged in a 1-liter high-density polyethylene marinelli beaker, labeled with its sample ID, and sealed prior to gamma spectroscopy analysis.

3.4.2 Onsite Sample Counting and Analysis

Sample analysis was performed using a Canberra Industries reverse electrode closed-end coaxial HPGe detector with a 60% relative efficiency. CABRERA utilized a customized radionuclide library to analyze the gamma spectral data consisting of naturally occurring radionuclides present in soil, along with cesium-137 (^{137}Cs), to analyze the gamma spectral data. ^{137}Cs is not naturally occurring, but is present in terrestrial soils as a result of global nuclear weapons testing fallout. Radionuclide gamma and x-ray energies and yields were

extracted from the National Nuclear Data Center (nuclide data updated as of 2002). CABRERA utilized directly measured ^{234}Th activity concentrations as a surrogate for its decay chain parent, ^{238}U, the prominent nuclide in DU. The nuclide concentrations of parent ^{238}U and daughter ^{234}Th are expected to be equal in the soil due to their secular equilibrium radioactive decay relationship. The ^{234}Th gamma energy lines used for determining the presence of DU particles were 63.3 kiloelectron volts (keV) at 4.8% yield, and 92.6 keV at 5.6% yield (summation of two indistinguishable peaks). Each soil sample count was acquired for 15 minutes to ensure adequate minimum detectable concentration (MDC) values that were a fraction of the 8.4 pCi/g DCGL.

All of the FSS soil samples collected were analyzed in the onsite laboratory. Quality control (QC) samples were shipped for off-site analysis, as discussed in Section 3.5. Soil samples counted onsite that were not designated for off-site analysis were sent back to Area 10 for treatment and disposal in conjunction with on-going soil and waste processing.

3.5 Off-Site Laboratory Analysis

Ten percent of the soil samples were transferred to an independent laboratory (i.e., Paragon Analytics Inc. [Paragon] of Fort Collins, Colorado) for analyses in accordance with documented laboratory-specific standard methods. Upon receipt at the off-site laboratory, the samples were weighed, dried, and reweighed. Gamma spectroscopy was performed by Paragon in accordance with the requirements presented in the *Quality Assurance Project Plan* (QAPP), which is Appendix H of the *Area 10 Sand Piles Removal Action Work Plan* (CABRERA, 2008b). Paragon's qualifications for performing these tests are documented in the QAPP, and recognized through certification by the State of Kansas.

Samples designated for shipment to the off-site laboratory were originally transferred from the 1-liter marinelli beaker used for onsite counting to a 16-ounce high-density polyethylene container provided by the off-site laboratory. However, this method was shown to introduce bias into the counting process, leading to discrepancies between reported concentrations of the onsite versus off-site sample results (see Section 6.2 for discussion). This issue was resolved by maintaining the same count geometry for the off-site lab as was used for the onsite lab. From that time on, samples were no longer repackaged, but instead were shipped in the original 1-liter marinelli beakers used onsite to be counted directly by the off-site lab.

Turn-around times for analysis results varied during the project. The majority required a standard 30-calendar day turnaround. However, expedited turnaround times of 10 and 21 calendar days were also utilized to meet certain project objectives.

4.0 FINAL STATUS SURVEY RESULTS

FSS data collected from each underlying and adjacent soil SU were compiled and evaluated to determine whether the individual SUs were suitable for unrestricted release. As presented in Section 3.0, there were a total of 10 footprint (FP) soil SUs and one adjacent (AJ) soil SU Plots of the GWS results and analytical data from systematic and biased sampling locations within each SU are provided in the FSS data reports in Appendix B. A summary of the results for each SU is presented in Table 4-1.

4.1 Survey Unit SU-FP01

The FSS evaluation of SU-FP01 entailed the performance of a GWS and the collection and gamma spectroscopy analysis of 14 systematic and 2 biased samples. The measured ^{234}Th concentrations ranged from 0.76 to 2.18 pCi/g, averaging 1.31 pCi/g with a standard deviation of 0.35 pCi/g. All FSS sample results for SU FP01 were below the soil DCGL of 29.2 pCi/g. This SU met the release criteria and is thereby suitable for unrestricted release.

4.2 Survey Unit SU-FP02

The FSS evaluation of SU-FP02 entailed the performance of a GWS and the collection and gamma spectroscopy analysis of 14 systematic and 1 biased samples. The measured ^{234}Th concentrations ranged from 0.70 to 1.58 pCi/g, averaging 1.08 pCi/g with a standard deviation of 0.31 pCi/g. All FSS sample results for SU-FP02 were below the soil DCGL of 29.2 pCi/g. This SU met the release criteria and is thereby suitable for unrestricted release.

4.3 Survey Unit SU-FP03

The FSS evaluation of SU-FP03 entailed the performance of a GWS and the collection and gamma spectroscopy analysis of 14 systematic and 2 biased samples. The measured ^{234}Th concentrations s ranged from -0.08 to 1.49 pCi/g, averaging 0.74 pCi/g with a standard deviation of 0.48 pCi/g. All FSS sample results for SU-FP03 were below the soil DCGL of 29.2 pCi/g. This SU met the release criteria and is thereby suitable for unrestricted release.

4.4 Survey Unit SU-FP04

The FSS evaluation of SU-FP04 entailed the performance of a GWS and the collection and gamma spectroscopy analysis of 14 systematic and 2 biased samples. The measured ^{234}Th

concentrations ranged from 0.31 to 1.23 pCi/g, averaging 0.83 pCi/g with a standard deviation of 0.23 pCi/g. All FSS sample results for SU-FP04 were below the soil DCGL of 29.2 pCi/g. This SU met the release criteria and is thereby suitable for unrestricted release.

4.5 Survey Unit SU-FP05

The FSS evaluation of SU-FP05 entailed the performance of a GWS and the collection and gamma spectroscopy analysis of 14 systematic and 1 biased samples. The measured ^{234}Th concentrations ranged from -0.41 to 2.88 pCi/g, averaging 1.09 pCi/g with a standard deviation of 0.76 pCi/g. All FSS sample results for SU-FP05 were below the soil DCGL of 29.2 pCi/g. This SU met the release criteria and is thereby suitable for unrestricted release.

4.6 Survey Unit SU-FP06

The FSS evaluation of SU-FP06 entailed the performance of a GWS and the collection and gamma spectroscopy analysis of 14 systematic samples. Since no contoured Z-score value was greater than 3.0, no biased samples were necessary in SU-FP06. The measured ^{234}Th concentrations ranged from -0.11 to 1.29 pCi/g, averaging 0.73 pCi/g with a standard deviation of 0.35 pCi/g. All FSS sample results for SU-FP06 were below the soil DCGL of 29.2 pCi/g. This SU met the release criteria and is thereby suitable for unrestricted release.

4.7 Survey Unit SU-FP07

The FSS evaluation of SU-FP07 entailed the performance of a GWS and the collection and gamma spectroscopy analysis of 14 systematic and 1 biased samples. The measured ^{234}Th concentrations ranged from 0.45 to 4.71 pCi/g, averaging 1.31 pCi/g with a standard deviation of 1.15 pCi/g. All SU-FP07 FSS sample results were below the soil DCGL of 29.2 pCi/g. This SU met the release criteria and is thereby suitable for unrestricted release.

4.8 Survey Unit SU-FP08

The FSS evaluation of SU-FP08 entailed the performance of a GWS and the collection and gamma spectroscopy analysis of 14 systematic samples. Since no contoured Z-score value was greater than 3.0, no biased samples were necessary in SU FP08. The measured ^{234}Th concentrations ranged from 0.37 to 1.71 pCi/g, averaging 1.04 pCi/g with a standard deviation of 0.39 pCi/g. All FSS sample results for SU-FP08 were below the soil DCGL of 29.2 pCi/g. This SU met the release criteria and is thereby suitable for unrestricted release.

4.9 Survey Unit SU-FP09

The FSS evaluation of SU-FP09 entailed the performance of a GWS and the collection and gamma spectroscopy analysis of 14 systematic and 2 biased samples. The measured ^{234}Th concentrations ranged from 0.37 to 4.84 pCi/g, averaging 1.53 pCi/g with a standard deviation of 1.20 pCi/g. All FSS sample results for SU-FP09 were below the soil DCGL of 29.2 pCi/g. This SU met the release criteria and is thereby suitable for unrestricted release.

4.10 Survey Unit SU-FP10

The FSS evaluation of SU-FP10 entailed the performance of a GWS and the collection and gamma spectroscopy analysis of 14 systematic and 2 biased samples. The measured ^{234}Th concentrations ranged from 0.71 to 1.75 pCi/g, averaging 1.12 pCi/g with a standard deviation of 0.30 pCi/g. All FSS sample results for SU-FP10 were below the soil DCGL of 29.2 pCi/g. This SU met the release criteria and is thereby suitable for unrestricted release.

4.11 Survey Unit SU-AJ01

The FSS evaluation of SU-AJ01 entailed the performance of a GWS and the collection and gamma spectroscopy analysis of 14 systematic samples. Since no contoured Z-score value was greater than 3.0, no biased samples were necessary in SU-AJ01. The measured ^{234}Th concentrations ranged from 0.65 to 2.07 pCi/g, averaging 1.32 pCi/g with a standard deviation of 0.39 pCi/g. All FSS sample results for SU-AJ01 were below the soil DCGL of 29.2 pCi/g. This SU met the release criteria and is thereby suitable for unrestricted release.

Table 4-1: Summary Statistics (^{234}Th) for Soil Survey Units

Survey Unit	Number of Samples	Activity Concentration (pCi/g)				
		Average	Standard Deviation	Median	Minimum	Maximum
SU-FP01	16	1.31	0.35	1.31	0.76	2.18
SU-FP02	15	1.08	0.31	1.11	0.70	1.58
SU-FP03	16	0.74	0.48	0.72	-0.08	1.49
SU-FP04	16	0.83	0.23	0.89	0.31	1.23
SU-FP05	15	1.09	0.76	1.08	-0.41	2.88
SU-FP06	14	0.73	0.35	0.75	-0.11	1.29
SU-FP07	15	1.31	1.15	0.93	0.45	4.71
SU-FP08	14	1.04	0.39	0.99	0.37	1.71
SU-FP09	16	1.53	1.20	1.16	0.37	4.84
SU-FP10	16	1.12	0.30	1.05	0.71	1.75
SU-AJ01	14	1.32	0.39	1.31	0.65	2.07

5.0 SITE RESTORATION

On March 21 and 22, 2009, the NRC, accompanied by USEPA and MDNR, conducted a confirmatory gamma walkover survey and soil sampling effort of the residual soil SUs. Upon receiving formal NRC approval to release Area 10 for unrestricted use, site restoration activities began. Prior to beginning site restoration a field crew did a sweep of the site and removed all visible MEC debris. This activity was conducted between June 29 and July 2, 2009. Approximately 6 inches of clean fill will be placed on top of the disturbed areas. The backfilled areas will be graded to blend the soil surface into the contours of the surrounding landscape and promote a suitable surface drainage flow pattern. After grading, these areas will be hydroseeded to re-establish a natural vegetative cover and minimize the potential for erosion. Additional details regarding site restoration are presented in the Area 10 Sand Piles Remedial Action Completion Report (CABRERA, 2009).

6.0 QUALITY ASSURANCE / QUALITY CONTROL

6.1 CABRERA Onsite Laboratory Quality Control Results

6.1.1 System Calibration

The CABRERA onsite laboratory HPGe detector was calibrated with a NIST-traceable multi-line gamma standard in a 1-liter marinelli beaker geometry prior to the performance of project sample analyses. The marinelli standard used for the system efficiency calibration consisted of an epoxy matrix manufactured to have a density of 1.6 grams per cubic centimeter, which approximated the average density of the project samples. A copy of the certificate of calibration for the marinelli beaker standard is provided in Appendix C.

6.1.2 Daily Quality Control Checks

Daily QC checks on the HPGe detector were also performed using a NIST-traceable marinelli standard. Analysis of the QC standard was performed daily to evaluate detector performance against established gamma spectroscopy QC criteria. The QC criteria consisted of detector resolution via measured Full Width at Half Maximum, energy calibration check using multi-line peak energy measurements, and detector efficiency check via decay-corrected activity concentration measurements. Each parameter was evaluated daily for americium-241 (^{241}Am) at 59.5 keV and cobalt-60 (^{60}Co) at 1332.5 keV. Quality control charts for each detector parameter are provided in Appendix F.

Daily QC results were satisfactory for all days that project sample analyses were performed, with the exception of October 13th. The HPGe displayed resolution values that were outside of the established tolerance bands (± 3 sigma [σ]) for both the initial count and procedurally required recount. When the system did not respond to basic troubleshooting techniques (high voltage recycle, computer re-boot, etc.), the operator contacted the Gamma Spectroscopy Manager. Inspection of the data indicated that although the daily result was outside of the 3σ tolerance band, the actual value was still within a normal operating band for that detector (less than 10% variance from the mean). It is not uncommon for field laboratory performance criteria to have small operating tolerances due to collection of the data in condensed periods of time. The Gamma Spectroscopy Manager deemed the system temporarily operable and instructed the operator to continue trending the condition with the understanding that if the problem continued to worsen, the system would be taken out of service.

At the beginning of the next shift, the system was completely powered down and all cable connections were reestablished and inspected prior to performance of the daily QC check on October 14th. The system satisfactorily completed all checks with values consistent with those observed previously. It is postulated that the resolution issues seen on October 13 were the result of abnormal electronic noise being injected into the system either through the detector cabling or preamp/amplifier. No other abnormal conditions were observed from that point forward. Results for all daily QC checks are provided in Appendix F.

6.1.3 Laboratory Blanks

The CABRERA gamma spectroscopy laboratory performed blank sample analyses to establish true laboratory backgrounds. Results of the blank analyses were used for background subtraction purposes from the sample analysis results. Blank analyses were performed weekly in accordance with the laboratory's written procedures. CABRERA typically uses a prepared sugar blank sample as a means for evaluating a true representative detector background since sugar contains very low concentrations of naturally occurring radioactive isotopes. However, at the beginning of the project, an alternate sand-based blank was also prepared as a means of testing sand pile samples against specific project objectives. The sand-based blank was originally used but discontinued when it was discovered that it resulted in too much subtraction of naturally occurring background constituents in each FSS sample. The use of the sand blank did not affect the reporting of any potential DU contamination in project samples.

6.1.4 Laboratory Replicate Sample Analyses

CABRERA performed replicate analyses on 10% of the samples analyzed in the onsite lab. Replicate analyses entailed repeating the analysis of a previously analyzed sample, without further processing, and comparing the results statistically using a Z-Replicate (Z_{Rep}) method as discussed in the *FSSP* (CABRERA, 2008b), consistent with the guidance of the *Multi-Agency Radiological Laboratory Analytical Protocols* (*MARLAP*) manual (EPA, 2004). Z_{Rep} evaluates a sample result against a replicate (or QC sample), including the stated uncertainties of each sample. The formula for Z_{Rep} is as follows:

$$Z_{\text{Replicate}} = \frac{Sample - Replicate}{\sqrt{\sigma^2_{Sample} + \sigma^2_{Replicate}}}$$

Where:

Sample	=	first sample value (original),
Replicate	=	second sample value (replicate),
σ_{Sample}	=	measurement uncertainty of the sample, and
$\sigma_{Replicate}$	=	measurement uncertainty of the replicate

The calculated Z_{Rep} results were compared to a performance criterion of ±1.96 as per the FSSP (CABRERA, 2008b). The ±1.96 criterion equates to a confidence level of 95%; at this level, a 5% failure rate is expected. Replicate analyses with Z_{Rep} results outside of ±1.96 were investigated. Of the 124 onsite replicate samples, 11 (or ~9%) were found to have a Z_{Rep} greater than the tolerance level of ±1.96. The complete set of Z_{Rep} results for the onsite lab is presented in Appendix G.

The replicate failure rate (~9%) was greater than what would be statistically expected at the chosen 95% confidence level (i.e., 5% failures). It was determined that more failures were induced by over-subtraction of natural products in the FSS samples by use of a "clean sand" blank rather than a true detector blank. Sand from a non-impacted area of LCAAP used for this purpose contains other naturally occurring radioactive products (e.g., potassium-40, thallium-208, etc.). This technique resulted in very low reported values on the Interference Corrected Report of the gamma spec software, which made Z_{Rep} comparisons difficult or impossible to perform due to higher relative error (samples where background subtracted to near-zero levels). This led to many more sets of data failing the prescribed ±1.96 σ criterion. The sand blank was abandoned in favor of a very low background material (i.e., sugar) which corrected this bias condition and returned the replicate analysis results to an expected performance level. A comparison of the nine replicate sets of data (for the nuclide thallium-208 [^{208}Tl] and ^{234}Th) are shown in Table 6-1 below, with original results for the sand blank and revised results using a sugar blank for background subtraction. The improvement in replicate performance is noticeable, with seven of the nine sets resulting in a passing condition, whereas the original results all failed the ±1.96 σ criterion. For the two samples that fell outside ±1.96 σ, the calculated values would still have passed a 99% confidence level (±2.57 σ) These replicate comparisons show that the onsite lab HPGe detector was functioning appropriately and that the data are acceptable.

Table 6-1: Reevaluation of Select Replicate Samples with Sugar Blank Background File

	Sand Background Subtracted					Sugar Background Subtracted				
Sample ID	**Nuclide**	**Result**	**Uncert**	**Z-Score**	**Eval**	**Nuclide**	**Result**	**Uncert**	**Z-Score**	**Eval**
SP06-111	Tl-208	2.62E-01	9.70E-02	**3.94**	**FAIL**	Tl-208	1.48E-01	3.00E-02	**-1.32**	**PASS**
SP06-111D	Tl-208	4.93E-02	4.19E-02			Tl-208	1.78E-01	3.24E-02		
SP11-111	Tl-208	3.49E-01	1.01E-01	**5.53**	**FAIL**	Tl-208	1.42E-01	2.80E-02	**-0.28**	**PASS**
SP11-111D	Tl-208	4.62E-02	3.62E-02			Tl-208	1.48E-01	2.87E-02		
SP11-220	Tl-208	3.44E-01	1.02E-01	**5.41**	**FAIL**	Tl-208	1.46E-01	3.06E-02	**-0.57**	**PASS**
SP11-220D	Tl-208	3.93E-02	4.14E-02			Tl-208	1.59E-01	3.29E-02		
SP14-220	Tl-208	3.52E-02	3.74E-02	**-2.91**	**FAIL**	Tl-208	1.48E-01	2.89E-02	**0.50**	**PASS**
SP14-220D	Tl-208	1.91E-01	9.83E-02			Tl-208	1.38E-01	2.91E-02		
SP19-111	Tl-208	2.66E-01	1.02E-01	**3.42**	**FAIL**	Tl-208	1.41E-01	3.20E-02	**-1.93**	**PASS**
SP19-111D	Tl-208	7.28E-02	4.15E-02			Tl-208	1.87E-01	3.35E-02		
SP20-111	Tl-208	2.96E-01	9.78E-02	**2.03**	**FAIL**	Tl-208	1.25E-01	2.84E-02	**-0.02**	**PASS**
SP20-111D	Tl-208	1.64E-01	8.26E-02			Tl-208	1.25E-01	2.71E-02		
SP20-220	Th-234	1.20E+00	4.91E-01	**-2.60**	**FAIL**	Th-234	1.77E+00	5.14E-01	**-2.38**	**FAIL**
SP20-220D	Th-234	2.10E+00	4.67E-01			Th-234	2.66E+00	5.21E-01		
SP21-111	Tl-208	3.23E-02	3.94E-02	**-3.94**	**FAIL**	Tl-208	1.52E-01	3.05E-02	**0.67**	**PASS**
SP21-111D	Tl-208	2.26E-01	8.79E-02			Tl-208	1.37E-01	3.05E-02		
SP23-111	Tl-208	2.83E-01	1.02E-01	**4.13**	**FAIL**	Tl-208	1.30E-01	3.09E-02	**-2.00**	**FAIL**
SP23-111D	Tl-208	5.09E-02	4.03E-02			Tl-208	1.75E-01	3.11E-02		

Notes: a) D=duplicate
b) Tl-208 reported for sand background as only nuclide reported with positive results
c) The pass/fail criteria are: "fail" if the z-score is greater than ±1.96, and "pass" is the z-score is less than ±1.96.

6.2 Off-site Laboratory Cross-Check Duplicate Analyses

Paragon Analytics performed cross-check gamma spectroscopy analyses on more than 10% of the soil samples collected and analyzed by the CABRERA onsite laboratory. Results of both laboratories were compared using the Z_{Rep} method as described in Section 6.4.1. The results of the laboratory comparisons are provided in Appendix H, along with the sample data.

Of the 150 samples evaluated during the off-site cross-check, 15 were found to have a Z_{Rep} greater than the tolerance level of ±1.96. Seven of these fifteen exceedances were samples analyzed with a different counting geometry (1-liter marinelli beaker vs. lab-supplied plastic bottle). These seven discrepancies are most likely due to Paragon utilizing 350-gram aliquot samples (i.e., a portion of the ~1000-1500 gram sample counted onsite) to perform their analyses. This sub-sampling introduces potential sample bias within the total volume, especially given the fact that small particles of DU could exist within sample volumes. Aliquot sampling can exacerbate self-shielding effects on samples like these since nearly all of the total activity within any given sample can reside in a very small volume. It is assumed that these failures are primarily due to preparation bias and should not be attributed to the

accuracy of the CABRERA laboratory. Of the comparisons falling outside the ±1.96 criterion, the CABRERA onsite results were always lower in value then the Paragon results, indicating that CABRERA samples (1-liter volume) were likely reporting a more representative volume average for the soil within the marinelli beaker. As a means of ensuring consistency between the onsite and off-site labs, it was decided that the off-site laboratory should also count intact marinelli beakers without further preparation prior to analysis.

Over the course of the project, there were 22 occurrences where Z_{Rep} exceeded the ±1.96 criterion. However, all but seven of these tests were performed with data that were less than method detection limits for either one or both of the laboratories, resulting in an adjusted failure rate of 4.7% (7 out of 150). The adjusted failure rate was less than what would be statistically expected at the chosen 95% confidence level (i.e., 5% failures), therefore, it is determined that no additional data qualification is warranted.

6.3 Field Instrumentation QC Results

The survey and stationary instruments used during sampling are listed in Table 6-2, along with the instrument information. Data collection activities were performed in accordance with written procedures and/or protocols in order to ensure consistent, repeatable results. The Site Radiation Safety Lead ensured that individuals were appropriately trained to use project instrumentation and other equipment, and that instrumentation met the required detection sensitivities.

Table 6-2: Field Instrumentation

Instrument Model	SN:	Detector Model	SN:	Principal Detectable Emissions	Primary Application
Ludlum 2360 datalogger	168043	Ludlum 43-93	PR199833	alpha, beta	Personnel & material frisking
Ludlum 2360 datalogger	202461	Ludlum 43-10-1 scint assembly	PR191325	alpha, beta	Smear counting
Ludlum 2929 smear counter	157329	Ludlum 43-10-1 scint assembly	PR207851	alpha, beta	Smear counting
Ludlum 2929 smear counter	129566	Ludlum 43-10-1 scint assembly	PR132720	alpha, beta	Smear counting
Ludlum 2221 scaler/ratemeter	218587	FIDLER	010807B1	gamma	Scanning
Ludlum 2221 scaler/ratemeter	149940	FIDLER	010807H	gamma	Scanning
Ludlum 2221 scaler/ratemeter	190171	FIDLER	120999C	gamma	Scanning

Table 6-2: Field Instrumentation (con't.)

Instrument Model	SN:	Detector Model	SN:	Principal Detectable Emissions	Primary Application
Ludlum 2221 scaler/ratemeter	149953	FIDLER	010807J1	gamma	Scanning
Ludlum 2221 scaler/ratemeter	132861	Bicron G5 FIDLER	A566F	gamma	Scanning
Ludlum 2221 scaler/ratemeter	176952	Alpha Spectra Inc FIDLER	051200A	gamma	Scanning
Ludlum 2221 scaler/ratemeter	174945	Alpha Spectra Inc FIDLER	010700D	gamma	Scanning
Ludlum 2224-1 scaler/ratemeter	162420	Ludlum 43-89 scintillator	PR171381	alpha, beta	Personnel & material frisking
Ludlum 3 survey meter	89973	Ludlum 44-9 pancake GM	PR084781	beta, gamma	Personnel & material frisking
Ludlum 3 survey meter	79517	Ludlum 44-9 pancake GM	PR137500	beta, gamma	Personnel & material frisking
Ludlum 3 survey meter	79552	Ludlum 44-9 pancake GM	PR085991	beta, gamma	Personnel & material frisking
Ludlum 12 ratemeter	128280	Ludlum 44-9 pancake GM	PR130951	beta, gamma	Personnel & material frisking
Ludlum 14C survey meter	172825	Ludlum 44-38 energy compensated GM	PR174016	beta, gamma	Personnel & material frisking
Ludlum 14C survey meter	172825	Ludlum 44-9 pancake GM	PR085115	beta, gamma	Personnel & material frisking
Ludlum 177 alarm/ratemeter	69751	Ludlum 44-9 pancake GM	PR269854	beta, gamma	Personnel & material frisking
Ludlum 177 alarm/ratemeter	89927	Ludlum 44-9 pancake GM	PR270362	beta, gamma	Personnel & material frisking
Ludlum 177 alarm/ratemeter	132453	Ludlum 44-9 pancake GM	PR269855	beta, gamma	Personnel & material frisking
Ludlum 177 alarm/ratemeter	132453	Ludlum 44-9 pancake GM	PR269855	beta, gamma	Personnel & material frisking
Ludlum 4609-3	207870	N/A	N/A	gamma	Conveyor monitoring system
Bicron MicroRem	C801F	N/A	N/A	gamma	Area dose rates

N/A – not applicable. These are one-piece instruments, while the others are meters with detectors attached.

6.3.1 Calibration Requirements

All instruments used during the course of the survey were in current calibration, traceable to the NIST. Copies of all vendor instrument calibration certificates are provided in Appendix I. Radiological instruments were used to scan soil surfaces, equipment, personnel, and clothing for radiological contamination. Current calibration/maintenance records were kept onsite for review and inspection. The records include, at a minimum, the following:

- equipment identification (model and serial number),
- manufacturer,
- date of last calibration, and
- calibration due date.

Instrumentation was maintained and calibrated to manufacturers' specifications to ensure that required traceability, sensitivity, accuracy, and precision of the equipment/instruments were maintained. Instruments were calibrated at a facility possessing appropriate NRC and/or Agreement State licenses for performing calibrations using NIST-traceable sources. Copies of these calibration certificates are included in Appendix C.

6.3.2 QC Source and Background Checks

Prior to daily use, instruments were QC-checked by comparing the instruments' response to a designated radiation source and to ambient background. Prior to the commencement of daily field operations, a reference location was used for performance of these checks. Background checks were performed in an identical fashion with the source removed. At the start of the field activities, this procedure was repeated ten times to establish an average instrument response.

QC checks were performed daily on all instruments each day they were in use. The results of these checks were entered into a control log or on a control chart to assess operability of each instrument prior to use in the field. For quantitative instruments (i.e., those used to report activity concentrations such as disintegrations per minute per 100 square centimeters), an operability criterion of $\pm 3\sigma$ was used. For qualitative instruments, i.e., dose rate meters and friskers, a ± 20% operability criterion was applied. During QC checks, instruments used to obtain qualitative radiological data were inspected for physical damage, current calibration, and erroneous readings in accordance with applicable procedures and protocols.

QC tracking sheets and control charts for check source response, background count rates (where applicable), and copies of the daily check source logs for all instruments are provided in Appendix J.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Sand pile removal and FSS activities were successfully performed within Area 10 of LCAAP. Field activities included GWS and surface sampling at systematic and biased locations within the sand pile and underlying/adjacent soil SUs, as well as onsite preparation and analysis of samples in a field gamma spectroscopy laboratory.

A total of 52 individual SU lifts of sand pile material were remediated for DU and radioactively contaminated sand. Release survey activities for the remaining material consisted of performing a 100% GWS for each one-foot lift of sand, and the collection and analysis of 20 systematic samples from each SU lift. Upon meeting the release criterion (i.e., analytical data were less than the sand DCGL of 8.4 pCi/g), the material was deemed suitable for unrestricted release and, thus, was excavated, treated with Maectite® to stabilize the leachable lead and disposed off-site at a Subtitle D industrial waste landfill. Sand pile material that did not meet the release criteria was separated from the main waste stream and set aside for disposal as special waste at a Subtitle C permitted landfill.

FSS activities for the underlying and adjacent soils consisted of a 100% GWS in ten Class 1 SUs and 50% GWS in one Class 2 SU. FSS systematic samples were obtained from a total of 154 locations. Biased samples were obtained from a total of 13 locations. Analytical results for these samples were all demonstrated to be less than the soil DCGL of 29.2 pCi/g.

Results of the FSS indicate that the underlying and adjacent soil remaining at Area 10 following removal of the sand piles is suitable for unrestricted release, in accordance with NRC license-specified release criterion of 35 pCi/g total uranium. Neither direct radiation measurements nor analytical data for the FSS samples indicate the presence of residual licensed radioactive materials at Area 10. In light of the information presented in this report, it is recommended that a license amendment be sought from the NRC to release Area 10 for unrestricted use with respect to radioactivity.

8.0 REFERENCES

Army, 1995. *Health and Environmental Consequences of Depleted Uranium Use in the Army: Technical Report.* U.S. Army Environmental Policy Institute. June 1995.

ATG, 1998. *Lake City Army Ammunition Plant Area 10 (Sand Pile) Radioactive Soil Decommissioning Plan*, Revision 5.1. Allied Technology Group, Inc., Oak Ridge, TN. April 1998.

CABRERA, 2004. *Area 10 Sand Piles Sampling and Analysis Report.* Draft Final. Cabrera Services, Inc., Baltimore, MD. September 2004.

CABRERA, 2005a. *Area 10 Sand Piles Field Treatability Study Report.* Final. Cabrera Services, Inc., Baltimore, MD. October 2005.

CABRERA, 2005b. *Area 10 Sand Engineering Evaluation and Cost Analysis.* Final. Cabrera Services, Inc., Baltimore, MD. October 2005.

CABRERA, 2007. *Technical Memorandum: Groundwater Sampling and Analysis Report for Area 10*. Cabrera Services, Inc., Baltimore, MD.

CABRERA, 2008a. *Area 10 Sand Piles Action Memorandum.* Revised Final. Cabrera Services, Inc., Baltimore, MD. August 2008.

CABRERA, 2008b. *Area 10 Sand Piles Removal Action Work Plan.* Final. Cabrera Services, Inc., Baltimore, MD. October 2008.

CABRERA, 2009. *Area 10 Sand Piles Removal Action Completion Report.* Draft. Cabrera Services, Inc., St. Louis, MO. [date] 2009.

EPA, 2004, Multi-Agency Radiological Laboratory Analytical Protocols Manual, NUREG-1576, Washington, D.C., EPA/402/B-04/001A, July 2004.

FFA, 1989. *Federal Facilities Agreement, Lake City AAP (Army), EPA Region VII, MDNR.* Docket Number VII-89-F-0019. September 1989.

NRC, 2000. *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM).* Rev. 1. NUREG-1575, EPA/402-R-97-016, DOE/EH-0624. U.S. Nuclear Regulatory Commission, U.S. Environmental Protection Agency, U.S. Department of Energy, and U.S. Department of Defense. August 2000.

NRC, 2001. *Deferral of Regulatory Oversight of Area 10 (The Sandpile) of the Lake City Army Ammunition Plant to the U.S. Environmental Protection Agency.* Policy Issue Memorandum No. SECY-01-0088. May 17, 2001.

NRC 2003. *Consolidated NMSS Decommissioning Guidance: Characterization, Survey, and Determination of Radiological Criteria*. NUREG 1757, Volume 2. U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards. September.

NRC, 2004. *Nuclear Materials License No. SUC-1380, Amendment No. 43*. U.S. Nuclear Regulatory Commission, Region III. May 10, 2004.

FIGURES

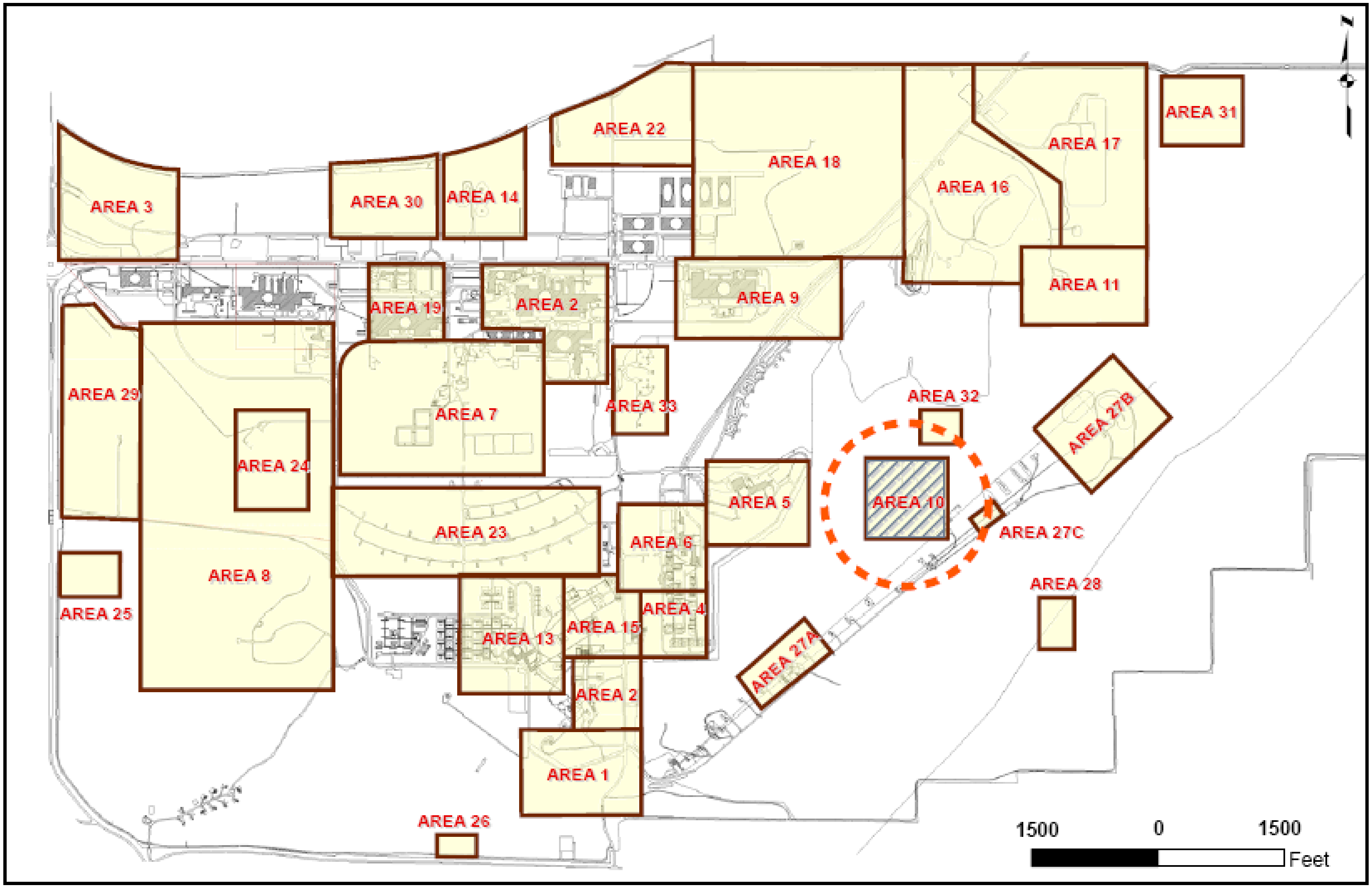

Figure 1-1: Lake City Army Ammunition Plant - Area 10

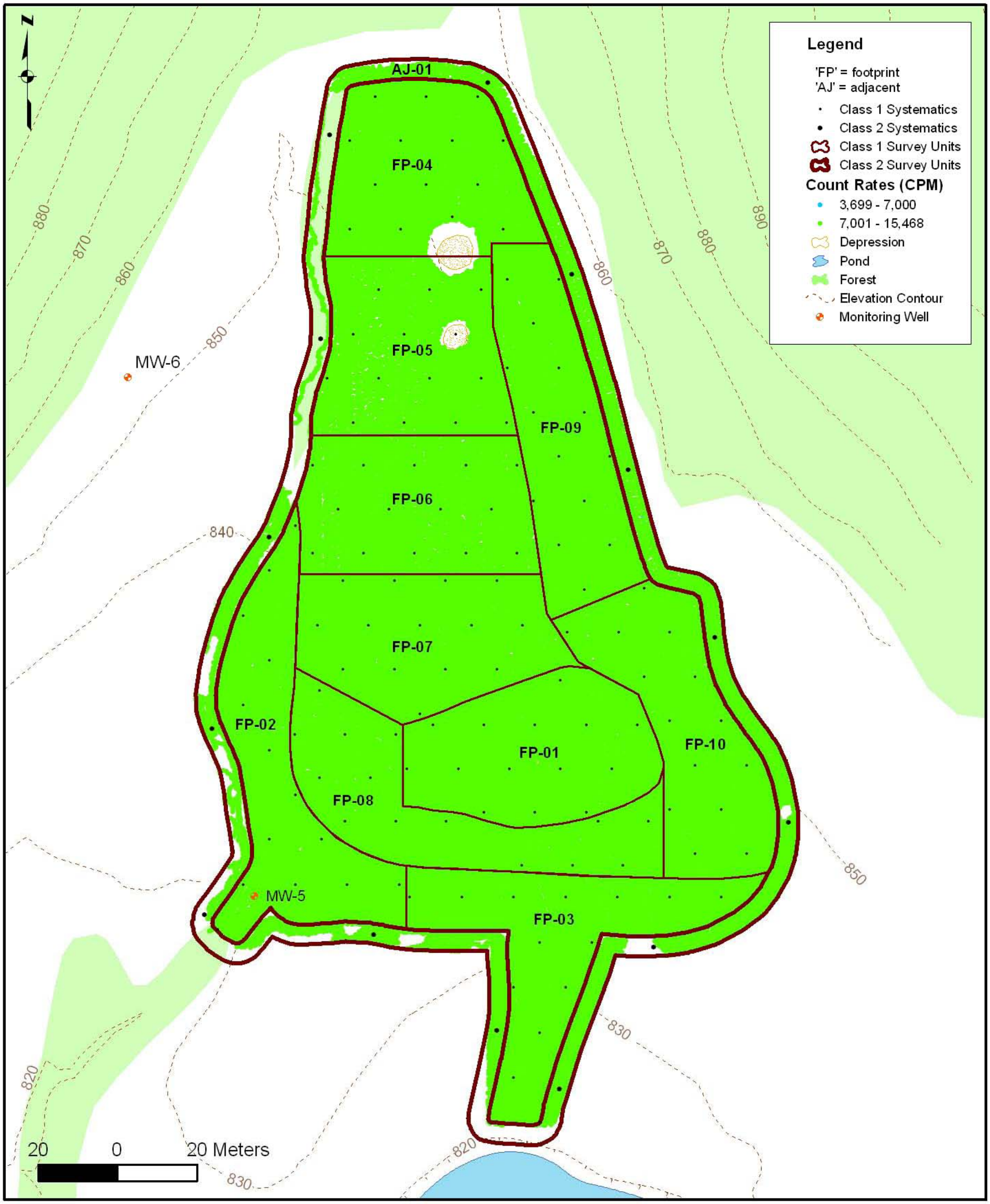

Figure 3-1: Final Status Survey Results - Soil Survey Units

APPENDICES

APPENDIX A

GAMMA WALKOVER SURVEY AND SAMPLING DATA PACKAGES
FOR SAND PILE SURVEY UNITS

(ON CD ONLY)

APPENDIX B

FINAL STATUS SURVEY DATA PACKAGES
FOR UNDERLYING/ADJACENT SOIL SURVEY UNITS

(ON CD ONLY)

APPENDIX C

NIST STANDARD CERTIFICATE S OF CALIBRATION

(ON CD ONLY)

APPENDIX D

ONSITE SAMPLE TRACKING LOG

(ON CD ONLY)

APPENDIX E

LOW VOLUME AIR SAMPLE RESULTS

(ON CD ONLY)

APPENDIX F

QUALITY CONTROL CHARTS AND DAILY QC RESULTS
FOR ONSITE LABORATORY

(ON CD ONLY)

APPENDIX G

Z-REPLICATE RESULTS FOR ONSITE LABORATORY

(ON CD ONLY)

APPENDIX H

PARAGON ANALYTICS QUALITY CONTROL DATA PACKAGES

(ON CD ONLY)

APPENDIX I

VENDOR INSTRUMENT CALIBRATION CERTIFICATES

(ON CD ONLY)

APPENDIX J

QUALITY CONTROL CHARTS AND DAILY QC RESULTS
FOR FIELD INSTRUMENTATION

(ON CD ONLY)