DEPARTMENT OF THE ARMY
HEADQUARTERS, U.S. ARMY JOINT MUNITIONS COMMAND
1 ROCK ISLAND ARSENAL
ROCK ISLAND, IL 61299-6000

REPLY TO
ATTENTION OF:

May 2, 2007

Safety/Rad Waste Directorate

Administrator
Nuclear Regulatory Commission
Nuclear Materials Licensing Branch
Region III
2443 Warrenville Road Ste 210
Lisle, Illinois 60532-4352

Reference docket number 040-08767

Dear Sir or Madam:

We request the Nuclear Regulatory Commission amend our SUC-1380 license and remove reference to soil from the Area 31 landfill of Lake City Army Ammunition Plant, Independence, Missouri. Cabrera Services, Inc., completed final status survey activities at Area 31 in November 2006 in accordance with the final status survey work plan transmitted to and approved by the Nuclear Regulatory Commission in October 2006.

During the final status survey field activities, Cabrera identified and removed four depleted uranium ammunition projectile bodies from the landfill waste staged at Area 31. These projectile bodies were in addition to the four found previously by ARCADIS, as discussed in the Work Plan, thus bringing the total number of projectiles bodies found at Area 31 to eight. The eight projectile bodies are currently stored in a B-12 metal container located at the Lake City Army Ammunition Plant Area 10 sand pile. We will complete a radioactive waste disposal action for the material in these containers at a later date.

Upon completion of final status survey activities at Area 31 and removal of the depleted uranium projectile bodies, ARCADIS shipped the waste to a local industrial waste landfill in Missouri. The final status survey data for the residual soils indicate that the site is now suitable for release for unrestricted use, without regard to the former presence of licensed radioactive material. We have enclosed a hardcopy of Cabrera's final status survey report, and a compact disc that contains back-up information to the hardcopy report.

The points of contact are Mr. Gary Buckrop and Mr. Mike Styvaert, AMSJM-SF, (309) 782-2969/0880, E-mail rock-amsjm-sf@conus.army.mil.

Sincerely,

Kristine K. Preston

Kristine K. Preston
Acting Director
Safety/Rad Waste Directorate

Enclosure

TECHNICAL MEMORANDUM

From: Barb Duletsky, Cabrera Services, Inc.

To: Eric Putnam, ARCADIS G&M, Inc.

Date: February 15, 2007

Subject: Results of Final Status Survey at Area 31, Lake City Army Ammunition Plant, Independence, MO - FINAL

EXECUTIVE SUMMARY

Final status survey (FSS) activities were conducted at Area 31 to support the Housekeeping Removal Action for the installation-wide operable unit (IWOU) at Lake City Army Ammunition Plant (LCAAP). Area 31 is a former waste dumpsite located within the LCAAP firing range, where depleted uranium (DU) projectile bodies were unexpectedly encountered during the course of waste removal activities. The purpose of the Area 31 FSS was to: 1) identify and remove any residual DU projectile bodies and peripherally impacted soils waste from the site, and 2) demonstrate whether 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 November 2006, 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 *Final Area 31 Final Status Survey Work Plan, Addendum to the Final Removal Action Memorandum and Work Plan – Housekeeping Removal Action* (*Work Plan*; CABRERA, 2006a), except as otherwise noted in Attachment 1. This memorandum presents the FSS results for the Area 31 excavation and waste pile footprints, as well as for the waste pile material itself.

A 100% GWS was conducted using a 2-inch (in.) by 2-inch (in.) sodium iodide (NaI) detector equipped with a global positioning system (GPS). The GWS results were used to identify regions of the site where surface radioactivity appeared to be elevated. The only regions of elevated activity identified during the GWS of the excavation and waste pile footprints coincided with areas where bedrock was at or close to the surface. It was assumed that the elevated readings were due to the presence of naturally occurring thorium, which is more abundant in rock than in soil. This assumption was confirmed by field screening results obtained using a portable soil analyzer.

Systematic soil samples were collected from the top 6 inches of soil in the excavation and waste pile footprints using a triangular grid pattern with 12-meter (m) spacing between sample locations. In addition, biased soil samples were collected from the locations of highest gamma

Enclosure

response, as measured during the GWS. Analytical results for the FSS support samples indicated no detectable DU in the native soil within the excavation or waste pile footprints.

The FSS of waste pile material was conducted in incremental one-foot lifts to ensure 100% survey coverage and even sample distribution. Elevated GWS results provided the basis for identification and removal of five separate pieces of radioactive material from the waste pile material. Remedial support soil samples were collected from directly beneath the radioactive items and shipped to the off-site laboratory for analysis. Upon removal of the sample material, the areas were scanned using a Geiger-Mueller (GM) pancake detector to ensure that all potential contamination had been removed and that residual radioactivity was consistent with natural background. In each case, removal of the sample volume alone was shown to be sufficient to remove any soil contamination discernable through the GM scan.

Analytical results from the systematic, biased, and remedial support soil sampling conducted on the waste pile material indicated only two sample locations with detectable DU. These samples were collected as remedial support samples from two of the locations where radioactive items were found. Gamma spectroscopy results were used to infer uranium-238 (^{238}U) concentrations of DU concentrations of 35.4 and 6.1 picocuries per gram (pCi/g) in the two samples. Alpha spectrometry results confirmed that the isotopic ratios were indicative of DU. Surface scans of each sampling location conducted after the sample material was removed indicated no remaining areas of elevated radioactivity.

Results of the FSS indicate that the waste pile material at Area 31 is suitable for release without regard to radioactivity. Neither direct radiation measurements nor analytical data for the FSS support samples, which are representative of these soils, indicate the presence of any remaining DU (i.e., licensed material) in the waste. The four DU projectile bodies and other radioactive item uncovered during the waste pile survey were removed from Area 31 and relocated to Area 10, the current LCAAP repository for licensed DU material. Analytical results for the remedial support samples collected from directly beneath these items indicate that small amounts of radioactivity were able to transfer from the DU projectile bodies to the soils immediately surrounding them. However, FSS results and confirmatory surface scans provided no evidence that any soil other than that which was in direct contact with the DU had been affected. Because the affected soils were remediated from the waste during collection of the remedial support samples, as confirmed by surface scans of the sample locations, it is concluded that no licensed radioactive material remains in the Area 31 waste.

Results of the FSS indicate that the residual soils remaining at Area 31 are suitable for release for unrestricted use, in accordance with NRC requirements set forth in 10 CFR 20.1402. Neither direct radiation measurements nor analytical data for the FSS support samples, which are representative of these soils, indicate the presence of residual licensed radioactive materials. In addition, comparisons to previously established background levels do not indicate any locations exhibiting radioactivity greater than background. In light of the information presented in this memorandum, it is recommended that a license amendment be sought from the NRC to release Area 31 for unrestricted use.

1.0 INTRODUCTION

Cabrera Services, Inc. (CABRERA) has been contracted by ARCADIS G&M, Inc. (ARCADIS), under Subcontract No. RN06-0017, to conduct final status surveys (FSS) at Area 31 of the Lake City Army Ammunition Plant (LCAAP). This work has been conducted in support of the Housekeeping Removal Action being performed by ARCADIS, who is the prime contractor to the U.S. Army for remediation of the installation-wide operable unit (IWOU) at LCAAP.

The rationale for and description of the final status survey (FSS) activities at Area 31 are presented in the *Final Area 31 Final Status Survey Work Plan, Addendum to the Final Removal Action Memorandum and Work Plan – Housekeeping Removal Action (Work Plan*; CABRERA, 2006a). This *Technical Memorandum* presents the FSS results and provides the documentation necessary to support a request for amendment to the Army's nuclear materials license (U.S. Nuclear Regulatory Commission [NRC] License No. SUC-1380) to release Area 31 for unrestricted use.

2.0 BACKGROUND

Area 31 is a former waste dumpsite located in the northeastern portion of LCAAP, within the boundaries of the active small arms test firing range. During the course of removal action activities at this site, ARCADIS unexpectedly encountered munitions and explosives of concern (MEC) in the form of 81-millimeter (mm) mortar shell casings. While processing the waste for removal of these casings, ARCADIS also encountered several 20-mm depleted uranium (DU) projectile bodies. The DU projectile bodies were identified as components of the Davy Crockett spotter rounds (XM-101) and/or target practice rounds (XM-106), both of which were manufactured and tested at LCAAP in the 1960s.

The discovery of DU projectile bodies in the Area 31 waste prompted the need for radiological FSS activities, in accordance with the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM; NRC, 2000), as described in the *Work Plan.* The purpose of these activities was to: 1) identify and remove any residual DU projectile bodies and peripherally impacted soils waste from the site, and 2) demonstrate whether the remaining soils are suitable for unrestricted release with respect to radioactivity, in accordance with NRC requirements specified in 10 CFR 20.1402. Results of the field activities and laboratory analyses conducted as part of the Area 31 FSS are presented in the sections that follow.

3.0 FIELD ACTIVITIES

CABRERA conducted FSS field activities at LCAAP Area 31 from November 6 to 21, 2006. Gamma walkover surveys (GWS) and soil sampling activities were conducted within the excavation and waste pile footprints, as described in the *Work Plan.* The waste pile material also was subject to MARSSIM-style survey and sampling activities to facilitate decisions regarding its disposition, as described in Attachment 1.

3.1 Excavation Footprint

The excavation footprint is an irregularly shaped area of approximately 3,500 square meters (m^2) from which waste was excavated during the first phase of the Area 31 removal action. Within the excavation footprint, a 100% GWS was performed using a 2-inch (in.) by 2-in. sodium iodide (NaI) gamma scintillation detector to identify areas of elevated radioactivity. The detector was attached to a ratemeter equipped with a global positioning system (GPS) unit, which measured and recorded count rate data at a rate of once per second, along with the corresponding geographical coordinates (i.e., northings and eastings) for the locations of data collection.

Systematic soil samples were collected from the top 6 inches of soil using a triangular grid pattern, with 12-meter (m) spacing between sample locations over the entire excavation footprint. In addition, biased soil samples were collected from the locations of highest gamma response, as measured during the GWS. In all, 29 systematic and 6 biased samples were collected from the excavation footprint, consistent with the MARSSIM requirements for an area slightly smaller than two 2,000-m^2 Class 1 survey units.

3.2 Waste Pile Footprint

The waste pile footprint is an elongated area of approximately 1,500 m^2 situated directly north of the excavation footprint. The waste pile footprint includes the area upon which the processed waste had been staged for the past year, as well as the area between the former pile and the excavation footprint where waste management activities occurred during the FSS. Within the waste pile footprint, a 100% GWS was performed and systematic soil samples were collected at 12-m intervals on a triangular grid pattern, similar to the approach used for the excavation footprint. In addition, biased soil samples were collected from the locations of highest gamma response, as measured during the GWS. In all, 15 systematic samples and 3 biased samples were collected from the former waste pile footprint, consistent with the MARSSIM requirements a single Class 1 survey unit.

The systematic and biased soil samples collected in support of the Area 31 FSS were sent to the off-site laboratory for gamma spectroscopy analysis. Field duplicates were collected at a rate of 10%, as specified in the *Work Plan*. Smear samples of the tools used to collect samples were evaluated periodically to confirm the adequacy of equipment decontamination techniques.

4.0 FINAL STATUS SURVEY RESULTS

Results of the GWS and soil sampling and analysis are presented below.

4.1 Gamma Walkover Survey Results

The GWS conducted within the excavation and waste pile footprints at Area 31 generated more than 11,300 unique data points, each consisting of a radiological count rate and the corresponding geographic northing and easting coordinates where the measurement was recorded. Upon download of the data, summary statistics and z-scores of each data set were calculated, and a color-coded contour map of the corresponding survey area was created. Z-scores, which represent the number of standard deviations the recorded result lies from the mean, were calculated based on the following formula:

$$Zscore = \frac{CountRate - Mean}{StdDeviation}$$

The complete set of GWS data and statistical summaries for each area surveyed is contained in the Excel® spreadsheet files provided on compact disc (CD) as Attachment 2. The statistical summaries for each data set include calculations of descriptive parameters such as the mean, standard deviation, variance, minimum, maximum, etc., as well as a probability distribution plot demonstrating the relationship between a predicted normal distribution assumption and the actual distribution of the field measurements observed.

The GWS data for each area surveyed were imported into geographical information system (GIS) software to produce three-dimensional representations of the GWS data. Graphical images were generated using the GPS easting as the X coordinate, the GPS northing as the Y coordinate, and the statistical z-score as the Z coordinate (i.e., color). A search radius of 1 m was used to create a meaningful image from the discrete data points comprising the survey, and an inverse distance algorithm was used to interpolate the data between measurements. The resulting geospatial images depicting the GWS results are presented as follows:

- Figure 1: Excavation Footprint Survey Units N1 and N2
- Figure 2: Waste Pile Footprint Survey Unit N3

The GWS identified a region of elevated surface activity in the western portion of the excavation footprint. Visual observations in this area revealed that there was only a thin, in some cases non-existent, layer of soil overlying the bedrock. The highest measurements recorded with the GWS instrumentation generally coincided with areas where the soil layer was thinnest. Because no visible DU fragments or soil discoloration typically associated with oxidized DU were observed in these areas, the higher count rates were assumed to be due to the presence of naturally occurring thorium, which is more abundant in rock than in soils.

4.2 Soil Sampling and Analysis Results

Systematic and biased soil sampling locations in the excavation and waste pile footprints are shown in Figures 1 and 2, respectively. Field sheets documenting the collection of FSS support samples from these locations are presented on CD as Attachment 3.

As part of the sample collection procedure, a static count rate measurement was obtained at each designated sampling location using a hand-held Geiger-Mueller (GM) detector both before and after sample collection. The GM measurements, which are recorded on the field sheets in Attachment 3, indicated count ranges before and after sample collection of 20 to 80 counts per minute (cpm) and 20 to 70 cpm, respectively, for the systematic samples, and 40 to 150 cpm and 40 to 120 cpm, respectively, for the biased samples. Count rates observed at the systematic sample locations are assumed to represent background activity in the native soil. Count rates higher than 80 cpm were observed at a few locations where bedrock was at or near the surface, and were assumed to be due to the presence of naturally occurring thorium.

The FSS support samples were analyzed at the off-site laboratory by gamma spectroscopy for thorium-234 (^{234}Th) and its decay progeny. Analytical data reports generated by the laboratory are contained in the Adobe® Acrobat files provided on CD as Attachment 4. Detailed tables presenting the ^{234}Th data for the target samples, as well as the field and laboratory quality control data, are contained on the Excel® spreadsheet file provided on CD as Attachment 5.

Table 1 presents a summary of the gamma spectroscopy results reported for the Area 31 soil samples. Results for all FSS support samples indicated that ^{234}Th either was not detected above the reporting limit or was reported as an estimated value (i.e., "J" flagged) based on unidentified energy peaks. The results reported for ^{234}Th were used to indicate the presence or absence of DU, based on the assumption that uranium-238 (^{238}U), the most abundant uranium isotope in DU by mass, and its short-lived daughter, ^{234}Th, are in secular equilibrium. In other words, the activity results reported for ^{234}Th are assumed to equal the activity of ^{238}U present in the sample material. The lack of detectable ^{234}Th in the FSS support samples indicates that there is also no detectable DU in the samples.

4.3 Background Comparisons

As a final confirmation that no licensed material is present at Area 31, the FSS results were evaluated with respect to local background conditions. The GWS data were evaluated by generating probability distribution plots of each survey area to correlate measured count rates to the predicted z-score at each measurement location. The data were also compared to previously reported GWS results for a background reference area situated south of the firing range. In addition, analytical results for the soil samples were compared to published background concentrations of uranium in Missouri soils.

Processed GWS data files were plotted on cumulative frequency diagrams (CFD) to obtain information on the shape of the data distribution for each footprint area. Within each set of normally distributed data, 2 to 3 of every 1,000 points are expected to exhibit a z-score of greater than 3. The purpose of the CFD plots is to identify count rate values in the data sets that do not reflect expected values within a normally distributed background set. Straight-line data sets represent an "expected" nominal range of a background distribution for a specific survey area. The data of interest on these CFD plots are those on the far right that deviate from the straight-line distribution(s). These distinctly elevated populations or individual outliers represent locations suited for further investigation, such as the collection and analysis of biased soil samples. CFD plots also have the capability of identifying multiple background distributions in the same general area. These distributions are exhibited as straight lines with either varying means or slopes. This is particularly useful in determining the impact of different surficial ground surfaces within a survey area that may contain variations in their natural background signatures (e.g., topsoil/grass, gravel, clay, etc). Probability distribution plots for the Area 31 survey data indicate that all locations exhibiting z-scores of greater than 3 were due to material variability and not to the presence of licensed uranium.

The Area 31 GWS data were also compared to data obtained during a previous investigation of surface gamma radiation at another portion of the LCAAP firing range. In that study (CABRERA, 2003), an area approximately 200 yards southeast of the 600-yard marker was designated as a

background reference area. This area met the MARSSIM requirements for a non-impacted area (NRC, 2000), and the GWS data collected in this area was observed to be normally distributed about the mean, confirming that it was an appropriate representation of local background conditions. The 2x2 NaI detectors used in the reference area survey were the same two instruments (i.e., matching serial numbers) used to collect GWS data at Area 31. Based on results of the GWS in the reference area, background was estimated as the mean plus or minus two standard deviations, or 11,653 to 14,561 cpm, Only 6 of the 11,300 readings obtained during the Area 31 GWS were higher than this background range, and all 6 of these were measured in areas where bedrock was at or close to the surface and elevated levels of natural thorium were assumed to be present.

The Area 31 soil sample data were compared to State-wide concentrations of 1.1 to 15 mg/kg measured during a comprehensive study of soil geochemistry in Missouri agricultural soils (Tidball, 1984). Based on the reported geometric mean of 3.8 mg/kg and standard deviation (σ) of 1.34, the upper bound of a normal background mass concentration of uranium was estimated as the mean plus two standard deviations, or 6.48 mg/kg. Assuming that uranium in background is present in naturally occurring isotopic ratios and, thus, has a specific activity of 0.68 pCi/µg, this is equivalent to an activity concentration of 4.4 pCi/g. Detection limits at the 95th percent confidence level (i.e., $+2\sigma$) achieved during the Area 31 gamma spectroscopy analysis were all less than this activity concentration, except as noted in Table 1, indicating that the analytical results reported as "non-detect" were within the established State-wide background.

5.0 INSTRUMENT QUALITY CONTROL

Quality control (QC) measurements for field instrumentation included initial response to a radioactive source and daily operability checks. All instruments were calibrated within the last twelve months by the instrument vendor, a certified calibration laboratory, sources traceable to the National Institute of Standards and Technology (NIST). Calibration certificates for each instrument are provided in Attachment 6. Prior to commencing the GWS, ten (10) initial readings were collected on each detector using a cesium-137 (^{137}Cs) source to establish a control chart for each unit and determine daily operability. The basis for daily operability for instruments of this type is $\pm 20\%$ of the average for the initial ten measurements. Results of the instrument source checks are also included in Attachment 6.

The GPS system was configured using the North American Datum 1983 (NAD83), State Plane coordinate system for Missouri West (2403) in units of meters. Operability of the GPS was determined by the available satellite coverage and associated position dilution of precision (PDOP) reported by the GPS handset. If the PDOP was observed to rise above 6, the surveyor immediately paused and waited for the PDOP to improve. PDOP increases are a direct result of line of sight interference between the GPS satellites and the receiver.

6.0 HEALTH AND SAFETY

The *Site Safety and Health Plan for the Area 31 Final Status Survey* (*SSHP*; CABRERA, 2006b) was used to guide safe conduct of the work. The work was conducted without incident relative

to health and safety, with the exception of the unexpected discovery of several 81-mm mortar shell casings in the work area. Prior to mobilization, it had been assumed that no MEC was present at the site because their removal had been the objective of previous field screening activities. However, the discovery of these items during the first part of the waste pile survey resulted in the suspension of field activities for one afternoon and part of the next morning while CABRERA coordinated with ARCADIS and Army personnel to determine an appropriate response to the change in conditions. Arrangements were made for MEC specialists from PIKA International, Inc. to mobilize to the site to provide MEC safety escort and clearance support, and the fieldwork resumed upon their arrival.

7.0 NRC LICENSE INSPECTION

FSS activities were performed under CABRERA's nuclear materials license (NRC License No. 06-30556-01), which is included in Attachment 7. During the first week of fieldwork, two representatives from NRC Region 3 conducted a 2-day site inspection to ensure that appropriate radiological controls were in place and that work was being conducted in accordance with CABRERA's license requirements. The CABRERA Radiation Safety Officer (RSO) was also onsite during the first few days of field work to perform an internal license audit and provide assistance to the NRC with respect to the field inspection and records review. The NRC inspection resulted in the issuance of a Form 591 documenting no findings.

While onsite, the NRC representatives also conducted field experiments to ensure that the methodology described in the *Work Plan* would be effective in locating radioactive materials at the site. They compared the responses of various radiation detectors when held in the vicinity of a DU projectile body buried under 12 inches of soil, and concluded that the methodology being used at Area 31 was sufficient to locate buried DU. They also performed confirmatory walkover surveys on portions of the excavation footprint, obtaining similar results as CABRERA had. In the western portion of the footprint, where gamma walkover results indicated regions of elevated radioactivity (see Figure 1), NRC personnel used a SAM 935 portable radiation surveillance and measurement system to determine which radioisotopes were present in the soil. The instrument identified naturally occurring thorium rather than ^{238}U as the predominant radioisotope in the regions of elevated gamma activity. This is consistent with the observation that the soil layer in this portion of the footprint was thin to nonexistent, with large areas of exposed bedrock.

8.0 CONCLUSIONS AND RECOMMENDATIONS

Results of the FSS indicate that the residual soils at Area 31 are suitable for release for unrestricted use, in accordance with NRC requirements set forth in 10 CFR 20.1402. Neither direct radiation measurements nor analytical data for the FSS support samples, which are representative of these soils, indicate the presence of residual licensed radioactive materials. In addition, comparisons to previously established background levels do not indicate any locations exhibiting radioactivity greater than representative local background variability. In light of the information presented in this memorandum, CABRERA recommends that a license amendment be sought from the NRC to release Area 31 for unrestricted use.

9.0 REFERENCES

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

CABRERA, 2003. *Area 27 Gamma Walkover Survey Report, Lake City Army Ammunition Plant, Independence, Missouri.* Cabrera Services, Inc. June 2003.

CABRERA, 2006a. *Final Area 31 Final Status Survey Work Plan, Addendum to the Final Removal Action Memorandum and Work Plan – Housekeeping Removal Action*. Cabrera Services, Inc. October 2006.

CABRERA, 2006b. *Site Safety and Health Plan for the Area 31 Final Status Survey*. Cabrera Services, Inc. October 2006.

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

Tidball, 1984. *Geochemical Survey of Missouri: Geography of Soil Geochemistry of Missouri Agricultural Soils*. Geological Survey Professional Paper 954-H. R. Tidball. U.S. Geological Survey. 1984.

TABLE

Table 1
LCAAP Area 31 Final Status Survey
Soil Sample Gamma Spectroscopy Data

CLIENT ID	COMPOUND NAME	RESULT	UNITS	FLAGS	ERROR	MDC	LAB ID
Native Soil Final Status Survey Support Samples - Systematic							
N-01	Thorium 234	1.5	pCi/g	U	2.1	3.1	F6K110161001
N-02	Thorium 234	-0.4	pCi/g	U	2.3	3.7	F6K110161002
N-03	Thorium 234	-1.1	pCi/g	U	2.1	3.2	F6K110161003
N-04	Thorium 234	0.7	pCi/g	U	2.2	3.1	F6K110161004
N-05	Thorium 234	0.4	pCi/g	U	2.4	4.3	F6K110161005
N-06	Thorium 234	-0.1	pCi/g	U	2	2.9	F6K110161006
N-07	Thorium 234	-0.04	pCi/g	U	1.4	2.7	F6K110161007
N-08	Thorium 234	1	pCi/g	U	1.6	2.6	F6K110161008
N-09	Thorium 234	1.7	pCi/g	U	2.4	3.5	F6K110161009
N-10	Thorium 234	0.4	pCi/g	U	1.9	3.2	F6K110161010
N-11	Thorium 234	0.3	pCi/g	U	2.5	3.8	F6K110161011
N-12	Thorium 234	0.4	pCi/g	U	1.5	2.3	F6K110161012
N-13	Thorium 234	1.5	pCi/g	U	2.1	3.3	F6K110161013
N-14	Thorium 234	2.1	pCi/g	U	3.2	4.2	F6K110161014
N-15	Thorium 234	4.2	pCi/g	*	3	4	F6K110161015
N-16	Thorium 234	-0.06	pCi/g	U	1.8	2.7	F6K110161016
N-17	Thorium 234	-0.1	pCi/g	U	2	2.7	F6K110161017
N-18	Thorium 234	1.7	pCi/g	U	2.1	3.4	F6K110161018
N-19	Thorium 234	-0.4	pCi/g	U	2.1	3.3	F6K110161019
N-20	Thorium 234	2	pCi/g	U	2.1	3.4	F6K150242016
N-21	Thorium 234	-1	pCi/g	U	2.6	4	F6K150242014
N-22	Thorium 234	1.2	pCi/g	U	3	3.9	F6K150242015
N-23	Thorium 234	0.5	pCi/g	U	2.5	3.7	F6K110161020
N-24	Thorium 234	1.9	pCi/g	U	2.4	3.6	F6K110161029
N-25	Thorium 234	1.6	pCi/g	U	2.1	4	F6K110161030
N-26	Thorium 234	-0.2	pCi/g	U	2.2	4.3	F6K150242017
N-27	Thorium 234	1.5	pCi/g	U	2.5	3.9	F6K150242018
N-28	Thorium 234	2	pCi/g	U	1.7	3.8	F6K150242019
N-29	Thorium 234	-2	pCi/g	U	2.6	4.4	F6K150242020
N3-01	Thorium 234	1.1	pCi/g	U	2.9	4.1	F6K210120001
N3-02	Thorium 234	0.6	pCi/g	U	2.2	3.8	F6K210120002
N3-03	Thorium 234	0.3	pCi/g	U	2.8	3.3	F6K210120003
N3-04	Thorium 234	-0.1	pCi/g	U	2.2	3.7	F6K210120025
N3-05	Thorium 234	1.1	pCi/g	U	2	3.5	F6K210120026
N3-06	Thorium 234	1.3	pCi/g	U	2.2	3.4	F6K210120027
N3-07	Thorium 234	-0.009	pCi/g	U	2.7	3.6	F6K210120028
N3-08	Thorium 234	2.3	pCi/g	U	2.6	3.7	F6K210120029
N3-09	Thorium 234	2.9	pCi/g	U	2	3.3	F6K210120030
N3-10	Thorium 234	-0.7	pCi/g	U	2.6	3.4	F6K210120004
N3-11	Thorium 234	-0.7	pCi/g	U	1.7	2.4	F6K210120005
N3-12	Thorium 234	-0.2	pCi/g	U	2.5	3.5	F6K210120031
N3-13	Thorium 234	1.3	pCi/g	U	2.2	3	F6K210120006
N3-14	Thorium 234	0.8	pCi/g	U	2.2	3	F6K210120032
N3-15	Thorium 234	2.5	pCi/g	U	2.2	2.7	F6K210120033
Native Soil Final Status Survey Support Samples - Biased							
N-B01	Thorium 234	-0.5	pCi/g	U	2.3	3.3	F6K150242021
N-B02	Thorium 234	0.4	pCi/g	U	2.5	3.2	F6K150242022
N-B03	Thorium 234	6.5	pCi/g	U**	4.7	6.6	F6K150242023
N-B04	Thorium 234	4	pCi/g	U**	3.4	4.7	F6K150242024
N-B05	Thorium 234	6.1	pCi/g	U**	4.4	6.4	F6K150242025
N-B06	Thorium 234	1.9	pCi/g	U	3.1	3.8	F6K150242026
N3-B01	Thorium 234	0.1	pCi/g	U	2	2.8	F6K210120036
N3-B02	Thorium 234	1.2	pCi/g	U	2.2	3.5	F6K210120007
N3-B03	Thorium 234	-2.6	pCi/g	U	2.4	3.7	F6K210120037

Table 1
LCAAP Area 31 Final Status Survey
Soil Sample Gamma Spectroscopy Data

CLIENT ID	COMPOUND NAME	RESULT	UNITS	FLAGS	ERROR	MDC	LAB ID
NOTES:							
Sample IDs with an "N" prefix are from the excavation footprint.							
Sample IDs with an "N3" prefix are from the waste pile footprint.							
FLAGS:							
U = Result is less than the sample detection limit.							
J = Result is greater than the sample detection limit but less than the stated reporting limit.							
* = The case narrative contains a note indicating that the reported Th-234 results are greater than the associated MDC for these samples, but the samples do not have peaks detected at either 63 or 92 keV. The software algorithm is calculating an activity based upon the region of interest rather than an identifiable peak and should be considered an estimate.							
** = The case narrative contains a note indicating that the MDC achieved for these samples is elevated due to the presence of Pb-214 and Bi-214.							

FIGURES

Legend

Systematic Sample Locations

Biased Sample Locations

1 m Contour of Z-score

<1

1-2

2-3

>3

0 3 6 12 18 24 Meters

Area 31 Excavation Footprint Survey Units N1 and N2
Gamma Walkover Survey Results and Sampling Locations

LAKE CITY ARMY AMMUNITION PLANT
INDEPENDENCE, MISSOURI

Date: 12/08 File Name: Fig.1

Project #: 07-1001.00 Prepared By: S.Pangelova

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Figure 1

Legend

Systematic Sample Locations

Biased Sample Locations

1 m Contour of Z-score

+1

1-2

2-3

+3

0 3 6 12 18 24 Meters

Area 31 Waste Pile Footprint Survey Unit N3
Gamma Walkover Survey Results and Sampling Locations

LAKE CITY ARMY AMMUNITION PLANT
INDEPENDENCE, MISSOURI

Date: 12/06 File Name: Fig.2

Project #: 07-1001.00 Prepared By: S.Pangelova

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Figure 2

ATTACHMENT 1

Area 31 Waste Pile Final Status Survey Results

Area 31 Waste Pile Material
Final Status Survey Activities and Results

Field Activities

CABRERA conducted final status survey (FSS) field activities on the Area 31 waste pile material as described in the *Work Plan,* except that modifications were made to the survey unit geometry in response to actual field conditions observed upon CABRERA's arrival at the site. The terrain within the excavation footprint was too sloping and uneven to provide a suitable surface for the waste to be laid out and surveyed as planned in 2,000-square meter (m^2) units. However, a relatively flat area was identified directly south of the waste pile (north of the excavation footprint), and this area was used to lay out the waste in incremental one-foot lifts (i.e., subunits) for survey and sampling activities. This field change was presented to and approved by the client, Army, and regulatory agencies prior to its implementation.

Beginning with the southern end of the waste pile, waste material was excavated from the pile and placed in an area approximately 11.5 meters (m) wide by 11.5 m long, in a layer approximately one foot (0.3 m) deep. Each subunit had an area of $1/15^{th}$ the size of the planned 2,000-m^2 survey unit, or approximately 130 m^2. Thus, 15 subunits were considered equivalent to a single survey unit. A 100% gamma walkover survey (GWS) was performed over each lift, using a 2-inch (in.) by 2-in. sodium iodide (NaI) gamma scintillation detector equipped with a global positioning system (GPS) unit. Gamma count rate data was recorded at a rate of once per second, along with the corresponding geographical coordinates (i.e., northings and eastings) for the locations of data collection.

A systematic soil sample was collected from the center of each waste lift, and a biased sample was collected from the location of highest NaI response, as measured during the GWS of that subunit. At each designated sampling location, a static count rate measurement was obtained using a hand-held Geiger-Mueller (GM) detector at the sampling location both before and after sample collection. At locations of high meter response (i.e., >100 counts per minute [cpm]) prior to sample collection, a search was initiated to locate any radioactive items that might be present below the surface. When radioactive items were identified, they were removed, bagged, and transferred to a secure location. A new static measurement was recorded at the location, sample material was collected from directly beneath where the item had been, and another static measurement was recorded after the sample was collected. The GM detector was also used to conduct a surface scan over a 1-m diameter area centered on each biased sampling location to determine whether any potentially radioactive material remained in the waste following sample collection.

Upon completion of survey and sampling activities for each subunit lift, the material comprising that lift was removed and staged at a designated location within the excavation footprint. Then, the next lift of material was laid out, surveyed, and sampled in a similar manner. This process was repeated for 48 individual subunits of waste, which were grouped into three survey units consisting of 15 subunits each and one survey unit consisting of three subunits. The four survey

units were stockpiled separately as survey and sampling activities were completed so that waste disposal decisions could be made individually for each, if necessary.

All of the systematic soil samples collected during the FSS were sent to the off-site laboratory for gamma spectroscopy analysis. Biased soil samples were collected and held until all of the subunits comprising a single survey unit had been evaluated. For each survey unit, biased samples from the three locations exhibiting the highest NaI response were also sent to the off-site laboratory for gamma spectroscopy analysis. Biased samples from locations where DU rounds were identified and removed were considered to be remedial support samples. All other biased and systematic samples were considered to be FSS support samples. Field duplicates were collected at a rate of 10%, as specified in the *Work Plan*. Smear samples of the tools used to collect samples were evaluated periodically to confirm the adequacy of equipment decontamination techniques.

Final Status Survey Results

Results of the GWS and soil sampling and analysis of the waste pile material are presented below.

Gamma Walkover Survey Results

The GWS conducted on the Area 31 waste pile material generated more than 22,600 unique data points, each consisting of a radiological count rate and the corresponding geographic northing and easting coordinates where the measurement was recorded. Summary statistics and z-scores of each data set were calculated in the same manner as that used for the excavation and waste pile footprint. The GWS data and statistical summaries for the waste pile material surveys are included in Attachment 2 (on CD). Color-coded contour maps of each survey unit are presented in the following figures:

- Figure A1-1: Waste Pile Survey Unit L1
- Figure A1-2: Waste Pile Survey Unit L2
- Figure A1-3: Waste Pile Survey Unit L3 and L4

Elevated GWS results provided the basis for identification and removal of five separate pieces of radioactive material from the waste pile material. One DU projectile body was found in each of Subunits L2-04, L2-11, and L2-15, and among the metal scrap on the west side of the waste pile. A fifth radioactive item (non-munitions) was discovered in Subunit L4-01. This item has not been positively identified; but its physical appearance and weak gamma emission rate suggests that it may have once been a component of process quality control instrumentation used at the plant. Upon removal from the Area 31 waste, the five items were appropriately containerized and relocated to Area 10, the current LCAAP repository for licensed DU material.

Remedial support soil samples were collected from directly beneath the radioactive items and shipped to the off-site laboratory for analysis. Upon removal of the sample material, the areas were scanned using the GM pancake detector to ensure that all potential contamination had been removed and that residual radioactivity was consistent with natural background. In each case,

removal of the sample volume alone was shown to be sufficient to remove any soil contamination discernable through the GM scan.

Soil Sampling and Analysis Results

The systematic and biased soil sampling locations are shown in Figures A1-1 through A1-3 for each waste pile material survey subunit. Field sheets documenting the collection of soil samples from these locations are included in Attachment 3 (on CD).

The GM count rate measurements recorded on the field sheets for each sample location are summarized in Table A1-1. The measurements indicated count ranges before and after sample collection of 30 to 80 cpm and 20 to 65 cpm, respectively, for the systematic samples, and 30 to 80 cpm and 20 to 60 cpm, respectively, for the biased and remedial support samples. Count rates observed at the systematic sample locations were assumed to represent general background activity in the waste pile material.

Soil samples collected in support of the waste pile FSS, as well as those collected as remedial support samples, were analyzed at the off-site laboratory by gamma spectroscopy for thorium-234 (^{234}Th) and its decay progeny. Analytical data reports generated by the laboratory are contained in the Adobe® Acrobat files provided in Attachment 4 (on CD). Detailed tables presenting the ^{234}Th data for the target samples, as well as the field and laboratory quality control data, are contained on the Excel® spreadsheet file provided in Attachment 5 (on CD).

Table A1-2 presents the gamma spectroscopy results reported for the Area 31 waste pile samples. The results reported for ^{234}Th were used to indicate the presence or absence of DU, based on the assumption that uranium-238 (^{238}U), the most abundant uranium isotope in DU by mass, and its short-lived daughter, ^{234}Th, are in secular equilibrium. In other words, the activity results reported for ^{234}Th are assumed to equal the activity of ^{238}U present in the sample material. Since ^{238}U comprises approximately 83.38% of DU activity (Army, 1995), DU activity in the soil can be calculated based on reported ^{234}Th activity using the following formula:

$$DU = \frac{^{234}Th}{0.8338}$$

Where: DU = Calculated activity of DU (pCi/g)
^{234}Th = Reported activity of ^{234}Th (pCi/g)

For all but two samples, the results indicated that ^{234}Th either was not detected above the reporting limit or was reported as an estimated value (i.e., "J" flagged) based on unidentified energy peaks. The two samples with detectable ^{234}Th (L2-B02 and L2-B03) were remedial support samples from waste pile subunits L2-11 and L2-15, respectively. These samples were collected from soils directly beneath two of the DU projectile bodies identified during the GWS. Analytical results indicate ^{234}Th activity concentrations of 35.4 and 6.1 pCi/g, respectively, for the two samples. Using the formula presented above, the corresponding DU activity concentrations in the sample material are 42.5 and 7.3 pCi/g, respectively. GM scans conducted at the locations from which these samples were collected indicated that residual radioactivity in

the waste pile returned to background levels upon removal of the DU and associated soil samples.

Confirmatory Analytical Tests

To verify the initial analytical results, samples L2-B02 and L2-B03 were recounted, with similar results obtained. Both sets of gamma spectroscopy results for these samples are presented in Table A1-3. The table also presents the results of an additional evaluation of these samples, which consisted of alpha spectrometry analysis to determine the isotopic makeup of the uranium in these samples. The high ^{238}U activity fraction reported in both samples (approximately 84%), confirmed the presence of DU. It should be noted that the percentages of isotopic uranium reported for these two samples were similar to those observed in soil samples from other LCAAP locations where Davy Crockett spotter rounds have been identified and removed.

The discontinuity of the gamma spectroscopy and alpha spectrometry results for ^{238}U are most likely the result of inherent sample heterogeneity. A typical gamma spectroscopy sample, with a total mass of approximately 1 kilogram (kg), is counted in its entirety to determine the total activity concentration of the sample as averaged over the entire mass. For alpha spectrometry samples, a relatively small aliquot (1 to 5 gram) is removed from the larger gamma spectroscopy sample and prepared for counting using radiochemical separation procedures. In order for these two analytical techniques to be directly comparable, the mass distribution of the contaminant (in this case DU) to the carrier (soil) must be homogeneous throughout the entire sample such that no matter the size of the aliquot collected, the relative distribution of the contaminant to the carrier never changes. This assumption rarely holds true for samples that contain DU in the form of hard metal oxides, which do not readily break down into smaller fines by means of natural weathering processes in the environment. Discrete metal particles (i.e., fragments or chunks) of DU tend to stay localized rather than binding to the surrounding soils, which prevents true homogenization from occurring regardless of the amount of mixing conducted at the laboratory.

The elevated ^{238}U result observed in the L2-B02 alpha spectrometry analyses is a reflection of a higher than average contaminant to carrier mass ratio in the aliquot analyzed. If one were to continue collecting 1 to 5 gram aliquots from the gamma spectroscopy sample and performing alpha spectrometry procedures, the collective results would resemble a distribution with the mean values of the two types of analyses in agreement. Taking into account the potentially wide variations in alpha spectrometry results for individual aliquots from a single 1-kg soil sample, gamma spectroscopy is generally considered a more reliable and practical means of quantifying the average activity concentration at a particular location.

Background Comparisons

As a final confirmation that no residual licensed material remains in the Area 31 waste, the FSS results were evaluated with respect to local background conditions. The GWS data were evaluated by generating probability distribution plots of each survey subunit to correlate measured count rates to the predicted z-score at each measurement location, under the assumption that the sampled data are normally distributed. The data were also compared to previously reported GWS results for a small reference area situated south of the firing range. In

addition, the soil sample data were compared to the published background concentration of uranium in Missouri soils.

The GWS data demonstrates that the waste pile does not contain any areas where surface radioactivity is inconsistent with background other than the locations specifically remediated for the removal of DU and associated soil. Probability distribution plots for the survey subunits indicate that all other locations exhibiting z-scores of greater than 3 were due to material variability and not to the presence of licensed uranium. In addition, the Area 31 GWS data indicate no measurements higher than the previously established LCAAP background range of 11,653 to 14,561 cpm (CABRERA, 2003), as measured using 2x2 NaI detectors.

Analytical data for the waste pile samples were compared to the State-wide background uranium activity concentration of 4.4 pCi/g derived from the results of a comprehensive study of soil geochemistry in Missouri agricultural soils (Tidball, 1984). Detection limits achieved during the Area 31 gamma spectroscopy analysis of waste pile samples are all less than this activity concentration, indicating that the analytical results for all samples reported as "non-detect" were within the established State-wide background. Only two samples, L2-B02 and L2-B03, exhibited detectable activity that exceeded this background concentration, as discussed above.

Conclusions

Results of the FSS indicate that the waste pile material at Area 31 is suitable for release without regard to radioactivity. Neither direct radiation measurements nor analytical data for the FSS support samples, which are representative of these soils, indicate the presence of any remaining DU (i.e., licensed material) in the waste.

The four DU projectile bodies and other radioactive item uncovered during the waste pile survey were removed from Area 31 and relocated to Area 10, the current LCAAP repository for licensed DU material. Analytical results for the remedial support samples collected from directly beneath these items indicate that small amounts of radioactivity were able to transfer from the DU projectile bodies to the soils immediately surrounding them. However, FSS results and confirmatory surface scans provided no evidence that any soil other than that which was in direct contact with the DU had been affected. Because the affected soils were remediated from the waste during collection of the remedial support samples, as confirmed by GM scans of the sample locations, it is concluded that no licensed radioactive material remains in the Area 31 waste.

TABLES

Table A1-1
LCAAP Area 31 Final Status Survey
Surface Geiger-Mueller Readings at Waste Pile Sample Locations

Biased Sample ID	Location	GM Detector Count Rate (cpm)			Notes
		Before DU Removal	Before Sample Collection •	After Sample Collection	
Waste Pile Final Status Survey Support Sample Locations - Systematic					
L1-01 to L1-15	Lift L1 - All Subunits	NA	35 to 80	30 to 60	
L2-01 to L2-15	Lift L2 - All Subunits	NA	30 to 80	30 to 60	
L3-01 to L3-15	Lift L3 - All Subunits	NA	30 to 70	20 to 60	
L4-01 to L4-03	Lift L4 - All Subunits	NA	40 to 50	20 to 50	
Waste Pile Final Status Survey Support Sample Locations - Biased					
L1-B01	Lift L1-01	NA	60	60	
L1-B06	Lift L1-06	NA	70	60	
L1-B09	Lift L1-09	NA	50	40	
L3-B01	Lift L3-08	NA	50	40	
L3-B02	Lift L3-09	NA	40	40	
L3-B03	Lift L3-11	NA	30	30	
L4-B02	Lift L4-02	NA	50	40	
L4-B03	Lift L4-03	NA	60	50	
Waste Pile Remedial Support Sample Locations					
L2-B01	Lift L2-04	3,000	50	40	DU body found in soil
L2-B02	Lift L2-11	NM	40	40	DU body found in soil
L2-B03	Lift L2-15	60,000	80	60	DU body found in soil
L4-B01	Lift L4-01	200	60	20	Rad item found, not DU
BDU-01 **	West of Waste Pile	10,000	NA	NA	DU body found in metal debris pile

NA = Not applicable NM = Not measured

NOTES:

• For remedial support sample locations, values in this column indicate count rates measured after DU removal and before sample collection.

** No soil analysis was performed at this location because the DU body was found in a pile of metal debris rather than in the soil. Surface radioactivity measurements did not identify a specific location of elevated activity in the soil underlying the debris pile.

Table A1-2
LCAAP Area 31 Final Status Survey
Waste Pile Gamma Spectroscopy Data

CLIENT ID	COMPOUND NAME	RESULT	UNITS	FLAGS	ERROR	MDC	LAB ID
Waste Pile Final Status Survey Support Samples - Systematic							
L1-01	Thorium 234	1.8	pCi/g	U	2.3	3.4	F6K110161021
L1-02	Thorium 234	0.4	pCi/g	U	1.6	2.4	F6K110161022
L1-03	Thorium 234	3.2	pCi/g	J*	2.1	2.6	F6K110161023
L1-04	Thorium 234	-0.2	pCi/g	U	1.8	2.5	F6K110161024
L1-05	Thorium 234	2.6	pCi/g	J*	1.7	2.5	F6K110161025
L1-06	Thorium 234	0.2	pCi/g	U	2.1	3.4	F6K110161026
L1-07	Thorium 234	-0.02	pCi/g	U	1.9	2.7	F6K110161027
L1-08	Thorium 234	0.4	pCi/g	U	1.5	3	F6K110161028
L1-09	Thorium 234	-0.2	pCi/g	U	2	2.9	F6K150242001
L1-10	Thorium 234	1.4	pCi/g	U	1.7	3.1	F6K150242002
L1-11	Thorium 234	0.4	pCi/g	U	1.7	3	F6K150242003
L1-12	Thorium 234	0.6	pCi/g	U	1.6	2.6	F6K150242004
L1-13	Thorium 234	0.9	pCi/g	U	1.6	2.8	F6K150242005
L1-14	Thorium 234	2.2	pCi/g	*	1.8	1.9	F6K150242006
L1-15	Thorium 234	-0.2	pCi/g	U	1.5	2.7	F6K150242007
L2-01	Thorium 234	0.3	pCi/g	U	1.7	2.9	F6K210120040
L2-02	Thorium 234	1.2	pCi/g	U	2.2	3.7	F6K210120041
L2-03	Thorium 234	1.1	pCi/g	U	1.3	2.5	F6K210120042
L2-04	Thorium 234	0.8	pCi/g	U	1.9	2.9	F6K210120043
L2-05	Thorium 234	0.5	pCi/g	U	1.6	3	F6K210120044
L2-06	Thorium 234	1.9	pCi/g	U	2.4	4.4	F6K210120045
L2-07	Thorium 234	0.4	pCi/g	U	1.9	2.5	F6K210120046
L2-08	Thorium 234	0.06	pCi/g	U	1.8	2.1	F6K210120047
L2-09	Thorium 234	0.2	pCi/g	U	1.5	2.8	F6K210120048
L2-10	Thorium 234	0.2	pCi/g	U	2.1	2.7	F6K210120049
L2-11	Thorium 234	0.4	pCi/g	U	1.6	2.4	F6K210120050
L2-12	Thorium 234	1	pCi/g	U	2	2.8	F6K210120051
L2-13	Thorium 234	-0.4	pCi/g	U	1.7	2.8	F6K210120052
L2-14	Thorium 234	-0.2	pCi/g	U	1.4	2.2	F6K210120053
L2-15	Thorium 234	-0.2	pCi/g	U	1.8	3.2	F6K210120054
L3-01	Thorium 234	1	pCi/g	U	2.2	3.3	F6K210120060
L3-02	Thorium 234	2	pCi/g	U	2.1	2.9	F6K210120061
L3-03	Thorium 234	0.2	pCi/g	U	1.3	2.2	F6K210120062
L3-04	Thorium 234	0.9	pCi/g	U	1.7	3.5	F6K210120063
L3-05	Thorium 234	0.4	pCi/g	U	2.1	3.2	F6K210120064
L3-06	Thorium 234	0.04	pCi/g	U	1.7	2.8	F6K210120065
L3-07	Thorium 234	-0.5	pCi/g	U	1.7	2.3	F6K210120066
L3-08	Thorium 234	0.2	pCi/g	U	1.7	3	F6K210120067
L3-09	Thorium 234	0.6	pCi/g	U	1.7	3	F6K210120012
L3-10	Thorium 234	1.3	pCi/g	U	1.7	3.1	F6K210120013
L3-11	Thorium 234	-0.8	pCi/g	U	1.7	2.7	F6K210120014
L3-12	Thorium 234	-0.2	pCi/g	U	1.7	2.7	F6K210120015
L3-13	Thorium 234	0.5	pCi/g	U	1.8	3.5	F6K210120016
L3-14	Thorium 234	1.6	pCi/g	U	1.7	2.9	F6K210120017
L3-15	Thorium 234	-0.5	pCi/g	U	2	3.1	F6K210120018
L4-01	Thorium 234	1.7	pCi/g	U	2.1	3.5	F6K210120021
L4-02	Thorium 234	-0.4	pCi/g	U	1.5	3.1	F6K210120022
L4-03	Thorium 234	1	pCi/g	U	2.1	2.8	F6K210120023
Waste Pile Final Status Survey Support Samples - Biased							
L1-B01	Thorium 234	0.6	pCi/g	U	2	2.8	F6K150242027
L1-B06	Thorium 234	0.6	pCi/g	U	1.7	3.4	F6K150242029
L1-B09	Thorium 234	1	pCi/g	U	1.6	2.8	F6K150242028
L3-B01	Thorium 234	1.2	pCi/g	U	1.9	3	F6K210120008
L3-B02	Thorium 234	0.7	pCi/g	U	1.7	2.4	F6K210120038

Table A1-2
LCAAP Area 31 Final Status Survey
Waste Pile Gamma Spectroscopy Data

CLIENT ID	COMPOUND NAME	RESULT	UNITS	FLAGS	ERROR	MDC	LAB ID
L3-B03	Thorium 234	0.9	pCi/g	U	1.6	2.5	F6K210120009
L4-B02	Thorium 234	-1.6	pCi/g	U	1.9	3.2	F6K210120010
L4-B03	Thorium 234	1.9	pCi/g	U	2.1	3.9	F6K210120011
Waste Pile Remedial Support Samples							
L2-B01	Thorium 234	0.9	pCi/g	U	1.8	3.3	F6K210120057
L2-B02	Thorium 234	35.4	pCi/g		8.1	4	F6K210120058
L2-B03	Thorium 234	6.1	pCi/g		2.4	2.7	F6K210120059
L4-B01	Thorium 234	1.5	pCi/g	U	1.5	2.8	F6K210120039
NOTES:							
U = Result is less than the sample detection limit.							
J = Result is greater than the sample detection limit but less than the stated reporting limit.							
* = The case narrative contains a note indicating that the reported Th-234 results are greater than the associated MDC for these samples, but the samples do not have peaks detected at either 63 or 92 keV. The software algorithm is calculating an activity based upon the region of interest rather than an identifiable peak and should be considered an estimate.							

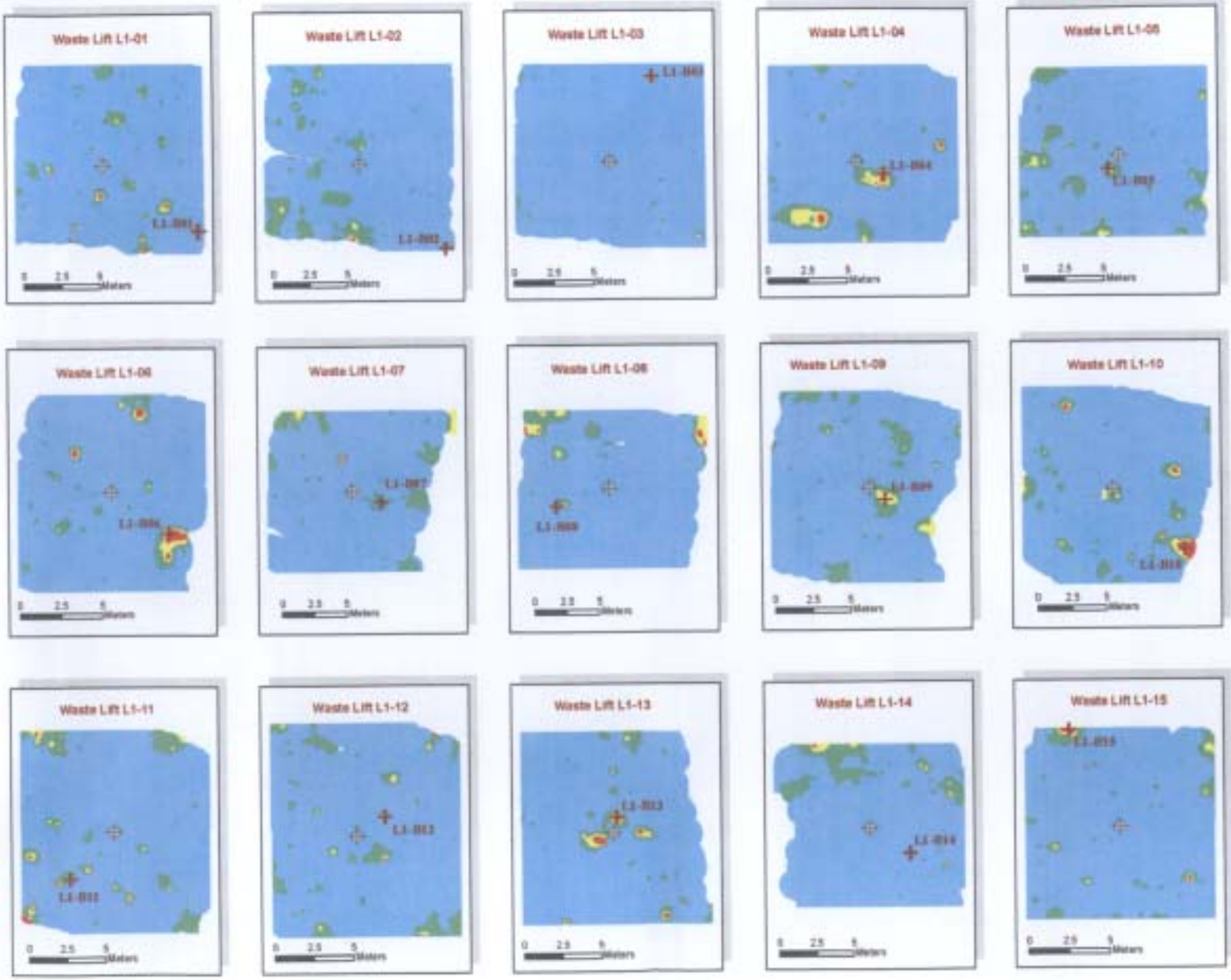
Table A1-3
LCAAP Area 31 Final Status Survey
Evaluation of Waste Pile Samples L2-B02 and L2B03

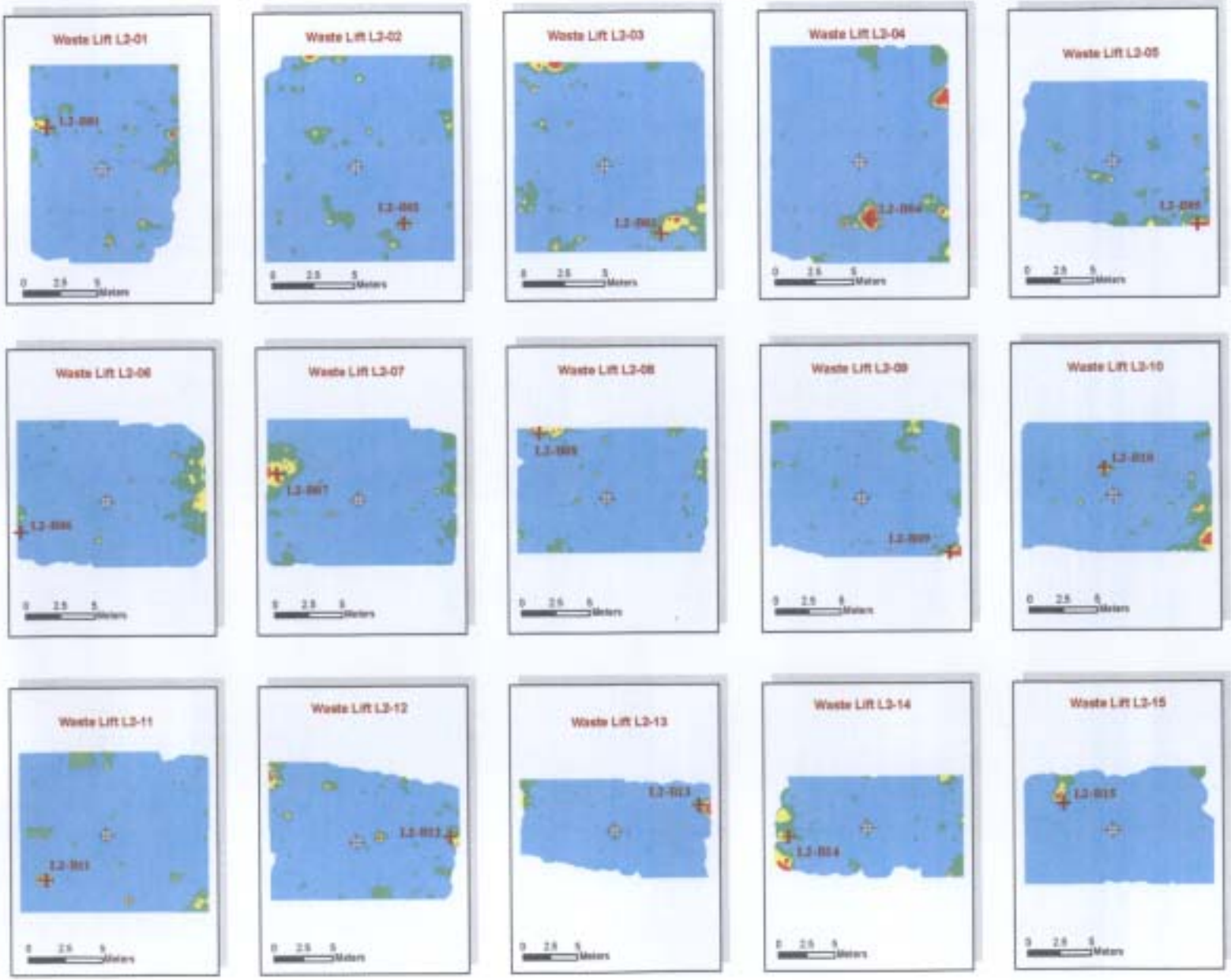
CLIENT ID	COMPOUND NAME	RESULT	UNITS	FLAGS	ERROR	MDC	LAB ID
Sample L2-B02							
Initial Gamma Spec Results							
L2-B02	Thorium 234	35.4	pCi/g		8.1	4	F6K210120058
Gamma Spec Recount Results							
L2-B02	Thorium 234	39.2	pCi/g		5.4	1.8	F6L070308001
L2-B02 DUP	Thorium 234	39.4	pCi/g		5.3	1.5	F6L070308001X
Alpha Spec Results							
L2-B02	Uranium 234	20.8	pCi/g		3.5	0.1	F6L070308001
L2-B02	Uranium 235/236	3	pCi/g		0.72	0.12	F6L070308001
L2-B02	Uranium 238	123	pCi/g		20	0.1	F6L070308001
Sample L2-B03							
Initial Gamma Spec Results							
L2-B03	Thorium 234	6.1	pCi/g		2.4	2.7	F6K210120059
Gamma Spec Recount Results							
L2-B03	Thorium 234	7.9	pCi/g		1.2	0.9	F6L070308002
Alpha Spec Results							
L2-B03	Uranium 234	3.4	pCi/g		0.59	0.07	F6L070308002
L2-B03	Uranium 238	19.3	pCi/g		2.7	0.05	F6L070308002
L2-B03	Uranium 235/236	0.26	pCi/g	J	0.12	0.06	F6L070308002

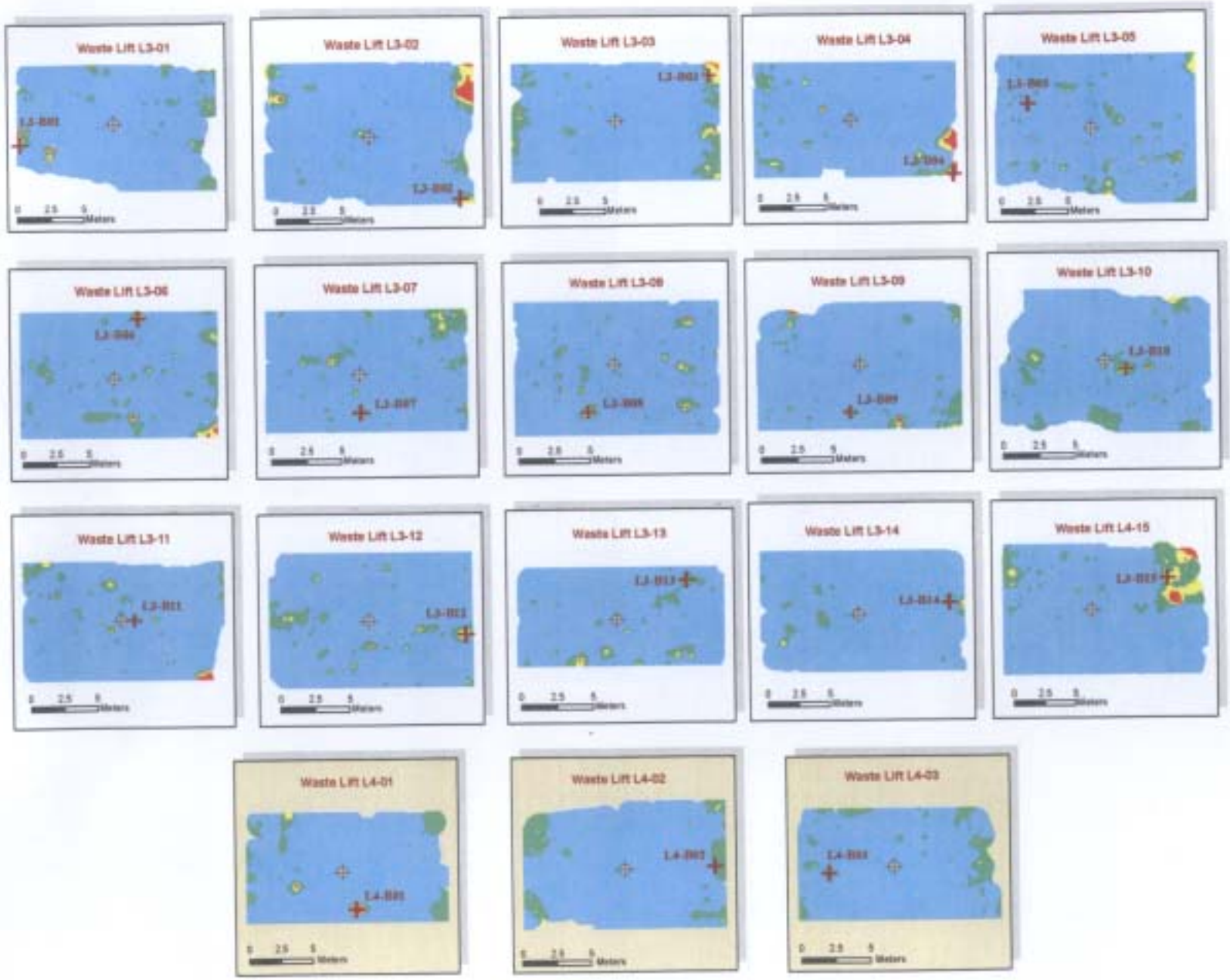
NOTE:
J = Result is greater than the sample detection limit but less than the stated reporting limit.

L2-B02			L2-B03		
Isoptope	pCi/g	% of total activity	Isotope	pCi/g	% of total activity
U-234	21	14%	U-234	3.4	15%
U-235	3	2%	U-235	0.26	1%
U-238	123	84%	U-238	19.3	84%
Total	147			23	

FIGURES


Waste Lift L1-01
Waste Lift L1-02
Waste Lift L1-03
Waste Lift L1-04
Waste Lift L1-05
Waste Lift L1-06
Waste Lift L1-07
Waste Lift L1-08
Waste Lift L1-09
Waste Lift L1-10
Waste Lift L1-11
Waste Lift L1-12
Waste Lift L1-13
Waste Lift L1-14
Waste Lift L1-15
0 2.5 5 Meters
N
Legend
Systematic Sample Locations
Biased Sample Locations
1 m Contour of Z-score
<1
1-2
2-3
>3
Note:
The biased sample on each waste lift subunit corresponds to the location with the highest Z-Score
AREA 31 WASTE PILE SURVEY UNIT L1
GAMMA WALKOVER SURVEY RESULTS
AND SAMPLE LOCATIONS
LAKE CITY ARMY AMMUNITION PLANT
INDEPENDENCE, MISSOURI
Figure A1-1
CABRERA SERVICES


Waste Lift L3-01
Waste Lift L3-02
Waste Lift L3-03
Waste Lift L3-04
Waste Lift L3-05
Waste Lift L3-06
Waste Lift L3-07
Waste Lift L3-08
Waste Lift L3-09
Waste Lift L3-10
Waste Lift L3-11
Waste Lift L3-12
Waste Lift L3-13
Waste Lift L3-14
Waste Lift L3-15
0 2.5 5 Meters
N
Legend
Systematic Sample Locations
Biased Sample Locations
1m Contour of Z-Scores
<1
1-2
2-3
3-4
Note
The biased sample on each waste lift subunit corresponds to the location with the highest Z-Score
AREA 31 WASTE PILE SURVEY UNIT L2
GAMMA WALKOVER SURVEY RESULTS AND SAMPLE LOCATIONS
LAKE CITY ARMY AMMUNITION PLANT
INDEPENDENCE, MISSOURI
Figure A1-2
CABRERA SERVICES



N

Legend

- Systematic Sample Locations
- Biased Sample Locations

1 m Contour of Z-score

- <1
- 1-2
- 2-3
- >3

Note
The biased sample on each waste lift subunit corresponds to the location with the highest Z-Score

AREA 31 WASTE PILE SURVEY UNITS L3 & L4 GAMMA WALKOVER SURVEY RESULTS AND SAMPLE LOCATIONS

LAKE CITY ARMY AMMUNITION PLANT INDEPENDENCE, MISSOURI

Date: 11/09
Project #: 07-1301.05
File Name: Figure A1-3
Prepared By: B.Pangelinan

Figure A1-3

CABRERA SERVICES

ATTACHMENTS ON CD

Attachment 2: Gamma Walkover Survey Data
Attachment 3: Soil Sample Collection Field Sheets
Attachment 4: Analytical Laboratory Data Reports
Attachment 5: Analytical Data Summary Spreadsheets
Attachment 6: Radiological Instrumentation Quality Control
Attachment 7: CABRERA NRC License No. 06-30556-01

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