Beltsville Agricultural Research Center (BARC)
Low Level Radioactive Burial Site (LLRBS)
Beltsville, Maryland

United States Department of Agriculture

Final Status Survey Report

FSSR-01
FINAL

Prepared for:

U.S. Army Joint Munitions Command
Rock Island, Illinois

Prepared by:

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ABBREVIATIONS AND ACRONYMS

α .... Type I error

AEC .... Atomic Energy Commission

ARS .... Agricultural Research Service

β .... Type II error

BARC....... Henry A. Wallace Beltsville Agricultural Research Center

BTM .... BARC Technical Memo

BWI.......... BARC Work Instruction

^{14}C carbon-14

CCOC ...... chemical contaminants of concern

CFR .... Code of Federal Regulations

^{36}Cl.......... chlorine-36

^{137}Cs cesium-137

CSM......... conceptual site model

Δ .... width of the gray region

DCGL....... Derived Concentration Guideline Level

$DCGL_{EMC}$.. Used when small areas of elevated radioactivity exist within larger areas ("EMC" stands for elevated measurement comparison).

$DCGL_{w}$ ..... Reference criterion, or radioactivity level for residual radioactivity evenly distributed over a wide area.

DGPS ...... Differentially-Corrected Global Positioning System

DoD .... U.S. Department of Defense

DOE......... U.S. Department of Energy

DP............ Decommissioning Plan

DQOs....... Data Quality Objectives

DSR .... dose-to-source ratio

EE/CA ...... Engineering Evaluation/Cost Analysis

EMC......... Elevated Measurement Comparison

EPA.......... U.S. Environmental Protection Agency

FDA.......... Food and Drug Administration

^{55}Fe iron-55

FIDLER .... Field Instrument for the Detection of Low Energy Radiation

FSS.......... Final Status Survey

FSSU .... Final Status Survey Unit

σ............... estimate of the standard deviation

GIS........... Geographic Information System

GM .... cluster pancake Geiger Mueller detector

GWS .... Gamma Walkover Survey

^{3}H............. hydrogen-3/tritium

H_a............. alternative hypothesis

H_0............. null hypothesis

IDW.......... investigation-derived waste

JMC .... (US Army) Joint Munitions Command

LBGR .... lower bound of the gray region

LLRBS...... Low Level Radiation Burial Site

LLRW .... low-level radioactive waste

µg/kg .... micrograms per kilogram

µg/L.......... micrograms per liter

m^2 .... square meters

mCi .... millicurie

MARSSIM Multi-Agency Radiation Survey and Site Investigation Manual (NUREG 1575)

MCL .... Maximum Contaminant Level

MDCs....... Minimum Detectable Concentrations

mg/kg....... milligrams per kilogram

mrem/y..... millirem per year

MSL .... mean sea level

^{22}Na sodium-22

NaI .... sodium iodide

^{63}Ni........... nickel-63

NIST .... National Institute of Standards and Technology

NRC......... U.S. Nuclear Regulatory Commission

ORP......... Oxidation Reduction Potential

PA/SI .... Preliminary Assessment/Site Investigation

^{210}Pb lead-210

^{32}P............ phorphorus-32

pCi/g .... picoCuries per gram

pCi/L .... picoCuries per liter

QA .... quality assurance

QC .... quality control

^{226}Ra radium-226

^{228}Ra radium-228

RBCs .... Risk Based Concentrations

RDRC ...... Radioactive Drug Research Committee

RESRAD .. Residual Radioactivity

RI .... Remedial Site Investigation

ROCs .... radionuclides of concern

RSO .... Radiation Safety Officer

SOR .... sum of the ratios

^{90}Sr........... strontium-90

SU............ survey unit

SSU .... stockpile survey unit

SVOC....... semi-volatile organic compound

TEDE .... total effective dose equivalent

^{230}Th......... thorium-230

USDA....... U.S. Department of Agriculture

VOCs .... volatile organic compound

VSP.......... Visual Sample Plan

W_r............. Sum of the ranks of the adjusted SORs from the background reference area for the WRS test

WRS .... Wilcoxon Rank Sum

1.0 INTRODUCTION

The United States Army Joint Munitions Command (JMC) contracted TPMC-EnergySolutions Environmental Services, LLC, Inc. (TES) to perform a NUREG-1575, Multi Agency Radiation Survey and Site Investigation Manual (MARSSIM) compliant Final Status Survey (FSS) in support of site decommissioning activities of a Low Level Radiation Burial site (LLRBS). The work was conducted for the U.S. Department of Agriculture (USDA), Agricultural Research Service (ARS), Henry A. Wallace Beltsville Agricultural Research Center (BARC), in Beltsville, Maryland. Hereafter, the BARC Low Level Radiation Burial site will be referred to as the LLRBS or the site (Figure 1, Appendix 1).

FSS activities included the following:

- Gamma walkover scan surveys and systematic and biased sampling of excavated soil that was planned for use as backfill;

- Post remediation gamma walkover scan surveys and systematic and biased sampling of the excavation bottom;

The FSS does not address chemical contaminants of concern (CCOC).

2.0 SITE DESCRIPTION

2.1 Project Location

The BARC Superfund site is comprised of a 6,600-acre parcel of property in northwestern Prince George's County near Beltsville, Maryland (Figure 1, Appendix 1). In 1910, the USDA purchased a 475-acre farm in order to conduct agricultural research. The facility expanded to a maximum of 12,000 acres and is now at its present size of 6,600 acres. Research at BARC involves soil, water, and air conservation, plant sciences, animal sciences, commodity conversion and delivery, and human nutrition. In addition, research is done on pesticides, herbicides, insecticides, and fungicides. Onsite laboratories are equipped with numerous chemicals, solvents, cleaners, and low-level radioactive chemicals for laboratory studies. Solid wastes generated at BARC included manure, waste bedding, animal carcasses, vegetative cuttings, wood, paper, scrap metal, laboratory waste, construction debris, and pesticide-, herbicide-, insecticide-, and fungicide-derived wastes.

The LLRBS is located approximately one-quarter mile north of the Cherry Hill Road overpass of the Capital Beltway (I95/495) in Beltsville, Maryland (Figure 1, Appendix 1), northeast of Washington D.C. Primary access is through BARC via US Route 1/Baltimore Avenue. Secondary access to the LLRBS is a gravel road that leads from Cherry Hill Road to a cluster of BARC maintenance buildings and continues along the western side of the BARC. This access is fenced, gated, and locked.

2.2 Disposal site Background

The LLRBS was established on June 23, 1949, and was used for the disposal of low-level radioactive waste (LLRW) until 1987. The LLRBS is permitted under the USDA multi-site license originally issued by the Atomic Energy Commission (AEC), and later by the Nuclear Regulatory Commission (NRC). Records indicate the last liquid burial at the LLRBS was on September 17, 1984. From September 24, 1985 until disposal activities ended in 1987, all burials were dry solids packed in 55-gallon drums (Entech, 2000).

Two contiguous fenced fields, the North Field and the South Field, made up the LLRBS, each of which was approximately 150 feet by 200 feet (Figure 2, Appendix 1). The South Field was reportedly never used for disposal of any waste materials, although individual disposal pits had been designated (Apex, 1993). The North Field contained approximately 50 waste disposal pits (Figure 3, Appendix 1).

Buried materials within the North Field disposal pits were anticipated to include radioactive isotopes and scintillation fluids (isotopes and organic fluids); contaminated metal, glass, and plastic objects; contaminated animal carcasses; and animal wastes. USDA records did not reveal the types of organic liquids contained in the scintillation vials, nor was any indication of volume included. Typically, organic liquids associated with scintillation fluids include the aromatic solvents: toluene and xylenes. Types of containers disposed, according to files, were cardboard boxes of one to four cubic feet, 1- to 5-gallon containers for liquids, plastic milk jugs, plastic carboys, solvent bottles, fiberboard drums, and 55-gallon drums. Liquid containers were placed in cardboard boxes, usually four to a box. There are no known records in existence that list the specific types of containers used for the early burials. Records from the 1980s indicate contaminated, non-flammable glass and plastic (vials, pipettes, needles, scalpels, etc.) were buried in cardboard boxes. Animal carcasses, bedding, and excreta were sealed in polyethylene bags and placed in boxes. Liquid wastes were packed in plastic containers and placed in cardboard boxes. Animal remains, generally contaminated with hydrogen-3/tritium (^{3}H) and carbon-14 (^{14}C), were routinely incinerated beginning in the early 1980s, in one of two incinerators located at the BARC. It is possible that incinerator ash, which tested positive for radioactivity, could have been sent to the LLRBS; however, known records do not exist for ash disposal.

2.3 Physical Setting

The BARC facility is situated in the Atlantic Coastal Plain Province, and this area can be described as gently rolling hills with broad valleys. The elevation varies from about 60 feet above mean sea level (MSL) where Indian Creek flows beneath Interstate 95/495 to 268 feet MSL in the extreme western portion of the facility on Cherry Hill Road near the LLRBS. Topography slopes to the east and southeast at 10 to 15 percent toward the nearest perennial stream, the Little Paint Branch, located approximately 2,000 feet east of the site boundary. Downstream, Little Paint Branch feeds into Paint Branch 1.4 miles to the south, and eventually draining into the Anacostia River. There are extensive wooded tracts in the central and eastern portions of BARC, while open agricultural fields are prevalent in the western section.

There are many perennial and intermittent streams, wetlands, and surface water bodies within BARC boundaries. Drainage features include Paint Branch and Little Paint Branch, which flow from north to south and are located in the western portion of the facility. Indian Creek also flows north to south parallel to Edmonson Road; and Beaver Dam Creek flows east to west in the south-central portion of BARC. All of these drainage features eventually flow southward into the Anacostia River (approximately 6 miles from the facility), which empties into the Potomac River at Washington, D.C.

There are not any wetlands adjacent to the LLRBS. The nearest wetlands are approximately 2,300 feet to the east, on the banks of the Little Paint Branch.

2.4 Geology

The USDA Natural Resources Conservation Service soil maps for Prince George's County describe numerous soil associations and groups of soils within the facility. Many of these units are described as comprising silty loam, loamy sand, and sandy loam of variable slope, drainage characteristics, and susceptibility to erosion. Surface soils are underlain by highly variable deposits ranging from gravels to clays, some as old as the Cretaceous Period.

The geology at BARC consists of Lower Cretaceous sediments of the Potomac Group, which consists of the Patuxent, the Arundel, and the Patapsco Formations, respectively decreasing in age. The Patuxent and Patapsco Formations are composed primarily of sand and gravel, and comprise the most prevalent water bearing aquifers in Prince George's County. The Arundel is mostly clay and creates artesian conditions in the underlying Patuxent Formation in some locations. Recharge of the Patuxent Formation occurs where it outcrops in the western portions of BARC. This wedge of sediments made up of the Patuxent, Arundel, and Patapsco Formations dips to the southeast, parallel to the regional groundwater flow (Apex, 1991).

The LLRBS lies on the Patuxent Formation. Soil textures beneath the site are well-sorted sand and gravel with minor clay lenses. This sand and gravel sequence overlies several feet of clay, below which are the igneous and metamorphic rocks of the Piedmont Province.

2.5 Hydrogeology

The site lies within the outcrop area of the Patuxent Formation, a part of the Potomac Group. The depth to groundwater is approximately 25 feet and the depth to bedrock is approximately 55 feet. The predominant soil texture is fine sand. Based on the results of three monitor wells, the mean hydraulic conductivity is estimated to be 6.5E-4 centimeters/second (Apex, 1993). Using the estimated average aquifer thickness of 30 feet and effective porosity of 30 percent, the average transmissivity beneath the site is estimated to be 1.78 square centimeters/second. Using the average gradient of 0.021 feet/foot, the average groundwater flow velocity is estimated to be 5.4 meters/year.

The Patuxent Formation is used as a drinking water supply in Prince George's county. Nine water supply wells on BARC property tap the Patuxent Aquifer (Apex, 1993).

2.6 Land Use

The BARC facility is best characterized as minimally developed, and is surrounded by land that is largely urbanized and densely populated. Inside the facility's boundaries, land use is agriculture, forest, and urban, with more than 800 buildings including laboratories, greenhouses, barns, office buildings, and some residences. A major portion of the facility is currently being used for crops, grazing livestock, and orchard research projects, primarily in the central and western portions of BARC. The central and eastern portions of the facility are primarily covered with mixed deciduous/evergreen forest. The urbanized portions of BARC are scattered throughout the property.

Land use outside of the facility boundaries is largely mixed urban and lightly developed, primarily forested parcels. There is widespread residential development along the western, southwestern, and northwestern boundaries of BARC. Commercial development is prevalent along U.S. Route 1 and the Beltsville Industrial Center, north of Sunnyside Avenue. Other major transportation routes that either border or pass through BARC are Interstate 95, Interstate 95/495, the Baltimore-Washington Parkway, and the B&O Railroad.

2.7 Previous Investigations

There have been a series of environmental investigations at BARC that were not specific to, but included investigation of the LLRBS starting with a Preliminary Assessment/Site Inspection (PA/SI) in 1991 (Apex, 1993), and continuing through a Remedial Site Investigation (RI) being conducted by Entech, Inc., that began in July 1997, and continues with ongoing groundwater monitoring. The relevant information is summarized below:

- PA/SI, May 1991: 44 potentially contaminated sites were identified (Apex, 1991), including the Low Level Radiation Burial site; the LLRBS was not included in the RI, and so analytical data did not result from this effort.
- Hydrologic Characterization and Monitoring of the LLRBS (Apex, 1993): study included eight soil borings to bedrock with split spoon samples taken every five feet (for lithology, radiological and organic contaminants); three monitoring wells were installed for potentiometric groundwater data.

- Environmental Monitoring Summary Report of the LLRBS, March 1994: five additional monitoring wells were installed to complement the initial three wells, forming three clusters (shallow/deep) and two additional side-gradient shallow wells.
- EPA Region III Technical Assistance Team Sampling, February 1996: sampling of the eight monitoring wells (analysis for volatile organic compounds [VOCs], semi volatile organic compounds [SVOCs], metals, gross alpha, gross beta, gamma isotopes, and selected radionuclides).
- Aerial Photographic site Analysis: BARC, January 1997.
- A Streamlined Risk Evaluation (Entech, 1998).

Conclusions from these investigations are summarized below:

- The stratigraphy at the LLRBS consists of silty sand and gravel terrace deposits overlying well-sorted sand and gravel of the Patuxent Formation; the hydrology can be described as a single, unconfined aquifer over bedrock varying in thickness from 20 to 30 feet, with southeasterly groundwater flow along topography.
- There are not any radiological or chemical constituents in soils up-gradient or down-gradient of the LLRBS above background levels.
- There is a chloroform groundwater plume down-gradient from the LLRBS.
- The EPA Technical Assistance Team concluded that there is a tritium source zone that likely originates from the LLRBS (contradicting the March 1994 Apex Environmental Report).
- The northern field was active from 1952 to 1987 (based on 11 sets of aerial photos taken from 1937 to 1993).
- There is not any evidence that the southern field was ever used for disposal, although it was used for drum storage of non-hazardous investigation-derived waste (IDW).

Residual radioactivity modeling performed as part of the Streamlined Risk Evaluation (Entech, 1998) indicates that the best long-term solution for the LLRBS will include removal of the source material.

2.8 Results of 2006 Characterization Survey

A characterization survey of the LLRBS was conducted in 2006 to assess conditions in the disposal pits and confirm existing assumptions about the nature of the disposed waste. The survey included the following tasks:

- Geophysical surveys in the North Field in order to delineate the burial cells, and in the South Field to confirm the assumption that burials have not taken place there;
- Gamma walkover surveys that map potential near-surface radiological materials;
- Sampling groundwater from selected wells in order to assess migration of contaminants away from source materials;

- Excavation, radiological characterization, segregation, and packaging of waste soils and materials in four of the documented waste cells;
- Sampling soil along the floor of each excavation;
- Installing temporary wells to sample groundwater from beneath each excavated disposal pit;
- Backfilling and restoring all excavations with clean fill.

The geophysical surveys of the South Field further substantiated the assumption that the South Field was not used for waste disposal.

2.8.1 Summary of Treatment and Disposal Activities Conducted Prior to January 2013

Less than 25 milliCuries of activity was removed from the excavated area. More than 75% of the activity was due to radium-226 (^{226}Ra) and ^{3}H. The ^{3}H activity was largely in groundwater pumped from Disposal Pits 26 and 34 during dewatering operations. Another 20% of the activity was from ^{14}C and nickel-63 (^{63}Ni), each with about 10% of the total. The remaining 5% was from lead-210 (^{210}Pb), chlorine-36 (^{36}Cl), and strontium-90 (^{90}Sr).

Twenty-eight drums of liquid scintillation vials, two drums of bulked liquids, and three radioactive sources/devices were shipped from the site for processing and disposal. The liquid scintillation vials and the bulked mixed waste were shipped to the Permafix facility in Gainesville, Florida for treatment and disposal. Two ^{226}Ra sources and a ^{63}Ni electron capture device were shipped to Alaron Corporation and were received under their source recycling license.

Approximately 8% (Disposal Pits 1, 14, 26, and 34) of the known disposal pits at the LLRBS were excavated as part of the characterization of the site. Waste materials encountered during excavation included laboratory trash (gloves, paper, metals, plastics, laboratory glassware, and other wastes generated during the process of performing laboratory analyses), liquid scintillation vials, radioactive sources, bulk soils containing small amounts of waste or debris not readily separable from soil, animal remains, and bulk liquids in their original containers (CABRERA, 2007a).

Disposed materials within the disposal pits often contained both radionuclides and hazardous wastes at concentrations that exceed NRC and/or Environmental Protection Agency (EPA) screening criteria for groundwater and soil. Radionuclide concentrations found in soil and water adjacent to the disposed materials were generally within regulatory limits.

2.9 Radionuclides of Concern (ROC)

The types of radioactive waste material at the LLRBS consisted of ^{3}H, ^{14}C, ^{36}Cl, ^{63}Ni, ^{90}Sr, ^{210}Pb, ^{226}Ra, sodium-22 (^{22}Na), phosphorus-32 (^{32}P), iron-55 (^{55}Fe), cesium-137 (^{137}Cs), and other radionuclides. Some of the radiological materials deposited in the LLRBS were short-lived (i.e., have a short radiological half-life), including ^{22}Na, and ^{32}P. Inventory records of burials from 1949 through 1960 could not be located.

2.9.1 ROC from the Characterization Survey Effort

Radiological contaminants ^{3}H and ^{14}C were found in low concentrations throughout the waste where liquid scintillation vials were present, with ^{90}Sr, ^{36}Cl, and ^{226}Ra occurring less frequently.

The maximum ^{3}H concentration found in subsurface soils was 140 picoCuries per gram (pCi/g), collected from Disposal Pit 14, which was slightly higher than the NRC guideline screening level of 110 pCi/g. All other results for ^{3}H in soil were 30 pCi/g or less.

The maximum ^{14}C concentration in soil samples was 210 pCi/g, collected from the bottom of Disposal Pit 26. Two other samples for ^{14}C, one collected from Disposal Pit 26 and another collected from Disposal Pit 14 had ^{14}C concentrations of approximately 15 pCi/g. These three results exceed the NRC guideline level of 12 pCi/g, while all other results were below that level.

The maximum ^{90}Sr concentration in soils was 0.278 pCi/g, compared to the NRC guideline level of 1.7 pCi/g. The maximum concentration of ^{36}Cl in soil was 0.11 pCi/g compared to a guideline level 0.36 pCi/g.

The maximum concentration of ^{226}Ra was 7.53 pCi/g, collected from the sidewall of Disposal Pit 34C. Seven of 13 soil samples collected from Disposal Pit 34C exceeded the NRC guideline level of 0.7 pCi/g. Two of eight samples collected from the background reference area also exceeded the NRC guideline level for ^{226}Ra. Historical records (CABRERA, 2008) indicate that ^{226}Ra was disposed in Pit 34, but only the total activity of all disposed radionuclides was listed in inventory records: 5.25 millicuries (mCi) among five nuclides. Soil samples from the background reference area had a mean ^{226}Ra concentration of 0.61 pCi/g, where the maximum was 0.87 pCi/g of eight background samples collected.

The only radionuclides that exceeded Risk Based Concentrations (RBCs) in water samples were radium-228 (^{228}Ra) and thorium-230 (^{230}Th). The maximum ^{228}Ra concentration in unfiltered groundwater was 29.7 picoCuries per liter (pCi/L), compared to a field-filtered aliquot of the same sample, which contained 13.9 pCi/L of ^{228}Ra. The EPA Maximum Contaminant Level (MCL) for ^{228}Ra and ^{226}Ra was a combined value of 5 pCi/L. The ^{228}Ra concentration in the field-filtered sample was comparable to regional results for the Patuxent Aquifer. Patuxent groundwater results ^{226}Ra + ^{228}Ra concentration from Fort Meade located seven miles away average 23 pCi/L. The ratio of ^{226}Ra to ^{228}Ra were roughly 1:1 in regional groundwater. (EPA, 2004)

Groundwater beneath Disposal Pits 1, 14, and 34 contained ^{230}Th concentrations ranging from 18 pCi/L to 28 pCi/L, compared to an MCL concentration of 15 pCi/L. These concentrations appear to be comparable to regional background concentrations. The documented elevated levels of ^{226}Ra in regional groundwater were thought to be due to elevated levels of ^{230}Th, which in turn were due to the presence of heavy minerals within the aquifer itself. According to EPA; “It is reasonable to assume that uranium and thorium are present in the aquifers because of the occurrence of zircon in the aquifer materials, the known presence of uranium and thorium in stream sediments, and the high radium concentrations in ground water. There is insufficient data currently available to determine the relationship between the distribution of uranium and thorium in the aquifer materials and the radium concentrations found in ground water. It is not known, for example, whether uranium and thorium occur in highly concentrated, low-solubility zones or whether they are widely dispersed in soluble forms.” (EPA, 2004)

The maximum ^3H concentration in groundwater beneath the disposal pits was 1,030 pCi/L, compared to the NRC derived concentration guideline level of 20,000 pCi/L.

2.10 Conceptual site Model

The conceptual site model (CSM) identifies the relationship between the sources of contamination, source areas, transport mechanisms, exposure routes, and the receptor. The CSM provides a description of how contaminants enter into the environment, how they are transported within the environment, and the routes of exposures to humans (CABRERA, 2007b).

Based on historical records provided by BARC, the top five feet of overburden associated with each burial pit was considered uncontaminated soil. There was not any known surface contamination. Due to previous burial activities within the LLRBS, subsurface soils associated with each burial pit have the potential for significant radiological and non-radiological contamination. As a part of the decommissioning activities, the waste and contaminated soil present within each pit will be excavated and shipped off-site for disposal. The residual radioactive material in this CSM was defined as contaminated soil present below the bottom of the pit to the depth of groundwater. As a conservative approach, the contamination was assumed to be uniformly distributed from the bottom of the burial pits to the top of the aquifer. Therefore, the thickness of contaminated zone was assumed to be 15 feet (4.6 meter). In addition, during the decommissioning of the site, excavated soils below the Derived Concentration Guideline Level (DCGL) criteria will be used as a backfill material for the site. The residual soil contamination may contribute additional dose to the exposed receptor. Therefore, soil DCGLs were developed based on thickness of the contaminated zone of 17 feet (5.18 meter). The BARC land was shielded from development by both state and federal law. Maryland law designates BARC property as “agricultural open space” and prohibits the Prince George’s County Council from changing that designation (Pierre 1993). Environmental pathways include external gamma radiation, inhalation of suspended dust, ingestion of impacted fruits and vegetables, ingestion of impacted fish, ingestion of impacted groundwater, and ingestion of contaminated soil. Note that the Residual Radioactivity (RESRAD) computer code models migration of contaminants into groundwater and subsequent dispersal though water dependent pathways. This modeling component was included in DCGL calculations. The critical receptor was a resident farmer.

3.0 DECOMMISSIONING

As discussed previously, BARC ceased use of the LLRBS in 1987 and as such terminated licensed disposal activities more than 20 years ago. There was not sufficient verifiable data to demonstrate that, prior to remediation, the LLRBS was suitable for release for unrestricted use (i.e., meets the 10 Code of Federal Regulations [CFR] 20 Subpart E unrestricted Radiological Criteria for License Termination). Thus, based on the criteria above, USDA was required to initiate the NRC decommissioning process in accordance with 10 CFR 30.36(d).

The USDA submitted a Decommissioning Plan (DP) to the NRC and received a license amendment to support planned removal actions, which included the following activities:

- Removal and off-site treatment/disposal of all waste materials from the LLRBS;
- Performance of walkover surveys for the detection of radiation;
- Sampling and analysis of soil that was anticipated to remain at the site;
- Subsurface sampling and analysis of vadose zone soils and water;
- Backfill of the excavation.

3.1 DP Amendments

Shortly after commencing site mobilization, TES identified several areas where DP requirements could be modified to provide better consistency with MARSSIM guidance. These recommendations were communicated to the USDA and subsequently to the NRC via documents referred to as BARC Technical Memos (BTM-##) that were generated by TES.

3.1.1 BTM-02, *Final Status Survey Plan Improvements*

BTM-02, *Final Status Survey Plan Improvements* (TES, 2014), was drafted in August of 2013 to identify proposed improvements to the final status survey plan. Revision 2 was issued in May 2014 and used as the basis for an amendment to the DP. BTM-02 is included in this report as Appendix 2. Modifications to the DP associated with BTM-02 are summarized below:

1. Consistent with MARSSIM guidance, the value of N/2 was changed from 20 to 16.
   a) The number of samples, intended for use in statistical testing, collected from each Class 1 interstitial soil survey unit (SU, Section 5.4, Survey Unit Classification), was increased from 1 sample to 16 samples.
   b) The number of samples, intended for use in statistical testing, collected from all other SUs was decreased from 20 samples to 16 samples.
2. The requirement to perform beta and gamma walkover surveys as part of the final status survey was modified to require only gamma scan surveys of land areas.
3. The requirement to excavate to a depth of 15 feet below grade was modified to require excavation to a relative depth of 1 foot below each waste pit with the

excavation bottom contoured as necessary to provide a relatively smooth surface suitable for the performance of planned survey and sampling activities.

4. The survey design described in Section 3.5 of BTM-02, consisting of two Class 1 SUs surrounded by one Class 3 SU, was adopted for the final status survey of the excavation bottom.

A significant portion of the excavation was completed prior to implementing the changes that were recommended in BTM-02. The most notable effects on the project are described below:

1. Twenty (20) soil samples were collected from the background reference area and analyzed at the off-site laboratory. The results from all 20 samples have been used for statistical testing. For the Wilcoxon Rank Sum (WRS) test, the value for W_r was chosen for situations where the background reference area has 20 measurements.

2. Class 1 interstitial soil SUs were sampled in the following manner prior to implementation of BTM-02 modifications:

   a) Twenty (20) systematic sample locations were plotted using VSP software. The sample locations used a triangular grid pattern with a random start point;

   b) The sample locations were identified in the field using GPS equipment;

   c) A soil sample was collected from each of the 20 sample locations and split for radiological analysis at the on-site laboratory and archiving for analysis at the off-site laboratory;

   d) One of the 20 samples from each SU was selected for immediate analysis at the off-site laboratory. The location of this sample was determined using a random number generator and the range 1-20, which placed the off-site sample location at one of the 20 systematic sample locations in the SU.

3. Once the BTM-02 modifications were implemented, five of the six Class 1 interstitial soil SUs had already been excavated and placed in the laydown area, one on top of the other with SSU-01 at the bottom of the pile and SSU-05 at the top. Many of the samples that were previously collected and archived had exceeded the six-month hold time allowed for radiological analysis at the off-site laboratory. Therefore the Class 1 interstitial soils SUs were resampled in the following manner:

   a) Sixteen (16) systematic sample locations were plotted using VSP software. The sample locations used a triangular grid pattern with a random start point. The same (x, y) coordinates were used for the identification of the 16 sample locations in all six Class 1 SUs;

   b) For each survey unit where a sample had already been collected and analyzed at the off-site laboratory, the initial sample served as one of the new 16 systematic samples, correlated by proximity to the nearest of the 16 systematic sample locations;

   c) The sample locations were identified in the field using GPS equipment;

   d) A soil sample was collected from each of the remaining 15 sample locations at depths corresponding to each of the six Class 1 survey units for analysis at the off-site laboratory.

3.1.2 BTM-06, *Post Excavation Sampling of Water and Undisturbed Soil*

BTM-06, *Post Excavation Sampling of Water and Undisturbed Soil* (TES, 2015), was drafted in October of 2015 to propose an alternate approach to post excavation sampling of water and undisturbed soil that is consistent with project technical goals while providing a more cost-effective methodology similar to that described in MARSSIM and NUREG/CR-7021, *A Subsurface Decision Model for Supporting Environmental Compliance* (NRC 2012). Revision 0 was issued in October of 2015 and was used as the basis for an amendment to the DP. BTM-06 is included in this report as Appendix 3. The EPA, NRC, and USDA agreed to the modified approach, which is summarized below:

1. CERCLA closure sampling will consist of the following:
    a. Soil samples will be collected from the 0-6 inch interval of undisturbed soil at 12 locations within the excavation;
    b. Groundwater samples will be collected from 14 locations within the excavation;
    c. Groundwater samples will be collected from 13 existing monitoring wells;
    d. Groundwater samples will be collected from 4 new monitoring wells in the spray irrigation fields;
    e. Three surface water samples will be collected from the Little Paint Branch Creek.
2. Vadose zone FSS sampling will consist of the following:
    a. Soil samples will be collected from the 0-6 inch interval of undisturbed soil at 12 locations within the excavation;
    b. Groundwater samples will be collected from 14 locations within the excavation;
3. The soil borings will be collected using the direct push method. A soil sample, of sufficient quantity to support the specified laboratory analyses, will be collected from the top 6 inches of the first soil core comprised of undisturbed soil. This will include the collection of three 5-gram En Core® samples for VOC analysis.
4. Each designated boring/monitoring well will be sampled for groundwater. A filtered water sample, of sufficient quantity to support the specified laboratory analyses, will be collected in a manner that is consistent with EPA's low flow groundwater sampling protocol (EQASOP-GW 001 dated January 19, 2010). When performing low flow groundwater sampling, water quality parameters including dissolved oxygen, temperature, salinity, pH, specific conductivity, oxidation reduction potential (ORP), and turbidity will be measured and recorded. Sampling will be performed once all parameters have stabilized per EPA guidance documents.
    a. Three additional 40ml VOA vials will be collected from the unfiltered groundwater sample for VOC analysis.

4.0 DATA QUALITY OBJECTIVES

Data Quality Objectives (DQOs) are qualitative and quantitative statements that establish a systematic procedure for defining the criteria by which data collection design is satisfied in order to make determinations regarding non-excavated soil following remedial activities. The DQOs at the site include:

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

The overall Quality Assurance (QA) objective for this project was to develop and implement procedures for obtaining and evaluating data that meet the DQOs for ensuring that the required remediation was accomplished. Specifically, radionuclide data were generated for demonstrating that the remedial effort has achieved the DCGLs. QA procedures were established to ensure that field measurements, sampling methods, and analytical data provided information that was comparable and representative of actual field conditions, and that the data generated were technically defensible.

To determine the project DQOs, a series of planning steps were used, as specified in the *EPA Guidance for Data Quality Objective Process QA/G-4* (EPA, 2000), to identify the data needed to support project decisions and develop a data collection program. The process was intended to be iterative, optimizing data collection to meet the applicable decision criteria. The six steps, as applied to the site, are detailed in Sections 4.1 through 4.6.

4.1 Step 1: State the Problem

4.1.1 Problem Description

The problem was the presence of radioactive material due to disposal activities between 1949 and 1987. The site ROCs are ^{3}H, ^{14}C, ^{36}Cl, ^{63}Ni, ^{90}Sr, ^{137}Cs, ^{210}Pb, and ^{226}Ra.

4.1.2 Primary Decision Maker

The ultimate decision regarding disposition of the site rests with the USDA Beltsville Agricultural Research Center, in consultation with NRC.

4.2 Step 2: Identify the Decision

4.2.1 Principal Study Question

Do ROC concentrations at the site exceed the DCGLs?

4.2.2 Decision Statement

Determine whether ROC concentrations at the LLRBS exceed the DCGLs and whether the ROC concentrations in excess of background meet the Sum of the Ratios (SOR) criteria of less than or equal to 1.0 following remedial activities.

4.3 Step 3: Identify Inputs to the Decision

The objective of the survey and sampling activities was to demonstrate that residual radioactivity in each SU, following remediation, satisfies the predetermined DCGLs. This section lists the data needs, describes the sources of that data, and discusses the means of obtaining the required data for resolving the decision statement listed in Section 4.2. SUs are described in Section 5.4.

4.3.1 Information Inputs

The required information is the concentration of residual radioactive material in the sidewalls and bottoms of excavated areas and in the disposal pit covering materials removed prior to excavation of the disposal pits. This information allows determination as to whether or not the survey units are suitable for unrestricted release in accordance with the DCGLs.

4.3.2 Information Sources for Above Listed Items

Decisions were based on the data received from a combination of scan survey and soil sampling events including gamma walkover surveys and off-site laboratory analytical results.

4.4 Step 4: Define the Study Boundaries

4.4.1 Population of Interest Defining Characteristics

The populations of interest for the site are the concentration of ROCs and their associated SORs in each survey unit.

4.4.2 Spatial Boundaries of the Decision Statement

The spatial boundaries of this project are horizontally limited to the land area within the North Field of the site. Vertically, the boundaries are limited to the bottoms of the exhumed disposal pits, 15 feet below original ground surface, and the groundwater interface (approximately 25 feet below original ground surface).

4.4.3 Temporal Boundaries of the Decision Statement

Timeframe to which the decision applies - DCGL values are based on dose to an average member of the critical group over a 1,000-year period following the study. The critical group was defined as a group of individuals expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances (NRC, 2000).

4.4.4 Scale of Decision Making

Decisions were made on a survey unit basis as to whether or not the concentrations of ROCs and their associated SORs are less than 1.0.

4.4.5 Constraints on Data Collection

Data collection activities were scheduled and performed in a manner that minimized the effects of excessive moisture or rain, extreme cold, extreme heat, or dramatic temperature changes within a single day.

4.5 Step 5: State the Decision Rules

4.5.1 Parameters of Interest

Parameters of interest are the mean, median, and standard deviation of ROC results collected during the FSS. Decisions were made according to the decision rules stated in Section 4.5.5.

4.5.2 Scale of Decision Making

Decisions were made on two fundamental scales: the SU, and smaller localized areas of elevated activity. Smaller localized areas of elevated activity were evaluated on an ongoing basis throughout the field effort. In cases where clear indications of elevated measurements are observed, decisions on remediation, SU subdivision, etc., were taken as appropriate. On a larger scale, and as a final determination, data was evaluated on a SU-specific basis.

4.5.3 Action Levels

Decisions on a SU's acceptability for release according to the DCGLs are based on two primary criteria: results of the gamma walkover surveys and off-site laboratory results of soil samples. Inputs to this decision are intended to avoid unnecessary analytical and/or remediation efforts, while also ensuring that project DQOs are met.

4.5.4 Decision Inputs

Geospatial modeling of position-correlated gamma walkover survey data provided a graphical view of surface gamma radiation levels and was updated as the survey progressed. During performance of the fieldwork, this was the primary decision input for identifying areas of elevated activity and selecting locations for collecting biased soil samples. Off-site laboratory soil sample results were used for statistical testing.

Field Measurements of Survey Unit Dimensions

The dimensions of the SUs were determined using Differentially-Corrected Global Positioning System (DGPS) data, downloaded and interpreted in the Geographic Information System (GIS). At a minimum, the corners of the SUs were logged using the DGPS system. The area of each SU was then calculated in units of m^2 or ft^2 to ensure that SUs do not exceed the maximum sizes recommended by MARSSIM.

Gamma Walkover Surveys in the Background Reference Area

Soon after the background reference area was established, a gamma walkover survey was performed. This data was used, in part, to evaluate and make decisions regarding the radiological status of the site SU data. Background reference area gamma walkover survey data was reduced and evaluated as follows:

- The mean and standard deviation of the gamma walkover survey data were calculated;
- The measurement results were plotted and color-coded for visual review and evaluation;
- Values associated with the "z-score" for each data point (i.e., number of standard deviations from the mean; one z-score = one standard deviation) were plotted and color-coded for visual review and evaluation;
- The data was reviewed for obvious anomalies to determine that the chosen background reference area was acceptable (i.e., non-impacted).

Gamma Walkover Surveys in Site Survey Units

The gamma walkover surveys of the SUs were performed after the gamma walkover survey in the background reference area was completed satisfactorily. The SU gamma walkover survey data was reduced and evaluated as follows:

- The measurements were plotted and color-coded for visual review and evaluation. The mean and standard deviation of each SU was calculated. The coordinates of the highest measurement were identified.
- A value associated with the z-score for each data point was plotted and color-coded for visual review and evaluation. A z-score tells how many standard deviations above the mean (positive) or below the mean (negative) a number falls. All areas exceeding three standard deviations above the mean (i.e., the z-score was equal to or greater than 3.0) were identified. The frequency of these occurrences and the maximum measurement in these areas were compared to the background reference area. The geospatial plot will also be visually inspected to identify anomalies in the distribution of measurement data.
- Z-score parameters were used for the selection of biased soil sample locations.

Off-site Laboratory Sample Results

Statistical testing of off-site laboratory sample results may include the following calculations

- Gross SOR
- Net SOR
- W_r

These calculations are described in greater detail in the following subsections.

<u>Sum of the Ratios</u>

Typically, each radionuclide $DCGL_w$ corresponds to the release criterion (e.g., regulatory limit in terms of dose or risk). However, in the presence of multiple radionuclides, the total of the $DCGL_W$s for all radionuclides could exceed the release criterion. In this case, the individual $DCGL_W$s need to be adjusted to account for the presence of multiple radionuclides contributing to the total dose. While there are several methods used for adjusting the $DCGL_W$s, the one used for this final status survey is the unity rule or SOR. The SOR is satisfied when radionuclide mixtures yield a combined fractional concentration limit that is less than or equal to one.

The SOR is calculated as follows:

$$SOR = \frac{^{226}Ra_{Conc}}{^{226}Ra_{DCGL_W}} + \frac{^{3}H_{Conc}}{^{3}H_{DCGL_W}} + \frac{^{14}C_{Conc}}{^{14}C_{DCGL_W}} + \frac{^{137}Cs_{Conc}}{^{137}Cs_{DCGL_W}} + \ldots$$

Where:

$^{226}Ra_{Conc}$	=	Measured activity concentration for ^{226}Ra
$^{3}H_{Conc}$	=	Measured activity concentration for ^{3}H
$^{14}C_{Conc}$	=	Measured activity concentration for ^{14}C
$^{137}Cs_{Conc}$	=	Measured activity concentration for ^{137}Cs
$^{226}Ra_{DCGLw}$	=	site-Specific $DCGL_W$ for ^{226}Ra
$^{3}H_{DCGLw}$	=	site-Specific $DCGL_W$ for ^{3}H
$^{14}C_{DCGLw}$	=	site-Specific $DCGL_W$ for ^{14}C
$^{137}Cs_{DCGLw}$	=	site-Specific $DCGL_W$ for ^{137}Cs

<u>Net SOR</u>

For every sample location within a SU where the SOR was greater than one, the Net SOR for that sample location was calculated. Net SOR considers the concentration of each radionuclide less its respective background concentration (as established by the background reference area soil sample results) divided by the $DCGL_W$ established for the radionuclide, as follows:

$$\text{Net SOR} = \sum_i \left[\frac{(Conc_i - B_i)}{DCGL_{W_i}} \right]$$

Where:

$Conc_i$	=	concentration of ROC "i" present in the soil sample
B_i	=	mean concentration of ROC "i" present in the background reference area
$DCGLw_i$	=	DCGLw of ROC "i"

<u>Elevated Measurement Comparison</u>

For every sample location within a SU where the Net SOR is greater than 1, an elevated measurement comparison was performed utilizing the alternative method specified in MARSSIM Chapter 8.5.2, and presented below:

<u>… As an alternative to the unity rule, the dose or risk due to the actual residual radioactivity distribution can be calculated if there is an appropriate exposure pathway model available.</u>

The residual radioactivity computer code (RESRAD version 6.5) was used to perform dose modeling on areas of elevated activity based on their actual radionuclide concentrations and maximum bounded areas. Other model input parameters were identical to those used for development of the project DCGLs. The dose associated with each area of elevated activity and the dose associated with the remaining portion of the survey unit were then summed to verify that the total dose due to residual radioactivity within the entire survey unit does not exceed 25 mrem/y.

$\underline{W_r}$

When necessary, comparison of background reference area (background) radionuclide concentrations with SU concentrations was performed using the two-sample WRS statistical test. This test was selected because some ROCs are present in natural background. The two-sample WRS statistical test assumes the background reference area and SU data distributions are similar except for a possible shift in the medians.

When the data are severely skewed, the value for the mean difference between SU measurements and reference measurements may be above the $DCGL_w$, while the median difference is below the $DCGL_w$. In such cases, the SU does not meet the release criterion regardless of the result of the statistical test. On the other hand, if the difference between the largest SU measurement and the smallest background reference area measurement was less than the $DCGL_w$, then the WRS statistical test will always show that the SU meets the release criterion.

In using this test, the hypotheses being tested are:

- *Null Hypothesis (H_0)*: The median concentration in the survey unit exceeds that in the background reference area by more than the DCGL;
- *Alternative Hypothesis (H_a)*: The median concentration in the survey unit exceeds that in the background reference area by less than the DCGL.

The WRS statistical test was applied to the laboratory sample data via the following sequential steps:

a. Reduce background reference area and SU isotopic data to SOR using the SOR equation presented previously in this section.

b. Add the $DCGL_w$ value (i.e., 1.0) to each background reference area SOR value, X_i, to obtain the adjusted background reference area SOR, Z_i, where:

$$Z_i = X_i + 1.0$$

c. The *m* adjusted SOR, Z_i, from the background reference area and the *n* SOR, Y_i, from the SU are pooled and assigned a rank in order of increasing measurement value from *1* to *N*, where:

$$N = m + n$$

d. If several SORs are equal (e.g., have the same value), then they are all assigned the mean rank of that group of tied measurements.

e. Sum the ranks of the adjusted SOR from the background reference area, W_r.

f. Compare W_r with the critical value given in MARSSIM, Appendix I, Table I.4, for the approximate values of *n*, *m*, and α. If W_r is greater than the tabulated value, then reject the null hypothesis that the SU exceeds the release criterion.

4.5.5 Decision Rules

Field Measurements of SU Dimensions

No measured dimensions of Class 1 SUs exceeded the 2,000 m^2 maximum recommended by MARSSIM. No Class 2 SUs were identified for this FSS. MARSSIM provides no recommended size limitation for Class 3 SUs.

Gamma Walkover Survey in the Background Reference Area

The background reference area gamma walkover survey data indicates that the chosen area exhibits acceptable variance and does not appear to be impacted by previous radiological activities at the LLRBS.

Gamma Walkover Survey in the site SUs

A biased soil sample was collected at the location where the highest gamma walkover survey data point was observed in each final status survey unit and each 6” lift in Class 3 stockpile survey units.

A more thorough scan survey was performed on any areas initially exhibiting elevated gamma exposure rates (defined as exceeding three standard deviations above the mean). If confirmed, additional remediation and/or biased sampling was performed.

Laboratory Sample Results

MARSSIM Table 8.2 “Summary of Statistical Tests” for radionuclides in background, provides decision rules for evaluating survey/sample results. This guidance was used to evaluate the LLRBS sample results.

MARSSIM Table 8.2
Summary of Statistical Tests, Radionuclide in background

Sample Result	Conclusion
Difference between largest survey unit measurement (SOR) and smallest background reference area measurement (SOR) is less than the $DCGL_W$ (1)	Survey unit meets release criterion
Difference of survey unit mean (SOR) and background reference area mean (SOR) is greater than $DCGL_W$ (1)	Survey unit does not meet release criterion
Difference between any survey unit measurement (SOR) and any background reference area measurement (SOR) is greater than $DCGL_W$ (1) and the difference of survey unit mean and	Conduct WRS test and elevated measurement comparison

background reference area mean is less than $DCGL_W$ (1)	

The purpose of the statistical testing is to determine if the null hypothesis should be accepted or rejected.

4.6 Step 6: Define Acceptable Decision Errors

NRC guidance provides a discussion regarding decision errors. This discussion includes the concept that acceptable error rates, which balance the need to make appropriate decisions with the financial costs of achieving a high degrees of certainty, must be specified:

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

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

The first type of decision error, called a Type I error, occurs when the null hypothesis is rejected when it is actually true. A Type I error is sometimes called a “false positive.” The probability of a Type I error is usually denoted by α. Considered in light of H_0 used for this site (discussed above), this error could result in higher potential doses to future site occupants than prescribed by the dose-based criterion.

The second type of decision error, called a Type II error, occurs when the null hypothesis is not rejected when it is actually false. A Type II error is sometimes called a “false negative.” The probability of a Type II error is usually denoted by β. The power of a statistical test is defined as the probability of rejecting the null hypotheses when it is false. It is numerically equal to 1- β where β is the Type II error rate. Consequences of Type II errors at the site include unnecessary remediation expense and project delays.

For the purposes of this FSS, the acceptable error rate for Class 1 and Class 3 survey units for both Type I and Type II errors is five percent ($\alpha = \beta = 0.05$). The classification system used in MARSSIM surveys is described in Section 5.4.

5.0 FINAL STATUS SURVEY DESIGN

The purpose of this section is to describe the technical approach to FSS that was implemented at the site. Site-specific soil cleanup criteria must be met before the site may be released for restricted use. Federal guidance listed below provides acceptable methodology to demonstrate compliance with project cleanup goals:

- MARSSIM (NRC, 2000)
- NUREG-1505, A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys (NRC, 1998a)

A major component of a survey design is the efficient use of laboratory sampling at distinct locations combined with scan surveys to accurately determine the final status of a given survey unit (SU). The statistical procedures described in this section were used to establish the number of samples taken at distinct locations needed to determine if the median concentration in a given SU exceeds the regulatory limit with a specified degree of precision. Thus, these statistical procedures are essential in the planning and design of the FSS and the analysis and interpretation of the resulting data.

The survey and sampling approach for the site described below encompasses both sampling at distinct locations, and scanning of the exposed soil surfaces. In this manner, both the mean concentration and elevated areas of residual radioactive material exceeding the cleanup criteria are addressed.

5.1 Detection Methods

The following radiation detection methods were used during the radiological surveys:

- Gross gamma fluence (count rate) measurements;
- Distinct locations (systematic) soil sampling and off-site laboratory analysis;
- Biased location soil sampling and off-site laboratory analysis.

Field survey methodology, techniques, and terminology are based on guidance contained in MARSSIM (NRC, 2000).

5.2 Derived Concentration Guideline Levels

A site-specific risk assessment was performed and used to derive cleanup criteria for each of the potential radionuclide contaminants. Some important inputs to the risk assessment include: 1) the radionuclides of concern and their mobility; 2) the volume of contaminated soil and concentrations of contaminants; 3) depth to groundwater; and 4) other physical site parameters. Potential risks associated with any chemical contaminants will be evaluated in a separate study, in accordance with applicable state and EPA guidance.

The NRC was the regulatory licensing authority for the site. The NRC has promulgated a primary limit of 25 millirem total effective dose equivalent (TEDE) in any one year, in excess of natural background, for releasing a radiologically contaminated site. This radiological criterion was used in the derivation of soil DCGLs.

DCGLs were derived using dose modeling and the RESRAD code Version 6.5. In the modeling, a resident farmer was considered as the critical receptor for the site. The resident farmer was assumed to move onto the site after the site was released for unrestricted use. The resident farmer builds a home and raises crops on the property for consumption. As a result, the resident farmer will be exposed to residual radioactive contamination.

The site has both soil and groundwater contamination. RESRAD model determines dose contribution from future groundwater contamination (soil to groundwater), and does not determine doses for existing groundwater contamination. Therefore, data evaluations were performed to determine whether groundwater contamination was present at the site. Groundwater sampling results for ^{14}C, ^{3}H and ^{226}Ra collected from 1997 to 2009 were utilized to determine the radiological potential concern in the groundwater. For ^{14}C and ^{3}H, there was not any background concentration information available. Therefore, the maximum concentrations or 95% of the upper confidence limits of the mean concentrations for those radionuclides were compared against their corresponding USEPA drinking water standard. For ^{226}Ra, the concentrations were compared with respect to regional background concentration. The results of the data evaluation did not identify any existing groundwater ROC for the site. Therefore, the soil DCGLs were determined based on the RESRAD model and NRC's regulatory dose limit of 25 millirem per year (mrem/yr). In the derivation of the soil DCGLs, soil dose assessments were performed by using a unit concentration of one picocurie per gram (1 pCi/g) for each of the radionuclides of concern, individually. RESRAD version 6.5 model was used for the dose assessments. The output of each RESRAD model run could then be interpreted as an estimate of the dose per unit activity (in mrem/year per pCi/g, or mrem). This was also called a dose-to-source ratio (DSR) that the receptor could receive in a single year from 1 pCi/g of the radionuclide in soil. The primary dose limit was divided by the DSR to yield a DCGL for that radionuclide, in units of pCi/g.

Three exposure scenarios were considered during the derivation of DCGLs for each ROC. A resident farmer was considered as the critical receptor as the base case exposure scenario for the site. Two additional exposure scenarios – (1) Well Drilling; and (2) Basement Construction were evaluated to confirm that the base-case resident farmer scenario was bounding for the development of soil DCGLs. During the first alternative, a resident farmer will be exposed to the residual contamination being brought to the surface by the well driller from the bottom of the burial pits. During the second alternative, the resident farmer will build a basement in the LLRBS. During construction of the basement, the farmer will excavate a two-foot thickness of contaminated soil for the basement and will spread that soil on the ground nearby. Therefore, the residential farmer would be exposed to both surface and subsurface contamination. Among three exposure scenarios, the most conservative DCGL for each ROC was selected as the site-specific DCGL. Table 5.2.1 presents the site-specific soil single DCGLs for the radionuclides of concern at the site. Each DCGL represents the concentration (based on the presented model) that would produce 25 mrem/yr.

Table 5.2.1
Site-Specific DCGLs

ROC	Site-Specific DCGL (pCi/g)
C-14	21.0
Cl-36	13.2
Cs-137	16.9
H-3	121.0
Ni-63	77,954.0
Pb-210	1.9
Ra-226	2.2
Sr-90	4.7

5.2.1 Sum of the Ratios

When there are multiple radionuclides present in the soil, the allowed soil concentration levels may be evaluated by employing the sum of the ratios (SOR). This will ensure that the sum of the individual fractions for each isotope to its individual DCGL fraction does not exceed unity and enables field measurement of a gross activity DCGL. The gross activity DCGL considering the isotopes of concern was described by:

$$Gross\ Activity\ DCGL = \frac{1}{\left(\frac{f_1}{DCGL_1} + \frac{f_2}{DCGL_2} + \ldots + \frac{f_n}{DCGL_n}\right)}$$

Where,

f_1 = Fraction of 1st isotope in the soil

$DCGL_1$ = DCGL for the 1st isotope, pCi/g

f_2 = Fraction of 2nd isotope in the soil

$DCGL_2$ = DCGL for the 2nd isotope, pCi/g

f_n = Fraction of nth isotope in the soil

$DCGL_n$ = DCGL for the nth isotope, pCi/g

5.2.2 Elevated Measurement Comparison

For every sample location within a SU where the Net SOR is greater than 1, an elevated measurement comparison was performed utilizing the alternative method specified in MARSSIM Chapter 8.5.2, and presented below:

… As an alternative to the unity rule, the dose or risk due to the actual residual radioactivity distribution can be calculated if there is an appropriate exposure pathway model available.

The residual radioactivity computer code (RESRAD version 6.5) was used to perform dose modeling on areas of elevated activity based on their actual radionuclide concentrations and maximum bounded areas. Other model input parameters were identical to those used for development of the project DCGLs. The dose associated with each area of elevated activity and the dose associated with the remaining portion of the survey unit were then summed to verify that the total dose due to residual radioactivity within the entire survey unit does not exceed 25 mrem/y.

5.3 Representative Reference (Background) Area

A background reference area is a geographical area from which representative samples of background conditions are selected for comparison with samples collected in specific survey units at the remediated site (NRC, 1998b). The background reference area has similar physical, chemical, radiological, and biological characteristics to the site being remediated, but it was not contaminated by site activities (NRC, 1998b). The distribution of measurements in the background reference area should be similar to the distribution of measurements in the SUs.

A background reference area was established south of the LLRBS in an area thought to be free of radiological contaminants. A gamma walkover survey was conducted to establish background gamma exposure rates then soil samples were collected from 20 locations determined using a systematic triangular grid pattern and a random start point (Figure 4, Appendix 1).

5.4 Survey Unit Classification

As discussed in MARSSIM, site areas that are final status surveyed should be classified according to their potential for residual radioactivity. This classification process is discussed in detail in MARSSIM Sections 2.2, 4.4, 5.5.2, and 5.5.3.

5.4.1 Non-Impacted versus Impacted

- **Non-Impacted** – Non-impacted areas are those areas identified through knowledge of site history or previous survey information where there was not any reasonable possibility (extremely low probability) for residual radioactive contamination.
- **Impacted** – According to MARSSIM, impacted areas have a potential for radioactive contamination based on historical data or contain known radioactive contamination based on past or preliminary radiological surveillance. This includes areas where radioactive materials were used and stored; records of spills, discharges, or other unusual occurrences resulting in the spread of contamination; and areas where radioactive materials were buried or disposed. Areas immediately surrounding or adjacent to these locations are included in this classification due to the potential for the inadvertent spread of contamination.

For the purposes of this FSS, the entire site was considered impacted because all areas within the North Field area have the potential for residual contamination. Impacted areas are further divided into one of three groups (Class 1, Class 2, and Class 3), as defined by MARSSIM (NRC, 2000).

5.4.2 Survey Unit Classification

Class 1 – Class 1 areas are areas that have, or had prior to remediation, known radioactive contamination that exceeds the DCGLw or a potential for such contamination. For the purposes of this FSS the following areas/soil types require a survey effort commensurate to that performed for a MARSSIM Class 1 survey unit:

- Soil surfaces residing at the bottom of the excavation at the conclusion of remediation activities that were previously covered by waste pits;
- Excavated interstitial soils ranging in elevation from ~1' above the top of the waste pits to the excavation bottom (excluding waste and soil designated as waste);

Class 2 – Class 2 areas are areas that have known radioactive contamination or a potential for such contamination, but they are not expected to exceed the $DCGL_w$. No Class 2 survey units were identified.

Class 3 – Class 3 areas are impacted areas that are not expected to contain any residual radioactivity, or are expected to contain levels of residual radioactivity at a small fraction of the $DCGL_w$, based on site operating history and previous radiological surveys. For the purposes of this FSS the following areas/soil types require a survey effort commensurate to that performed for a MARSSIM Class 3 survey unit:

- Soil surfaces residing on the sloped perimeter of the excavation at the conclusion of remediation activities that were not previously covered by waste pits;
- Clean cover fill material utilized in disposal pits from original surface grade to ~1' above the top of the waste.

The suggested maximum survey unit size for the variously classified areas is given in Table 5.4.2.1. These areas are suggested because they give a reasonable sampling density. However, the size and shape of a particular survey unit may be adjusted to conform to the actual shape and size of the excavations.

Table 5.4.2.1
Suggested Land Area Survey Unit Size

Classification of Area	Suggested Survey Unit Size
Class 1	Up to 2,000 m^2
Class 2	2,000 to 10,000 m^2
Class 3	No limit

5.5 Establish the Survey Reference Coordinate System

A differentially-corrected global positioning system (DGPS) was used for the following project activities, which were tied to the Maryland State Plane coordinate system:

- Marking survey unit perimeters;
- Calculating survey unit dimensions by, at a minimum, logging the corners of the survey units;
- Marking sample locations in the field;
- Recording the perimeter of the completed excavation;
- Performing gamma walkover surveys;
- Recording the location of identified pits;
- Recording the location of identified anomalies.

5.6 Identify Survey Units

5.6.1 Final Status Survey Units

The excavation area was divided into three survey units, as shown in Figure 5 (Appendix 1). The portion of the excavation bottom which was previously occupied by the burial site was divided into two Class 1 survey units, each having an area of approximately 1,455 m^2. The sloped portion of the excavation surrounding the Class 1 survey units comprised one Class 3 survey unit with an area of approximately 1,395 m^2.

5.6.2 Stockpile Survey Units

Two laydown areas were established adjacent to the excavation area for storage, survey, and sampling of excavated soils that were anticipated to be reused as backfill material. The locations of the laydown areas relative to the site are detailed in Figure 6 (Appendix 1).

One Class 3 stockpile survey unit (SSU) was established on the east side of the excavation area with a total volume of about 17,114 yd^3. It consisted of the (excavated) soil ranging in elevation from original surface grade to ~1' above each pit in the planned excavation area. The soil in this survey unit was spread out in the laydown area in 43 six-inch lifts for evaluation. Each lift had a maximum volume of 398 yd^3.

Six Class 1 SSUs were established on the south side of the excavation area. Each Class 1 SSU consisted of the (excavated) interstitial soils between individual disposal pits (including one foot of soil above and below the exhumed disposal pits) spread out in the laydown area in six-inch lifts for evaluation. Each Class 1 SSU had a maximum volume of 398 yd^3.

5.7 Number of Sample Locations

MARSSIM Section 5.5 specifies the criteria and methods used to design final status surveys. Section 5.5.2.2 contains the criteria for determining the number of data points for statistical tests when the contaminant is present in background. Select portions of Section

5.5.2.2 are provided below as *underlined and italicized text* to aid the reader in understanding the final status survey design.

The comparison of measurements from the background reference area and survey unit is made using the WRS test, which should be conducted for each survey unit…

This section introduces several terms and statistical parameters that will be used to determine the number of data points needed to apply the nonparametric tests. An example is provided to better illustrate the application of these statistical concepts.

5.7.1 Calculate the Relative Shift

The lower bound of the gray region (LBGR) is selected during the DQO Process along with the target values for α and β. The width of the gray region, equal to ($DCGL_W$ - LBGR), is a parameter that is central to the WRS test. This parameter is also referred to as the shift, Δ. The absolute size of the shift is actually of less importance than the relative shift, Δ/σ, where σ is an estimate of the standard deviation of the measured values in the survey unit. This estimate of σ includes both the real spatial variability in the quantity being measured and the precision of the chosen measurement system. The relative shift, Δ/σ, is an expression of the resolution of the measurements in units of measurement uncertainty.

The shift ($\Delta = DCGL_W - LBGR$) and the estimated standard deviation in the measurements of the contaminant (σ_r and σ_s) are used to calculate the relative shift, Δ/σ.

The relative shift (Δ/σ) describes the relationship of site residual radionuclide concentrations to the $DCGL_w$ and was calculated using the following equation:

$$\Delta/\sigma = \frac{DCGL_W - LBGR}{\sigma}$$

Where:

$DCGL_w$	=	the derived concentration guideline level (i.e., release limit)
LBGR	=	concentration at the lower bound of the gray region (LBGR) (the LBGR was the concentration to which the SU must be remediated in order to have an acceptable probability of passing the statistical tests; the LBGR effectively becomes the survey's action level); for conservatism, the LBGR is set to 0.5 times the $DCGL_w$ for this FSS
Δ	=	The width of the gray region, i.e., $DCGL_w$ - LBGR
σ	=	estimate of the standard deviation of the concentration of residual radioactivity in the SU (which includes real spatial variability in the concentration as well as the precision of the measurement system); σ was estimated as 0.3 times the $DCGL_w$

The $DCGL_W$ is equal to a sum of the ratios value of 1. The LBGR is set at half the $DCGL_W$ and has a value of 0.5. σ is estimated as 0.3 times the $DCGL_W$ (0.3*1 = 0.3) or 0.3.

$$\Delta/\sigma = \frac{1-0.5}{0.3} = \frac{0.5}{0.3} = 1.67$$

5.7.2 Determine P_r

The probability that a random measurement from the survey unit exceeds a random measurement from the background reference area by less than the $DCGL_W$ when the survey unit median is equal to the LBGR above background is defined as P_r. P_r is used in Equation 5-1 for determining the number of measurements to be performed during the survey. MARSSIM Table 5.1 lists relative shift values and values for P_r. Using the relative shift calculated in the preceding section, the value of P_r can be obtained from MARSSIM Table 5.1. Information on calculating individual values of P_r is available in NUREG-1505 (NRC 1998).

If the actual value of the relative shift is not listed in MARSSIM Table 5.1, always select the next lower value that appears in the table. For example, Δ/σ =1.67 does not appear in MARSSIM Table 5.1. The next lower value is 1.6, so the value of P_r would be 0.871014.

MARSSIM Table 5.1
Values of P_r for Given Values of the Relative Shift, Δ/σ, when the Contaminant is Present in Background

Δ/σ	P_r	Δ/σ	P_r
0.1	0.528182	1.4	0.838864
0.2	0.556223	1.5	0.855541
0.3	0.583985	**1.6**	**0.871014**
0.4	0.611335	1.7	0.885299
0.5	0.638143	1.8	0.898420
0.6	0.664290	1.9	0.910413
0.7	0.689665	2.0	0.921319
0.8	0.714167	2.25	0.944167
0.9	0.737710	2.5	0.961428
1.0	0.760217	2.75	0.974067
1.1	0.781627	3.0	0.983039
1.2	0.801892	3.5	0.993329
1.3	0.820978	4.0	0.997658

If Δ/σ > 4.0, use P_r = 1.000000

5.7.3 Determine Decision Error Percentiles

The next step in this process is to determine the percentiles, $Z_{1-\alpha}$ and $Z_{1-\beta}$, represented by the selected decision error levels, α and β, respectively (see MARSSIM Table 5.2). $Z_{1-\alpha}$ and $Z_{1-\beta}$ are standard statistical values (Harnett 1975).

MARSSIM Table 5.2
Percentiles Represented by Selected Values of α and β

α (or β)	Z1-α (or Z1-ß)	α (or β)	Z1-α (or Z1-ß)
0.005	2.576	0.10	1.282
0.01	2.326	0.15	1.036
0.015	2.241	0.20	0.842
0.025	1.960	0.25	0.674
0.05	**1.645**	0.30	0.524

Acceptable decision errors for the survey units are established in Section 4.6 as α = β = 0.05, with a corresponding $Z_{1-\alpha}$ and $Z_{1-\beta}$, *= 1.645.*

5.7.4 Calculate Number of Data Points for WRS Test

The number of data points, N, to be obtained from each background reference area/survey unit pair for the WRS test is next calculated using Equation 5-1:

$$N = \frac{\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2}{3\left(P_r - 0.5\right)^2} \quad (5\text{-}1)$$

For the BARC LLRBS project:

$$N = \frac{\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2}{3\left(P_r - 0.5\right)^2} = \frac{\left(1.645 + 1.645\right)^2}{3\left(0.871014 - 0.5\right)^2} = \frac{(3.29)^2}{3(0.371014)^2} = \frac{10.8241}{0.412954} = 26.21$$

The value of N calculated using equation 5-1 is an approximation based on estimates of σ and P_r, so there is some uncertainty associated with this calculation. In addition, there will be some missing or unusable data from any survey. The rate of missing or unusable measurements, R, expected to occur in survey units or background reference areas and the uncertainty associated with the calculation of N should be accounted for during survey planning. The number of data points should be increased by 20%, and rounded up, over the values calculated using equation 5-1 to obtain sufficient data points to attain the desired power level with the statistical tests and allow for possible lost or unusable data. The value of 20% is selected to account for a reasonable amount of uncertainty in the parameters used to calculate N and still allow flexibility to account for some lost or unusable data. The recommended 20% correction factor should be applied as a minimum value. Experience and site-specific considerations should be used to increase the correction factor if required. If the user determines that the 20% increase in the number of measurements is excessive for a specific site, a retrospective power curve should be used to demonstrate that the survey design provides adequate power to support the decision (see MARSSIM Appendix I).

For BARC LLRBS:

N with 20% overage = N+(N*0.2) = 26.21+(26.21*0.2) = 26.21+5.242 = 31.452

N must be divisible by two; therefore the value 31.452 is rounded up to the next whole number divisible by two, which in this case is 32.

N = 32

N is the total number of data points for each survey unit/background reference area combination. The N data points are divided between the survey unit, n, and the background reference area, m. The simplest method for distributing the N data points is to assign half the data points to the survey unit and half to the background reference area, so n=m=N/2. This means that N/2 measurements are performed in each survey unit, and N/2 measurements are performed in each background reference area. If more than one survey unit is associated with a particular background reference area, N/2 measurements should be performed in each survey unit and N/2 measurements should be performed in the background reference area.

N/2 = 16

Therefore a minimum of 16 samples will be collected from the background reference area and each SU for statistical testing. The selected value for N/2 is further confirmed using MARSSIM Table 5.3 below:

MARSSIM Table 5.3, Values of N/2 for Use with the Wilcoxon Rank Sum Test

Δ/σ	α=0.01					α=0.025					α=0.05					α=0.10					α=0.25				
	β					β					β					β					β				
	0.01	0.025	0.05	0.10	0.25	0.01	0.025	0.05	0.10	0.25	0.01	0.025	0.05	0.10	0.25	0.01	0.025	0.05	0.10	0.25	0.01	0.025	0.05	0.10	0.25
0.1	5452	4627	3972	3278	2268	4627	3870	3273	2646	1748	3972	3273	2726	2157	1355	3278	2646	2157	1655	964	2268	1748	1355	964	459
0.2	1370	1163	998	824	570	1163	973	823	665	440	998	823	685	542	341	824	665	542	416	243	570	440	341	243	116
0.3	614	521	448	370	256	521	436	369	298	197	448	369	307	243	153	370	298	243	187	109	256	197	153	109	52
0.4	350	297	255	211	146	297	248	210	170	112	255	210	175	139	87	211	170	139	106	62	146	112	87	62	30
0.5	227	193	166	137	95	193	162	137	111	73	166	137	114	90	57	137	111	90	69	41	95	73	57	41	20
0.6	161	137	117	97	67	137	114	97	78	52	117	97	81	64	40	97	78	64	49	29	67	52	40	29	14
0.7	121	103	88	73	51	103	86	73	59	39	88	73	61	48	30	73	59	48	37	22	51	39	30	22	11
0.8	95	81	69	57	40	81	68	57	46	31	69	57	48	38	24	57	46	38	29	17	40	31	24	17	8
0.9	77	66	56	47	32	66	55	46	38	25	56	46	39	31	20	47	38	31	24	14	32	25	20	14	7
1.0	64	55	47	39	27	55	46	39	32	21	47	39	32	26	16	39	32	26	20	12	27	21	16	12	6
1.1	55	47	40	33	23	47	39	33	27	18	40	33	28	22	14	33	27	22	17	10	23	18	14	10	5
1.2	48	41	35	29	20	41	34	29	24	16	35	29	24	19	12	29	24	19	15	9	20	16	12	9	4
1.3	43	36	31	26	18	36	30	26	21	14	31	26	22	17	11	26	21	17	13	8	18	14	11	8	4
1.4	38	32	28	23	16	32	27	23	19	13	28	23	19	15	10	23	19	15	12	7	16	13	10	7	4
1.5	35	30	25	21	15	30	25	21	17	11	25	21	18	14	9	21	17	14	11	7	15	11	9	7	3
1.6	32	27	23	19	14	27	23	19	16	11	23	19	**16**	13	8	19	16	13	10	6	14	11	8	6	3
1.7	30	25	22	18	13	25	21	18	15	10	22	18	15	12	8	18	15	12	9	6	13	10	8	6	3
1.8	28	24	20	17	12	24	20	17	14	9	20	17	14	11	7	17	14	11	9	5	12	9	7	5	3
1.9	26	22	19	16	11	22	19	16	13	9	19	16	13	11	7	16	13	11	8	5	11	9	7	5	3
2.0	25	21	18	15	11	21	18	15	12	8	18	15	13	10	7	15	12	10	8	5	11	8	7	5	3
2.25	22	19	16	14	10	19	16	14	11	8	16	14	11	9	6	14	11	9	7	4	10	8	6	4	2
2.5	21	18	15	13	9	18	15	13	10	7	15	13	11	9	6	13	10	9	7	4	9	7	6	4	2
2.75	20	17	15	12	9	17	14	12	10	7	15	12	10	8	5	12	10	8	6	4	9	7	5	4	2
3.0	19	16	14	12	8	16	14	12	10	6	14	12	10	8	5	12	10	8	6	4	8	6	5	4	2
3.5	18	16	13	11	8	16	13	11	9	6	13	11	9	8	5	11	9	8	6	4	8	6	5	4	2
4.0	18	15	13	11	8	15	13	11	9	6	13	11	9	7	5	11	9	7	6	4	8	6	5	4	2

MARSSIM Table 5.3 provides a list of the number of data points used to demonstrate compliance using the WRS test for selected values of α and β (decision errors), and the relative shift (Δ/σ). The values listed in MARSSIM Table 5.3 represent the number of measurements to be performed in each survey unit as well as in the corresponding background reference area. The values were calculated using Equation 5-1 and increased by 20% for the reasons discussed in the previous section.

5.7.5 Biased Samples

Gamma walkover survey data was used to identify areas of elevated radioactivity. Biased soil samples were collected at locations where gamma walkover survey data z-scores (i.e., number of standard deviations from the mean; one z-score = one standard deviation) exceeded 3.0. If no measurements exceeding a z-score of 3.0 were observed then a biased sample was collected from the location exhibiting the highest gamma exposure rate. These samples were evaluated using DCGLs and the SOR calculation. A minimum of one biased sample was collected in each final status survey unit, at the location of the highest gamma walkover measurement.

5.7.6 Specify Sampling Locations

Field personnel marked the perimeter of each SU using DGPS. SU dimensions were determined using DGPS interpretation software. The DGPS interpretation software output was then imported into Visual Sample Plan (VSP) software so that sampling locations could be established. The following parameters were used for the VSP sample design for each SU:

- N/2 = 16;
- Random start point;
- Systematic sample locations;
- Triangular grid pattern.

After the systematic sample locations for each SU were established and prior to sample collection, the soil sample locations were marked in the field using a DGPS. Coordinates for FSSU sample locations are provided in Appendix 17. For added conservatism, measurement locations in Class 3 survey units were established using the method previously described for biased sample locations.

5.8 Survey Instrumentation

Gamma walkover surveys were performed with the following equipment:

- DGPS Rover: Trimble Pathfinder Pro-XRS (or equivalent)
- Bicron G-5 five-inch by 0.063-inch sodium iodide (NaI) scintillation detector (field instrument for the detection of low energy radiation [FIDLER]) and associated ratemeter/scaler, equipped with RS-232 download port (or equivalent)
- Hardware: IBM-compatible Pentium (minimum) PC, color printer, large capacity data storage device (e.g., CD writer), modem, and large format plotter (note that some hardware may not be site-based)
- Software: Trimble Pathfinder Office, GIS software with coordinate geometry capability (or equivalent)

The gamma walkover surveys were performed following MARSSIM protocol by walking straight parallel lines over an area at a rate of approximately 0.5 meters per second while moving the FIDLER detector in a side to side, serpentine motion, 0.05 to 0.10 meters (two to four inches) above the ground surface. Survey passes were approximately one meter apart. Data from the ratemeter/scaler was automatically logged into the DGPS unit at the rate of once per second.

After completion of the surveys, the raw data was downloaded from the DGPS and processed for export into a geospatial software program. A map of the processed scan data with the contoured results of the survey was then produced for each survey unit.

5.9 Soil Sampling

Soil samples were collected in the manner described in BARC Work Instruction 01 (BWI-01), *Field Sampling for License Termination* (TES, 2013), which is included as Appendix 4. Specific sample identifiers will be explained in the sections where they are presented.

5.10 FSS Execution Summary

The LLRBS was excavated in vertical segments by focusing on a small localized area containing a waste pit and excavating from the top down. A waste pit and the soil immediately surrounding it would be excavated from original surface grade down to about 1 foot below the waste pit before moving on to the next adjacent waste pit to the east. Excavation began in the northwest corner of the North field; the first row of pits was excavated in order from west to east then the next row was excavated, again in order from west to east. This process was continued until all of the waste pits had been excavated and the south boundary of the North field had been reached. FSS activities that were performed in parallel with excavation activities are summarized below:

1) A background reference area was established then surveyed by gamma walkover survey before collecting 20 soil samples for analysis at the off-site laboratory.

2) The North Field area was then surveyed via gamma walkover survey.

3) The Class 3 soil above individual pits was excavated in one-foot increments to ensure each individual pit's specific location was identified in a controlled manner. The excavated soil was transported to the east laydown area where it was laid out in six-inch lifts. When a maximum of 398 yd^3 of material was placed in the laydown area then that area was evaluated as follows:

    - A gamma walkover scan survey was performed on 100% of the exposed surfaces, as practicable;
    - the scan survey data was used to identify the area exhibiting the highest activity, where one sample was collected for analysis at the off-site laboratory;
    - The sample location was identified in the field using GPS equipment;
    - Forty-three (43) samples (excluding QA samples) were collected from the Class 3 survey unit.
    - If anything was discovered during the excavation of the Class 3 survey unit, such as landfill debris or radioactive contamination, then excavation of Class 3 soil was stopped and the immediate area associated with the respective waste pit was controlled as Class 1 interstitial soils and/or waste.

4) The exposed disposal pit(s) were then excavated and the wastes were removed for off-site disposal.

5) Once the waste materials were removed from a given disposal pit, the Class 1 soil was excavated and transported to the south laydown area where it was laid out in six-inch lifts. When a maximum of 398 yd³ of material had been placed in one of the laydown areas then that area was considered a Class 1 stockpile survey unit.

   Class 1 interstitial soils SUs were sampled in the following manner prior to implementation of BTM-02 modifications:

   - Twenty (20) systematic sample locations were plotted using VSP software. The sample locations used a triangular grid pattern with a random start point;
   - The sample locations were identified in the field using GPS equipment;
   - A soil sample was collected from each of the 20 sample locations and split for radiological analysis at the on-site laboratory and archiving for analysis at the off-site laboratory;
   - One of the 20 samples from each SU was selected for immediate analysis at the off-site laboratory. The location of this sample was determined using a random number generator and the range 1-20, which placed the off-site sample location at one of the 20 systematic sample locations in the SU.

   Once the BTM-02 modifications were implemented Class 1 interstitial soils SUs were resampled in the following manner:

   - Sixteen (16) systematic sample locations were plotted using VSP software. The sample locations used a triangular grid pattern with a random start point. The same (x, y) coordinates were used for the identification of the 16 sample locations in all six Class 1 SUs;
   - For each survey unit where a sample had already been collected and analyzed at the off-site laboratory, the initial sample served as one of the new 16 systematic samples, correlated by proximity to the nearest of the 16 systematic sample locations;
   - The sample locations were identified in the field using GPS equipment;
   - A soil sample was collected from each of the remaining 16 sample locations at depths corresponding to each of the six Class 1 survey units for analysis at the off-site laboratory.

6) When excavation was complete a geophysical survey was performed with a DGPS to define the horizontal and vertical extents of the excavation.

7) FSS of the excavated area was performed in the following manner:

   - The bottom of the excavation was defined as two Class 1 SUs;
   - The sloped area surrounding the excavation bottom was defined as one Class 3 SU;
   - A gamma walkover scan survey was performed on 100% of the exposed surfaces of each SU, as practicable;

- the scan survey data was used to identify the area exhibiting the highest activity, where one biased sample was collected from each SU for analysis at the off-site laboratory;
- 16 systematic sample locations were plotted for each SU using VSP software. The sample locations used a triangular grid pattern and a random start point;
- The sample locations were identified in the field using GPS equipment;
- A soil sample was collected from each of the 16 sample locations for radiological analysis at the off-site laboratory.

6.0 METHODOLOGY AND APPROACH TO PERFORMING SURVEYS

6.1 Estimated Scan Sensitivity of the Gamma Walkover Survey

MARSSIM Section 6.7.2.1 describes the methodology used to calculate the scan minimum detectable concentrations (MDCs) for land areas that are delineated in MARSSIM Table 6.7. Using this methodology and parameters associated with G-5 FIDLER NaI instrumentation, the approximate detection sensitivity of the gamma walkover surveys was calculated to be 4.3 pCi/g for ^{137}Cs and 1.7 pCi/g for ^{226}Ra. The detection sensitivity for ^{226}Ra was modeled with 40 years in-growth of associated progeny. This methodology was based on a scan speed of 0.5 meters per second and a minimum contaminated area 56 centimeters in diameter, 15 centimeters in depth, and assumes saturated soil. The gross gamma walkover scan surveys for this FSS were designed using these parameters (NRC, 1997). Attachment A from the LLRWS Decommissioning Plan (CABRERA, 2012), provides details regarding the calculations used to determine the MDCs for ^{137}Cs and ^{226}Ra.

6.2 DGPS Unit and Data File Setup

A DGPS was used to provide high quality, precision geospatial positioning data to support the final status survey data verification and remediation. The DGPS unit performed data logging functions and was configured to record the data output of the ratemeter/scalers at least every two seconds. This gamma walkover survey/data logging protocol provides a minimum data density of one measurement per square meter of ground surface.

In order for the DGPS unit to achieve sub-meter accuracy, differential position correction was necessary. Each technician carried his/her own rover unit operating both the detector and DGPS (making entries into the DGPS and checking detector responses).

Each survey was designed to optimize the data collection procedure, taking into account the SU's configuration, hazards, and other obstructions. Copies of the base map on which temporary structures, roads, or other major features have been located were available onsite. Technicians annotated copies of the base map with information relevant to the survey, as appropriate. Each survey was assigned a SU number and date of collection.

6.3 Scan Survey Coverage for Class 1 and Class 3 Survey Units

Section 5.5.3 in MARSSIM discusses the recommended scanning survey coverage for land areas. The objective of the scanning surveys is to detect small areas of elevated activity that are not detected by the soil samples collected using the systematic pattern. To achieve this goal Class 1 scanning protocols were implemented for all SUs regardless of classification. To the extent practicable 100% of accessible SU surfaces were scanned via gamma walkover survey. Any areas exhibiting elevated gamma exposure rates were marked for additional investigation.

6.4 Final Status Survey Data Evaluation

All data collected as part of the final status survey of the site was evaluated in accordance with MARSSIM protocols. To validate the adequacy and completeness of soil removal from impacted areas, soil sample results were evaluated using the methodology described in detail in Section 4.5 of this report.

6.5 Field Records

For surveys of all types, it is essential that significant events be documented and retained for future reference. Project logs were used to provide a practical means of capturing information that was not otherwise documented in a specific manner. Project logs could be hardbound or electronic. Logs for the LLRBS project included instrument quality control logs, field survey logs, and the Project Manager's daily log.

6.6 Project Electronic Data

6.6.1 Data Backup

Raw electronic data collected during the day was backed-up at the end of the same day on which it was collected, before processing or editing. The raw data archive, once created, was not altered. Field computer(s) used to store project data were backed up weekly, at a minimum. Raw archived data was stored in a different location from the weekly field computer backups.

6.6.2 Data Processing

Gamma walkover survey/DGPS data was processed daily, as necessary, and the data was reviewed for errors. Data processing specialists informed the Project Manager or designee of any identified deficiencies and made corrections as directed. Conversions, errors, corrections, and/or adjustments to project data were documented in the data log.

7.0 SURVEY QUALITY ASSURANCE AND QUALITY CONTROL

Activities associated with this work plan were performed in accordance with written procedures and/or protocols in order to ensure consistent, repeatable results. Topics covered in project procedures and protocols may include proper use of instrumentation, QC requirements, equipment limitation, etc. Implementation of QA measures for this work plan was described herein.

7.1 Instrumentation Requirements

The radiological technical lead was responsible for determining which instrumentation was required to properly execute planned survey activities. Additionally, the project manager and/or Corporate Health Physicist reviewed and approved equipment used to collect radiological data. Instrumentation was operated in accordance with either a written procedure or the manufacturer's manual. The procedures and/or manual provided guidance to field personnel on the proper use and limitations of the instrument.

7.1.1 Calibration

Instrumentation was maintained and calibrated to the manufacturer's specifications to ensure that the required traceability, sensitivity, accuracy and precision of the instruments was maintained. Instruments were calibrated at a facility possessing the appropriate NRC and/or Agreement State licenses for performing calibrations using National Institute of Standards and Technology (NIST) traceable sources. Calibration and/or maintenance records for instruments used during the survey were maintained onsite for review and inspection. The records included the following information, at a minimum:

- Name of the equipment
- Equipment identification (model and serial number)
- Manufacturer
- Date of Calibration
- Calibration Due Date

7.1.2 Source and Background Checks

Prior to and after daily use, instruments were QC checked by comparing the instrument's response to ambient background and to a designated gamma radiation source. Instrument QC checks and inspections were performed in accordance with the appropriate instrument-specific procedure and the results were recorded in the applicable instrument QC log.

7.2 DGPS Requirements and Quality Control

DGPS QC goals were accomplished by using calibration points, reviewing plotted survey data, and keeping detailed field notes. A calibration point is a location with known horizontal and vertical coordinates (e.g., a benchmark) that can be used to check the accuracy of DGPS data. Use of calibration points ensured that the differential position corrections were calculated properly, and that equipment was performing according to manufacturer's specifications. DGPS calibration points were set in convenient locations near the areas to be surveyed. Calibration points were set in areas that were clear of overhead obstructions.

One or more DGPS calibration points was established prior to beginning the FSS. At each calibration point, ten initial DGPS position readings were collected, each having a one-minute duration or more. Each set of ten readings was used to develop the average position of the applicable calibration point. Prior to beginning and following completion of a survey, technicians collected position data at one of the calibration points. Data was also collected at a calibration point at any point in a survey if anomalous readings or other indications of potential DGPS data quality problems were observed. Data was collected at the calibration point at least two times for each day's survey. Each time calibration point data was collected, the result was compared to the average location of that point, as calculated above. Measurements differing from the average by more than one meter were investigated and corrective measures were implemented as appropriate.

7.3 Soil Sampling Quality Assurance

Soil samples were sent to a laboratory chosen to perform QA analyses on samples collected for ^{14}C (method EERF C-01 mod), ^{36}Cl (method ST-RC-0036), ^{63}Ni (method ST-RC-0055), ^{90}Sr (method 905.0 mod), ^{3}H (method 906.0 mod), and gamma spectroscopy scan (method 901.1 mod/HASL 300) for ^{226}Ra, ^{210}Pb, ^{137}Cs, and other gamma emitting isotopes. Duplicate samples were collected at a rate of 5%. The samples were numbered using a unique identifier and were sent to the laboratory for analysis. Additionally, the analytical laboratory performed duplicate analyses on selected samples as specified in their QA procedures. Duplicate analyses performed by the laboratory were compared to the initial analytical results by determining a z-score value for each data set by the following equation:

$$Z = \frac{|S - D|}{\sqrt{\sigma_S^2 + \sigma_S^2}}$$

Where: S. D. = the value of (S)ample and (D)uplicate measurements

σ = one sigma error associated with (S)ample and (D)uplicate measurements

The calculated z-score results were compared to a performance criteria of less than or equal to 2.57. The value of 2.57 corresponds to a 99% confidence level, or 99% of the z-score values were below 2.57 and only 1% of the values were above this acceptance criterion, if the sample and the duplicate are truly of the same distribution. Calculated z-scores less than 2.57 were considered acceptable and values greater than 2.57 were investigated for possible discrepancies in analytical precision, or for sources of disagreement with the following assumptions of the test:

- The sample measurement and duplicate measurement are of the same normally-distributed population
- The standard deviations, σ_S and σ_D, represent the true standard deviation of the measured population

7.4 Data Verification and Validation

Samples collected from the Beltsville Agricultural Research Center for Reference Area, Final Status Survey, and Stockpile Survey Unit remediation activities were submitted to Test America Laboratory. The quality indicators from every aspect of the data collection have been reviewed, and an assessment of the data with regard to project-specific objectives is presented in Appendix 18. Successful execution of project-specific objectives and procedures provides strong support for the acceptance of the data generated as adequate for the purpose of evaluating the analytical results from this assessment at BARC. The overall results of the analyses, as discussed in Appendix 18, suggest that representative samples were collected and analyzed, and the results are indicative of the media analyzed, with the exception of the few anomalies noted. The data are usable for their intended purpose.

8.0 ANALYSIS OF SURVEY AND SAMPLE RESULTS

8.1 Background Reference Area

The background reference area was established in a non-impacted area to the south of the LLRBS (Figure 2, Appendix 1). A gamma walkover survey was conducted to establish background gamma exposure rates then soil samples were collected from 20 locations determined using a systematic triangular grid pattern and a random start point (Figure 4, Appendix 1). Detailed survey and sample results are presented in Appendix 5. NOTE: Analytical results that are reported as less than the minimum detectable activity (MDA) are assigned the MDA value to ensure quality and conservatism in data reporting.

8.1.1 Analysis of Background Reference Area Gamma Walkover Surveys

Gamma scan values associated with z-scores were calculated using the background reference area scan data. Scan data was collected with multiple survey instruments that were anticipated to be used for the performance of scan surveys. The collected data was evaluated for compatibility then a statistically correlated multi-instrument color ramp was generated. The investigation level for SU scan surveys was established at the background reference area mean plus 3 standard deviations (z-score = 3). The color ramp assessment in Appendix 5 shows that a z-score of three correlates to an investigation level of 11,194 cpm (8,269 cpm + 3*975 cpm). Notable statistical values associated with the background reference area SORs are presented in Table 8.1.1.

Table 8.1.1
Background Reference Area
Multi-Instrument Scan Data Statistical Summary

Statistic	Value (cpm)
Mean	8,269
Median	8,250
Maximum	11,460
Minimum	1,020
Standard Deviation	975
Investigation Level (z-score = 3)	11,194

8.1.2 Analysis of Background Reference Area Sample Results

After verification and validation, sample results from the off-site laboratory were processed using Microsoft® Excel® 2013. Calculation worksheets for individual samples are presented in Appendix 5. Notable statistical values associated with the background reference area ROCs are presented in Table 8.1.2.1. The mean for each ROC is used for the Net SOR calculation.

Table 8.1.2.1
Background Reference Area
ROCs Statistical Summary

Analyte	Mean (pCi/g)	Median (pCi/g)	σ
C-14	1.01	0.82	0.31
Cl-36	0.51	0.51	0.05
Cs-137	0.10	0.09	0.03
H-3	0.41	0.37	0.17
Ni-63	1.89	1.84	0.15
Pb-210	0.91	0.86	0.24
Ra-226	0.77	0.78	0.08
Sr-90	0.17	0.17	0.02

Notable statistical values associated with the background reference area SORs are presented Table 8.1.2.2. The minimum and mean background reference area SORs are used for SU evaluation as described in Section 4.5.5. The individual sample SOR+$DCGL_W$ values are used for the WRS Test.

Table 8.1.2.2
Background Reference Area
SOR Summary

Sample ID	SOR	SOR + $DCGL_W$
BLT-RA-SO-01	0.826	1.826
BLT-RA-SO-02	0.921	1.921
BLT-RA-SO-03	0.873	1.873
BLT-RA-SO-04	0.847	1.847
BLT-RA-SO-05	1.158	2.158
BLT-RA-SO-06	0.842	1.842
BLT-RA-SO-07	0.934	1.934
BLT-RA-SO-08	1.130	2.130
BLT-RA-SO-09	0.870	1.870
BLT-RA-SO-10	0.846	1.846
BLT-RA-SO-11	0.768	1.768
BLT-RA-SO-12	1.079	2.079
BLT-RA-SO-13	0.851	1.851
BLT-RA-SO-14	0.821	1.821
BLT-RA-SO-15	1.026	2.026
BLT-RA-SO-16	1.065	2.065
BLT-RA-SO-17	1.026	2.026
BLT-RA-SO-18	1.026	2.026
BLT-RA-SO-19	0.958	1.958
BLT-RA-SO-20	1.333	2.333
Avg	0.960	
Min	0.768	
Max	1.333	

Sample ID: **BLT-RA-SO-01**

Where,

BLT indicates the site (Beltsville);

RA indicates that it is the background reference area;

SO indicates that the sample media was soil;

01 indicates the sequential sample location (01-20) for this survey unit;

8.2 Class 1 FSSU-01

Class 1 final status survey unit 1 (C1-FSSU-01) is the north SU on the bottom of the excavation (Figure 2, Appendix 1). Systematic sample locations are shown on Figure 5 (Appendix 1). Detailed survey and sample results are presented in Appendix 6.

8.2.1 Analysis of C1-FSSU-01 Gamma Walkover Surveys

Scan data from the survey unit was evaluated by comparison to background reference area scan data. Notable statistical values are presented in Table 8.2.1 below:

Table 8.2.1
C1-FSSU-01 Scan Data Comparison

Statistic	SU Value (cpm)	[1]BRA Value (cpm)
Mean	6,522	8,269
Median	6,420	8,250
Maximum	11,460	11,460
Minimum	1,200	1,020
Standard Deviation	924	975

[1]BRA = Background Reference Area

Areas that exhibited readings above the investigation level of 11,194 cpm were further investigated by visual examination guided by field survey instruments. No additional waste material was identified during the investigation. A biased soil sample was collected at the location exhibiting the highest reading during the scan survey. The results of the laboratory analysis are included in Appendix 6.

8.2.2 Analysis of C1-FSSU-01 Sample Results

After verification and validation, sample results from the off-site laboratory were processed using Microsoft® Excel® 2013. Calculation worksheets for individual samples are presented in Appendix 6.

A summary of the SU SORs and a comparison to relevant background reference area SOR values are presented in Table 8.2.2 below:

Table 8.2.2
C1-FSSU-01 SOR Summary

Sample Sum of the Ratios		
Sample ID	**SOR**	**Net SOR**
BLT-FSSB-C1-01-SO-01	1.727	0.792
BLT-FSS-C1-01-SO-01	0.659	0.000
BLT-FSS-C1-01-SO-02	0.632	0.000
BLT-FSS-C1-01-SO-03	0.552	0.000
BLT-FSS-C1-01-SO-04	0.939	0.113
BLT-FSS-C1-01-SO-05	0.707	0.001
BLT-FSS-C1-01-SO-06	0.646	0.001
BLT-FSS-C1-01-SO-07	0.499	0.001
BLT-FSS-C1-01-SO-08	0.988	0.213
BLT-FSS-C1-01-SO-08-FD01	0.545	0.001
BLT-FSS-C1-01-SO-09	0.637	0.001
BLT-FSS-C1-01-SO-10	0.674	0.025
BLT-FSS-C1-01-SO-11	1.445	0.900
BLT-FSS-C1-01-SO-12	1.304	0.365
BLT-FSS-C1-01-SO-13	0.474	0.033
BLT-FSS-C1-01-SO-14	0.544	0.008
BLT-FSS-C1-01-SO-15	0.693	0.006
BLT-FSS-C1-01-SO-16	0.465	0.001
	SU	**RA**
Avg	0.785	0.960
Min	0.465	0.768
Max	1.727	1.333
SU Max SOR - RA Min SOR	0.959	
SU Avg SOR - RA Avg SOR	-0.175	
SU meets release criterion		

Sample ID: **BLT-FSS-C1-01-SO-01**

Where,

BLT indicates the site (Beltsville);

FSS indicates that it is a final status survey

FSSB indicates that it is a biased sample (where applicable);

SO indicates that the sample media was soil;

FD indicates that it is a field duplicate sample (where applicable);

01 indicates the sequential sample location (01-16) for this survey unit;

8.2.3 Class 1 FSSU-01 Conclusions

The difference between largest survey unit measurement (SOR) and smallest background reference area measurement (SOR) is less than the $DCGL_W$ (1). Therefore the SU meets the release criterion. Adding further strength to this argument is the fact that the results of the biased sample (BLT-FSSB-C1-01-SO-01) were included in the comparison, even though they are not required to be included by MARSSIM.

8.3 Class 1 FSSU-02

Class 1 final status survey unit two (C1-FSSU-02) is the south SU on the bottom of the excavation (Figure 2, Appendix 1). Systematic sample locations are shown on Figure 5 (Appendix 1). Detailed survey and sample results are presented in Appendix 7.

8.3.1 Analysis of C1-FSSU-02 Gamma Walkover Surveys

Scan data from the survey unit was evaluated by comparison to background reference area scan data. Notable statistical values are presented in Table 8.3.1 below:

Table 8.3.1
C1-FSSU-02 Scan Data Comparison

Statistic	SU Value (cpm)	[1]BRA Value (cpm)
Mean	7,924	8,269
Median	7,920	8,250
Maximum	12,960	11,460
Minimum	1,440	1,020
Standard Deviation	1,259	975

[1]BRA = Background Reference Area

Areas that exhibited readings above the investigation level of 11,194 cpm were further investigated by visual examination guided by field survey instruments. No additional waste material was identified during the investigation. A biased soil sample was collected at the location exhibiting the highest reading during the scan survey.

8.3.2 Analysis of C1-FSSU-02 Sample Results

After verification and validation, sample results from the off-site laboratory were processed using Microsoft® Excel® 2013. Calculation worksheets for individual samples are presented in Appendix 7.

A summary of the SU SORs and a comparison to relevant background reference area SOR values are presented in Table 8.3.2 below:

Table 8.3.2
C1-FSSU-02 SOR Summary

Sample Sum of the Ratios		
Sample ID	**SOR**	**Net SOR**
BLT-FSSB-C1-02-SO-01	0.927	0.080
BLT-FSS-C1-02-SO-01	0.844	0.001
BLT-FSS-C1-02-SO-02	0.727	0.001
BLT-FSS-C1-02-SO-02-FD02	1.188	0.260
BLT-FSS-C1-02-SO-03	0.947	0.016
BLT-FSS-C1-02-SO-04	1.276	0.344
BLT-FSS-C1-02-SO-05	0.847	0.001
BLT-FSS-C1-02-SO-06	0.852	0.023
BLT-FSS-C1-02-SO-07	1.172	0.259
BLT-FSS-C1-02-SO-08	0.845	0.114
BLT-FSS-C1-02-SO-09	0.676	0.014
BLT-FSS-C1-02-SO-10	0.793	0.018
BLT-FSS-C1-02-SO-11	0.915	0.016
BLT-FSS-C1-02-SO-12	0.823	0.014
BLT-FSS-C1-02-SO-13	0.780	0.014
BLT-FSS-C1-02-SO-14	1.324	0.407
BLT-FSS-C1-02-SO-15	0.977	0.070
BLT-FSS-C1-02-SO-16	0.824	0.005
	SU	**RA**
Avg	0.930	0.960
Min	0.676	0.768
Max	1.324	1.333
SU Max SOR - RA Min SOR	0.556	
SU Avg SOR - RA Avg SOR	-0.030	
SU meets release criterion		

8.3.3 Class 1 FSSU-02 Conclusions

The difference between largest survey unit measurement (SOR) and smallest background reference area measurement (SOR) is less than the $DCGL_W$ (1). Therefore the SU meets the release criterion. Adding further strength to this argument is the fact that the results of the biased sample (BLT-FSSB-C1-02-SO-01) were included in the comparison, even though they are not required to be included by MARSSIM.

8.4 Class 3 FSSU-01

Class 3 final status survey unit 1 (C3-FSSU-01) is the sloped portion of the excavation surrounding the two Class 1 SUs (Figure 2, Appendix 1). Systematic sample locations are shown on Figure 5 (Appendix 1). Detailed survey and sample results are presented in Appendix 8.

8.4.1 Analysis of C3-FSSU-01 Gamma Walkover Surveys

Scan data from the survey unit was evaluated by comparison to background reference area scan data. Notable statistical values are presented in Table 8.4.1 below:

Table 8.4.1
C3-FSSU-01 Scan Data Comparison

Statistic	SU Value (cpm)	[1]BRA Value (cpm)
Mean	7,380	8,269
Median	7,140	8,250
Maximum	13,920	11,460
Minimum	1,320	1,020
Standard Deviation	1,855	975

[1]BRA = Background Reference Area

Areas that exhibited readings above the investigation level of 11,194 cpm were further investigated by visual examination guided by field survey instruments. No additional waste material was identified during the investigation. A biased soil sample was collected at the location exhibiting the highest reading during the scan survey.

8.4.2 Analysis of C3-FSSU-01 Sample Results

After verification and validation, sample results from the off-site laboratory were processed using Microsoft® Excel® 2013. Calculation worksheets for individual samples are presented in Appendix 7.

A summary of the SU SORs and a comparison to relevant background reference area SOR values are presented in Table 8.4.2 below:

Table 8.4.2
C3-FSSU-01 SOR Summary

Sample Sum of the Ratios		
Sample ID	**SOR**	**Net SOR**
BLT-FSSB-C3-01-SO-01	1.164	0.223
BLT-FSS-C3-01-Q1-SO-01	0.746	0.000
BLT-FSS-C3-01-Q1-SO-02	0.986	0.086
BLT-FSS-C3-01-Q1-SO-03	0.767	0.047
BLT-FSS-C3-01-Q1-SO-04	0.880	0.030
BLT-FSS-C3-01-Q1-SO-04-FD03	0.978	0.038
BLT-FSS-C3-01-Q1-SO-05	0.868	0.024
BLT-FSS-C3-01-Q1-SO-06	0.892	0.023
BLT-FSS-C3-01-Q1-SO-07	0.645	0.031
BLT-FSS-C3-01-Q1-SO-08	0.864	0.023
BLT-FSS-C3-01-Q1-SO-09	0.704	0.101
BLT-FSS-C3-01-Q1-SO-10	0.496	0.024
BLT-FSS-C3-01-Q2-SO-11	0.862	0.026
BLT-FSS-C3-01-Q2-SO-12	0.596	0.023
BLT-FSS-C3-01-Q3-SO-13	1.037	0.109
BLT-FSS-C3-01-Q3-SO-14	0.777	0.015
BLT-FSS-C3-01-Q4-SO-15	1.234	0.302
BLT-FSS-C3-01-Q4-SO-16	0.555	0.000
	SU	**RA**
Avg	0.836	0.960
Min	0.496	0.768
Max	1.234	1.333
SU Max SOR - RA Min SOR	0.466	
SU Avg SOR - RA Avg SOR	-0.124	
SU meets release criterion		

8.4.3 Class 3 FSSU-01 Conclusions

The difference between largest survey unit measurement (SOR) and smallest background reference area measurement (SOR) is less than the $DCGL_W$ (1). Therefore the SU meets the release criterion. Adding further strength to this argument is the fact that the results of the biased sample (BLT-FSSB-C3-01-SO-01) were included in the comparison, even though they are not required to be included by MARSSIM.

8.5 Class 1 SSU-01

Class 1 stockpile survey unit one (C1-SSU-01) is comprised of the -30” to -36” layer of excavated Class 1 soil placed in laydown area B (Figure 2, Appendix 1). Systematic sample locations are shown on Figure 6 (Appendix 1). Detailed survey and sample results are presented in Appendix 9.

8.5.1 Analysis of C1-SSU-01 Gamma Walkover Surveys

Scan data from the survey unit was evaluated by comparison to background reference area scan data. Notable statistical values are presented in Table 8.5.1 below:

Table 8.5.1
C1-SSU-01 Scan Data Comparison

Statistic	SU Value (cpm)	[1]BRA Value (cpm)
Mean	7,633	8,269
Median	7,560	8,250
Maximum	12,000	11,460
Minimum	1,020	1,020
Standard Deviation	1,202	975

[1]BRA = Background Reference Area

Areas that exhibited readings above the investigation level of 11,194 cpm were further investigated by visual examination guided by field survey instruments. No additional waste material was identified during the investigation. Only one of the seven areas investigated (Location 2) exhibited exposure rates above the investigation level during verification, with a maximum reading of 12,000 cpm.

8.5.2 Analysis of C1-SSU-01 Sample Results

After verification and validation, sample results from the off-site laboratory were processed using Microsoft® Excel® 2013. Calculation worksheets for individual samples are presented in Appendix 9.

A summary of the SU SORs and a comparison to relevant background reference area SOR values are presented in Table 8.5.2 below:

Table 8.5.2
C1-SSU-01 SOR Summary

Sample Sum of the Ratios		
Sample ID	**SOR**	**Net SOR**
BLT-SSU-01-C1-SO-01	0.737	0.017
BLT-SSU-01-C1-SO-02	1.242	0.577
BLT-SSU-01-C1-SO-03	0.760	0.051
BLT-SSU-01-C1-SO-04	1.489	0.538
BLT-SSU-01-C1-SO-05	0.572	0.014
BLT-SSU-01-C1-SO-06	0.720	0.012
BLT-SSU-01-C1-SO-07	3.162	2.219
BLT-SSU-01-C1-SO-08	0.633	0.013
BLT-SSU-01-C1-SO-09	1.267	0.321
BLT-SSU-01-C1-SO-09-FD05	1.092	0.147
BLT-SSU-01-C1-SO-10	0.841	0.009
BLT-SSU-01-C1-SO-11	2.433	1.493
BLT-SSU-01-C1-SO-12	0.756	0.008
BLT-SSU-01-C1-SO-13	0.691	0.009
BLT-SSU-01-C1-SO-14	0.748	0.010
BLT-SSU-01-C1-SO-15	0.680	0.010
BLT-SSU-01-C1-SO-16	0.619	0.011
	SU	**RA**
Avg	1.085	0.960
Min	0.572	0.768
Max	3.162	1.333
SU Max SOR - RA Min SOR	2.394	
SU Avg SOR - RA Avg SOR	0.125	
Perform WRS Test & EMC		

The difference between the largest survey unit measurement (SOR) and the smallest background reference area measurement (SOR) is greater than the $DCGL_W$ (1). The difference of the survey unit mean and the background reference area mean is less than the $DCGL_W$ (1). Therefore the WRS Test and the Elevated Measurement Comparison are performed.

8.5.3 Class 1 SSU-01 WRS Test

In using this test, the hypotheses being tested are:

- *Null Hypothesis (H_0)*: The median concentration in the survey unit exceeds that in the background reference area by more than the DCGL;
- *Alternative Hypothesis (H_a)*: The median concentration in the survey unit exceeds that in the background reference area by less than the DCGL.

The WRS Test calculation worksheet for C1-SSU-01 is presented in Appendix 9. The WRS statistical test was applied to the laboratory sample data via the following sequential steps:

1. Reduce background reference area and SU isotopic data to SOR using the SOR equation presented previously in this section. Refer to the Individual Sample Results section of Appendix 5 for background reference area SOR calculations and Appendix 9 for the survey unit SOR calculations.

2. Add the $DCGL_w$ value (i.e., 1.0) to each background reference area SOR value, X_i, to obtain the adjusted background reference area SOR, Z_i, where:

$$Z_i = X_i + 1.0$$

Adjusted background reference area values are presented in Table 8.5.3 below:

Table 8.5.3
C1-SSU-01 WRS Test

BRA X_i (SOR)	**BRA Z_i** (SOR+$DCGL_w$)	**Ranks**	**BRA Ranks**
0.825706805	1.825706805	18	18
0.921380538	1.921380538	25	25
0.873495699	1.873495699	24	24
0.846944061	1.846944061	21	21
1.157740287	2.157740287	34	34
0.841743122	1.841743122	19	19
0.934067157	1.934067157	26	26
1.13009195	2.13009195	33	33
0.870092312	1.870092312	23	23
0.846418527	1.846418527	20	20
0.767855247	1.767855247	16	16
1.079295965	2.079295965	32	32
0.851102683	1.851102683	22	22
0.820641368	1.820641368	17	17
1.025772216	2.025772216	28	28
1.065078933	2.065078933	31	31
1.02595448	2.02595448	29	29
1.026344395	2.026344395	30	30
0.957934772	1.957934772	27	27
1.332832267	2.332832267	35	35

SU Y_i (SOR)	**Ranks**	**BRA Ranks**
0.737137933	7	0
1.242125648	13	0
0.759800825	10	0
1.489104836	15	0
0.572261175	1	0
0.71989914	6	0
3.162218744	37	0
0.633383675	3	0
1.266527931	14	0
1.09154311	12	0
0.841404638	11	0
2.432593612	36	0
0.756126851	9	0
0.691002661	5	0
0.747786447	8	0
0.68024353	4	0
0.619428684	2	0
Sum	**703**	**510**

3. The *m* adjusted SOR, Z_i, from the background reference area and the *n* SOR, Y_i, from the SU were pooled and assigned a rank in order of increasing measurement value from *1* to *N*, where:

$$N = m + n$$

$$N = 20 + 17 = 37$$

Overall ranks and background reference area ranks are presented in Table 8.5.3 above.

4. Sum the ranks of the adjusted SOR from the background reference area, W_r. Refer to Table 8.5.3 above.

$$W_r = 510$$

5. From MARSSIM, Appendix I, Table I.4, for the values of $n = 17$, $m = 20$, and $\alpha = 0.05$:

$$WRS_{crit} = 434$$

W_r (510) is greater than WRS_{crit} (434). Therefore the null hypothesis that the SU exceeds the release criterion can be rejected, pending results of elevated measurement comparison.

8.5.4 Class 1 SSU-01 Elevated Measurement Comparison

For each sample location within the SU where the Net SOR is greater than 1 (see Table 8.5.2 above), an elevated measurement comparison was performed utilizing the alternative method specified in MARSSIM Chapter 8.5.2, and presented below:

… As an alternative to the unity rule, the dose or risk due to the actual residual radioactivity distribution can be calculated if there is an appropriate exposure pathway model available.

The residual radioactivity computer code (RESRAD version 6.5) was used to perform dose modeling on areas of elevated activity based on their actual radionuclide concentrations and maximum bounded areas. Other model input parameters were identical to those used for development of the project DCGLs. The dose associated with each area of elevated activity and the dose associated with the remaining portion of the survey unit were then summed to verify that the total dose due to residual radioactivity within the entire survey unit does not exceed 25 mrem/y. Refer to Appendix 16 for detailed calculations and modeling associated with the elevated measurement comparison.

Location SSU-01-C1-SO-07 provides a maximum dose rate from all pathways of 5.972 mrem/y at time = 369 y. Location SSU-01-C1-SO-11 provides a maximum dose rate from all pathways of 3.869 mrem/y at time = 369 y. The balance of SSU-01-C1 provides a maximum dose rate from all pathways of 3.869 mrem/y at time = 0.832 y. The sum of the dose rates from the two locations and the balance of the survey unit is 15.225 mrem/y. This is a conservative estimate since the peak dose rates for the two locations are achieved ~ 368 years after the peak dose rate from the survey unit. Additionally the maximum values, rather than the average values, were used for modeling the balance of the survey unit.

The maximum dose rate from all pathways associated with the survey unit is 15.225 mrem/y, which is less than the release criterion of 25 mrem/y.

8.5.5 Class 1 SSU-01 Conclusions

The survey unit passes the WRS Test and the elevated measurement comparison. Therefore the survey unit meets the release criterion.

8.6 Class 1 SSU-02

Class 1 stockpile survey unit two (C1-SSU-02) is comprised of the -24” to -30” layer of excavated Class 1 soil placed in laydown area B (Figure 2, Appendix 1). Systematic sample locations are shown on Figure 6 (Appendix 1). Detailed survey and sample results are presented in Appendix 10.

8.6.1 Analysis of C1-SSU-02 Gamma Walkover Surveys

Scan data from the survey unit was evaluated by comparison to background reference area scan data. Notable statistical values are presented in Table 8.6.1 below:

Table 8.6.1
C1-SSU-02 Scan Data Comparison

Statistic	SU Value (cpm)	[1]BRA Value (cpm)
Mean	7,879.6	8,269
Median	7,860	8,250
Maximum	11,580	11,460
Minimum	5,040	1,020
Standard Deviation	988.68	975

[1]BRA = Background Reference Area

During the initial scan survey intermodal containers loaded with waste were staged along the west boundary of the Laydown Area, which resulted in elevated exposure rates along the western portion of the SU. The intermodal containers were moved and the SU was resurveyed the following day. Areas that exhibited readings above the investigation level of 11,194 cpm were further investigated by visual examination guided by field survey instruments. No additional waste material was identified during the investigation.

8.6.2 Analysis of C1-SSU-02 Sample Results

After verification and validation, sample results from the off-site laboratory were processed using Microsoft® Excel® 2013. Calculation worksheets for individual samples are presented in Appendix 10.

A summary of the SU SORs and a comparison to relevant background reference area SOR values are presented in Table 8.6.2 below:

Table 8.6.2
C1-SSU-02 SOR Summary

Sample Sum of the Ratios		
Sample ID	**SOR**	**Net SOR**
BLT-SSU-02-C1-SO-01	0.787	0.007
BLT-SSU-02-C1-SO-01-FD04	0.688	0.015
BLT-SSU-02-C1-SO-02	1.303	0.351
BLT-SSU-02-C1-SO-03	0.809	0.092
BLT-SSU-02-C1-SO-04	0.586	0.029
BLT-SSU-02-C1-SO-05	0.740	0.006
BLT-SSU-02-C1-SO-06	0.741	0.027
BLT-SSU-02-C1-SO-07	1.041	0.126
BLT-SSU-02-C1-SO-08	0.734	0.015
BLT-SSU-02-C1-SO-09	0.855	0.036
BLT-SSU-02-C1-SO-10	0.938	0.028
BLT-SSU-02-C1-SO-11	2.433	1.487
BLT-SSU-02-C1-SO-12	0.773	0.003
BLT-SSU-02-C1-SO-13	0.684	0.005
BLT-SSU-02-C1-SO-14	0.660	0.002
BLT-SSU-02-C1-SO-15	0.642	0.003
BLT-SSU-02-C1-SO-16	0.762	0.001
	SU	**RA**
Avg	0.893	0.960
Min	0.586	0.768
Max	2.433	1.333
SU Max SOR - RA Min SOR	1.665	
SU Avg SOR - RA Avg SOR	-0.067	
Perform WRS Test & EMC		

The difference between the largest survey unit measurement (SOR) and the smallest background reference area measurement (SOR) is greater than the $DCGL_W$ (1). The difference of the survey unit mean and the background reference area mean is less than the $DCGL_W$ (1). Therefore the WRS Test and the Elevated Measurement Comparison are performed.

8.6.3 Class 1 SSU-02 WRS Test

In using this test, the hypotheses being tested are:

- *Null Hypothesis (H_0)*: The median concentration in the survey unit exceeds that in the background reference area by more than the DCGL;
- *Alternative Hypothesis (H_a)*: The median concentration in the survey unit exceeds that in the background reference area by less than the DCGL.

The WRS Test calculation worksheet for C1-SSU-02 is presented in Appendix 10. The WRS statistical test was applied to the laboratory sample data via the following sequential steps:

1. Reduce background reference area and SU isotopic data to SOR using the SOR equation presented previously in this section. Refer to the Individual Sample Results section of Appendix 5 for background reference area SOR calculations and Appendix 10 for the survey unit SOR calculations.

2. Add the $DCGL_w$ value (i.e., 1.0) to each background reference area SOR value, X_i, to obtain the adjusted background reference area SOR, Z_i, where:

$$Z_i = X_i + 1.0$$

Adjusted background reference area values are presented in Table 8.6.3 below:

Table 8.6.3
C1-SSU-02 WRS Test

BRA X_i (SOR)	**BRA Z_i** (SOR+$DCGL_w$)	**Ranks**	**BRA Ranks**
0.825706805	1.825706805	19	19
0.921380538	1.921380538	26	26
0.873495699	1.873495699	25	25
0.846944061	1.846944061	22	22
1.157740287	2.157740287	35	35
0.841743122	1.841743122	20	20
0.934067157	1.934067157	27	27
1.13009195	2.13009195	34	34
0.870092312	1.870092312	24	24
0.846418527	1.846418527	21	21
0.767855247	1.767855247	17	17
1.079295965	2.079295965	33	33
0.851102683	1.851102683	23	23
0.820641368	1.820641368	18	18
1.025772216	2.025772216	29	29
1.065078933	2.065078933	32	32
1.02595448	2.02595448	30	30
1.026344395	2.026344395	31	31
0.957934772	1.957934772	28	28
1.332832267	2.332832267	36	36

SU Y_i (SOR)	**Ranks**	**BRA Ranks**
0.786551275	11	0
0.688142055	5	0
1.30342983	16	0
0.808560653	12	0
0.586044694	1	0
0.739743823	7	0
0.741163138	8	0
1.041329252	15	0
0.733755666	6	0
0.854510337	13	0
0.938362471	14	0
2.432875557	37	0
0.772966313	10	0
0.683668706	4	0
0.660159746	3	0
0.642453823	2	0
0.762208656	9	0
Sum	**703**	**530**

3. The *m* adjusted SOR, Z_i, from the background reference area and the *n* SOR, Y_i, from the SU were pooled and assigned a rank in order of increasing measurement value from *1* to *N*, where:

$$N = m + n$$

$$N = 20 + 17 = 37$$

Overall ranks and background reference area ranks are presented in Table 8.6.3 above.

4. Sum the ranks of the adjusted SOR from the background reference area, W_r. Refer to Table 8.5.3 above.

$$W_r = 530$$

5. From MARSSIM, Appendix I, Table I.4, for the values of $n = 17$, $m = 20$, and $\alpha = 0.05$:

$$WRS_{crit} = 434$$

W_r (530) is greater than WRS_{crit} (434). Therefore the null hypothesis that the SU exceeds the release criterion can be rejected, pending results of elevated measurement comparison.

8.6.4 Class 1 SSU-02 Elevated Measurement Comparison

For each sample location within the SU where the Net SOR is greater than 1 (see Table 8.6.2 above), an elevated measurement comparison was performed utilizing the alternative method specified in MARSSIM Chapter 8.5.2, and presented below:

… As an alternative to the unity rule, the dose or risk due to the actual residual radioactivity distribution can be calculated if there is an appropriate exposure pathway model available.

The residual radioactivity computer code (RESRAD version 6.5) was used to perform dose modeling on areas of elevated activity based on their actual radionuclide concentrations and maximum bounded areas. Other model input parameters were identical to those used for development of the project DCGLs. The dose associated with each area of elevated activity and the dose associated with the remaining portion of the survey unit were then summed to verify that the total dose due to residual radioactivity within the entire survey unit does not exceed 25 mrem/y. Refer to Appendix 16 for detailed calculations and modeling associated with the elevated measurement comparison.

Location SSU-02-C1-SO-11 provides a maximum dose rate from all pathways of 3.463 mrem/y at time = 369 y. The balance of SSU-02-C1 provides a maximum dose rate from all pathways of 1.953 mrem/y at time = 0.832 y. The sum of the dose rates from the location and the balance of the survey unit is 5.416 mrem/y. This is a conservative estimate since the peak dose rate for the location is achieved ~ 368 years after the peak dose rate from the survey unit. Additionally the maximum values, rather than the average values, were used for modeling the balance of the survey unit.

The maximum dose rate from all pathways associated with the survey unit is 5.416 mrem/y, which is less than the release criterion of 25 mrem/y.

8.6.5 Class 1 SSU-02 Conclusions

The survey unit passes the WRS Test and the elevated measurement comparison. Therefore the survey unit meets the release criterion.

8.7 Class 1 SSU-03

Class 1 stockpile survey unit three (C1-SSU-03) is comprised of the -18” to -24” layer of excavated Class 1 soil placed in laydown area B (Figure 2, Appendix 1). Systematic sample locations are shown on Figure 6 (Appendix 1). Detailed survey and sample results are presented in Appendix 11.

8.7.1 Analysis of C1-SSU-03 Gamma Walkover Surveys

Scan data from the survey unit was evaluated by comparison to background reference area scan data. Notable statistical values are presented in Table 8.7.1 below:

Table 8.7.1
C1-SSU-03 Scan Data Comparison

Statistic	SU Value (cpm)	[1]BRA Value (cpm)
Mean	6,419	8,269
Median	6,420	8,250
Maximum	9,960	11,460
Minimum	4,080	1,020
Standard Deviation	697	975

[1]BRA = Background Reference Area

No areas exhibiting readings above the investigation level of 11,194 cpm were identified.

8.7.2 Analysis of C1-SSU-03 Sample Results

After verification and validation, sample results from the off-site laboratory were processed using Microsoft® Excel® 2013. Calculation worksheets for individual samples are presented in Appendix 11.

A summary of the SU SORs and a comparison to relevant background reference area SOR values are presented in Table 8.7.2 below:

Table 8.7.2
C1-SSU-03 SOR Summary

Sample Sum of the Ratios		
Sample ID	**SOR**	**Net SOR**
BLT-SSU-03-C1-SO-01	0.746	0.009
BLT-SSU-03-C1-SO-02	0.935	0.016
BLT-SSU-03-C1-SO-03	0.720	0.066
BLT-SSU-03-C1-SO-04	0.621	0.001
BLT-SSU-03-C1-SO-05	0.572	0.001
BLT-SSU-03-C1-SO-06	0.735	0.002
BLT-SSU-03-C1-SO-07	0.933	0.002
BLT-SSU-03-C1-SO-08	0.796	0.018
BLT-SSU-03-C1-SO-09	0.561	0.008
BLT-SSU-03-C1-SO-10	0.731	0.002
BLT-SSU-03-C1-SO-11	0.838	0.095
BLT-SSU-03-C1-SO-12	0.793	0.005
BLT-SSU-03-C1-SO-13	0.874	0.082
BLT-SSU-03-C1-SO-14	0.648	0.023
BLT-SSU-03-C1-SO-15	0.865	0.135
BLT-SSU-03-C1-SO-16	0.718	0.004
BLT-SSU-03-C1-SO-01	0.746	0.009
BLT-SSU-03-C1-SO-02	0.935	0.016
	SU	**RA**
Avg	0.755	0.960
Min	0.561	0.768
Max	0.935	1.333
SU Max SOR - RA Min SOR	0.167	
SU Avg SOR - RA Avg SOR	-0.205	
SU meets release criterion		

8.7.3 Class 1 SSU-03 Conclusions

The difference between largest survey unit measurement (SOR) and smallest background reference area measurement (SOR) is less than the $DCGL_W$ (1). Therefore the SU meets the release criterion.

8.8 Class 1 SSU-04

Class 1 stockpile survey unit four (C1-SSU-04) is comprised of the -12” to -18” layer of excavated Class 1 soil placed in laydown area B (Figure 2, Appendix 1). Systematic sample locations are shown on Figure 6 (Appendix 1). Detailed survey and sample results are presented in Appendix 12.

8.8.1 Analysis of C1-SSU-04 Gamma Walkover Surveys

Scan data from the survey unit was evaluated by comparison to background reference area scan data. Notable statistical values are presented in Table 8.8.1 below:

Table 8.8.1
C1-SSU-04 Scan Data Comparison

Statistic	SU Value (cpm)	[1]BRA Value (cpm)
Mean	6,837	8,269
Median	6,840	8,250
Maximum	9,840	11,460
Minimum	4,260	1,020
Standard Deviation	749	975

[1]BRA = Background Reference Area

No areas exhibiting readings above the investigation level of 11,194 cpm were identified.

8.8.2 Analysis of C1-SSU-04 Sample Results

After verification and validation, sample results from the off-site laboratory were processed using Microsoft® Excel® 2013. Calculation worksheets for individual samples are presented in Appendix 12.

A summary of the SU SORs and a comparison to relevant background reference area SOR values are presented in Table 8.8.2 below:

Table 8.8.2
C1-SSU-04 SOR Summary

Sample Sum of the Ratios		
Sample ID	**SOR**	**Net SOR**
BLT-SSU-04-C1-SO-01	0.877	0.193
BLT-SSU-04-C1-SO-02	0.846	0.103
BLT-SSU-04-C1-SO-03	1.137	0.270
BLT-SSU-04-C1-SO-04	1.130	0.550
BLT-SSU-04-C1-SO-05	0.705	0.030
BLT-SSU-04-C1-SO-06	0.690	0.010
BLT-SSU-04-C1-SO-07	0.763	0.036
BLT-SSU-04-C1-SO-08	0.839	0.087
BLT-SSU-04-C1-SO-09	0.632	0.010
BLT-SSU-04-C1-SO-10	1.107	0.180
BLT-SSU-04-C1-SO-11	1.153	0.231
BLT-SSU-04-C1-SO-12	0.831	0.075
BLT-SSU-04-C1-SO-13	0.814	0.011
BLT-SSU-04-C1-SO-14	0.770	0.011
BLT-SSU-04-C1-SO-15	0.749	0.073
BLT-SSU-04-C1-SO-16	0.730	0.067
BLT-SSU-04-C1-SO-16-FD03	0.867	0.057
BLT-SSU-04-C1-SO-01	0.877	0.193
	SU	**RA**
Avg	0.861	0.960
Min	0.632	0.768
Max	1.153	1.333
SU Max SOR - RA Min SOR	0.385	
SU Avg SOR - RA Avg SOR	-0.099	
SU meets release criterion		

8.8.3 Class 1 SSU-04 Conclusions

The difference between largest survey unit measurement (SOR) and smallest background reference area measurement (SOR) is less than the $DCGL_W$ (1). Therefore the SU meets the release criterion.

8.9 Class 1 SSU-05

Class 1 stockpile survey unit five (C1-SSU-05) is comprised of the -6” to -12” layer of excavated Class 1 soil placed in laydown area B (Figure 2, Appendix 1). Systematic sample locations are shown on Figure 6 (Appendix 1). Detailed survey and sample results are presented in Appendix 13.

8.9.1 Analysis of C1-SSU-05 Gamma Walkover Surveys

Scan data from the survey unit was evaluated by comparison to background reference area scan data. Notable statistical values are presented in Table 8.9.1 below:

Table 8.9.1
C1-SSU-05 Scan Data Comparison

Statistic	SU Value (cpm)	[1]BRA Value (cpm)
Mean	7,821	8,269
Median	7,740	8,250
Maximum	12,060	11,460
Minimum	5,040	1,020
Standard Deviation	897	975

[1]BRA = Background Reference Area

Areas that exhibited readings above the investigation level of 11,194 cpm were further investigated by visual examination guided by field survey instruments. No additional waste material was identified during the investigation.

8.9.2 Analysis of C1-SSU-05 Sample Results

After verification and validation, sample results from the off-site laboratory were processed using Microsoft® Excel® 2013. Calculation worksheets for individual samples are presented in Appendix 13.

A summary of the SU SORs and a comparison to relevant background reference area SOR values are presented in Table 8.9.2 below:

Table 8.9.2
C1-SSU-05 SOR Summary

Sample Sum of the Ratios		
Sample ID	**SOR**	**Net SOR**
BLT-SSU-05-C1-SO-01	0.937	0.191
BLT-SSU-05-C1-SO-02	1.072	0.285
BLT-SSU-05-C1-SO-03	1.459	0.556
BLT-SSU-05-C1-SO-03-FD02	1.269	0.415
BLT-SSU-05-C1-SO-04	0.695	0.054
BLT-SSU-05-C1-SO-05	0.770	0.017
BLT-SSU-05-C1-SO-06	0.843	0.050
BLT-SSU-05-C1-SO-07	0.863	0.048
BLT-SSU-05-C1-SO-08	0.926	0.090
BLT-SSU-05-C1-SO-09	0.882	0.060
BLT-SSU-05-C1-SO-10	0.863	0.046
BLT-SSU-05-C1-SO-11	0.935	0.057
BLT-SSU-05-C1-SO-12	0.758	0.044
BLT-SSU-05-C1-SO-13	0.759	0.050
BLT-SSU-05-C1-SO-14	0.898	0.048
BLT-SSU-05-C1-SO-15	0.779	0.053
BLT-SSU-05-C1-SO-16	0.782	0.035
BLT-SSU-05-C1-SO-01	0.937	0.191
	SU	**RA**
Avg	0.911	0.960
Min	0.695	0.768
Max	1.459	1.333
SU Max SOR - RA Min SOR	0.691	
SU Avg SOR - RA Avg SOR	-0.049	
SU meets release criterion		

8.9.3 Class 1 SSU-05 Conclusions

The difference between largest survey unit measurement (SOR) and smallest background reference area measurement (SOR) is less than the $DCGL_W$ (1). Therefore the SU meets the release criterion.

8.10 Class 1 SSU-06

Class 1 stockpile survey unit six (C1-SSU-06) is comprised of the 0" to -6" layer of excavated Class 1 soil placed in laydown area B (Figure 2, Appendix 1). Systematic sample locations are shown on Figure 6 (Appendix 1). Detailed survey and sample results are presented in Appendix 14.

8.10.1 Analysis of C1-SSU-06 Gamma Walkover Surveys

Scan data from the survey unit was evaluated by comparison to background reference area scan data. Notable statistical values are presented in Table 8.10.1 below:

Table 8.10.1
C1-SSU-06 Scan Data Comparison

Statistic	SU Value (cpm)	[1]BRA Value (cpm)
Mean	8,594	8,269
Median	8,580	8,250
Maximum	11,880	11,460
Minimum	1,560	1,020
Standard Deviation	833	975

[1]BRA = Background Reference Area

Areas that exhibited readings above the investigation level of 11,194 cpm were further investigated by visual examination guided by field survey instruments. No additional waste material was identified during the investigation.

8.10.2 Analysis of C1-SSU-06 Sample Results

After verification and validation, sample results from the off-site laboratory were processed using Microsoft® Excel® 2013. Calculation worksheets for individual samples are presented in Appendix 14.

A summary of the SU SORs and a comparison to relevant background reference area SOR values are presented in Table 8.10.2 below:

Table 8.10.2
C1-SSU-06 SOR Summary

Sample Sum of the Ratios		
Sample ID	**SOR**	**Net SOR**
BLT-SSU-06-C1-SO-01	0.981	0.094
BLT-SSU-06-C1-SO-02	0.929	0.239
BLT-SSU-06-C1-SO-03	1.004	0.078
BLT-SSU-06-C1-SO-04	0.779	0.046
BLT-SSU-06-C1-SO-05	1.007	0.098
BLT-SSU-06-C1-SO-06	1.229	0.284
BLT-SSU-06-C1-SO-07	0.956	0.046
BLT-SSU-06-C1-SO-08	0.842	0.016
BLT-SSU-06-C1-SO-09	1.296	0.500
BLT-SSU-06-C1-SO-10	0.980	0.065
BLT-SSU-06-C1-SO-11	1.062	0.146
BLT-SSU-06-C1-SO-11-FD01	0.918	0.024
BLT-SSU-06-C1-SO-12	0.961	0.041
BLT-SSU-06-C1-SO-13	0.803	0.001
BLT-SSU-06-C1-SO-14	0.908	0.007
BLT-SSU-06-C1-SO-15	0.885	0.038
BLT-SSU-06-C1-SO-16	0.635	0.002
BLT-SSU-06-C1-SO-01	0.981	0.094
	SU	**RA**
Avg	0.951	0.960
Min	0.635	0.768
Max	1.296	1.333
SU Max SOR - RA Min SOR	0.529	
SU Avg SOR - RA Avg SOR	-0.009	
SU meets release criterion		

8.10.3 Class 1 SSU-06 Conclusions

The difference between largest survey unit measurement (SOR) and smallest background reference area measurement (SOR) is less than the $DCGL_W$ (1). Therefore the SU meets the release criterion.

8.11 Class 3 SSU-01

Class 3 stockpile survey unit one (C3-SSU-01) is comprised of 43 six inch layers of excavated Class 3 soil placed in laydown area A (Figure 2, Appendix 1). Biased sample locations are shown on the scan maps for each 6" lift presented in Appendix 15. Detailed survey and sample results are presented in Appendix 15.

8.11.1 Analysis of C3-SSU-01 Gamma Walkover Surveys

Scan data from the survey unit was evaluated by comparison to background reference area scan data. Notable statistical values are presented in Table 8.11.1. A biased soil sample was collected from the location exhibiting the highest reading during the scan survey in each of the 43 six inch lifts that comprise the survey unit.

Table 8.11.1
C3-SSU-01 Scan Data Comparison

Lift #	Mean	Median	Maximum	Minimum	Standard Deviation	Comments
1	8,134.4	8,100	11,880	4,800	823.55	Areas that exhibited readings above the investigation level of 11,194 cpm were further investigated by visual examination guided by field survey instruments. No additional waste material was identified during the investigation.
2	7,039.7	7,020	14,220	1,020	846.64	Areas that exhibited readings above the investigation level of 11,194 cpm were further investigated by visual examination guided by field survey instruments. No additional waste material was identified during the investigation.
3	8,847.9	8,820	14,100	6,060	851.25	1 disc source found during investigation. Item and portion of surrounding soil removed and disposed as waste. Exposure rates returned to the normal background range.
4	8,435.9	8,400	11,760	5,520	792.78	2 disc sources found in Lift 3 during investigation. Items and portion of surrounding soil removed and disposed as waste. Exposure rates returned to the normal background range.
5	8,177.1	8,160	11,940	5,280	800.23	Areas that exhibited readings above the investigation level of 11,194 cpm were further investigated by visual examination guided by field survey instruments. No additional waste material was identified during the investigation.
6	7,974.4	7,980	11,580	5,160	917.71	Areas that exhibited readings above the investigation level of 11,194 cpm were further investigated by visual examination guided by field survey instruments. No additional waste material was identified during the investigation.

Lift #	Mean	Median	Maximum	Minimum	Standard Deviation	Comments
7	6,640.9	6,600	11,160	1,080	770.15	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
8	6,597.7	6,600	9,720	1,020	714.91	Investigated areas that exhibited elevated exposure rates during initial scan. Locations were checked at the surface and 6” below grade using a shovel and stainless steel trowel. No readings above background were observed at depth 0-6" except as noted. An area represented by a 4ft by 6ft rectangle was centered on the suspect locations to accommodate for any GPS offset. Note that two locations measured about 35,400 cpm at 0” depth (Locations 1 and 2). Location 1 was sampled and served as one of the biased samples for this soil survey unit. Laboratory analysis identified no unusual activity. A resurvey of the area with the RemCAT returned similar results to the initial survey. Therefore, a more rigorous investigation was performed. A small glass bottle with yellow crystalline material was found at Location 2 – the item and surrounding soil were removed and disposed off-site. Post removal gamma measurements were in the normal background range. On-site gamma spectroscopy analysis results were used to produce a MicroShield model to closely replicate field conditions using the isotopes U-238 and Ra-226 (decayed 20y)
9	6,259.2	6,240	9,120	1,020	727.52	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
10	6,973.5	6,960	9,600	5,220	701.41	Several locations exhibited elevated exposure rates during the initial scan survey. However verification surveys produced observations within the normal background range, with a maximum observed count rate of 9,180 cpm.
11	6,145.7	6,120	9,180	3,660	690.70	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
12	5,872.1	5,880	8,880	3,600	636.55	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
13	7,021.3	7,020	9,660	4,680	675.58	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
14	7,111.5	7,080	10,140	1,620	736.34	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
15	7,181.1	7,140	9,840	1,020	672.11	No areas exhibiting readings above the investigation level of 11,194 cpm were identified

Lift #	Mean	Median	Maximum	Minimum	Standard Deviation	Comments
16	7,013.4	7,020	9,420	4,560	680.19	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
17	7,113.9	7,080	10,440	4,800	687.47	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
18	7,009.9	7,020	10,500	1,020	707.93	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
19	7,072.9	7,080	9,840	1,620	726.97	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
20	6,852.4	6,840	9,420	1,200	681.80	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
21	7,373.1	7,320	10,140	1,260	734.18	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
22	7,320.2	7,320	11,040	4,740	713.91	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
23	7,723.3	7,680	10,740	4,980	738.25	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
24	7,563.1	7,560	10,620	4,980	760.62	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
25	7,132.2	7,140	9,960	4,380	887.89	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
26	6,561.1	6,540	10,800	4,080	825.91	One location exhibiting elevated exposure rate during initial scan survey was investigated. Discovered a cylindrical metal object that measured about 0.5" x 6". Contact exposure rate was ~ 850K cpm. Once the item was removed, a sample was collected from the soil that had surrounded the object and sent to off-site lab for analysis and ultimate off-site disposal. Exposure rates in the area returned to background levels.
27	7,129.4	7,140	10,620	3,480	880.14	One location exhibiting elevated exposure rate during initial scan survey was investigated. Discovered a small rock that measured about 2.5" in diameter with a contact exposure rate of ~ 85K cpm. Once the item was removed, a sample was collected from the soil that had surrounded the object and sent to off-site lab for analysis. Exposure rates in the area returned to background levels. The rock was sent to the on-site lab for evaluation and then dispositioned off-site.

Lift #	Mean	Median	Maximum	Minimum	Standard Deviation	Comments
28	6,183.1	6,060	9,720	3,960	868.55	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
29	6,569.9	6,540	10,080	1,320	885.13	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
30	6,477.1	6,480	9,840	3,960	771.54	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
31	7,204.9	7,200	10,560	4,740	796.80	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
32	7,052.6	7,080	10,080	4,080	842.93	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
33	6,578.4	6,540	10,020	3,960	767.37	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
34	6,854.4	6,840	10,500	1,140	826.04	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
35	6,778.6	6,720	12,720	3,960	816.59	Areas that exhibited readings above the investigation level of 11,194 cpm were further investigated by visual examination guided by field survey instruments. No additional waste material was identified during the investigation.
36	7,360.7	7,320	10,560	4,560	786.46	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
37	7,686.6	7,680	10,560	5,160	733.95	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
38	8,301.5	8,340	11,760	5,340	864.95	Areas that exhibited readings above the investigation level of 11,194 cpm were further investigated by visual examination guided by field survey instruments. No additional waste material was identified during the investigation.
39	7,173.9	7,140	10,140	4,680	823.80	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
40	8,355.7	8,340	10,980	5,760	750.32	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
41	8,555.5	8,520	12,660	1,020	868.58	Areas that exhibited readings above the investigation level of 11,194 cpm were further investigated by visual examination guided by field survey instruments. No additional waste material was identified during the investigation.

Lift #	Mean	Median	Maximum	Minimum	Standard Deviation	Comments
42	8,850.1	8,880	11,640	1,020	857.68	Areas that exhibited readings above the investigation level of 11,194 cpm were further investigated by visual examination guided by field survey instruments. No additional waste material was identified during the investigation.
43	8,009.7	7,980	11,040	5,460	823.80	No areas exhibiting readings above the investigation level of 11,194 cpm were identified
Max	8,850.1	8,880	14,220	6,060	917.71	The maximum and average of the Mean, Median, Maximum, Minimum, and Standard Deviation are provided for comparison to the Background Reference Area (BRA) values. The average of the Mean, Median, Maximum, and Standard Deviation are all less than the corresponding values associated with the BRA, which further strengthens the argument that the survey unit meets the release criteria.
Avg	7,262.1	7,245	10,679	3,534	778.31	
BRA	8,269.0	8,250	11,460	1,020	975.00	

[1]BRA = Background Reference Area

8.11.2 Analysis of C3-SSU-01 Sample Results

After verification and validation, sample results from the off-site laboratory were processed using Microsoft® Excel® 2013. Calculation worksheets for individual samples are presented in Appendix 15.

A summary of the SU SORs and a comparison to relevant background reference area SOR values are presented in Table 8.11.2 below:

Table 8.11.2
C3-SSU-01 SOR Summary

Sample Sum of the Ratios		
Sample ID	**SOR**	**Net SOR**
BLT-SSU-01-C3-SO-01	0.633	0.029
BLT-SSU-02-C3-SO-01	0.975	0.060
BLT-SSU-02-C3-SO-02	1.059	0.112
BLT-SSU-03-C3-SO-01	0.967	0.090
BLT-SSU-04-C3-SO-01	1.258	0.303
BLT-SSU-05-C3-SO-01	0.688	0.029
BLT-SSU-06-C3-SO-01	0.789	0.039
BLT-SSU-07-C3-SO-01	0.636	0.007
BLT-SSU-08-C3-SO-01	0.603	0.011
BLT-SSU-09-C3-SO-01	0.705	0.001
BLT-SSU-10-C3-SO-01	0.481	0.008
BLT-SSU-11-C3-SO-01	0.644	0.011
BLT-SSU-12-C3-SO-01	0.653	0.028
BLT-SSU-13-C3-SO-01	1.197	0.333
BLT-SSU-14-C3-SO-01	0.760	0.000
BLT-SSU-15-C3-SO-01	1.037	0.206
BLT-SSU-16-C3-SO-01	0.767	0.028
BLT-SSU-17-C3-SO-01	0.569	0.035
BLT-SSU-18-C3-SO-01	1.259	0.393
BLT-SSU-19-C3-SO-01	1.429	0.634
BLT-SSU-20-C3-SO-01	1.231	0.433
BLT-SSU-21-C3-SO-01	1.146	0.302
BLT-SSU-22-C3-SO-01	0.759	0.025
BLT-SSU-23-C3-SO-01	1.136	0.214
BLT-SSU-24-C3-SO-01	0.983	0.039
BLT-SSU-25-C3-SO-01	1.006	0.164
BLT-SSU-26-C3-SO-01	0.767	0.034
BLT-SSU-27-C3-SO-01	0.757	0.033
BLT-SSU-28-C3-SO-01	0.796	0.018
BLT-SSU-29-C3-SO-01	0.873	0.030
BLT-SSU-30-C3-SO-01	0.876	0.035
BLT-SSU-30-C3-SO-01-FD01	0.701	0.070

Sample Sum of the Ratios		
Sample ID	**SOR**	**Net SOR**
BLT-SSU-31-C3-SO-01	0.764	0.013
BLT-SSU-32-C3-SO-01	0.775	0.150
BLT-SSU-33-C3-SO-01	0.682	0.000
BLT-SSU-34-C3-SO-01	1.212	0.285
BLT-SSU-35-C3-SO-01	0.488	0.000
BLT-SSU-36-C3-SO-01	0.616	0.000
BLT-SSU-37-C3-SO-01	0.804	0.002
BLT-SSU-38-C3-SO-01	0.788	0.005
BLT-SSU-39-C3-SO-01	0.733	0.021
BLT-SSU-40-C3-SO-01	0.748	0.010
BLT-SSU-40-C3-SO-01-FD02	0.721	0.012
BLT-SSU-41-C3-SO-01	1.008	0.073
BLT-SSU-42-C3-SO-01	1.205	0.270
BLT-SSU-42-C3-SO-01-FD03	0.982	0.091
BLT-SSU-43-C3-SO-01	0.905	0.009
BLT-SSU-43-C3-SO-02	1.006	0.074
	SU	**RA**
Avg	0.866	0.960
Min	0.481	0.768
Max	1.429	1.333
SU Max SOR - RA Min SOR	0.661	
SU Avg SOR - RA Avg SOR	-0.094	
SU meets release criterion		

8.11.3 Class 3 SSU-01 Conclusions

The difference between largest survey unit measurement (SOR) and smallest background reference area measurement (SOR) is less than the $DCGL_W$ (1). Therefore the SU meets the release criterion.

8.12 Post Excavation Sampling of Undisturbed Soil and Water

Soil samples were collected from the 0-6 inch interval of undisturbed soil at 12 locations within the excavation. The soil samples have been evaluated as a single SU. After verification and validation, sample results from the off-site laboratory were processed using Microsoft® Excel® 2013. Calculation worksheets for individual samples are presented in Appendix 21. A summary of the SU SORs and a comparison to relevant background reference area SOR values are presented in Table 8.9.2 below:

Table 8.12
SOR Summary for
Post Excavation Sampling of Undisturbed Soil

Sample Sum of the Ratios		
Sample ID	**SOR**	**Net SOR**
BA18-PIT-A-S	0.558	0.022
BA18-PIT-B-S	0.629	0.026
BA18-PIT-C-S	0.436	0.020
BA18-PIT-C-S-DUP	0.498	0.021
BA18-PIT-D-S	0.760	0.021
BA18-PIT-E-S	0.767	0.021
BA18-PIT-F-S	0.405	0.000
BA18-PIT-G-S	0.689	0.036
BA18-PIT-G-S-DUP	0.624	0.023
BA18-PIT-H-S	0.536	0.021
BA18-PIT-I-S	0.473	0.003
BA18-PIT-J-S	0.575	0.000
BA18-PIT-K-S	0.601	0.022
BA18-PIT-L-S	0.415	0.018
	SU	**RA**
Avg	0.569	0.960
Min	0.405	0.768
Max	0.767	1.333
SU Max SOR - RA Min SOR	-0.001	
SU Avg SOR - RA Avg SOR	-0.391	
SU meets release criterion		

The difference between largest survey unit measurement (SOR) and smallest background reference area measurement (SOR) is less than the DCGLW (1). Therefore the SU meets the release criterion.

Post excavation sampling of groundwater was performed by BMT Designers and Planners. A detailed report of on-site activities associated with groundwater sampling as well as laboratory analytical results is included as Appendix 22. The following text is an excerpt from page 4 of the BMT report that specifically addresses post excavation sampling of groundwater:

As part of the post removal action sampling program a total of fourteen (14) temporary piezometers were installed using Geoprobe® direct push technology (DPT) methods within the footprint of the LLRBS excavation cavity. Prior to the advancement of Geoprobe tooling, groundwater elevations were measured within LLRBS monitoring wells adjacent to the temporary well point location to ascertain the estimated sampling depth for the tooling. Each piezometer was consisted of a single five (5) foot length of 1" inside diameter (ID) PVC screen with ten (10) foot lengths of 1" ID well screen above.

Of the 14 temporary piezometers installed, refusal was encountered at six (6) piezometer well locations (PW1, PW2, PW4, PW5, PW7 and PW10). Piezometers were *installed at these locations to collect water from perched water tables, if present. A site map featuring the excavation and temporary well locations is included as Figure 4.*

For the eight (8) successfully installed piezometer wells, three well volumes of water were purged prior to the collection of groundwater quality parameters and sample collection. Groundwater samples were collected using dedicated polyethylene tubing equipped with a ball and check valve. Groundwater physical parameters, and total piezometer well depths are summarized in Table 4.

Radiological analytical results are located in Appendix 22, Table A-10, *LLRBS Radionuclides in Monitoring Well Groundwater Analytical Results, May 2016 (Appendix page 35)*.

8.13 ORAU Confirmatory Survey Activities

ORAU performed confirmatory survey activities at the project during the period September 23-26, 2014. Their findings were published in a report dated February 2015, which is included as Appendix 19. The summary from that report is provided below:

At the NRC's request, ORAU conducted confirmatory surveys of SUs 1, 2, 3, 4, and 5 at the LLRBS in Beltsville, Maryland during the period of September 23–26, 2014. The survey activities included visual inspections, gamma radiation surface scans, gamma and beta radiation measurements, and soil sampling activities. Confirmatory activities also included the review and assessment of the licensee's project documentation and methodologies.

The majority of gamma surface scans were not distinguishable from background. Even though the Ra-226 waste stored in the building adjacent to SU 4 influenced gamma scans in the area surrounding it, confirmatory sample results indicated ROC concentrations were near background levels. With the exception of samples 5246S0009 and 5246S0010, the confirmatory sample results were below the respective DCGL and SOF values for the site ROCs.

Based on the results of the confirmatory surveys and provided SU 4 satisfies the DCGLEMC calculation for the elevated concentrations of H-3, C-14 and Cs-137 or contamination above the guidelines is removed, ORAU is of the opinion that TES has accurately and adequately demonstrated that SUs 1–5 of the LLRBS site satisfy the site criteria for release from radiological controls.

ORAU SU 4 is comprised of six Class 1 SSUs. Location 5246S0009 correlates to TES sample SSU-04-C1-SO-01, which resides in SSU-04-C1. Location 5246S0010 correlates to TES sample SSU-05-C1-SO-03, which resides in SSU-05-C1. Elevated measurement comparisons were performed for each of the two samples and the balance of their respective survey units utilizing the alternative method specified in MARSSIM Chapter 8.5.2, and presented below:

… As an alternative to the unity rule, the dose or risk due to the actual residual radioactivity distribution can be calculated if there is an appropriate exposure pathway model available.

The residual radioactivity computer code (RESRAD version 6.5) was used to perform dose modeling on the areas of elevated activity based on their actual radionuclide concentrations and maximum bounded areas. Other model input parameters were identical to those used for development of the project DCGLs. The dose associated with each area of elevated activity and the dose associated with the remaining portion of the survey unit were then summed to verify that the total dose due to residual radioactivity within the entire survey unit does not exceed 25 mrem/y. Refer to Appendix 20 for detailed calculations and modeling associated with the elevated measurement comparison.

Location 5246S0009 (SSU-04-C1-SO-01) provides a maximum dose rate from all pathways of 5.33 mrem/y at time = 0.00 y. The balance of SSU-04-C1 provides a maximum dose rate from all pathways of 5.962 mrem/y at time = 0.832 y. The sum of the dose rates from location 5246S0009 and the balance of the survey unit is 11.292 mrem/y. This is a conservative estimate since the maximum values, rather than the average values, were used for modeling the balance of the survey unit.

The maximum dose rate from all pathways associated with the survey unit is 11.292 mrem/y, which is less than the release criterion of 25 mrem/y.

Location 5246S0010 (SSU-05-C1-SO-03) provides a maximum dose rate from all pathways of 4.322 mrem/y at time = 0.00 y. The balance of SSU-05-C1 provides a maximum dose rate from all pathways of 1.878 mrem/y at time = 0.00 y. The sum of the dose rates from location 5246S0010 and the balance of the survey unit is 6.20 mrem/y. This is a conservative estimate since the maximum values, rather than the average values, were used for modeling the balance of the survey unit.

The maximum dose rate from all pathways associated with the survey unit is 6.20 mrem/y, which is less than the release criterion of 25 mrem/y.

9.0 CONCLUSION

For all survey units except Class 1 SSU-01, Class 1 SSU-02, and ORAU SU-4:

The difference between the largest survey unit measurement (SOR) and the smallest background reference area measurement (SOR) is less than the $DCGL_W$ (1).

For survey units Class 1 SSU-01 and Class 1 SSU-02:

The difference between the largest survey unit measurement (SOR) and the smallest background reference area measurement (SOR) is greater than the $DCGL_W$ (1). The difference of the survey unit mean and the background reference area mean is less than the $DCGL_W$ (1). Therefore the WRS Test and the Elevated Measurement Comparison are performed.

The survey units pass the WRS Test.

Elevated measurement comparison modeling shows that the maximum dose rate associated with the survey units is less than 25 mrem/y.

For ORAU SU-4:

Elevated measurement comparison modeling shows that the maximum dose rate associated with the identified TES survey units is less than 25 mrem/y.

Therefore the BARC LLRBS meets the release criteria and can be removed from the USDA's radioactive material license by the NRC pending their review and acceptance of this FSSR.

10.0 REFERENCES

(Apex, 1991) Preliminary site Assessment/site Investigation for the Beltsville Agricultural Research Center, Beltsville, Maryland, May 1991.

(Apex, 1993) Hydrogeologic Characterization and Monitoring of the BARC Radiation Burial site, September 1993.

(Cabrera, 2007a) Low Level Radiation Burial site Characterization Survey, prepared for U.S. Department of Agriculture, Agricultural Research Service, Beltsville, MD, August 2007.

(Cabrera, 2007b) site-Specific Derived Concentration Guideline Level, prepared for U.S. Department of Agriculture, Agricultural Research Service, Beltsville, MD, August 2007.

(Cabrera, 2012), BARC LLRWS Decommissioning Plan, Revised Final, prepared for U.S. Department of Agriculture, Agricultural Research Service, Beltsville, MD, January 2012.

(Entech, 1998) RESRAD Modeling in Support of BARC LLRBS Decommissioning, prepared for U.S. Department of Agriculture, Agricultural Research Service, Beltsville, MD, April 1998.

(Entech, 2000) Low-Level Radiation Burial site Engineering Evaluation/Cost Analysis, Beltsville Agricultural Research Center, prepared for U.S. Department of Agriculture, Agricultural Research Service, Beltsville, MD, July 2000.

(EPA, 2000) Guidance for the Data Quality Objectives Process, (EPA QA/G-4, EPA/600/R-96/055). United States Environmental Protection Agency, Office of Research and Development. Washington, D.C.: U.S. Government Printing Office, August 2000.

(NRC, 1997) Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions, (NUREG-1507). United States Nuclear Regulatory Commission. Washington, D.C.: U.S. Government Printing Office, December 1997.

(NRC, 1998a) A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys, (NUREG-1505, Rev.1). United States Nuclear Regulatory Commission. Washington, D.C.: U.S. Government Printing Office, June 1998.

(NRC, 1998b) Demonstrating Compliance with the Radiological Criteria for License Termination, (Draft Regulatory Guide DG-4006). United States Nuclear Regulatory Commission. Washington, D.C.: U.S. Government Printing Office, August 1998.

(NRC, 2000) Multi-Agency Radiation Survey and site Investigation Manual MARSSIM, Revision 1, (NUREG-1575). United States Nuclear Regulatory Commission. Washington, D.C.: U.S. Government Printing Office, August 2000.