Hill Air Force Base, Utah

Final

WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench Decommissioning Plan

September 2015

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This Final Decommissioning Plan outlines the specific procedures for execution of the work, quality control measures, assessment and oversight planning, and health and safety including radiation safety protocols to ensure the quality and safety of the decommissioning activities and site closure at the Little Mountain Test Annex Magnesium-Thorium Disposal Trench Site, Hill Air Force Base, in Ogden, Utah, under Contract No. FA8903-09-D-8560, Task Order 0006.

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FINAL

Hill Air Force Base
Performance-Based Remediation

WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench Decommissioning Plan

Contract No: FA8903-09-D-8560
Task Order 0006

Prepared for:
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SEPTEMBER 2015

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Executive Summary

This Decommissioning Plan was developed by EA Engineering, Science, and Technology, Inc. and Cabrera Services, Inc. to support investigation, remediation, decommissioning, and site closeout at the Little Mountain Test Annex (LMTA) Magnesium-Thorium Disposal Trench Site, Hill Air Force Base (AFB), in Ogden, Utah, under the Hill AFB PBR Contract No. FA8903-09-D-8560, Task Order 0006. The WR111 site is given US Air Force (USAF) Permit # UT-00517-xx/xxAFP and Docket #040-00517. The authority for this permit is under USAF MML # 42-23539-xx and Docket # 030-28641 issued to USAF by the U.S. Nuclear Regulatory Commission (NRC). This decommissioning is being performed in accordance with the requirements for a Group 4 facility (NRC, 2006). Investigations have confirmed radiological impact to surface and subsurface soil at the Magnesium-Thorium Disposal Site, which will be referred to herein as Site WR111. This Decommissioning Plan provides the overall plan for completing decommissioning at Site WR111 and incorporates the measures necessary to protect the health and safety of workers and the public and to prevent the spread of contamination during work activities.

Site WR111 is located within the LMTA, which is approximately 15 miles northwest of Hill AFB and adjacent to the Great Salt Lake. The disposal trench is approximately 200 × 150 feet in an area enclosed by a chain-link fence in the far southeastern corner of the LMTA. The global positioning system coordinates of the four corners of the site are provided below in Table ES-1. Historical information indicates that magnesium-thorium scrap and waste materials associated with the manufacture of controls, accessories, and engine parts were burned/buried in the trench from 1959 through 1961. Results of a recent investigation (2007-2009) indicate that site soils within the fenced area of Site WR111 have been impacted with thorium-232 (^{232}Th) and decay progeny above background levels (AECOM 2009). A 2013 characterization study was conducted to fill data gaps along the eastern and southern boundaries of the site and further define the nature and extent of contamination. Sampling results show subsurface contamination in the eastern section of the site and only surface contamination in the center and southwestern areas. Results of groundwater sampling that was conducted in 2006 indicate that there are no radiological impacts to groundwater from the thorium alloy scrap metal buried at Site WR111 (Parsons Infrastructure and Technology Group, Inc. 2007).

Radium-226 (^{226}Ra), thorium-230 (^{230}Th), and ^{232}Th were identified as the radionuclides of concern (ROCs) for soil. Therefore, dose-based criteria, called derived concentration guideline levels (DCGLs), were developed for the ROCs. *RESidual RADioactivity, Version 6.5* was used to derive the soil DCGLs for Site WR111 based on Nuclear Regulatory Commission (NRC)'s regulatory acceptable dose limit of 25 millirem per year (mrem/yr). A residential farmer was considered as the base-case exposure scenario. One additional exposure scenario, for a typical airman at the site, was evaluated to confirm that the base-case resident farmer scenario is bounding for the development of soil DCGLs. Among the two exposure scenarios, the most conservative DCGL for each ROC was selected as the site-specific DCGL as presented below in Table ES-2.

Implementation of decommissioning activities outlined in this Decommissioning Plan will result in the removal of radiologically-impacted soil (estimated at 2,420 cubic yards) for transport to an offsite permitted disposal facility. The decommissioning activities will follow specific procedures for work execution, quality control, assessment and oversight planning, and health and safety including radiation safety protocols to ensure the quality and safety of the decommissioning activities. Completion of decommissioning is expected to result in the unrestricted release of Site WR111.

Environmental remediation and site closeout activities at WR111 will be coordinated with the NRC through the U.S. Air Force Radioisotope Committee. In support of site closeout, a final status survey will be conducted following *Multi-Agency Radiation Survey and Site Inspection Manual* (NRC 2000) requirements, after the remediation activities are completed to demonstrate compliance with established acceptable dose-based criteria.

TABLE ES-1
Global Positioning System Coordinates
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench
Decommissioning Plan, Hill Air Force Base, Utah

Corner of Site	Coordinates	
	Northing (meters)	**Easting (meters)**
Northwest	4566662.701	396188.558
Northeast	4566668.444	396233.685
Southeast	4566662.701	396188.558
Southwest	4566601.165	396186.507

NOTE: Coordinate system is UTM Zone 12N 1984 meters

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TABLE ES-2
Site-Specific, Radionuclide-Specific, Soil Derived Concentration Guideline Levels
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench
Decommissioning Plan, Hill Air Force Base, Utah

Radionuclides of Concern	Site-Specific Derived Concentration Guideline Levels (picoCuries/gram)
^{226}Radium	1.6
^{230}Thorium	4.3
^{232}Thorium	1.9

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Acronyms and Abbreviations

AEC	Atomic Energy Commission
AFB	Air Force Base
AFCEC	Air Force Civil Engineer Center
ALARA	As Low As (is) Reasonably Achievable
^{214}Bi	Bismuth-214
bgs	Below ground surface
Cabrera	Cabrera Services, Inc.
Ci	Curie
CDE	Committed Dose Equivalent
CEDE	Committed Effective Dose Equivalent
CFR	Code of Federal Regulation
DAC	Derived Air Concentration
DCGL	Derived Concentration Guideline Level
DDE	Deep Dose Equivalent
DQA	Data Quality Assessment
EA	EA Engineering, Science, and Technology, Inc.
EPA	U.S. Environmental Protection Agency
FSS	Final Status Survey
FSSP	Final Status Survey Plan
ft	Feet(foot)
HS&E	Health, safety, and environmental
GWS	Gamma walkover survey
LDE	Lens Dose Equivalent
LMTA	Little Mountain Test Annex
Mg-Th	Magnesium-thorium
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
mrem/yr	Millirem per year
NRC	U.S. Nuclear Regulatory Commission
NUREG	Nuclear Regulatory Commission Guidance
Parsons	Parsons Infrastructure and Technology Group, Inc.
PBR	Performance-based remediation
^{214}Pb	Lead-214
pCi/g	Picocuries per gram
QA	Quality assurance
QC	Quality control

QCM	Quality Control Manager
^{226}Ra	Radium-226
RESRAD	RESidual RADioactivity
ROC	Radionuclide of concern
ROPC	Radionuclide of potential concern
SDE	Shallow Dose Equivalent
SOP	Standard operating procedure
SOR	Sum of Ratios
SOR_G	Sum of Ratios based on gross concentration
SOR_N	Sum of Ratios based on net concentration
SSHP	Site-Specific Health and Safety Plan
SSHO	Site Safety and Health Officer
SSV	Soil screening value
^{228}Th	Thorium-228
^{230}Th	Thorium-230
^{232}Th	Thorium-232
TEDE	Total Effective Dose Equivalent
^{234}U	Uranium-234
^{235}U	Uranium-235
^{238}U	Uranium-238
USAF	United States Air Force

1.0 Facility Operating History

Site WR111 is a former disposal area located in the southeast corner of the Little Mountain Test Annex (LMTA) of Hill Air Force Base (AFB) in northern Utah. The LMTA is federal government property. The area was used from 1957 to 1961 to dispose of magnesium-thorium (Mg-Th) excess scrap and waste material from the manufacture of aircraft and engine parts, which resulted in radiological impacts to surface and subsurface soil. The area consists of pits and/or trenches where the scrap and waste were buried or burned in a remote and controlled area of the annex. Site WR111 is the subject of this Decommissioning Plan, which is being prepared as part of Hill AFB Performance-Based Remediation (PBR) Contract No. FA8903-09-D-8560, Task Order 0006. The WR111 site is given U.S. Air Force (USAF) Permit # UT-00517-xx/xxAFP and Docket #040-00517. The authority for this permit is under USAF MML # 42-23539-xx and Docket # 030-28641 issued to USAF by the U.S. Nuclear Regulatory Commission (NRC). This decommissioning is being performed in accordance with the requirements for a Group 4 facility (NRC, 2006).

Construction of the Marquardt Aircraft Ramjet manufacturing plant in Ogden, Utah began in July 1956 and was completed in June 1957. The plant made rocket and missile engine parts for the USAF. The U.S. Atomic Energy Commission (AEC) issued a Source Material License to Marquardt Aircraft Company for the use of Mg-Th alloy in the manufacture of aircraft controls, accessories, and engine parts.

Located 15 miles west of Ogden, the Air Force-Marquardt Jet Laboratory, owned by the U.S. Air Force and operated by Marquardt, was a testing facility for the Ramjet engines manufactured in Ogden. This laboratory was within the LMTA of Hill AFB, a remote area west of Odgen, Utah, adjacent to the Great Salt Lake. The location of LMTA is presented on Figure 1-1. With approval from AEC, Marquardt disposed of Mg-Th alloy scrap material from the manufacturing processes in disposal pit(s) located in a remote and controlled area of LMTA. This burial/burn area is referred to as Site WR111, the Magnesium-Thorium Disposal Trench.

1.1 License Status and Authorized Activities

In 1957, AEC issued Source Material License C-3650 to Marquardt Aircraft Company of Van Nuys, California, for the possession and use of Mg-Th at its Ogden, Utah plant during the manufacture of aircraft controls, accessories, and engine parts. The maximum amount of thorium-232 (^{232}Th) allowed by this license was 4,600 pounds, or approximately 0.23 curie (Ci) of ^{232}Th.

In September 1961, Source Material License C-3650 expired and AEC issued License STB-434 for the Marquardt facility in Ogden. This license included permission to incinerate source material in accordance with AEC regulations associated with the treatment or disposal by incineration. According to historical records, the last incineration of scrap material onsite occurred in August 1961. License STB-434 was terminated in April 1971.

1.1.1 License Number/Status

Under the two licenses listed above, Marquardt, as the licensee, was authorized to use Mg-Th alloy from 1957 to 1971, including the burial or burning of scrap and waste material associated with the manufacturing process.

1.1.2 Authorized Activities

Authorized activities under the two AEC licenses included:

- Possess and use Mg-Th in the aircraft manufacturing processes up to the maximum amount of 4,600 pounds, or approximately 0.23 Ci of ^{232}Th
- Dispose of scrap material generated in the manufacturing processes by burning or burying machine chips and small pieces of Mg-Th scrap in disposal pits located in a remote and controlled area of LMTA. Documentation indicates the following:

  — 500 pounds of scrap Mg-Th were buried in June 1959.
  — 1,500 pounds were buried in February 1960.
  — 3,600 pounds were incinerated in August 1961.

Historical records indicate that this amount included sludge from the wet collectors from the pickling tanks (containing thorium fluoride), and lathe turnings/milling scraps (possibly containing cutting oil and/or solvents). No other documentation of disposal was identified in the docket files.

1.2 License History

AEC issued Source Material License C-3650 to Marquardt Aircraft Company of Van Nuys, California in 1957, for the possession and use of Mg-Th at its Ogden, Utah plant. The maximum amount of ^{232}Th allowed by this license was 4,600 pounds, or approximately 0.23 Ci of ^{232}Th.

In April 1959, Marquardt sent a letter to the AEC concerning disposition of Mg-Th scrap material. The licensee indicated that there was difficulty in finding a supplier who would accept its scrap material. In June 1961, Marquardt requested AEC approval to burn the machine chips and small pieces of Mg-Th scrap material accumulated at the Ogden facility. The licensee proposed to burn the material in pit(s) that were 10 feet (ft) deep, 8 ft wide, and 20 ft long that would be located in a remote controlled area of LMTA, which was government property. The area is now referred to as Site WR111.

In September 1961, Source Material License C-3650 expired and License STB-434 was issued for the Marquardt facility in Ogden. This license included permission to incinerate source material in accordance with AEC regulations associated with treatment or disposal of Mg-Th scrap material by incineration.

Available documents show that 500 pounds of scrap Mg-Th were buried in June 1959, 1,500 pounds were buried in February 1960, and 3,600 pounds were incinerated in August 1961. Historical records indicate that this amount included sludge from the wet collectors from the pickling tanks (containing thorium fluoride) and lathe turnings/milling scraps (possibly containing cutting oil and/or solvents).

License STB-434 terminated on 12 April 1971. No documentation is in NRC docket files to show that the AEC performed a closeout inspection or survey for this license or facility. In addition, the materials-disposition documentation was incomplete.

1.3 Previous Decommissioning Activities

No previous decommissioning activities have been performed at the Mg-Th Disposal Trench. When the U.S. Air Force identified elevated radioactive levels in the area between two soil mounds at Site WR111 (1994), a fence was constructed around the entire area to limit potential exposure.

1.4 Spills

No spills of hazardous substances have been reported in the area of Site WR111.

1.5 Prior Onsite Burials

The onsite burial and incineration of Mg-Th scrap material within LMTA are reported to have occurred between June 1959 and August 1961. During this time, 5,600 pounds of Mg-Th scrap, containing wet collector sludge from pickling tanks, and lathe turning/milling scraps were incinerated or disposed of in the disposal trench.

Historical records do not indicate any other disposal events prior to or after the termination of the STB-434 license in April 1971.

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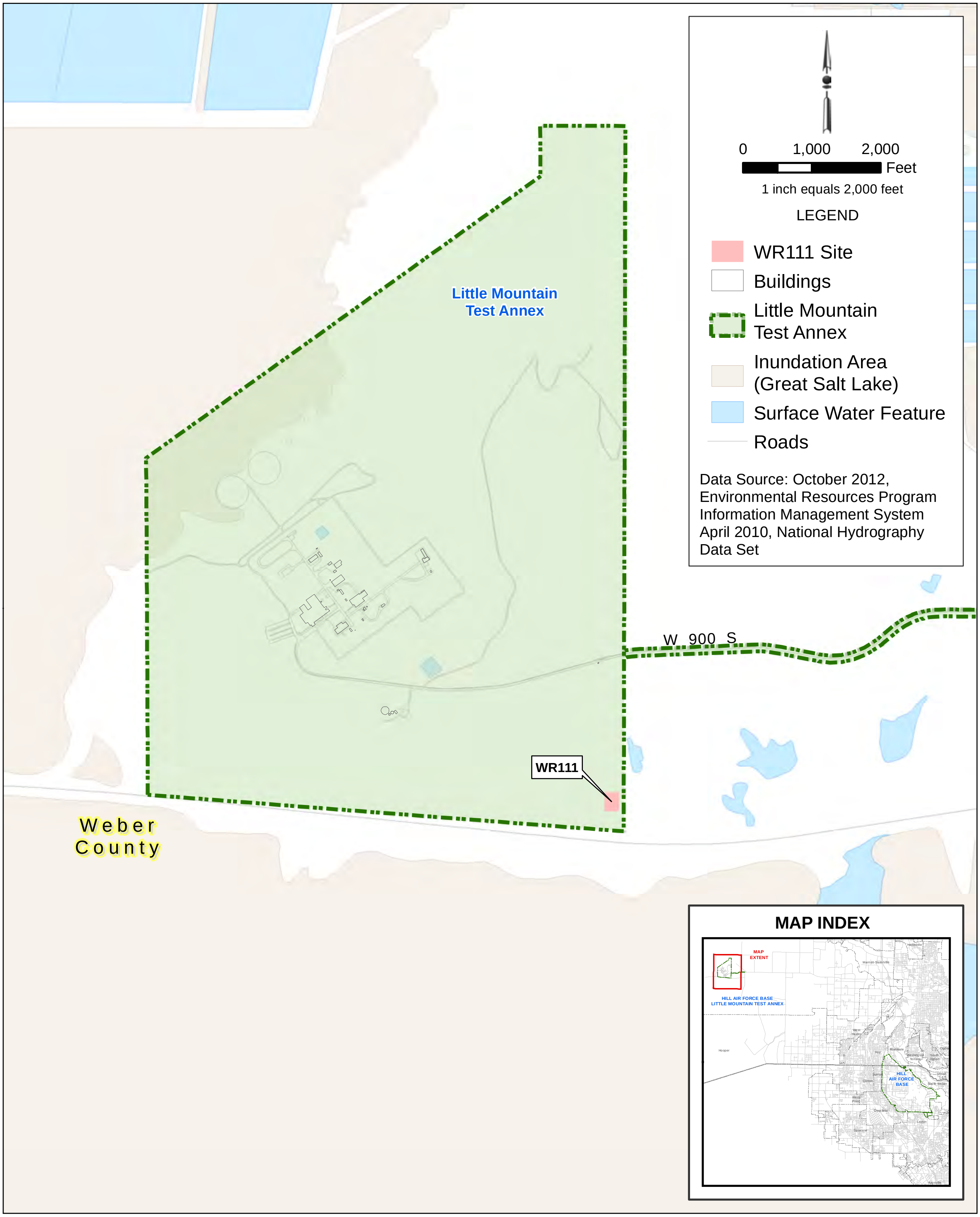
K:\arcgis\Cabrera GIS Projects\Hill AFB\MXDs\Figure 1-1 - Site Location.mxd 2/17/2014



75th AIR BASE WING

FIGURE 1-1
SITE LOCATION
WR111 DECOMMISSIONING PLAN
HILL AIR FORCE BASE, UTAH

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2.0 Facility Description

2.1 Site Location and Description

The LMTA is located in Weber County, Utah approximately 15 miles northwest of Hill AFB in a remote area adjacent to the Great Salt Lake and west of Ogden, Utah (Figure 1-1). Topographic contours in the area of LMTA and Site WR111 are shown on Figure 2-1. The site of the disposal trench is in the far southeast section of LMTA. The terrain in the area of Site WR111 is gently sloping at an approximate elevation of 4,245 ft above mean sea level. The former disposal trench area is roughly 0.5 acres in size and is situated between two small mounds of soil.

As shown on Figure 2-2, Site WR111 is located in the far southeast corner of the LMTA property. The LMTA fence line is approximately 70 ft to the east of the site WR111 boundary. The adjacent property to the east is owned by Weber County. Approximately 350 ft south of Site WR111 is the railroad right-of-way and marsh land, mud flats associated with the Great Salt Lake.

2.2 Population Distribution

The U.S. Census Bureau listed the total population of Weber County, Utah as 231,236 in 2010. This was an 8.5 percent increase over the 2000 census results. At this time, the population density was 342 people per square mile. Weber County has a total area of 659 square miles, 12.7 percent of which is water (84 square miles) and extends from the Watasch Mountains in the east to the eastern shore of the Great Salt Lake. The Weber and Ogden rivers and their tributaries run through the valleys of the Watasch front. The county is divided into the Lower Valley and Upper Valley. The Lower Valley, adjacent to the Great Salt Lake, is the more populous part of the county. The eastern part of the county, Upper Valley, consists of the Ogden Valley, the watershed of the Ogden River. Odgen, Utah is the largest city in the county.

2.3 Current/Future Land Use

The LMTA is located in a remote area of Weber County near the eastern shoreline of the Great Salt Lake. The current land use in the vicinity of LMTA is considered military and industrial, with considerable rangeland present approximately 2 miles northeast of LMTA. Residential areas exist to the east of LMTA toward the communities of Plain City (northeast) and Ogden (east). The nearest residence is 2 miles east of Site WR111. Industrial parks or facilities exist approximately 1 mile to the northeast of the Site WR111 fence. Land use in the area of LMTA is not expected to change in the future; current research and development activities, as well as environmental restoration, will continue at LMTA under the direction of Hill AFB.

2.4 Meteorology and Climatology

Climatological data for this area from 1981 through 2010 are presented in Table 2-1. Ogden and the surrounding area experience a dry summer continental climate where the summers are hot and dry, with temperatures typically reaching 95 degrees Fahrenheit. Annual rainfall is typically less than 22 inches.

2.5 Geology and Seismology

Based on historical surface geological mapping and subsequent characterization efforts by EA Engineering, Science, and Technology, Inc. (EA)/Cabrera Services, Inc. (Cabrera), the subsurface at Site WR111 consists of slaty argillite with a thin veneer of surface sediment. The surface sediments or alluvium consist of sand, silt, and clay sequences of varying thicknesses. Geological cross sections for Site WR111 were prepared to represent the subsurface conditions based on the characterization investigations conducted in 2006, 2008, and 2013. Boring/sample locations and monitoring well locations at Site WR111 are shown on Figure 2-3. The boring logs and well construction details from these locations were used to prepare the generalized cross sections as shown on Figures 2-4, 2-5, and 2-6. Section A–A' on Figure 2-4 runs from north to south along the eastern boundary of Site WR111, Section B-B' on Figure 2-5 runs west to east in an area that showed elevated radiological sampling results, and Section C-C' on Figure 2-6 runs from the southwestern edge of Site WR111 to the lower southeastern boundary of Site WR111.

Bedrock within WR111 occurs at depths ranging from 2 to 13 ft bgs and is highly fractured. The bedrock surface occurs at a maximum depth of 13 ft bgs in the eastern portion of Site WR111 and shallows to 3 ft at the far western boundary of Site WR111 in the vicinity of WR702. Further west at monitoring well LM061, the bedrock surface, although weathered, is approximately 2 ft bgs.

The bedrock in the area of Site WR111 consists of two lithologic units, slate argillite and tillite. These units contact along a fault line in the south, which continues in a northwesterly direction. Monitoring wells LM-060 and LM- 063 are screened in the tillite, whereas LM-061 and LM-062 are screened in slate as shown in the boring logs (Appendix A). A north-trending fault on the east side of the fenced area is inferred from a surface escarpment in the area and the presence of tillite further south at LM-063. The bedrock stratigraphic sequence in the LMTA area consists of the slate overlain by a relatively thin clastic, calcareous unit, loosely-termed calcareous phyllite that transitions upward to a greenstone. The thick tillite overlays the calcareous phyllite and greenstone sequence (these are more thoroughly described in previous reports [Parsons 2007]). Tillite juxtaposed against the slate suggests a large offset along this fault with an apparent strike-slip component to the offset. Low water yield during drilling, development, and sampling of the site monitoring wells indicate low permeability of the bedrock at all well locations and limited groundwater flow. Low permeability is also consistent with the relatively steep hydraulic gradient observed.

2.6 Surface Water Hydrology

LMTA is within the Weber River Watershed. The Weber River Basin is a flat, fertile plain, which was formed by alluvial deposits from the former Lake Bonneville. The Ogden River is a major tributary to the Weber River and drains the Ogden Valley and the eastern portion of Weber County. The flow of the Weber River and its tributaries is controlled by reservoirs that have a great effect on water quality. The Willard Reservoir, commonly known as Williard Bay, is the last major reservoir in the Weber River Basin. Located on the shores of the Great Salt Lake, the Williard Reservoir is closest to Site WR111, and is used for irrigation in the lower basin as well as some recreational fishing and boating.

There are no surface water bodies or features within the boundaries of Site WR111. Great Salt Lake is the predominant surface water feature in the area, located approximately one mile west of Site WR111.

2.7 Groundwater Hydrology

Groundwater at this site occurs between 34 and 57 ft bgs, corresponding to an elevation range of approximately 4,208 to 4,185 ft above mean sea level. The site-specific groundwater flow direction is southerly with a southwesterly component. In 2006, four monitoring wells were installed in the vicinity of Site WR111 and were screened in bedrock (see Figure 2-3 for locations). Monitoring wells LM-060 (north) and LM-063 (east) are generally upgradient of the waste burial trench, and LM-062 (south) is directly downgradient of Site WR111. LM-061 is located approximately 250 ft west of the WR111 fence line. Low water yield during drilling, development, and sampling of the monitoring wells indicate low permeability of the bedrock at all well locations and limited groundwater flow. Low permeability is also consistent with the relatively steep hydraulic gradient observed.

2.8 Natural Resources

Located within the Great Salt Basin and Wasatch Valley, the area is known for its many natural resources and related benefits. High snowfall promotes the best snow for winter sports recreation. During other times of year, residents and tourists experience a dry desert environment and enjoy camping, fishing, hiking, and outdoor recreation. The area spans a range of geologies, elevation, climates, and uses. Natural resources of the Great Salt Lake shoreline support mineral extraction and brine shrimping industries. Commodities produced include salt, deicing materials, fertilizer, and magnesium metal.

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TABLE 2-1
Average Meteorological Data (1981-2010), Ogden, Utah
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench
Decommissioning Plan, Hill Air Force Base, Utah

Month	***Jan***	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***	***Year***
Record High degrees Fahrenheit	65	68	78	87	98	102	106	102	97	93	75	66	106
Average High degrees Fahrenheit	37	42.5	53.8	62.2	71.4	82.0	91.4	89.5	78.7	65.4	49.2	38.3	63.45
Average low degrees Fahrenheit	21.3	24.3	33.1	39.5	47.0	55.9	63.9	62.6	52.9	41.6	31.0	22.9	41.33
Record Low degrees Fahrenheit	-16	-11	3	17	21	33	37	34	29	11	-12	-12	-16
Precipitation inches	2.20	1.92	2.11	2.18	2.58	1.54	0.83	0.92	1.67	2.22	1.96	1.86	21.98
Snowfall inches	7.8	5.9	1.3	0.7	0	0	0	0	0	0.1	2.8	3.6	22.1
Average precipitation days (>0.01inch)	9.3	7.8	8.3	8.0	8.5	5.1	3.8	4.0	6.0	6.4	7.7	7.8	82.7
Average snowy days (>0.1 inch)	3.4	2.2	0.8	0.3	0	0	0	0	0	0.1	1.2	1.6	9.6

NOTE:
Source: National Oceanic and Atmospheric Administration, online weather data (http://www.nws.noaa.gov/climate).

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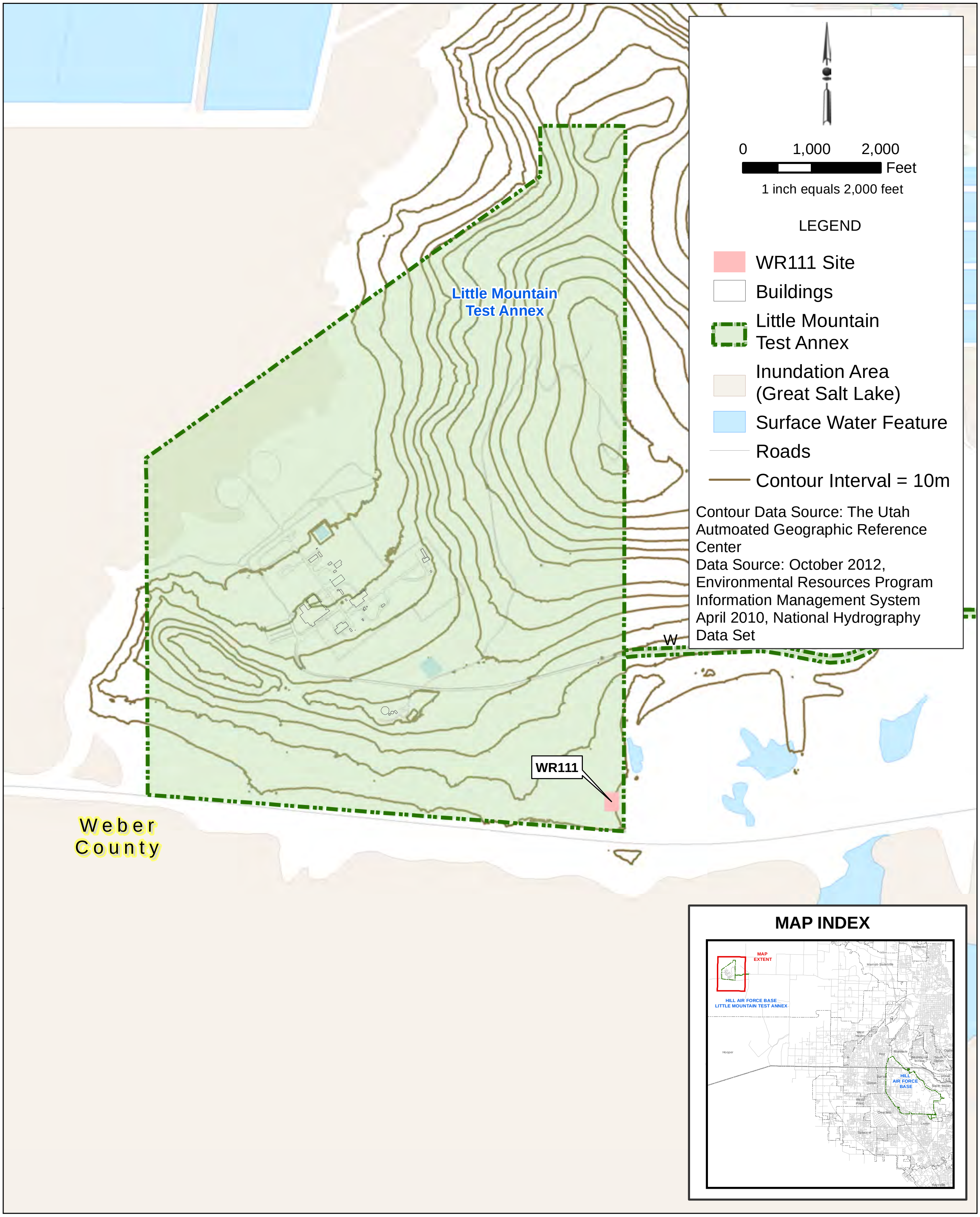

FIGURE 2-1
TOPOGRAPHIC FEATURES
WR111 DECOMMISSIONING PLAN
HILL AIR FORCE BASE, UTAH

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K:\arcgis\Cabrera GIS Projects\Hill AFB\MXDs\Figure 2-2 - Site Layout.mxd 2/17/2014 K. Wheatley

N

0 50 100 200 Feet

1 inch = 200 feet

Legend

Approximate Property Boundary

WR111 Magnesium Thorium Disposal Trench

Aerial: 2012, The Utah Automated Geographic Reference Center
Data Source: October 2012, Environmental Resources Program Information Management System

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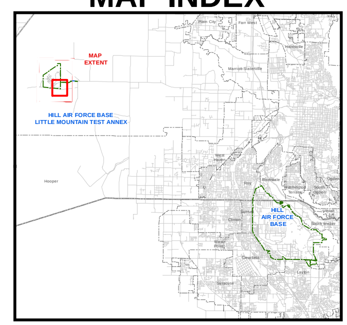

75th AIR BASE WING

FIGURE 2-2
SITE LAYOUT
WR111 DECOMMISSIONING PLAN
HILL AIR FORCE BASE, UTAH

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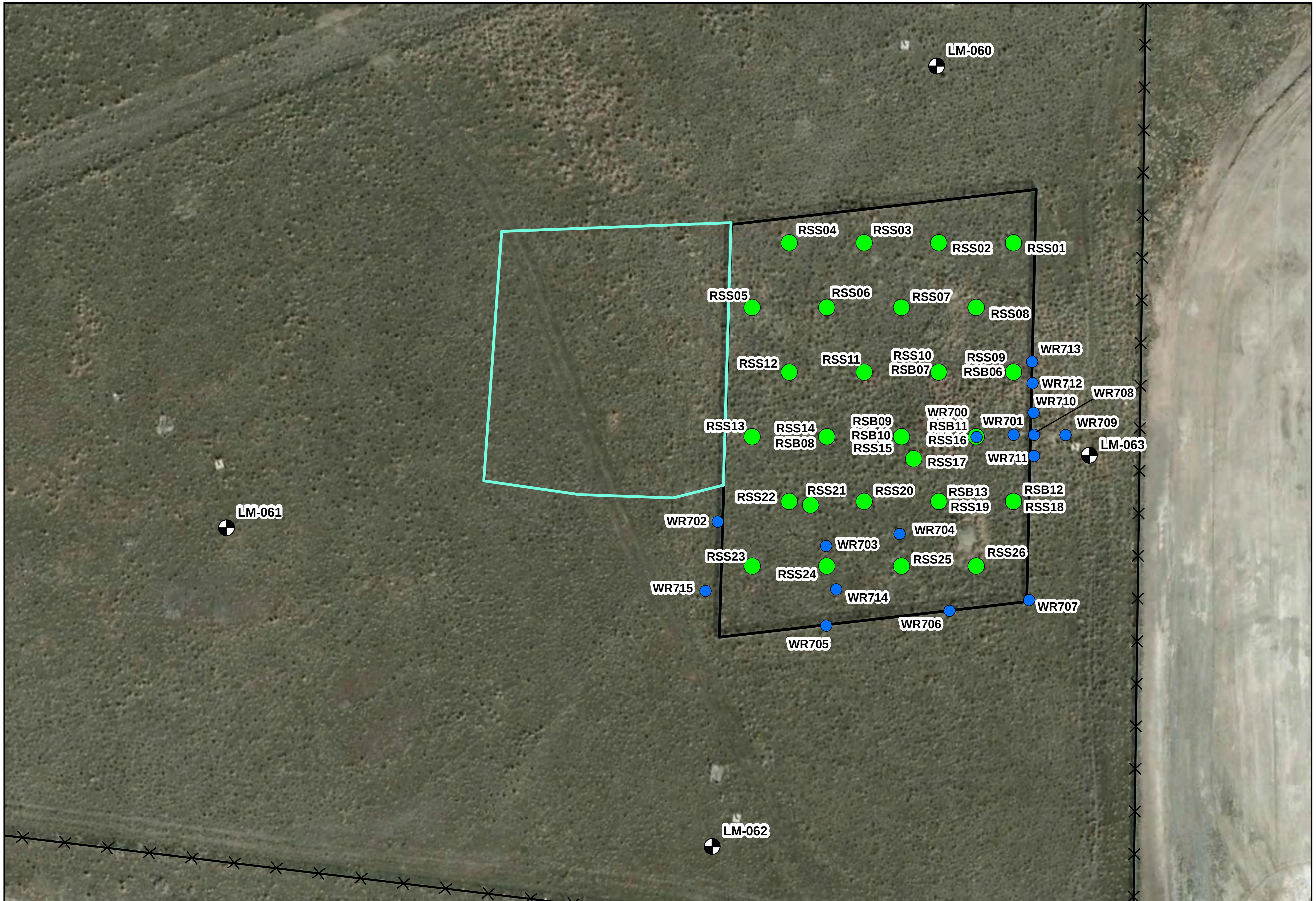
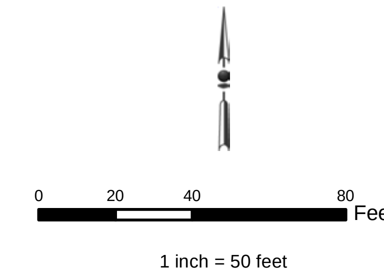
K:\arcgis\Cabrera GIS Projects\Hill AFB\MXDs\Figure 2-3 - Area of Investigation and Background Reference Area.mxd 2/17/2014 K. Wheatley





LEGEND

Sample Locations

Year Taken

- 2008
- 2013
- Monitoring Well Locations
- WR111 Fence
- Property Fence
- Background Reference Area

Aerial: 2012, The Utah Automated Geographic Reference Center
Data Source: October 2012, Environmental Resources Program Information Management System

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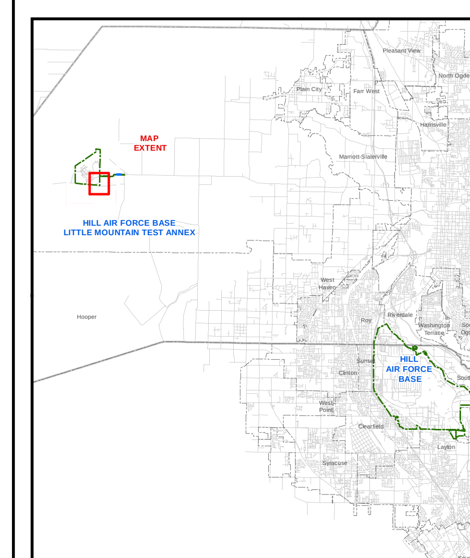

75th AIR BASE WING

FIGURE 2-3
AREA OF INVESTIGATION AND BACKGROUND REFERENCE AREA
WR111 DECOMMISSIONING PLAN
HILL AIR FORCE BASE, UTAH

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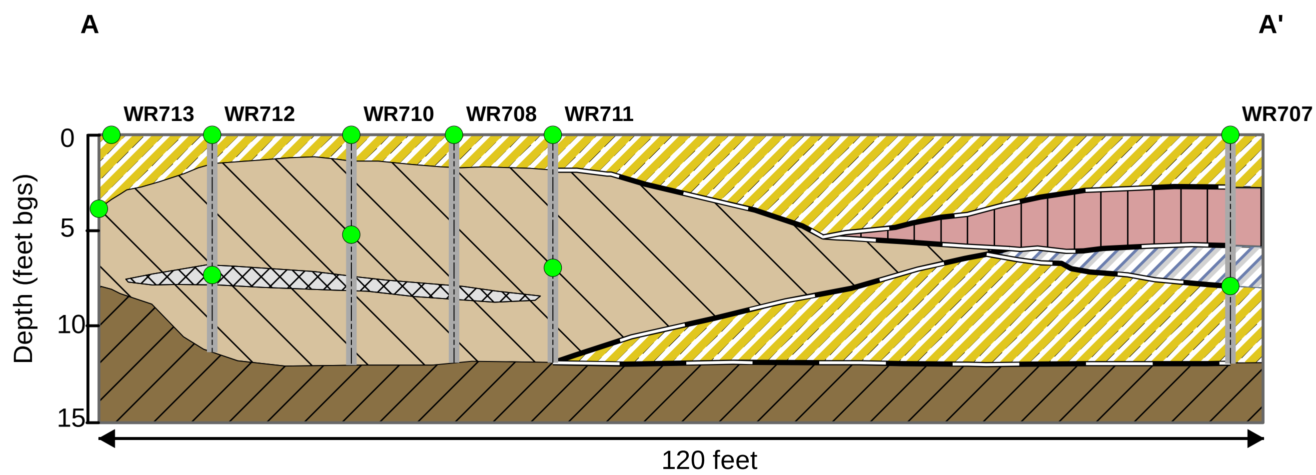
K:\arcgis\Cabrera GIS Projects\Hill AFB\MXDs\Figure 2-4 - Cross Section A-A'.mxd 2/17/2014 K. Wheatley



0 10 20
Feet
1 inch equals 20 feet

LEGEND

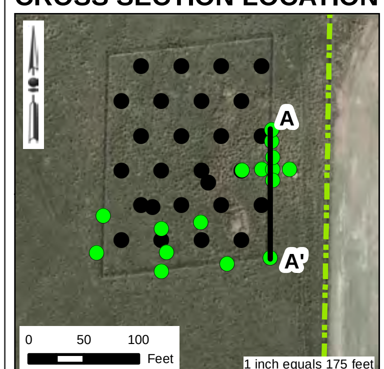
Soil Sample Location (2013)
Soil Boring
Inferred Soil Type

Soil Layers

Ash
Bedrock
Clayey Sand
Sand with Gravel
Silt/Sandy Silt
Silty Sand

Note:
Cross Section has a vertical exaggeration of 2x

CROSS SECTION LOCATION



Aerial: 2012, The Utah Automated Geographic Reference Center
Data Source: October 2012, Environmental Resources Program Information Management System

FIGURE 2-4
GEOLOGIC CROSS SECTION A-A'
WR111 DECOMMISSIONING PLAN
HILL AIR FORCE BASE, UTAH

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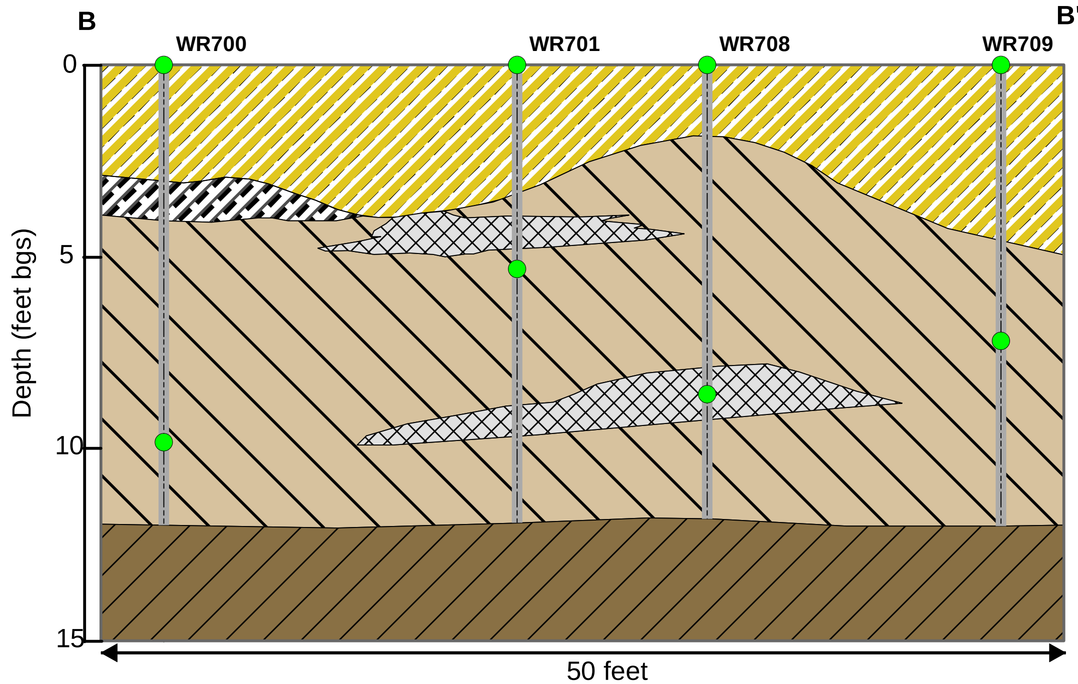
K:\arcgis\Cabrera GIS Projects\Hill AFB\MXDs\Figure 2-5 - Cross Section B-B'.mxd 2/17/2014 K. Wheatley



0 5 10
Feet
1 inch equals 10 feet

LEGEND

Soil Sample Location (2013)

Soil Boring

Soil Layers

Ash

Cobbles

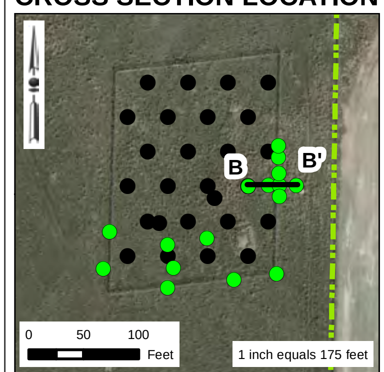
Bedrock

Silt/Sandy Silt

Clayey Sand

Note:
Cross Section has a vertical exaggeration of 2x

CROSS SECTION LOCATION



Aerial: 2012, The Utah Automated Geographic Reference Center
Data Source: October 2012, Environmental Resources Program Information Management System

FIGURE 2-5
GEOLOGIC CROSS SECTION B-B'
WR111 DECOMMISSIONING PLAN
HILL AIR FORCE BASE, UTAH

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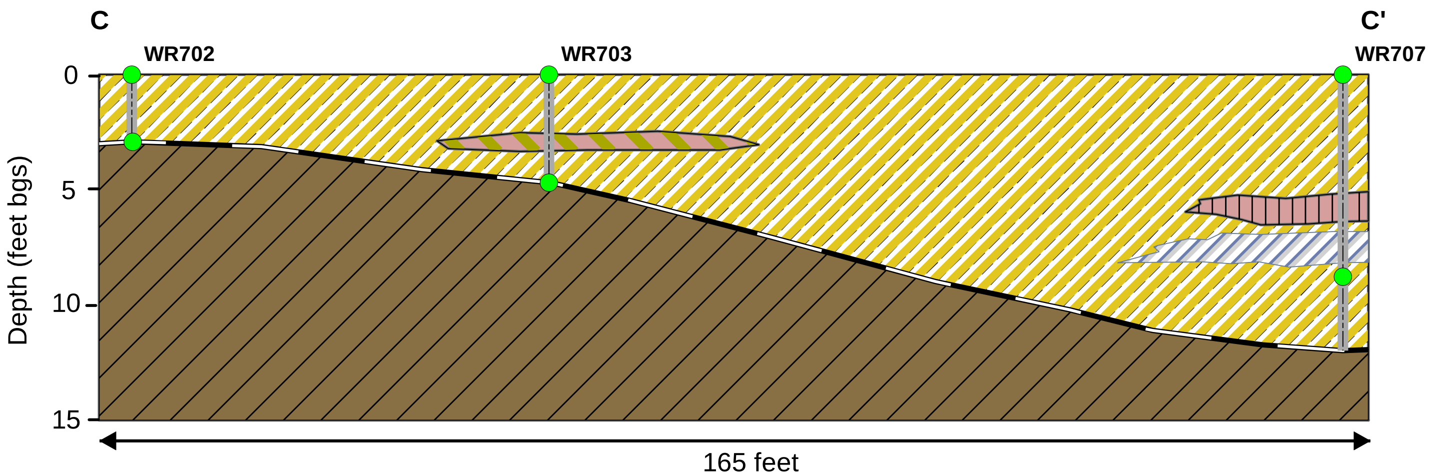
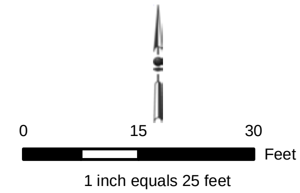
K:\arcgis\Cabrera GIS Projects\Hill AFB\MXDs\Figure 2-6 - Cross Section C-C'.mxd 2/17/2014 K. Wheatley





LEGEND

Soil Sample Location (2013)

Soil Boring

Inferred Soil Type

Soil Layers

Bedrock

Silt/Sandy Silt

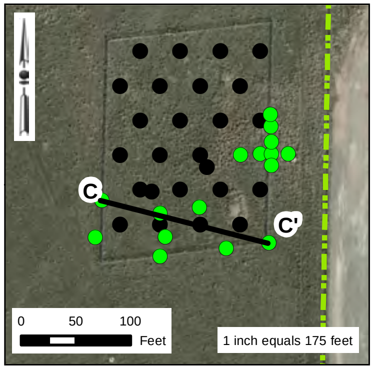
Clay/Silt

Silty Sand

Sand with Gravel

Note:
Cross Section has a vertical exaggeration of 3x

CROSS SECTION LOCATION



Aerial: 2012, The Utah Automated Geographic Reference Center
Data Source: October 2012, Environmental Resources Program Information Management System

FIGURE 2-6
GEOLOGIC CROSS SECTION C-C'
WR111 DECOMMISSIONING PLAN
HILL AIR FORCE BASE, UTAH

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3.0 Radiological Status of WR111

There have been five investigations conducted at Site WR111 between 1994 and 2013 to determine the nature and extent of radiological contamination. The results of these investigations show that radiological contamination in the form of residual ^{232}Th exists in the surface and subsurface soil. The investigations support the historical documentation that the radiological contamination originated from the Mg-Th scrap material that was deposited and burned onsite between 1959 and 1961. The *Radiological Disposal Site Characterization for Little Mountain Training Annex* (AECOM 2009) provided additional radiological information to define the extent of contamination but stated that residual ^{232}Th contamination may extend beyond the southern boundary of the fenced area. Therefore, a subsequent investigation was conducted in 2013 to evaluate the horizontal and vertical extent of radiological contamination at areas beyond the southern and eastern boundaries of the disposal trench to confirm the nature and extent of radiological impact in surface and subsurface soil at Site WR111. Section 3.1 summarizes each site investigation at Site WR111. Sections 3.2 through 3.4 summarize the nature and extent of radiological contamination at Site WR111. Appendices A and B provide the boring logs and a summary of radiological soil sampling analytical results from the 2013 characterization, respectively. Appendix A also includes monitoring well boring logs for four monitoring wells installed in the vicinity of Site WR111 but outside the area's designated boundaries.

3.1 Results of Site Investigations

3.1.1 Low Level Radioactive Waste Contamination Characterization (Jacobs Engineering Group, Inc. 1994)

In the early 1990s, a number of investigations were conducted at Site WR111. The results of the investigations were summarized in the *Final Summary Report: Low Level Radioactive Waste Contamination, LMTA* (Jacobs Engineering Group Inc. 1994), and according to the report:

- In 1993, the NRC performed an inspection at the LMTA and identified two disposal pits where the highest exposure rate was about twice the background exposure rate recorded in the vicinity.
- In 1993, the Hill AFB Radiation Safety Officer (RSO) collected 10 surface soil samples from a potential radioactive disposal area and a background surface soil sample. The results indicated that gross alpha concentrations for all 10 samples were greater than the background concentration.
- The Final Summary Report identified an area in the southeast corner of the LMTA as the radioactive disposal area, which is in the general vicinity of the elevated gamma measurements observed by NRC. The gamma-scan results for an area (north of the radioactive disposal area) also exhibited elevated count rates; however, these were within 25 percent of the area background and were subsequently determined not impacted by radiological contamination (Section 3.1.2).

3.1.2 Survey of Little Mountain Annex, Hill Air Force Base, Utah (U.S. Air Force Institute for Operational Health 2007)

In 2006, the U.S. Air Force Institute for Operational Health performed a Global Positioning System-referenced gamma radiation survey of various areas of interest at the LMTA (U.S. Air Force Institute for Operational Health 2007). The radioactive disposal area showed elevated gamma count rates. The area originally thought to be the disposal trench (north-northeast of WR111) did not show elevated gamma count rates. Therefore, U.S. Air Force Institute for Operational Health concluded that areas outside of the fenced radioactive disposal area were not impacted.

3.1.3 North Disposal Area, Thorium Site and Oil Emulsion Disposal Area Data Summary Report Little Mountain Test Annex Operable Unit A Remedial Investigation 2006 Program (Parsons 2007)

In 2006, Parsons conducted a remedial investigation of Operable Unit A at LMTA (Parsons 2007), which included Site WR111. As a part of the remedial investigation, four shallow bedrock monitoring wells (LM-060 through LM-063) were installed in the vicinity of WR111 (upgradient, downgradient, and sidegradient). In November 2006, samples from the four wells were collected and analyzed for volatile and semivolatile organic compounds, metals, water quality parameters, gross alpha and gross beta, select gamma emitters, and thorium isotopes. Thorium-228 (^{228}Th) and ^{232}Th were not detected in groundwater, indicating that Mg-Th impact is not migrating to groundwater. Low concentrations of thorium-230 (^{230}Th), which is direct progeny of ^{238}U, were identified in groundwater; however, the concentrations were random and less than 1 picocurie per liter, which is indicative of natural uranium decay. Gross alpha radiation was detected in the downgradient well only. Low levels of gross beta radiation were detected at all four wells. The Parsons report concluded that the random pattern of low-level detections of ^{230}Th, combined with the absence of ^{232}Th and ^{228}Th, represented radioactive decay of naturally occurring uranium rather than leaching of the scrap metal.

Bismuth-214 (^{214}Bi) and lead-214 (^{214}Pb), which are also ^{238}U progeny, and often used as surrogates to determine ^{226}Ra concentrations, were detected in both the upgradient and downgradient wells at WR111. A statistical evaluation was performed on the upgradient and downgradient data by assuming a null hypothesis that ^{214}Bi and ^{214}Pb concentrations in the upgradient and downgradient wells are equal. Sampling results and uncertainties associated with both samples were utilized to perform the statistical evaluation. The result of the evaluation did not reject the null hypothesis, which means that the activity concentration data for upgradient (assumed to be representative of background) and downgradient wells are essentially equal and the ^{238}U progeny are from a naturally occurring source and not the disposal trench. The 2007 Parsons report interpreted the data similarly and stated the same conclusion. Groundwater results for radiological constituents are provided in Table 3-4.

Volatile and semivolatile organic compounds were not detected in the groundwater. Metal detections in groundwater were considered to be consistent with background concentrations. The report concluded that the analytical results from monitoring wells in the vicinity of Site WR111 did not indicate groundwater contamination from the thorium alloy scrap metal.

3.1.4 Radiological Disposal Site Characterization for Little Mountain Training Annex (AECOM 2009)

From 2007 to 2009, AECOM performed an additional investigation to further assess site conditions at WR111. Investigative work included identifying and sampling appropriate background location(s), geophysical surveying to define site boundaries, performing gamma walkover survey (GWS) measurements with Global Positioning System mapping, and collection of surface and subsurface soil samples for radiological and chemical analytes (i.e., volatile and semi-volatile organic compounds).

A total of 26 surface soil samples and 14 subsurface soil samples were collected within the fenced area of Site WR111. In addition, AECOM collected 26 surface soil samples and 14 subsurface soil samples within a background reference area. All soil samples were analyzed via gamma spectroscopy at the American Radiation Services laboratory in Port Allen, Louisiana, with the six samples exhibiting the highest activity also analyzed for isotopic thorium via alpha spectroscopy. GWS results, soil sampling locations, sampling results, and the location of the background reference area are shown on Figure 3-1.

The characterization survey showed that there is radiological contamination of soil at Site WR111 in the form of residual ^{232}Th. Maximum ^{232}Th concentrations were reported to be 7.1 ± 0.4 and 99 ± 3 picocuries per gram (pCi/g) for surface soil and subsurface soil, respectively. The ^{232}Th mean background concentration for surface soils was calculated to be 1.65 ± 0.03 (pCi/g) and for subsurface soils was 1.60 ± 0.04 pCi/g (uncertainties are two standard deviations). The AECOM report concluded that site soils within the fenced radioactive disposal area were impacted with ^{232}Th and decay progeny above background levels (AECOM 2009), and the impacted area included the southern three-quarters of the fenced area with the highest measurements located on the eastern side of the site between the two onsite soil mounds (AECOM 2009). Based on the results of the geophysical conductivity survey that was conducted, the AECOM report concluded that the extent of the subsurface impact was limited to the eastern portion of the site between the soil mounds, which are within the WR111 fence line. Surface sample results indicated that residual ^{232}Th contamination in surface soil may extend beyond the southern and eastern boundaries of the fenced area (surveying and sampling was conducted only within the fenced area). While radium-226 (^{226}Ra) was also detected in the soil samples, the AECOM report indicated that the concentrations appeared to be consistent with background, and ^{226}Ra was not considered to be a site radionuclide of concern (ROC).

Sampling results from the investigation also showed that no volatile or semivolatile organic compounds were detected above reportable limits in soil.

3.1.5 Supplemental Site Characterization WR111 Little Mountain Test Annex (EA and Cabrera 2013)

In July 2013, EA and Cabrera performed a supplemental site characterization survey to confirm existing assumptions regarding impacted soil and confirm the nature and extent of radiological impact in surface and subsurface soil at Site WR111. Investigative activities included:

- Conducting a limited GWS of the central and southeastern portions of the site with a 3 ×3-inch sodium iodide detector coupled with a Global Positioning System, to identify areas of elevated activities and soil boring locations in areas beyond those previously identified as radiologically-impacted. GWS was performed with the detector 10 centimeters above the ground surface.

- Advancing 14 soil borings by direct-push technology and collecting subsurface soil samples using a steel macro-sampler core barrel (minimum 2-inch outside diameter) with acetate sleeves to a depth of 12-15 ft bgs. Core scans were obtained from each soil boring. Five out of the 14 boreholes did not advance to the investigational depth due to refusal and an additional two boreholes collapsed. As a result, downhole gamma readings were not collected from each soil boring.

- Scanning subsurface soil cores for radiological contamination using a 3 × 3-inch sodium iodide detector.

- Performing downhole gamma logging, in conjunction with core scanning, to select the location of biased subsurface soil samples. Downhole gamma measurements were conducted utilizing a Ludlum 44-2 (1 × 1-inch) sodium iodide detector not collimated with lead shielding. The instrument was lowered into the borehole to the target depth and one-minute static measurements were collected at half a foot intervals proceeding upward until the top of the borehole was reached.

- Selecting surface and subsurface soil intervals with the highest gross count rates for biased soil sampling.

- Collecting a total of 29 soil samples, including two duplicate samples, for radiological analyses at an offsite laboratory.

In addition to radiological analysis, three samples were submitted to the offsite laboratory for chemical analyses to support future disposal activities, including toxicity characteristic leaching procedure for U.S. Environmental Protection Agency (EPA)-regulated analytes, polychlorinated biphenyls, ignitability, corrosivity, and reactivity.

As part of the GWS, a Ludlum Model 2221 scaler/ratemeter and 3 × 3 sodium iodide detector were utilized to scan the soil surface for elevated gamma emissions in gross counts per minute. GWS data were collected in gross counts per minute from the ratemeter/scaler and automatically logged into the Global Positioning System unit once per second. The data logging protocol allowed for a data-density equivalent of two logged measurements per square meter of ground surface.

The surface GWS results were evaluated in order to select biased sample locations. The data were used to generate geospatial imaging for visual trend analysis and calculation of Z-scores. The Z-score method was used to provide the statistical evaluation of a data population for purposes of identifying data points that fell outside of the population mean and were within a specific confidence interval. In this usage, the Z-score method readily identifies small areas of elevated gamma activity (fluence) within a one-sided 99.5 percent confidence interval. The Z-scores were calculated by comparing each data point against the mean and standard deviation of the data set as a whole.

Data were reviewed to determine whether individual data points exceeded three times the standard deviation of the set (or Z-score ≥ 3.0-sigma) in order to identify spatial patterns or trends that might indicate relatively elevated activity and their corresponding locations. The GWS enabled project personnel to discern impacted areas to the south and east of the fence line. The Z-score results, which are shown on Figure 3-2, showed that elevated radiological activity was present in the central and southern areas of Site WR111.

Based on the results of previous investigations, field instrument readings of soil core scans and downhole gamma logging, and GWS, 29 soil samples were collected to support the supplemental characterization at Site WR111. These samples were submitted to the project laboratory, TestAmerica, and analyzed for natural radium, thorium, uranium isotopes and potassium-40 using gamma spectroscopy via EPA Method 901.1. Three of the samples had reported results of elevated ^{226}Ra and ^{232}Th. In order to obtain a more accurate ^{226}Ra activity value, the three samples were re-analyzed for ^{226}Ra via EPA Method 901.1M, which measures the ^{226}Ra daughter progeny (bismuth-214 [^{214}Bi] and lead-214]^{214}Pb]) at equilibrium. The three samples were also analyzed for isotopic thorium (including ^{228}Th, ^{230}Th, and ^{232}Th) by the alpha spectroscopy method EML HASL 300 Modified (Department of Energy 1997) in order to determine the source of the elevated ^{226}Ra activity (^{226}Ra is a daughter of ^{230}Th). One of the three elevated activity samples (analyzed by gamma spectroscopy) also had an elevated uranium concentration with high uncertainty. Therefore, all three samples were analyzed by Isotopic Uranium (including Uranium-234 [^{234}U], Uranium-235]^{235}U], and Uranium-238]^{238}U]) by EML HASL 300 Modified (Department of Energy 1997). Alpha spectroscopy is more accurate with a higher confidence level for reporting the activity of alpha emitting radionuclides. For this reason, the alpha spectroscopy results for the three reanalyzed samples (WR111-SB-WR701-BS-P-05, WR111-SB-WR708-BS-P-08, and WR111-SB-WR710-BS-P-05) were used during subsequent data evaluation activities. Appendices B-1 and B-2 include the offsite laboratory sampling results and offsite laboratory sampling report. Alpha spectroscopy results are provided in Table B-1 (pages 1 through 8) in Appendix B.

As a part of project requirements, quality indicator samples were also collected and were analyzed at offsite laboratory. These samples were collected concurrently with the primary environmental samples and equally represent the medium at a given time and location. Quality indicator samples consisted of the following types –laboratory control sample, lab duplicate, field duplicate, and method blank. The quality indicator samples are used to evaluate the usability of data. The identity of duplicate samples is held blind to the analysts and the purpose of these samples is to provide activity-specific, field-originated information regarding the homogeneity of the sampled matrix and the consistency of the sampling effort.

A data quality assessment (DQA) was performed to assess the quality of the offsite laboratory soil sampling results. Appendix B-3 presents the results of the DQA. The overall quality of the sampling information meets or exceeds the established project objectives. Data, as presented, have been qualified as usable, but estimated when necessary. Data produced for this project demonstrate that they can withstand scientific scrutiny, are appropriate for its intended purpose, are technically defensible, and are of known and acceptable precision, and accuracy. Data integrity has been documented through proper implementation of quality assurance (QA) and quality control (QC) measures.

The 2013 characterization resulted in delineating the extent of the radiological contamination along the eastern and southern perimeters of Site WR111. A detailed discussion of the analytical results is provided in Section 3.2.

3.2 Identification of Radionuclides of Potential Concern

Analytical data from the 2009 and 2013 investigations were combined to screen and identify the radionuclides of potential concern (ROPCs) for Site WR111. ROPCs are the radionuclides that have been detected in soil samples through laboratory analysis and have gone through the following two screening processes. ROPCs form the basis for evaluating site contamination and determining its nature and extent. Two types of screening were performed to identify ROPCs for the site and are summarized below:

- ***Data Reduction***—For radiological constituents, when secular equilibrium exists in the decay series, the activities of all members of the series will be the same. Measurement of the activity of one member of the series then provides the activities for all members of the series. Based on that:

  — ^{232}Th is assumed to be in secular equilibrium with respect to its short-lived daughter products. Therefore, sampling results for ^{232}Th are the same as that for its daughter products (^{228}Th, actinium-228, radium-228, lead-212, bismuth-212, and thallium-208). Therefore, ^{232}Th sampling results were utilized during the data evaluation.

  — ^{226}Ra is assumed to be in secular equilibrium with respect to its short-lived daughter products. Therefore, sampling results for ^{226}Ra are the same as that for its daughter products (^{214}Pb and ^{214}Bi). Therefore, ^{226}Ra sampling results were utilized during the data evaluation.

  — Similarly, ^{238}U is assumed to be in secular equilibrium with respect to its short-lived daughter products. Therefore, sampling results for ^{238}U are the same as that for its daughter product (thorium-234). Therefore, ^{238}U sampling results were utilized during the data evaluation.

- ***Weight-of-Evidence Screening***—The weight-of-evidence screening was performed for each radiological constituent that passed the data reduction screening. If the frequency of detection for a radiological constituent in a medium is 5 percent or less (i.e., a minimum of one detection out of 20 analytical results), generally, the radiological constituent is excluded from further evaluation. This rationale is consistent with EPA's Risk Assessment Guidance (EPA 1989). Under this screening, radiological constituents that were detected in less than 5 percent of the samples from a given medium may be artifacts in the data due to sampling, analytical, or other problems, and may not be related to site activities. Therefore, the following constituents were not included in the evaluation to identify the ROPCs: ^{235}U and its daughter product, actinium-227.

  — In addition, even though potassium-40 was detected in all samples, it was not considered as a ROPC since it is an essential nutrient and naturally occurring in soils. It is the predominant radioactive component in common foods and normal human tissues. The results of the screenings identified four ROPCs for Site WR111: ^{226}Ra, ^{230}Th, ^{232}Th, and ^{238}U. Further data evaluations used the sampling results for all four ROPCs to identify the radionuclides that need to be addressed in a remedial action at Site WR111.

3.3 Identification of Radionuclides of Concern

Sample results of ROPCs were evaluated using two methods to determine the ROCs for the site. These evaluations are discussed below.

3.3.1 Data Evaluation Based on Site-Specific Soil Screening Values

During this evaluation, individual sampling results for each ROPC were compared to each ROPC's corresponding site-specific soil screening value (SSV), thus defining ROCs and, therefore, areas where potential radiological contamination may be present. SSVs for each ROPC were calculated by adding site-specific soil background values to the Surface SSVs provided in NRC Regulatory Guidance (NUREG) 1757, Volume 2, Appendix H (NRC 2006). When the individual sampling result was found to be in excess of a corresponding site-specific SSV, the area associated with that result is potentially contaminated. Mean background values for two ROPCs (^{226}Ra and ^{232}Th) were established during the

2009 characterization survey (AECOM 2009). The surface soil arithmetic average background concentration was considered during the calculation of SSV for each ROPC. It should be noted that site-specific background for ^{230}Th was not calculated during the 2009 site characterization survey. As a conservative approach, the NRC's Surface SSV for ^{230}Th was used as its SSV. In addition, it should be noted that a wide range of ^{226}Ra background concentrations exist in the background reference area data set (2.4-6.2 pCi/g). Conservative calculation of the radium SSV as the mean background plus the NRC screening value (0.7 pCi/g – small relative to the background values) with a widely variable background distribution likely causes more sample results that are within the range of the background distribution to be considered exceedances.

The calculated site-specific SSVs are presented in Tables 3-1 and 3-2. A comparison for each ROPC with respect to its SSV for the sampling results from 2009 and 2013 are presented in Tables 3-1 and 3-2, respectively. ROPC results are bolded and grey shaded to indicate when the result is greater than its corresponding site-specific SSV. It should be noted that the conservative calculation of the radium soil screening value, which is the mean background plus the NRC screening value (0.7 pCi/g –– a small value relative to the background values), with a widely variable background distribution likely causes more sample results that are within the range of the background distribution to be considered potential exceedances.

For the 2009 site characterization samples, surface soil sampling results for nine ^{226}Ra samples and 12 ^{232}Th samples exceeded their corresponding SSVs. In addition, subsurface soil sample results for two ^{226}Ra samples and two ^{232}Th samples exceeded their corresponding SSVs. These results are shown in Table 3-1. All of these results in Table 3-1 are gamma spectroscopy results.

For the 2013 site characterization samples, only two surface soil sample results for ^{232}Th exceeded the corresponding SSVs. In addition, subsurface soil sampling results for two ^{226}Ra samples, three ^{230}Th samples, and six ^{232}Th samples exceeded their corresponding SSVs. These results are shown in Table 3-2. All of these results in Table 3-2 are gamma spectroscopy results, with the exception of samples WR111-SB-WR701-BS-P-05, WR111-SB-WR708-BS-P-08, and WR111-SB-WR710-BS-P-05, which are alpha spectroscopy results.

Sampling results for ^{226}Ra and/or ^{230}Th and/or ^{232}Th exceed their corresponding SSVs at 29 sample locations as presented in Tables 3-1 and 3-2 and shown on Figure 3-3. These exceedances indicate that potential radiological contamination may be present at those locations. Characterization sample results collected in 2009 and 2013 did not exceed the site-specific SSV for ^{238}U.

3.3.2 Data Evaluation based on the Sum-of-the-Ratios

When there are multiple ROCs present in the soil, the allowed soil concentration levels must follow the sum of the ratios (SOR). This will ensure that the sum of the individual fractions for each isotope to its individual site-specific SSV fraction does not exceed unity. The SOR at Site WR111 is calculated as follows:

$$\mathrm{SOR} = \frac{\mathrm{Ra\text{ - }226}_{\mathrm{Conc}}}{\mathrm{Ra\text{ - }226}_{\mathrm{SSV}}} + \frac{\mathrm{Th\text{ - }232}_{\mathrm{Conc}}}{\mathrm{Th\text{ - }232}_{\mathrm{SSV}}} + \frac{\mathrm{Th\text{ - }230}_{\mathrm{Conc}}}{\mathrm{Th\text{ - }230}_{\mathrm{SSV}}}$$

where

^{226}Ra Conc = Gross activity for ^{226}Ra
^{232}Th Conc = Gross concentration for ^{232}Th

^{230}Th Conc = Gross concentration for ^{230}Th
^{226}Ra SSV = Site-Specific SSV for ^{226}Ra
^{232}Th SSV = Site-Specific SSV for ^{232}Th
^{230}Th SSV = Site-Specific SSV for ^{230}Th

Two types of ratios were calculated for each sample based on the site and background soil sampling results for ^{226}Ra, ^{230}Th, and ^{232}Th and their corresponding site-specific SSVs:

- Ratio based on gross concentration (SOR_G)
- Ratio based on net concentration (SOR_N) (Net = Gross – Background Concentration).

When the SOR_N result in excess of unity is present in a specific area, potential radiological contamination may be present at that location. If the SOR_N result is below unity, no further evaluation may be required. Table 3-3 also presents the results of the ratios where the SOR_N results are greater than unity.

An example of a SOR_N calculation is provided below.

Sample WR111-SB-WR708-BS-P-08 had ^{226}Ra, ^{232}Th, and ^{230}Th results of 2.24 pCig, 190 pCi/g, and 58 pCi/g, respectively. The background concentrations for ^{226}Ra and ^{232}Th are 3.97 pCig and 1.65 pCi/g, respectively (^{230}Th was not evaluated in background), equaling net activities for ^{226}Ra, ^{232}Th, and ^{230}Th of -1.73 pCi/g, 188.4 pCi/g, and 58 pCi/g. The ^{226}Ra concentration is conservatively set to 0 pCi/g to not negatively bias SOR_N results. The SOR_N is then calculated as follows:

$$SOR_N = \frac{0\ \text{pCi/g}}{0.7\ \text{pCi/g}} + \frac{188.4\ \text{pCi/g}}{1.1\ \text{pCi/g}} + \frac{58\ \text{pCi/g}}{1.8\ \text{pCi/g}}$$

The SOR_N is calculated as 203.4 as shown in Table 3-3.

Based on the above evaluation of the 69 total samples, 32 samples had SOR_N results exceeding unity. As shown in Table 3-3 and Figure 3-3, three of the 32 sample locations (RSS07, RSS15, and RSS16) have SOR_N results exceeding unity, although the individual ROC concentrations are less than the site-specific SSVs at those locations. More detailed information regarding ROC exceedances is provided in Section 3.4.

3.3.3 Summary of Radionuclides of Concern Based on the Results of Data Evaluations

Four ROPCs (^{226}Ra, ^{230}Th, ^{232}Th, and ^{238}U) were identified for Site WR111. Two data evaluations were performed by comparing the sampling results for the four ROPCs with respect to their corresponding SSVs to identify the ROCs for Site WR111. The results of the evaluations showed that sampling results for 3 ROPCs (^{226}Ra and/or ^{230}Th and/or ^{232}Th) exceeded their corresponding SSVs as well as having SOR_N results exceeding unity at 29 sample locations. Additionally, three locations (RSS07, RSS15, and RSS16) had SOR_N results exceeding unity although the individual ROC concentrations were less than the site-specific SSVs unity. Therefore, ^{226}Ra, ^{230}Th, and ^{232}Th were identified as the ROCs for Site WR111.

The Mg-Th scrap material deposited in the disposal trench was chemically manufactured using thorium bearing ores. Most of the thorium used commercially has been extracted from the mineral monazite (NUREG 1717, 3.1.5). The monazite contains varying amount of uranium and ^{230}Th. Albert (1966) reported that monazite contains an activity of ^{230}Th equal to 11 percent of the activity of ^{232}Th and ^{228}Th.

In addition, ^{238}U decays to ^{230}Th, which decays to ^{226}Ra. This explains why both ^{226}Ra and ^{230}Th are present in the sample results.

3.4 Nature and Extent of Radiological Contamination

Results of the data evaluations performed in Section 3.3 were utilized to determine the nature and extent of the radiological contamination in the surface and subsurface soil based on comparison to generic SSVs. The results of the 2013 characterization survey were used to bound the limits of potential radiological contamination along the eastern and southern perimeters.

3.4.1 Surface and Subsurface Soil

A total of 39 surface and 30 subsurface soil samples were collected between the 2009 and 2013 characterization events at WR111. Sampling results for ^{226}Ra and/or ^{230}Th and/or ^{232}Th exceeded their corresponding SSVs at 29 of 69 sample locations, which resulted in the samples exceeding the SOR criterion of unity. Three additional sample locations have SOR_N results that exceed the SOR criterion of unity, even though sampling results for ^{226}Ra, ^{230}Th, and ^{232}Th at these locations did not exceed their corresponding SSVs. Sample locations exceeding the SSVs and/or SOR_N are presented on Figure 3-3.

A total of 14 surface soil locations exceeded the site specific SSV of 2.75 pCi/g for ^{232}Th. Concentrations ranged from 2.9 pCi/g in sample RSS13 to 9 pCi/g in sample RSS10. Nine locations exceeded the site specific SSV of 4.67 pCi/g for ^{226}Ra with concentrations ranging from 4.70 pCi/g in sample RSS13 to 8.7 pCi/g in sample RSS21. Figure 3-3 indicates that the majority of the elevated radiological activity in the surface soil is located in the southern two-thirds of Site WR111 with ^{232}Th being the dominant ROC. Only one subsurface soil location (4-5 ft) in the southwest portion of Site WR111 was reported to have a ^{232}Th concentration (3.17 pCi/g) that exceeded its SSV. The downhole gamma reading at that location is consistent with background measurements, indicating that only surface soil contamination exists in the western and southwest portion of Site WR111.

Since GWS identified elevated surface activities in the southern portion of Site WR111, additional soil samples outside the southern fence line were collected and submitted for radiological analysis. Results of the surface soil samples indicate that radiological impact is bounded along the southern fence line, although there is one sample location at the southwest corner that has a ^{232}Th concentration that slightly exceeds the SSV.

Eleven of 29 subsurface soil samples exceeded their respective SSVs for ^{232}Th, ^{230}Th, and ^{226}Ra. Nine exceeded the site-specific SSV for ^{232}Th with concentrations ranging from 2.76 pCi/g (sample RSB10 at a depth of 5 ft) to 563 pCi/g (sample WR111-SB-WR701-BS-P-05 at a depth of 5 ft). Three locations exceeded the site-specific SSV for ^{230}Th of 1.8 pCi/g (WR111-SB-WR701-BS-P-05 [373 pCi/g], WR111-SB-WR708-BS-P-08 [58 pCi/g], and WR111-SB-WR710-BS-P-05 [448 pCi/g]). These three samples also represent locations that were reanalyzed by alpha spectroscopy. Four subsurface soil sample locations exceeded the ^{226}Ra site specific SSV of 4.67 pCi/g. These locations included RSB07 (5 pCi/g) at a depth of 5 ft, RSB13 (5.6 pCi/g) at a depth of 2 ft, WR111-SB-WR701-BS-P-05 (11 pCi/g) at a depth of 5 ft, and WR111-SB-WR710-BS-P-05 (15.47 pCi/g) at a depth of 5 ft. It was shown in Figure 3-3 that elevated radiological activity in subsurface soil is present in the east-central portion including RSB10 and continuing eastward to WR701 and WR708. Those radiological activities are present at a depth of 5-10 ft bgs. Downhole gamma readings from soil borings in the east-central portion of the site indicate that the highest gamma readings are measured between 5 and 10 ft bgs. The downhole gamma readings after 10 ft are consistent with background gamma readings. Since radiological activity is located at least 5 ft bgs, the GWS instrumentation could not detect gamma activities at those locations due to shielding from surficial soils. Therefore, there is no apparent elevated activity at the eastern portion of the site (Figure 3-2). It should be noted that four borings (WR708, WR710, WR711, and WR712) are located to the east of the WR111 perimeter fence. This area of elevated activity is bounded to the north by boring WR713 and to the east by boring WR709 since the sample results for these borings indicate that ROPCs did not exceed their respective SSVs at those locations.

Two sample locations (WR111-SB-WR710-BS-P-05 and WR111-SB-WR701-BS-P-05), as shown on Figure 3-3, have elevated concentrations of ^{226}Ra and three locations (WR111-SB-WR701-BS-P-05, WR111-SB-WR708-BS-P-08, and WR111-SB-WR710-BS-P-05) have elevated concentrations of ^{230}Th. The highest concentrations for ^{232}Th were also identified at those same locations. Therefore, it can be concluded that the highest concentrations for ^{232}Th are co-located with respect to the highest concentrations of the other two ROPCs. Therefore, a remedial action conducted for ^{232}Th will also address the other ROPCs at the site.

3.4.2 Surface Water

The area of investigation does not contain any surface water features. The Great Salt Lake is the predominant surface water body in the area and is located about 100 ft from Site WR111. However, there is no mechanism for contaminant migration via surface water from Site WR111 and, therefore, surface water decommissioning activities are not warranted.

3.4.3 Groundwater

Natural thorium is not typically mobile in the environment and, therefore, is unlikely to leach into groundwater. The soil to water adsorption coefficient for thorium is high (60,000 square centimeters per gram). The higher the soil to water adsorption coefficient value, the more likely the radionuclide will attract to the soil and the least likely for the radionuclide to leach into the groundwater. The water adsorption coefficient for thorium suggests a strong affinity for adsorbing to soil. At Site WR111, the lack of thorium mobility is confirmed based on a review of groundwater quality data that were obtained from four monitoring wells at the site, as summarized in the *Final North Disposal Area, Thorium Site, Oil Emulsion Disposal Area Data Summary Report Little Mountain Test Annex Operable Unit A Remedial Investigation Report 2006 Program* (Parsons 2007). In Table C.2 of the Parsons report, upgradient, sidegradient, and downgradient radionuclide sampling results show no detection of ^{232}Th and ^{228}Th in groundwater at any of the wells. Low concentrations of ^{230}Th (progeny of ^{238}U) were identified in groundwater at all wells but the concentrations are random and less than 1 picocurie per liter, which is indicative of natural uranium decay. Low concentrations of ^{214}Bi and ^{214}Pb (surrogates for ^{226}Ra) progeny from the naturally occurring uranium decay chain were also detected at approximately equal concentrations in the upgradient, sidegradient, and downgradient wells.

Based on the groundwater data and the analysis above, and consistent with the conclusions provided in the Parsons report, radiological concentrations in groundwater are due to natural uranium decay and are not associated with the Mg-Th alloy. As such, groundwater decommissioning activities are not warranted for Site WR111.

TABLE 3-1
Radionuclides of Concern Exceedances – 2009
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench
Decommissioning Plan, Hill Air Force Base, Utah

		Concentration (pCi/g)			
Radionuclides		**^{232}Th+C**		**^{226}Ra**	
Site-Specific Soil Screening Values (SSVs)[a]		**2.75 pCi/g**		**4.67 pCi/g[a]**	
Sample Identification	**Depth (ft)**	**Result[b]**	**±TPU**	**Result [b]**	**±TPU**
		Surface Soil Sampling Results (in pCi/g)			
RSS02	0-1	1.71	0.16	**6**	0.8
RSS06	0-1	1.87	0.17	**5.2**	0.9
RSS09	0-1	2.28	0.17	**5.4**	0.8
RSS10	0-1	**9**	0.4	**—**	
RSS11	0-1	2.1	0.2	**5.8**	0.7
RSS13	0-1	**2.9**	0.2	**4.7**	0.8
RSS14	0-1	**3.05**	0.2	3.3	0.6
RSS17	0-1	**7.1**	0.4	**—**	
RSS19	0-1	**3.5**	0.2	4.3	0.9
RSS20	0-1	**5.2**	0.3	**6.5**	1.1
RSS21	0-1	**4.8**	0.3	**8.7**	1
RSS22	0-1	**4**	0.2	3.3	0.6
RSS23	0-1	**4.5**	0.3	4.1	0.8
RSS24	0-1	**4.3**	0.2	**5.6**	0.8
RSS25	0-1	**3.7**	0.2	3.5	0.9
RSS26	0-1	**3.44**	0.2	**5.9**	0.9
		Subsurface Soil Sampling Results (pCi/g)			
RSB07	5-6	1.88	0.13	**5**	0.6
RSB10	5-6	**2.76**	0.16	3.5	0.6
RSB11	7-8	**99**	3	3.1	1.8
RSB13	2-3	2.51	0.16	**5.6**	0.7

NOTES:

a. Source: Table H.2 of Appendix H in NUREG 1757 Volume 2 (NRC, 2006). The conservative calculation of the radium soil screening value as the mean background plus the Nuclear Regulation Commission screening value (0.7 pCi/g – a small value relative to the background values) with a widely variable background distribution likely causes more sample results that are within the range of the background distribution to be considered exceedances.

b. Radionuclide concentrations are gamma spectroscopy analysis results. Samples were analyzed at the American Radiation Services laboratory in Port Allen, Louisiana.

pCi/g = picocuries per gram
^{226}Ra = Radium-226
^{232}Th+C = Thorium-232 plus daughter products
TPU = Total Propagated Uncertainty

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TABLE 3-2

Radionuclides of Concern Exceedances – 2013

WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench Decommissioning Plan, Hill Air Force Base, Utah

Radionuclide		^{226}Radium			^{230}Thorium			^{232}Thorium		
Site-Specific Soil Screening Values (SSVs)[a]		4.67 picoCuries/gram[(a)]			1.8 picoCuries/gram[(b)]			2.75 picoCuries/gram		
Soil Sample Locations	Depth (ft)	Result	±TPU	MDC	Result	±TPU	MDC	Result	±TPU	MDC
	Surface Soil Sampling Results (pCi/g)									
WR111-SB-WR714-SS-P-00	0-1	1.38	0.32	0.25	NA	NA	NA	**3.63**	0.58	0.31
WR111-SB-WR715-SS-P-00	0-1	1.44	0.29	0.20	NA	NA	NA	**3.64**	0.59	0.22
	Subsurface Soil Sampling Results (pCi/g)									
WR111-SB-WR700-BS-P-09	9-10	1.26	0.35	0.30	NA	NA	NA	**3.04**	0.57	0.28
WR111-SB-WR701-BS-P-05[c]	5-6	**11.00**	2.41	2.31	**373**	89	1.81	**563**	122	3.26
WR111-SB-WR703-BS-P-04	4-5	2.08	0.38	0.22	NA	NA	NA	**3.17**	0.49	0.12
WR111-SB-WR708-BS-P-08[c]	8-9	**2.24**[d]	0.88	1.25	**58.00**	26.90	4.13	**190.00**	55.10	2.83
WR111-SB-WR710-BS-P-05[c]	5-6	**15.47**	3.39	2.97	**448.00**	100.00	2.59	**222.00**	59.40	1.64
WR111-SB-WR711-BS-P-07	7-8	1.16	0.30	0.23	NA	NA	NA	**2.85**	0.49	0.35
WR111-SB-WR712-BS-P-07	7-8	2.28	0.88	0.85	NA	NA	NA	**63.90**	6.83	1.15

NOTES:

a. Source: Table H.2 of Appendix H in NUREG 1757 Volume 2 (NRC, 2006). It should be noted that the conservative calculation of the radium SSV as the mean background plus the NRC screening value (0.7 pCi/g - small relative to the background values) with a widely variable background distribution likely causes more sample results that are within the range of the background distribution to be considered exceedances.

b. Screening value does not include background concentration for ^{230}Th since there is not one available for the site.

c. Radionuclide concentrations are alpha spectroscopy analysis results. All other concentrations are gamma spectroscopy analysis results. Samples were analyzed at TestAmerica laboratory in St. Louis, Missouri.

d. Sample result was reported as undetected for that location

ft = Feet.

MDC = Minimal detectable concentration.

NA = Not analyzed.

TPU = Total propagated uncertainty.

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TABLE 3-3
Calculation of the Sum-of-the-Ratios
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench
Decommissioning Plan, Hill Air Force Base, Utah

	^{226}Ra (pCi/g)	**^{230}Th (pCi/g)**	**^{232}Th (pCi/g)**	**SOR_G (pCi/g)**	**SOR_N (pCi/g)**
Screening Values	0.7	1.8	1.1		
Background Values	3.97		1.65		
Calculation of Gross and Net Sum-of-the-Ratios					
Sample Identifications	**^{226}Ra (pCi/g)**	**^{230}Th (pCi/g)**	**^{232}Th (pCi/g)**	**SOR_G (pCi/g)**	**SOR_N (pCi/g)**
WR111-SB-WR700-BS-P-09	1.26	Not Analyzed	3.04	4.56	**1.3**
WR111-SB-WR701-BS-P-05	11	373	563	734.75	**727.6**
WR111-SB-WR703-BS-P-04	2.08	Not Analyzed	3.17	5.85	**1.4**
WR111-SB-WR708-BS-P-08	2.24	58	190	208.15	**203.4**
WR111-SB-WR710-BS-P-05	15.47	448	222	472.81	**465.6**
WR111-SB-WR711-BS-P-07	1.16	Not Analyzed	2.85	4.25	**1.1**
WR111-SB-WR712-BS-P-07	2.28		63.9	61.35	**56.6**
WR111-SB-WR714-SS-P-00	1.38		3.63	5.27	**1.8**
WR111-SB-WR715-SS-P-00	1.44		3.64	5.37	**1.8**
RSS02	6.00		1.71	10.13	**3.0**
RSS06	5.20		1.87	9.13	**2.0**
RSS07	4.60		2.06	8.44	**1.3**
RSS09	5.40		2.28	9.79	**2.6**
RSS10	0.00		9.00	8.18	**6.7**
RSS11	5.80		2.10	10.19	**3.0**
RSS13	4.70		2.90	9.35	**2.2**
RSS14	3.30		3.05	7.49	**1.3**
RSS15	4.60		1.86	8.26	**1.1**
RSS16	4.60	Not Analyzed	2.13	8.51	**1.3**
RSS17	0.00		7.10	6.45	**5.0**
RSS19	4.30		3.50	9.32	**2.2**
RSS20	6.50		5.20	14.01	**6.8**
RSS21	8.70		4.80	16.79	**9.6**
RSS22	3.30		4.00	8.35	**2.1**
RSS23	4.10		4.50	9.95	**2.8**
RSS24	5.60		4.30	11.91	**4.7**
RSS25	3.50	Not Analyzed	3.70	8.36	**1.9**
RSS26	5.90		3.44	11.56	**4.4**
RSB07	5.00		1.88	8.85	**1.7**
RSB10	3.50		2.76	7.51	**1.0**
RSB11	3.10		99.00	94.43	**88.5**
RSB13	5.60		2.51	10.28	**3.1**

NOTES:
^{226}Ra = Radium-226.
^{230}Th = Thorim-230.
^{232}Th = Thorium-232.
pCi/g = Picocuries per gram.
SOR_G = Sum of Ratios – Gross.
SOR_N = Sum of Ratios – Net.

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TABLE 3-4
LMTA Operable Unit A 2009 Remedial Investigation Groundwater Analytical Detections
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench
Decommissioning Plan, Hill Air Force Base, Utah

			Sample Location	LM-060-1				LM-060-1			
			Depth (feet)	19				Field Duplicate			
Analysis	Analyte	Units	MCL	Value	MDL	RL	Flag	Value	MDL	RL	Flag
Thorium Isotopes	Thorium-230	PCI/L		0.22	0.18	0.18		0.38	0.13	0.13	
Gross Alpha/Beta	Alpha, Gross	PCI/L									
	Beta, Gross	PCI/L		16	15	15		14.9	14	14	
Gamma	Bismuth-214	PCI/L		75	27	27		71	26	26	
	Lead-214	PCI/L		84	32	32		56	32	32	

NOTES:
1. Only detected radiochemicals are listed.
2. Data are verified and flags are applied per HAFB Basewide QAPP Table 12-1.
3. MCL = Safe Drinking Water Act Maximum Contamination Level.
4. MDL = Sample specific method detection limit.
5. RL = Sample specific reporting limit.
6. PCI/L = Picocuries per liter.
7. Underlined data signifies that the value exceeds the MCL.
8. J = Result is estimated due to associated QC problems, or the value is between the RL and MDL.
9. Locations of monitoring wells LM-060, LM-061, LM-062, and LM-063 are shown in Figure 2-3 of this plan.

TABLE 3-4 Cont.
LMTA Operable Unit A 2009 Remedial Investigation Groundwater Analytical Detections
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench
Decommissioning Plan, Hill Air Force Base, Utah

			Sample Location	LM-061-1				LM-062-1			
			Depth (feet)	34				24			
Analysis	Analyte	Units	MCL	Value	MDL	RL	Flag	Value	MDL	RL	Flag
Thorium Isotopes	Thorium-230	PCI/L		0.14	0.12	0.12		0.25	0.12	0.12	
Gross Alpha/Beta	Alpha, Gross	PCI/L						19	16	16	
	Beta, Gross	PCI/L		12	8.2	8.2		44	16	16	
Gamma	Bismuth-214	PCI/L		85	31	31					
	Lead-214	PCI/L		81	30	30					

NOTES:
1. Only detected radiochemicals are listed.
2. Data are verified and flags are applied per HAFB Basewide QAPP Table 12-1.
3. MCL = Safe Drinking Water Act Maximum Contamination Level.
4. MDL = Sample specific method detection limit.
5. RL = Sample specific reporting limit.
6. PCI/L = Picocuries per liter.
7. Underlined data signifies that the value exceeds the MCL.
8. J = Result is estimated due to associated QC problems, or the value is between the RL and MDL
9. Locations of monitoring wells LM-060, LM-061, LM-062, and LM-063 are shown in Figure 2-3 of this plan.

TABLE 3-4 Cont.
LMTA Operable Unit A 2009 Remedial Investigation Groundwater Analytical Detections
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench
Decommissioning Plan, Hill Air Force Base, Utah

			Sample Location	LM-063-1			
			Depth (feet)	34			
Analysis	Analyte	Units	MCL	Value	MDL	RL	Flag
Thorium Isotopes	Thorium-230	PCI/L		0.12	0.12	0.12	
Gross Alpha/Beta	Alpha, Gross	PCI/L					
	Beta, Gross	PCI/L		114	66	66	
Gamma	Bismuth-214	PCI/L					
	Lead-214	PCI/L		38	22	22	

NOTES:
1. Only detected radiochemicals are listed.
2. Data are verified and flags are applied per HAFB Basewide QAPP Table 12-1.
3. MCL = Safe Drinking Water Act Maximum Contamination Level.
4. MDL = Sample specific method detection limit.
5. RL = Sample specific reporting limit.
6. PCI/L = Picocuries per liter.
7. Underlined data signifies that the value exceeds the MCL.
8. J = Result is estimated due to associated QC problems, or the value is between the RL and MDL
9. Locations of monitoring wells LM-060, LM-061, LM-062, and LM-063 are shown in Figure 2-3 of this plan.

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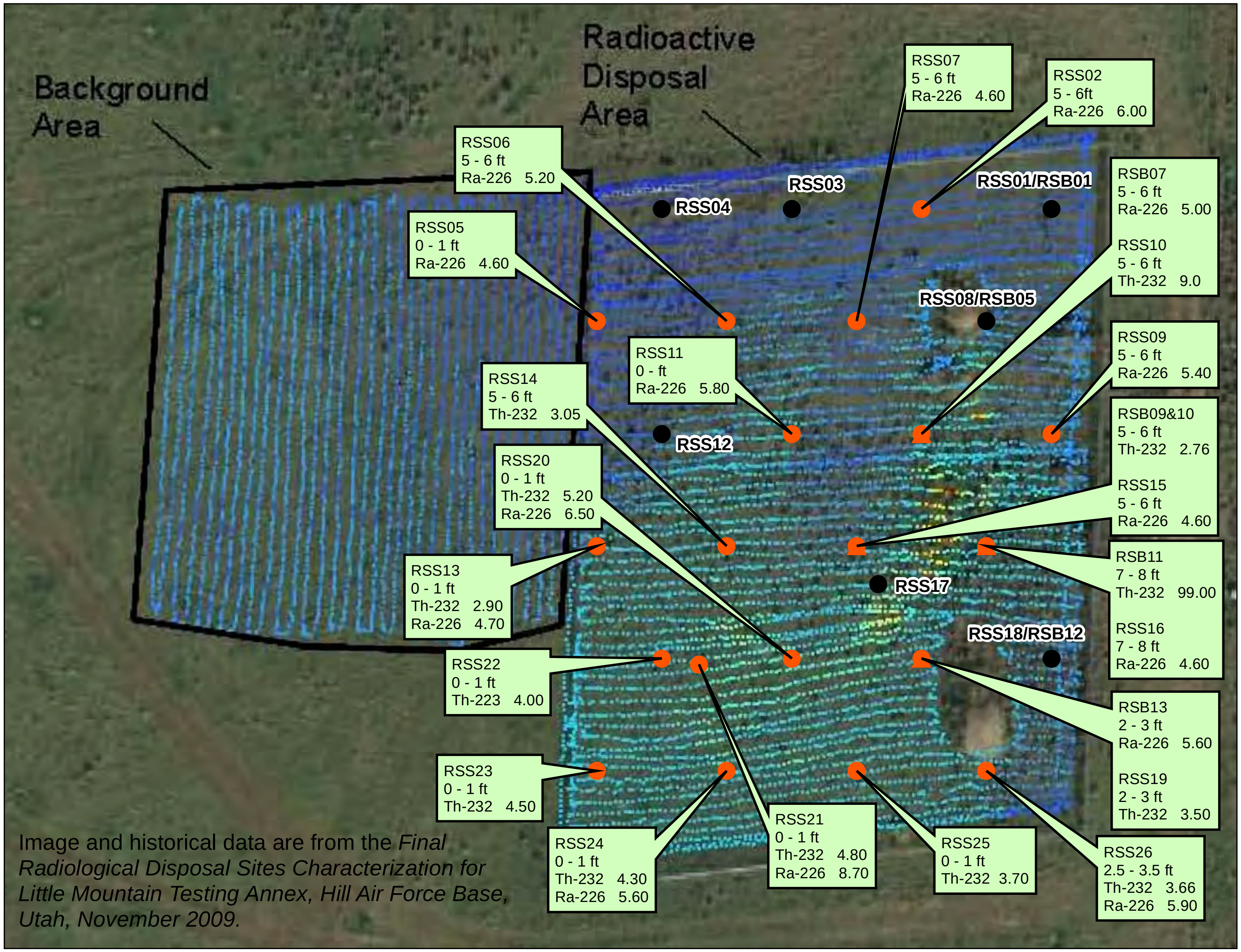

0 25 50 Feet

1 inch equals 45 feet

LEGEND

Historical Sample Locations (Approximate)

- Sample Locations Exceeding Screening Level (Surface)
- Sample Locations Exceeding Screening Level (Subsurface)
- Sample Locations Not Exceeding Screening Level (Surface or Subsurface)

Sample ID
Depth in feet
Thorium-232 Result (pCi/g)
Radium-226 Result (pCi/g)

Note:
Gamma Walkover Survey Results - results range from 108,201 to 547,096 counts per minute (cpm). Higher cpm are yellow to orange. Source: AECOM, 2009

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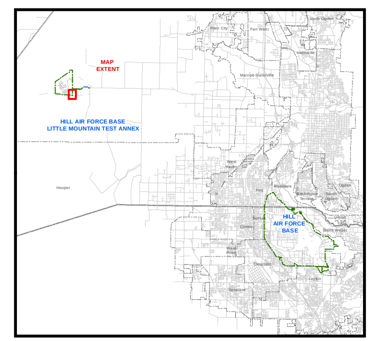

FIGURE 3-1
SURVEY RESULTS AND GAMMA WALKOVER
WR111 DECOMMISSIONING PLAN
HILL AIR FORCE BASE, UTAH

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K:\arcgis\Cabrera GIS Projects\Hill AFB\MXDs\Figure 3-2 - Gamma Walkover Results (2013).mxd 2/17/2014 K. Wheatley

FIGURE 3-2
GAMMA WALKOVER SURVEY RESULTS (2013)
WR111 DECOMMISSIONING PLAN
HILL AIR FORCE BASE, UTAH

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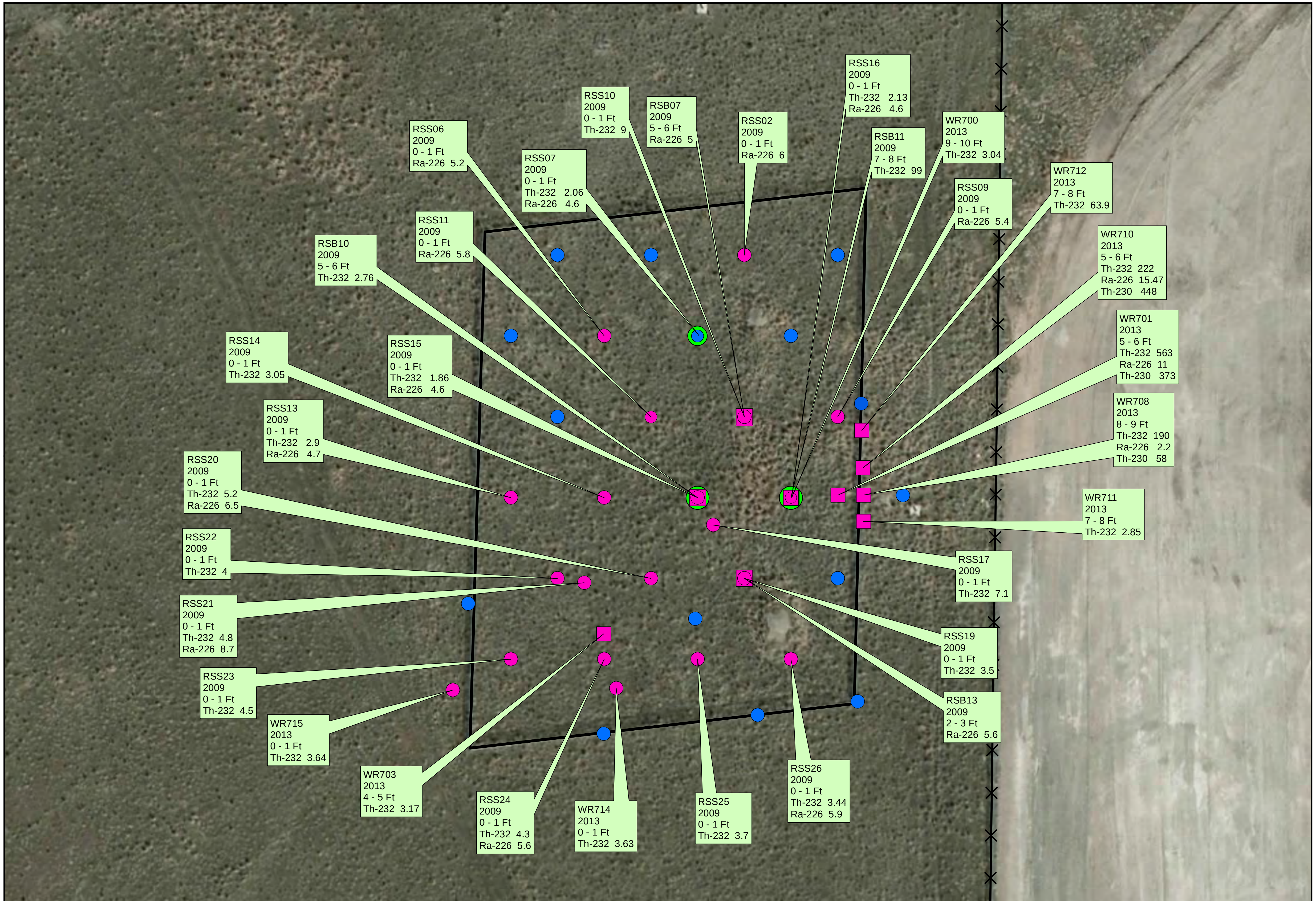

0 10 20 40 Feet
1 inch = 40 feet

LEGEND

Soil Sample Location

- Surface Sample
- Subsurface Sample
- Indicates results exceed at least 1 generic screening value (screening values are shown below)
- Indicates results less than generic screening values
- Result SOR > 1.0 and less than Generic Screening Values
- WR111 Fence
- Property Fence

Sample ID
Year
Depth (Ft bgs)
Thorium-232 Result (pCi/g)
Radium-226 Result (pCi/g)
Thorium-230 Result (pCi/g)

Notes:
pCi/g = picocuries per gram
Ft = Feet
bgs = Below ground surface
SOR = Sum of Ratios

Screening Values
Th-232 = 2.75 pCi/g
Ra-226 = 4.67 pCi/g
Th-230 = 1.8 pCi/g

Aerial: 2012, The Utah Automated Geographic Reference Center
Data Source: October 2012, Environmental Resources Program Information Management System

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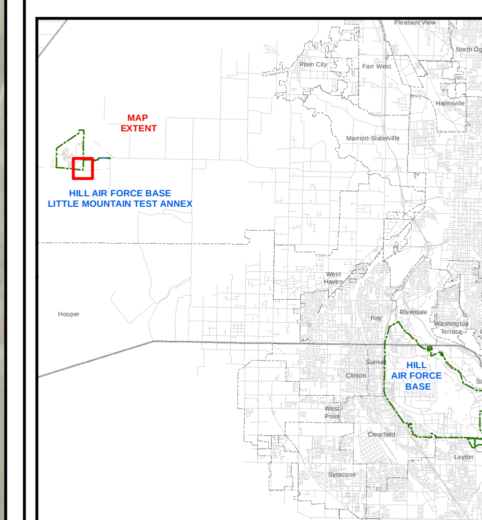

75th AIR BASE WING

FIGURE 3-3
SCREENING VALUE EXCEEDANCES (2009 AND 2013)
WR111 DECOMMISSIONING PLAN
HILL AIR FORCE BASE, UTAH

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4.0 Dose Modeling Evaluations

On 21 June 1997, the NRC published the final rule on "Radiological Criteria for License Termination," the License Termination Rule, as Subpart E to 10 Code of Federal Regulation (CFR) Part 20. The criteria for termination with unrestricted release are:

1. Residual radioactivity that is distinguishable from background, and results in a total effective dose equivalent to an average member of the critical group that does not exceed 25 millirems per year (mrem/yr), including that from groundwater sources used for drinking water

2. Residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA).

Determination of the residual radioactivity levels, which are ALARA, must take into account consideration of any detriments, such as deaths from transportation accidents expected to potentially result from excavation and waste disposal activities. For the decommissioning of Site WR111, a dose objective of 25 mrem/yr above background is applicable and, therefore, is used as the basis for demonstrating that Site WR111 may be released for unrestricted use. During remediation, field instruments used for remedial support surveys will provide detection capabilities ensuring removal of residual activity below the dose objective and meeting the ALARA requirement. The method for evaluating the dose objective is provided in Appendix C and is summarized below.

Unrestricted release of a site requires an evaluation of the potential to produce a radiation dose to individuals that might be exposed to future soil, water, and foodstuffs derived from the site. The radiation dose provides a measure of risk due to the residual radioactivity remaining in the soil after site remediation has occurred. The residual radioactivity is that amount of radioactivity in the soil that is in excess of the naturally occurring background radioactivity in the surrounding areas.

The potential risk, in turn, may be translated into a soil derived concentration guideline level (DCGL). The DCGL is a site-specific soil concentration determined to be protective of the health of individuals who may become exposed to the residual radioactive materials remaining at the site. The DCGL establishes a soil concentration consistent with the exposure scenario and dose pathways determined for the site to ensure any dose or risk remains protective of the health of individuals and is less than regulatory guidelines. The guideline is conservatively developed to address the risk to an average member of the critical exposure group.

The DCGLs are based on conservative assumptions with a dose criteria limit of 25 mrem/year peak annual total effective dose equivalent over a 1,000 year time period as provided by 10 CFR Part 20 Subpart E.

4.1 Evaluation of Derived Concentration Guideline Level Determination Options

The site-specific soil DCGL or soil-screening DCGL may be determined by one of two methods. The first option may include utilizing a conservative generic soil screening radioactivity level in the soil, as described by the NRC screening levels listed in 64 Federal Register 68395 and further detailed in NUREG 1757 (NRC 2006). Alternatively, the derivation of site-specific soil concentrations based on the health hazard (dose) posed by residual radioactive material remaining in the soil on the site may be used.

The soil guideline level may also be tied to restricted or unrestricted use. In the restricted use case, the residual levels of radioactivity may require occupancy and/or use restrictions along with third party custodial care, control, and maintenance of the site. In the unrestricted use situation, restrictions are not attached to the site and special custodial care, control, or maintenance are not required.

Consideration and inclusion of exposure scenarios and pathway inputs may be varied so a conservative bounding approach is assumed. This bounding scenario assumes the resident farmer scenario, whereby a member of the critical exposure group is expected to live on the site and utilize water, food stuffs, meat, milk, and fish derived from the site. The generic scenario was selected and utilized for this DCGL evaluation.

4.1.1 Potential Application of Screening Levels

The generic soil guideline levels were based on limiting and conservative assumptions with respect to occupancy time, water consumption, food consumption, and default site-specific factors. They may result in decisions resulting in the removal of larger than needed land areas due to conservatisms embodied within the generic screening level DCGL derivations. Additional detriments include a higher degree of excavation, truck traffic associated with a higher level of removal operations, and disposal of increased amounts of soil waste.

As described in the guidance presented in Federal Register, Volume 65, 13 June 2000, the use of the SSVs presented in Federal Register, Volume 64, 7 December 1999 (NRC 1999a) may be used to demonstrate compliance for soils under specific guidelines. The four guidelines by which soils may be deemed acceptable for release for unrestricted use are as follows:

1. The residual radioactivity has been reduced to levels that are ALARA.
2. The residual radioactivity is contained in the top layer of the surface soil (i.e., within approximately 30 centimeters from surface in accordance with NUREG-1757 Volume 2 [NRC 2006]).
3. The unsaturated zone and the groundwater are initially free of radiological contamination.
4. The vertical saturated hydraulic conductivity at the specific site is greater than the infiltration rate.

As mentioned in Section 3.4, surface soil contamination exists in the southern portion and subsurface soil contamination exists in the east-central portion of Site WR111. SSVs presented in Federal Register, Volume 64, 7 December 1999 will not be applicable for subsurface contamination.

4.1.2 Application of Site-Specific Soil Guidelines

This option provides for a property-specific guideline that utilizes site-specific parameters along with exposure scenarios and pathways best suited to the site. Likely future uses of the site and dose pathways result in a corresponding acceptable and safe level of potential risk to an average member of the general public, without applying the generic default guidelines utilized by the screening level method. This approach minimizes the potential for significant soil excavation and the accompanying damage to the ecosystem surrounding the site, as well as reducing truck traffic and excavated soil disposal volumes. This site-specific option has been selected and utilized for the evaluation presented herein. Certain input parameter values will remain as the computer code default values.

4.2 Development of Derived Concentration Guideline Levels Using Site-Specific Information

RESidual RADioactivity (RESRAD) computer code was used to determine the DCGLs for the ROCs present in Site WR111. RESRAD model is typically used to estimate the potential dose to the average member of the critical group for unrestricted release based on site-specific and generic parameters. Developed by Argonne National Laboratory for the U.S. Department of Energy, the code calculates site-specific cleanup criteria for radioactive materials in soils and is widely used by government (Department of Energy, NRC, EPA, U.S. Army Corps of Engineers), industrial firms, universities, and foreign governments.

The code provides radiation dose assessment and guideline calculations based on internal models and database information. The code calculates direct dose, inhalation dose, and ingestion doses from air, water, produce, meat, milk, fish and aquatic foodstuffs, and incidental ingestion of contaminated soils. The code utilizes the EPA Federal Guidance Report No. 11 and Federal Guidance Report No. 12 for inhalation and ingestion dose and for direct external dose conversion factors, respectively. The DCGL analysis provided herein was produced with the aid of the latest version of RESRAD available at the time of analysis, RESRAD 6.5 (ANL 2009). More detailed information regarding development of site-specific DCGLs for three ROCs is presented in Appendix C.

4.2.1 Development of Conceptual Site Model

A conceptual site model was developed to establish the relationship between the sources of contamination, source areas, transport mechanisms, exposure routes, and receptors. The conceptual site model representing post-remediation or as-left conditions will be used for the DCGL modeling and is presented in Appendix C, Section 3.2.

As a part of the decommissioning activities, it is anticipated that any radiologically contaminated soil will be excavated from approximately 0 to 10 ft bgs in the east-central portion of the site, and approximately 1 ft of radiological contaminated soil will be excavated from the northern, western, and southern portion of Site WR111. The excavated areas will be backfilled with clean backfill material (either off-site borrow material or non-impacted layback soils from outside of WR111. Under post-remediation conditions, near background levels of residual radiological activity may be present in the remaining soils at the walls of the excavation area and at the bottom of the excavation area. As a conservative approach, the conceptual site model assumes potential residual radiological activity at a depth from the estimated bottom of the excavation (10 ft) to a depth of 20 ft (with no cover) as the basis to calculate potential dose and risk to the critical group from concentrations of the ROCs that meet the release criterion.

4.2.2 Definition of Critical Group

NRC guidance document *Decision Methods for Dose Assessment to Comply with Radiological Criteria for License Termination* (NRC 1998) recommends the use of a residential farmer scenario as the basis for the DCGLs for residual contamination in site-wide soils. Hence, a resident farmer scenario was utilized as the base-case exposure scenario for the derivation of soil DCGLs. Under a resident farmer scenario, a family is assumed to move onto the site after it has been released for use without radiological restrictions, build a home, and raise crops and livestock for family consumption.

The resident farmer is exposed through different exposure pathways to residual radioactivity present in the site soil after unrestricted release of the site. To be conservative during modeling, the areal extent of residual radioactivity is assumed to be within the site boundaries of Site WR111 (60,500 square feet, or 5,620 square meters), and the thickness interval is assumed to be 10 ft (3.05 meters). Members of the resident farmer critical group can incur a radiation dose via the following pathways:

1. Direct radiation from radionuclides in the soil
2. Inhalation of re-suspended dust (if the contaminated area is exposed at the ground surface)
3. Ingestion of food from crops grown in contaminated soil
4. Ingestion of milk from livestock raised in the contaminated area
5. Ingestion of meat from livestock raised in the contaminated area
6. Direct ingestion of contaminated soil.

Due to existing groundwater data indicating that water quality and yield are poor for domestic use, a complete groundwater pathway does not exist for the site. Additional discussion of the conceptual site model for the site is provided in Appendix C. The aquatic foods pathway is not considered in the Site WR111 model since a complete surface water pathway does not exist. In addition, the radon pathway is also suppressed in this assessment due to its inapplicability.

An additional exposure scenario was evaluated to confirm that the base-case resident farmer scenario is bounding for the development of soil DCGLs. This scenario is referred to as the airman scenario. Site WR111 is currently located within a federally-owned facility; therefore, a very conservative airman exposure scenario was selected. Under this scenario, the airman (soldier) is assumed to be exposed to residual radioactivity being brought to the surface from the bottom of the burial trench.

Based on the nature and extent of radiological contamination currently present in soil, the area of impacted soil is approximately 5,400 square feet (500 square meters), and to a depth of approximately 10 ft bgs. As a conservative modeling approach for the airman scenario, it was assumed that all remaining soil at the site (i.e., post-remediation soils) will be excavated to a depth of 10 ft bgs and uniformly spread over the entire ground surface (60,500 square feet, or 5,620 square meters) of Site WR111. As a result, the thickness of the soil zone was calculated to be 0.89 feet (0.27 meters).

The airman is modeled as a typical outdoor site worker who spends most of the time outdoors. The airman will be at the site for 25 years (EPA 1991). A typical industrial worker usually spends 250 days per year at the site. As a conservative approach, the airman will spend 300 days per year at this site, with a 10-hour work day. During the 10-hour working day, the airman is assumed to spend 2 hours indoors and 8 hour outdoors.

Complete exposure pathways applicable to the airman scenario include:

1. Direct radiation from radionuclides in the soil
2. Inhalation of re-suspended contaminated dust
3. Ingestion of contaminated soil.

4.2.3 RESidual RADioactivity Parameter Definition

The RESRAD model utilizes numerous parameters that calculate dose. Section 3.3 of Appendix C presented the hierarchy that was used in assigning values for RESRAD input parameters for both the residential farmer and airman scenarios. The assigned values for RESRAD input parameters and their justification under residential farmer and airman scenarios are presented in Attachments A and B of Appendix C, respectively.

4.2.4 Methodologies to Determine Soil Derived Concentration Guideline Levels

The RESRAD model was used to calculate DCGLs from exposure to direct and indirect pathways. Direct pathways include soil ingestion, dust inhalation, and external gamma. Indirect pathways include plant ingestion. The dose from all complete exposure pathways was included in soil DCGLs.

RESRAD 6.5 was used to perform the dose assessments for soil sources. The actual fractional residual concentration activities of the ROCs for the site will not be known until final sampling is complete after remediation. Therefore, a unit concentration of 1 pCi/g for ROC and the recommended model input parameters (provided in Attachments A and B of Appendix C) were used during the dose assessments and DCGL determination. The dose resulting from a unit concentration for a given ROC is defined as the dose-to-source ratio. The output summary reports of dose assessments for both exposure case scenarios are presented in Attachment C of Appendix C. The maximum dose-to-source ratio (in units mrem/yr per pCi/g) over the 1,000-year evaluation period for each ROC was then divided into the 25 mrem/yr primary limit to determine the soil DCGLs for each ROC, in units that can be applied to the net soil sample results. Attachment C of Appendix C presents the RESRAD output summary under both receptor scenarios.

4.2.4.1 Determination of Soil Derived Concentration Guideline Levels for Base Case – Residential Farmer Scenario

The base case Soil DCGL for each ROC was determined for residential farmer scenario. Selected exposure pathways and recommended assigned values for Site WR111 and exposure parameters presented in Attachment A of Appendix C were utilized during the determination of soil DCGL for each ROC. Report C-1 of Attachment C presents the results of output summary report for base case residential farmer scenario.

4.2.4.2 Determination of Soil Derived Concentration Guideline Levels for the Alternative Case – Airman Scenario

Alternative case soil DCGL for each ROC was determined for airman scenario. Selected exposure pathways and recommended assigned values for site and exposure parameters in Attachment B of Appendix C were utilized during the determination of soil DCGL for each ROC. Report C-2 of

Attachment C in Appendix C presents the results of output summary report for alternative case airman scenario.

4.2.5 Results of Soil Derived Concentration Guideline Levels

The summary DCGL results from the RESRAD computer program are provided in Attachment C of Appendix C. The DCGLs are based on conservative assumptions with a dose criterion limit of 25 mrem/yr peak annual total effective dose equivalent over a 1,000-year time period as provided by 10 CFR Part 20 Subpart E. The report shows the dose conversion factors, a summary of the site-specific parameters and pathway selections, a summary of the contaminated zone and total dose, total dose components by time, the single radionuclide soil guideline DCGL, the dose by nuclide summed over all pathways, and the soil concentration by nuclide.

Table 4-1 presents the results of ROC-specific DCGL under the base case residential farmer scenario and the airman scenario. The most conservative DCGL from the two receptor scenarios, for each ROC, was selected as the site-specific DCGL for Site WR111. The NRC SSVs are presented in the table for reference purposes only.

4.2.6 Derived Concentration Guideline Level Sum of Ratios Rule

When there are multiple ROCs present in the soil, the allowed soil concentration levels must follow the SOR rule. This will be performed as part of the final status survey (FSS) to ensure that the sum of the individual fractions for each isotope to its individual site-specific DCGL fraction does not exceed unity.

4.3 ALARA Analysis

This section presents the ALARA analysis used to address compliance with the requirements of 10 CFR Part 20 Subpart E. Soil DCGLs were developed based on the unrestricted release dose limit of 25 mrem/yr to meet the requirements of 10 CFR Part 20 Subpart E. Section 4.2 presents the results of soil DCGLs for three ROCs. Following the guidance of NUREG-1757, Consolidated NMSS Decommissioning Guidance, Vol. 2, (NRC, 2003), the performance-based compliance approach shall be used to ensure that residual radioactivity at the conclusion of the decommissioning has been reduced to levels that are ALARA. The following requirements will be met under the performance based compliance approach.

4.3.1 Requirement #1 – Proposed Decommissioning Strategy should be based on valid assumptions, and result in residual activity to ALARA levels.

Site investigations identified the nature and extent of residual radiological contamination at the Site. Soil exceeding DCGLs will be remediated under proposed decommissioning activities. All remaining residual material with concentration below DCGLs would be located 4 to 10 ft below ground surface and will be covered with backfill. Both of these factors limit the risk associated with the environmental media concentration and provide ALARA does results for the most conservative exposure scenarios.

The proposed decommissioning activities, as explained in Section 5, include bulk soil removal techniques using equipment such as excavators and backhoes to remove contaminated soil. Typically, they remove more soil than necessary so that the remaining concentration falls well below the DCGL. Therefore, the average residual contamination generally will be well below the DCGL.

In addition to protect the average member of the public, ALARA principle will be applied during remediation activities by utilizing the safest conditions to the field crew. The annual occupational exposure limits are provided in Table 4-2. The limits provided in Table 4-2 are applicable to an adult worker (above the age of 18). Work performed on-site will be in accordance with these levels. Exposure rates will be frequently monitored at the Site. If it is discovered that the exposure levels may exceed the site limits, the Corporate RSO and management may modify a task, minimize exposure time and/or institute engineering controls to maintain exposure ALARA. Sections 7 and 8 provided more detail information regarding the ALARA principle applicable for the Site.

4.3.2 Requirement #2 – Establishment of Decommissioning Guidelines

Decommissioning guidelines were developed based on dose criterion established in 10 CFR Part 20 Subpart E. For the decommissioning of WR111, a dose objective of 25 mrem/yr above background is therefore used as the basis for demonstrating that the site may be released for unrestricted use. The site-specific soil DCGL was calculated based on this conservative assumption as described in Section 4.2.

4.3.3 Requirement #3 - ALARA Tracking

Under the performance-based compliance approach, the licensee must provide a documented method for reviewing the effectiveness of the remediation activities. In order to meet this requirement, ALARA dose tracking shall be used. ALARA in-progress reviews will also be performed, in addition to the pre-job reviews. The reviews will last as long as the duration of the task. Periodic ALARA in-progress reports will be submitted no less frequently than each calendar quarter when work is performed, to the Site Manager as well as designated health physics staff for review. These reports will serve as the primary means for ALARA-based work plan changes or revisions.

An ALARA pre-job review is required if any of the following situations occur:

1. An individual dose is expected to exceed 25 mrem Total Effective Dose Equivalent (TEDE).
2. The collective dose for the job/task is expected to exceed 0.1 person-rem TEDE.
3. Airborne exposures expected to exceed 12 Derived Air Concentration (DAC) hours per week for any single individual.
4. General area dose rates expected to exceed 5 mrem/hour.
5. Installation, removal, or modification of temporary shielding

Following the completion of each task that required an ALARA pre-job review, the actual occupational exposure received will be compared to the exposure estimate. The ALARA post-job reviews will be performed in accordance with standard operating procedures (SOPs) and will evaluate the inputs to the pre-job review, such as the overall task performed, estimated and actual person-hours for task performance, administrative and engineering controls, changes in work plan or work performance, etc., to determine the cause of any deviation and identify lessons-learned, as necessary.

4.3.4 Post-Remediation Requirements

A final status survey will be conducted at the completion of remediation activities to ensure that the site has met the release criteria for unrestricted use. The remediation goal is to ensure that residual activity above the DCGL is removed. This process follows guidance in NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)* (NRC 2000) and the MARSSIM statistical techniques require the average residual radioactivity concentrations to be less than the DCGL values. Since by definition the soil radioactivity concentrations can vary around the average and still meet the site dose objectives, the remediation approach to the excavate activity above the DCGL value will drive the mean of any residual activity below the DCGL and provide ALARA dose results.

If there are any weaknesses in the ALARA program noted by the NRC during inspections, the Corporate RSO and project HP personnel will work to resolve these to the satisfaction of the NRC. Any deviation from the decommissioning goal will be documented and justified by the RSO and project stakeholders before being implemented.

TABLE 4-1
Results of Derived Concentration Guideline Level for Each Radionuclide of Concern
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench
Decommissioning Plan, Hill Air Force Base, Utah

Radionuclide of Concern	Receptor-Specific Derived Concentration Guideline Levels (pCi/g)		Site-Specific Derived Concentration Guideline Level (pCi/g)	Nuclear Regulatory Commission Screening Values[1]
	Base Case Scenario	Airman Scenario		
^{226}Ra	1.6	7.5	1.6	0.7
^{230}Th	4.3	135.2	4.3	1.8
^{232}Th	1.9	5.5	1.9	1.1

NOTES:
^{226}Ra = Radium-226.
^{230}Th = Thorium-230.
^{232}Th = Thorium-232.
pCi/g = picocuries per gram.
(1) Nuclear Regulatory Commission screening values are from Table H.2 of NUREG 1757 Vol. 2, Appendix H (NRC, 2006). They were derived based on selection of the 90th percentile of the output dose distribution for each specific radionuclide.

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TABLE 4-2
WR111 Site Exposure Limits
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench Decommissioning Plan, Hill Air Force Base, Utah

	NRC Annual Occupational Exposure Limits (rem)
Total Effective Dose Equivalent (TEDE) which is the sum of the Deep Dose Equivalent (DDE)[1] and Committed Effective Dose Equivalent (CEDE)	5.0
Sum of the DDE and Committed Dose Equivalent (CDE) To Any Organ or Tissue Other than the Lens of the Eye	50
Lens of the Eye (Lens Dose Equivalent or LDE)	15
Skin of the Whole Body[2] or Extremities[3] (Shallow Dose Equivalent or SDE[4])	50

NOTES:
1 The assigned DDE must be for the part of the body receiving the highest exposure.
2 Whole body is defined as the head, trunk (including male gonads), arms above the elbow and legs above the knee.
3 Extremity is defined as the hand, elbow and arm below the elbow; foot, knee and leg below the knee.
4 The assigned SDE must be the exposure averaged over the contiguous 10 square centimeters of skin receiving the highest exposure

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5.0 Planned Decommissioning Activities

The scope of decommissioning activities at Site WR111 will include the excavation and removal of the waste materials and soils impacted above the radiological DCGLs. The scope of decommissioning activities also includes the proper packaging and transportation of the radioactive soils. The contaminated soils will be shipped to U.S. Ecology for disposal (or other suitable licensed disposal facility). The waste acceptance criteria at U.S. Ecology are provided in Attachment A of the Waste Management Plan (Appendix D of the Remedial Design/Remedial Action Work Plan). Following completion of the remedial action, a radiological FSS will be performed using the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) (NRC 2000) guidance. Section 5.3 and Appendix D describe the FSS Plan (FSSP) in more detail.

5.1 Contaminated Soil

Based on the 2009 and 2013 characterization results, the volume of impacted soil was estimated. The volume was estimated by utilizing the calculated DCGL for ^{232}Th of 1.9 pCi/g and adding the ^{232}Th background concentration (1.6 pCi/g). Therefore, the cleanup criterion is 3.5 pCi/g for ^{232}Th. Based on these calculations, there is one proposed area of excavation as shown on Figure 5-1. The excavation footprint extends from the eastern side of Site WR111, outside the fence line, where contamination is at its greatest depth (maximum depth of 10 ft bgs) to the southwest corner of the fenced area. The remaining footprint of the proposed excavation is relatively shallow at less than 2 ft bgs. The excavation footprint is approximately 170 ft long and 170 ft wide. Toward the southwestern and southeastern perimeter of Site WR111, data results show predominantly surface contamination, and for this reason soils will only be excavated to a depth of 1 ft bgs. The estimated *in situ* soil volume for the excavation footprint is 1,862 cubic yards. A swelling and over-excavation factor was applied to the total *in situ* volume to obtain a calculated *ex situ* soil volume of 2,420 cubic yards.

Decommissioning activities are planned to be executed in a single phase, but based on availability of funding, more than one phase may be required and scheduled. If more than one field event is required, FSS samples will be collected from each part of the excavation, and low-permeability fill and clean cover soil may be used to backfill the excavation. Following excavation, a MARSSIM FSS will be performed on the excavated surface in order to ensure that further excavation is not required.

Decommissioning activities will be performed by a contractor (Cabrera) who possesses an NRC decommissioning radioactive materials license [redacted] The contractor's license safety procedures will serve as the primary radiation protection protocols. All onsite decommissioning activities will be governed under the contractor's license. A written agreement will be executed between the USAF and the contractor prior to initiation of decommissioning. This agreement will unambiguously describe the license responsibilities of the USAF and the contractor. The USAF recognizes that this approach does not in any way affect its responsibility to conduct decommissioning activities in a timely manner.

Several decommissioning tasks will be performed under this Decommissioning Plan. The tasks are listed below in the general order of performance; however, some tasks may be performed concurrently:

1. Mobilize trailers and all necessary equipment to the site. Perform any necessary incoming surveys on any equipment or tools that may come in contact with the impacted soils. Delineate the areas of excavations utilizing a global positioning unit. Once the area of investigation has been delineated, install any erosion control barriers, and post all pertaining radiological and safety signs.

2. Perform a gamma walkover survey of the stockpile area and install permeation barriers and engineering controls.

3. Excavate the waste from the proposed excavation footprint. The soils shall be surveyed as the area is excavated. During excavation, the contractor/licensee will conduct surveys of sufficient quality to serve as portions of the FSS.

4. Perform an FSS of Site WR111 to support release for unrestricted use.

5. Package wastes, prepare shipping papers, and transport the removed wastes to the licensed disposal facility.

6. Backfill excavation using approved off-site borrow material and non-impacted layback soils below DCGLs as described in Section 4.5 of the Remedial Design Remedial Action Work Plan.
7. Restore the site to pre-excavation conditions as described in Section 4.6 of the Remedial Design Remedial Action Work Plan.

8. Perform "as left" surveys of soil stockpile areas, outgoing material and equipment surveys, and demobilize from the site.

5.2 Surface and Groundwater

Surface water and groundwater are not impacted at Site WR111 and therefore, remedial action and decommissioning are not included.

5.3 Final Status Survey Plan

Following the completion of remediation activities, an FSS will be performed to demonstrate compliance with the established DCGLs to ensure that the unrestricted release criteria have been achieved. An FSSP for conducting a MARSSIM-compliant FSS as part of this Decommissioning Plan for Site WR111 is included in Appendix D. All remedial action activities, including the FSS at WR111, are being conducted in coordination with the NRC via the U.S. Air Force Radioisotope Committee.

The purpose of this FSSP is to provide the basis for conducting a FSS after the completed remediation at Site WR111 to assess site radiological conditions and document compliance with radiological cleanup criteria to achieve unrestricted release. The FSSP addresses post-removal action surveys for radiological contaminants. Cleanup activities will be accomplished in accordance with a Remedial Design/Remedial Action Work Plan, which will be prepared under separate cover. The expected outcome of the selected remedy is that Site WR111 will not present an unacceptable risk to future land users via exposure to contaminated soil and would be suitable for a resident farmer.

The FSSP provides a consistent approach for planning, performing, and assessing ROCs present in site surface soils through FSS in order to demonstrate compliance with established DCGLS. The dose-based cleanup criterion is met when residual soils impacted by past operations have been remediated, and an FSS has verified that any residual radioactivity is below remediation goals. The results from implementation of the FSSP will be summarized in an FSS Report and submitted to the Air Force for review and approval.

5.4 Schedule

Table 5-1 presents the activities and their schedules that are anticipated following the submission of this DP to the NRC.

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TABLE 5-1
Schedule
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench Decommissioning Plan, Hill Air Force Base, Utah

Activity	Estimated Date
Receive Nuclear Regulatory Commission Approval of Decommissioning Plan	September 2015
Finalization of Work Plans	September 2015
Field Activities	September 2015-March 2016
Submit Final Status Survey Report to Nuclear Regulatory Commission	June 2016

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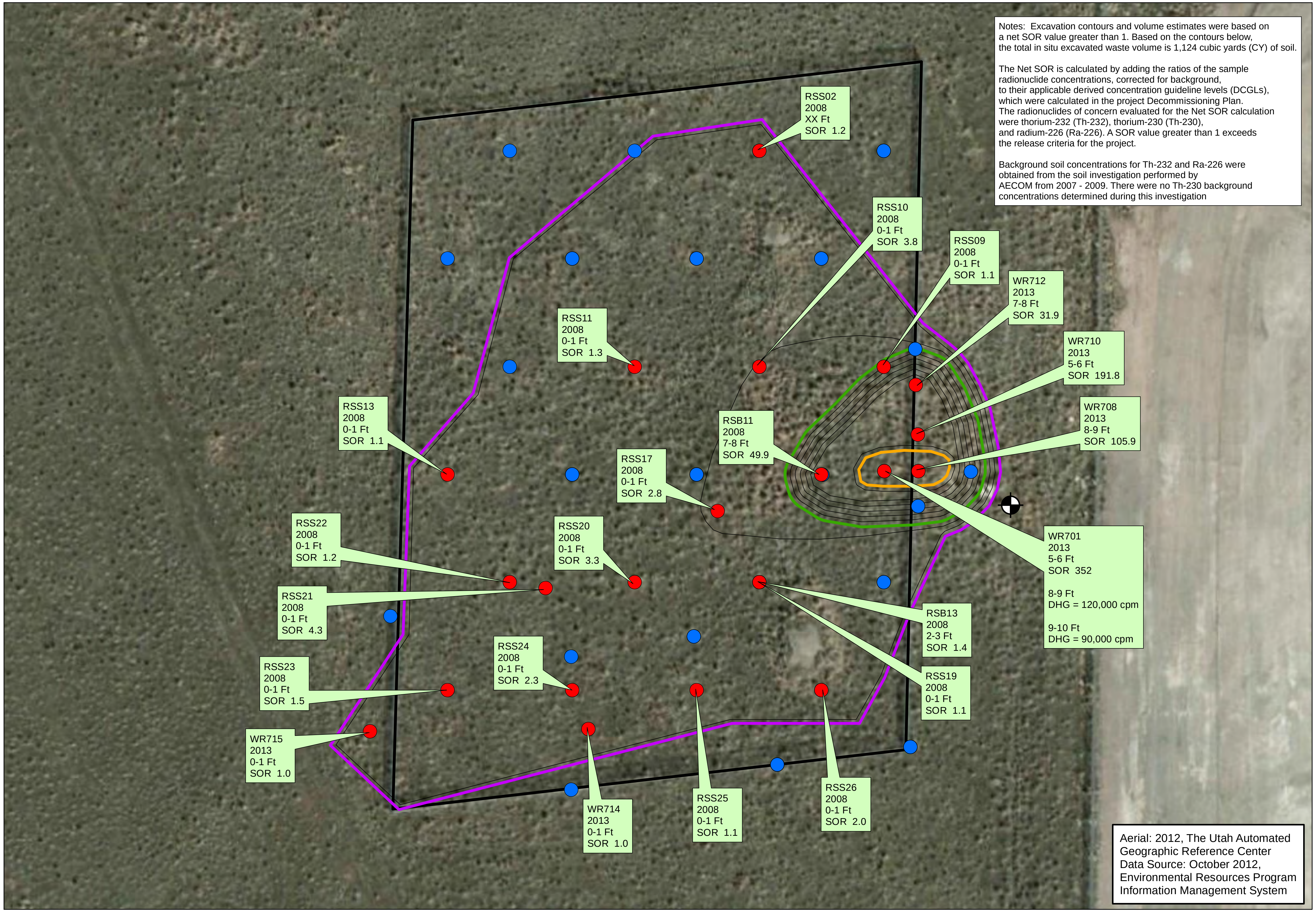
I:\GIS Projects\Hill AFB\MXDs\Decommissioning Plan\Figure 5-1 - Soil Excavation Volume Est_041715.mxd 4/17/2015 K. Wheatley



0 10 20 30 60 Feet

1 inch equals 30 feet

SOR Value (Net)

- < 1.0 SOR
- > 1.0 SOR

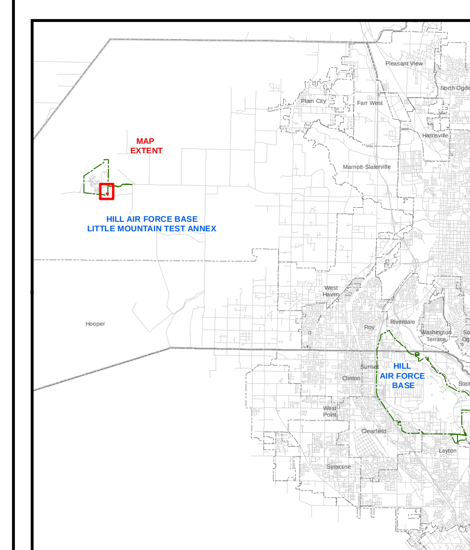
Excavation Contours

- 0 Ft bgs
- 3 Ft bgs
- 10 Ft bgs
- (1 Ft Interval)
- WR111 Fence
- Monitoring Well Location

Sample ID
Date
Depth (Ft. bgs)
SOR Value (Net)

Notes:
SOR = Sum of Ratios (Net)
pCi/g = pico curies per gram
Ft = Feet
bgs = Below ground surface
DHG = Downhole Gamma
cpm = Counts per minute

MAP INDEX



AIR FORCE CIVIL ENGINEER CENTER

FIGURE 5-1
SOIL EXCAVATION VOLUME ESTIMATE
WR111 DECOMMISSIONING PLAN
HILL AIR FORCE BASE, UTAH

6.0 Project Management and Organization

Implementation of this Decommissioning Plan be performed within the general management and organizational structure described in this section. An organization chart showing the principal decommissioning management positions is provided in Figure 6-1.

6.1 Decommissioning Management Organization

Hill AFB, through the Air Force Radioisotope Committee will retain overall responsibility for management and execution of this Decommissioning Plan. EA is responsible for obtaining site closeout to include, but not be limited to, excavation, transport, and disposal of contaminated soil from Site WR111. Management will be provided by EA; health physics and technical support will be provided by Cabrera.

6.2 Decommissioning Task Management

Remediation activities will be managed by EA and executed by Cabrera in accordance with this Decommissioning Plan. The Decommissioning Plan contains the requirements necessary to successfully decommission the site to achieve unrestricted release of the property for future use. Decommissioning tasks will be performed in accordance with the schedule presented in Section 5.3. Several key programs are fundamental to the safe execution of decommissioning activities. These are the Contractor Radiation Safety Program and Site-Specific Safety and Health Plan (SSHP). Cabrera's Field Site Manager, Site Radiation Safety Lead/Site Safety and Health Officer, here in referred to as the Site Safety and Health Officer (SSHO), are responsible for executing day-to-day field activities in accordance with the Decommissioning Plan, Radiation Safety Program and applicable Radiation Work Permits, and SSHP.

6.3 Decommissioning Management Positions

The specific responsibilities of key management personnel, as they relate to the field implementation of this Decommissioning Plan, are discussed in this section. Qualifications for these positions are later discussed in Section 6.4.

6.3.1 Air Force Civil Engineer Center

The AFCEC retains ultimate responsibility for the execution of requirements set forth in this Decommissioning Plan, as well as for compliance with all applicable federal and state regulatory requirements and will review and approve all regulatory required documents prior to submittal to the appropriate regulatory agency.

6.3.2 Hill Air Force Base Radiation Safety Officer

The Hill AFB RSO, as identified in NRC License No. 42-23539-XXAF, reports to the U.S. Air Force Radioisotope Committee and has responsibility for ensuring that decommissioning activities are conducted in accordance with the NRC license. The Hill AFB RSO will ensure that the project Radiation Safety Program and implementing procedures are sufficient to fully address NRC license requirements and applicable regulatory radiation safety requirements.

6.3.3 Project Managers

The EA Site Project Manager reports to the Hill AFB Project Manager and has overall responsibility for ensuring that decommissioning activities are conducted in accordance with the Decommissioning Plan, as well as with the project Radiation Safety Program and SSHP. The EA Site Project Manager is responsible for ensuring the appropriateness and adequacy of technical services provided during decommissioning, as well as for the successful integration of input from Hill AFB project management personnel, contractor support disciplines, and specialty subcontractors. The EA Site Project Manager is responsible for executing project administration and controls, ensuring appropriate project staffing and training, and establishing personnel responsibilities and lines of communication.

The Cabrera Project Manager reports to the EA Site Project Manager and is responsible for the execution of the radiological components of the decommissioning activities. The Cabrera Project Manager will ensure that personnel assigned to the project are appropriately trained and have the necessary equipment and materials to perform their duties.

6.3.4 Corporate Radiation Safety Officer

The Corporate RSO is responsible for the acceptance of portions of the Decommissioning Plan and SSHP that address radiation safety during decommissioning activities. Specifically, the RSO will:

- Assist the Cabrera Project Manager, as necessary, to ensure that the project Radiation Safety Program and Decommissioning Plan comply with all federal, state, and local requirements related to radiation safety.

- Oversee implementation of the Radiation Safety Program, including procedures applicable to decommissioning radiation safety.

- Review applicable Radiation Work Permits, as necessary, prior to implementation of field activities.

- Ensure that the SSHO is appropriately qualified and trained to implement the portions of the Decommissioning Plan, Radiation Safety Program, and SSHP related to radiation safety, and that communication is maintained with the RSO throughout decommissioning activities. The RSO will provide direction to the SSHO on any significant radiation safety issues that arise in the field.

- Assist in the training of field personnel, as necessary, with respect to the identification and mitigation of site-specific radiation hazards and the use of radiation monitoring instruments, personal dosimetry, and contamination surveys.

The RSO may also conduct periodic onsite site inspections and audits of the radiation safety program to ensure that the requirements of the Decommissioning Plan, Radiation Safety Program, and Radiation Work Permits are being implemented properly.

6.3.5 Corporate Health and Safety Manager

The Corporate Health and Safety Manager will be responsible for the review and approval of the SSHP. Additionally, the Health and Safety Manager will:

- Assist the EA Site Project Manager, as necessary, to ensure that the SSHP complies with all federal, state, and local health and safety requirements; modifying specific aspects of the SSHP, as necessary, to address field changes that may impact safety

- Implement and oversee the Corporate Health and Safety Program, in accordance with the established Health and Safety Program

- Ensure that the SSHO is appropriately qualified and trained to implement the SSHP. Maintain communication with the SSHO to ensure proper implementation of the SSHP, and provide direction on any significant safety issues that arise in the field

- Assist in the training of field personnel, as necessary, with respect to the identification and mitigation of site-specific hazards and the use of air monitoring instruments, personal protective equipment, decontamination procedures, and emergency/spill response.

The Health and Safety Manager may also conduct a minimum of one onsite site health and safety inspection to ensure that the safety requirements of the Decommissioning Plan and SSHP are properly implemented.

6.3.6 Quality Control Manager

The Quality Control Manager (QCM) will assist the Cabrera Project Manager in ensuring the quality of decommissioning work. The QCM will ensure that the project team properly implements the protocols and procedures required under the Hill AFB PBR contract and the Decommissioning Plan, and that corrective action is taken if performance does not meet internal or Hill AFB quality requirements. The QCM will be responsible for directing planning, implementing, and tracking QC activities, and for maintaining internal communication regarding QC matters. The QCM will work with the Cabrera Project Manager to ensure that established QC measures are implemented in all phases of the work. The QCM may conduct periodic onsite and/or project audits, as necessary, to ensure that work activities are being implemented properly and that the data generated during the project are sufficient to satisfy the quality objectives outlined in the Decommissioning Plan.

6.3.7 Field Site Manager

The Field Site Manager reports to the Cabrera Project Manager and is responsible for supervising the day-to-day activities of the project team. The Field Site Manager is responsible for implementing the Decommissioning Plan in accordance with the requirements of the Radiation Safety Program and SSHP. The Field Site Manager has the authority to stop work, if necessary, and take appropriate actions to ensure the health and safety of all field personnel, the environment, and the surrounding community. In addition, the Field Site Manager will:

- Coordinate the decommissioning task schedule with the SSHO to ensure that radiation safety and health and safety requirements are adequately specified in Radiation Work Permits, work plans, SSHP, and/or job hazard analyses

- Conduct daily plan-of-the-day/tailgate safety briefings (with assistance from the SSHO) to provide direction and supervision to field personnel regarding the requirements of the Decommissioning Plan and supporting documents

- Ensure that the work zones are established in such a way as to minimize potential health and safety hazards and contamination risks

- Oversee field staff and subcontractors during day-to-day operations to ensure proper execution of field activities in accordance with the Decommissioning Plan, Radiation Safety Program, and SSHP requirements

- Assist in the preparation of project work schedules, reports, field drawings, and required compliance submittals

- Maintain close communication with the Cabrera Project Manager regarding project progress and any problems encountered in the field, as well as coordinating with the Cabrera Project Manager to initiate corrective actions that may be necessary.

6.3.8 Site Safety and Health Officer

The SSHO reports to the Cabrera Project Manager, RSO, and Health and Safety Manager. The SSHO is responsible for the day-to-day implementation of the Radiation Safety Program and SSHP. Like the Field Site Manager, the SSHO has the authority to shut down any operation that jeopardizes the health and safety of site personnel, the environment, or the local community. In addition, the SSHO has the following responsibilities:

- Provide onsite training of field personnel to convey Radiation Work Permit, and SSHP requirements

- Ensure proper implementation of the Radiation Safety Program and SSHP during field activities, including personal protective equipment requirements, health and safety monitoring, and radiation safety procedures

- Develop, implement, and brief affected decommissioning workers on Radiation Work Permits for radiological aspects of decommissioning activities

- Provide daily updates during the morning safety briefings to review applicable activity hazard analyses and alert the field crew to any changed conditions and/or additional radiation or other safety hazards likely to be encountered that day

- Maintain site health and safety documentation such as training records, air monitoring equipment calibration forms, air monitoring results, accident report forms, etc., ensuring that the Cabrera Project Manager and Health and Safety Manager receive copies of all documentation on a daily basis

- Maintain communication with the RSO and Health and Safety Manager during field activities and coordinate on any health and safety issues that may arise

- Investigate any accidents/incidents or “near misses,” and coordinate with the RSO and Health and Safety Manger to ensure that all reporting requirements are met

- Continuously monitor the work place for unsafe acts or conditions, and initiate corrective actions as necessary.

6.3.9 Waste Transportation and Disposal Coordinator

The Waste Transportation and Disposal Coordinator reports directly to the Cabrera Project Manager and is responsible for supervising activities associated with the transportation of hazardous material and disposal of hazardous wastes. The Waste Transportation and Disposal Coordinator will be responsible for preparing waste characterization/classification paperwork, generating profile and shipping manifest documents, and ensuring that radioactive material and waste leaving the site is packaged, labeled, and shipped in accordance with U.S. Department of Transportation and U.S. Air Force and Department of Defense regulations. The Waste Transportation and Disposal Coordinator will be responsible for overseeing the radiological survey of packages and conveyances containing radioactive material leaving the site, and for providing all survey and shipping records to the Cabrera Project Manager for inclusion in the project file.

6.3.10 Other Project Personnel

Individuals assigned to the project will be responsible for performing their work in a manner consistent with the project quality, radiological safety, and general safety and health requirements. Personnel will take all reasonable precautions to prevent injury to themselves and their fellow employees and be alert to potentially unsafe or harmful situations while performing their work. In addition, project personnel will:

- Know and understand the requirements of the Decommissioning Plan, SSHP, Radiation Safety Program, and Radiation Work Permits with respect to their individual responsibilities

- Perform only tasks that they can perform safely and for which they have the proper tools and training

- Comply with necessary personal protective equipment and personal monitoring requirements, as directed by the SSHO

- Notify the SSHO of special medical conditions (e.g., allergies, illnesses, etc.), as well as prescription or non-prescription medication they are taking, which might affect their performance, safety, or safety of other decommissioning personnel

- Prevent spillage and splashing of materials to the greatest extent possible to prevent the spread of contamination and/or safety hazards

- Practice good housekeeping by keeping their work areas neat, clean, and orderly

- Immediately report all injuries and contamination incidents to the SSHO.

6.4 Training

Personnel who participate in decommissioning activities at the site will be appropriately trained to perform their assigned tasks, and will receive site-specific training specific to decommissioning activities and hazards. Current training certificates and records will be maintained onsite in the project file for the duration of the fieldwork.

Personnel requiring unescorted access to decommissioning work areas will be trained and qualified in accordance with 29 CFR 1910.120, Hazardous Waste Operations and Emergency Response. Hazardous Waste Operations and Emergency Response training and qualification will be verified complete prior to performance of work and repeated annually thereafter. Additional training and qualifications may include general construction safety, radiation safety, first aid and cardiopulmonary resuscitation, waste transportation, and/or other relevant topics.

Personnel with unescorted access to decommissioning work areas will be trained in regard to the types and magnitude of radiological, chemical, and physical hazards they might encounter. Visitors to the site will be escorted by appropriately trained personnel at all times. The following subsections briefly describe the various training requirements.

6.4.1 Visitor Training

Visitors (i.e., non-working observers) to the job site will participate in an abbreviated form of the initial site safety training prior to entering the work zone. This training will focus on potential health and safety hazards likely to be encountered while observing the work and will provide instructions regarding any limitations or restrictions on specific activities in which the visitor may or may not engage while onsite. A record of the site-specific visitor safety training and signatures of those participating will be maintained onsite. Visitors to the decommissioning work site will be escorted while in the work area and will not be allowed to enter contamination, radiation, or airborne radioactivity areas without specific approval from the Hill AFB RSO.

6.4.2 General Employee Training

General Employee Training in radiation protection will be administered to project personnel who provide support during decommissioning activities but do not require unescorted access to radiological areas and do not work with licensed radioactive material. This may include employees that access the site infrequently or new employees who have not completed radiation worker training, both of which require a fully trained and qualified escort, as well as authorization from the SSHO.

General Employee Training be provided at the start of fieldwork and will consist of an oral presentation, handout materials, and completion of a form acknowledging receipt of training. General Employee Training will address the following topics:

- The type and form of radioactive material present at the facility
- The location of radiation protection policies and procedures
- Employee and management responsibilities for radiation safety
- Identification of radiation postings and barriers
- Protective equipment and procedures
- Work zone setup and decontamination procedures
- Emergency procedures
- How to contact project radiation safety staff.

6.4.3 Radiation Worker Training

Field personnel who require unescorted access to engage in activities within radiological areas at the site or who work with licensed radioactive material will complete Radiation Worker Training prior to their initial work assignment. Radiation Worker Training will address the following topics:

- Rights and responsibilities of personnel, as specified in 10 CFR 19, including the content of NRC Form 3, *Notice to Employees*

- The general content and location of the *Radiation Protection Program*, implementing procedures applicable to radiation protection for the site decommissioning, as well as applicable NRC regulations

- Radioactivity and radioactive decay, characteristics of ionizing radiation, and man-made radiation sources

- Radiological hazards specific to the site and planned decommissioning activities

- Modes and effects of exposure to radiation (internal and external), risks associated with occupational radiation exposures, including the content of NRC *Regulatory Guide 8.29: Instruction Concerning Risks from Occupational Radiation Exposure* (NRC 1996), and special considerations with respect to exposure of women of reproductive age, including NRC *Regulatory Guide 8.13: Instruction Concerning Prenatal Exposure* (NRC 1999b)

- Dose-equivalent limits and dose-equivalent determinations

- Radiation survey instrumentation (e.g., calibration, use, and limitations), radiation monitoring programs and procedures, and warning signs, labels, and alarms

- Basic protective measures (time, distance, and shielding), specific procedures for maintaining exposures ALARA, including the content of NRC *Regulatory Guide 8.10: Operating Philosophy for Maintaining Occupational Radiation Exposures As Low As Is Reasonably Achievable* (NRC

1997), contamination control (e.g., protective clothing, equipment, workplace design, contamination monitoring), and radiation work permits

- Personnel decontamination and emergency procedures.

Radiation Worker Training will consist of classroom lecture, a practical demonstration, and a question/answer period. The typical duration of Radiation Worker Training is 8 hours. A graded exam to test employee proficiency in the class subject matter will be administered, and a passing score of 80 percent will be required. A challenge test may be administered in lieu of the formal classroom training session for individuals previously trained in the subject matter or demonstrating knowledge regarding radiological hazards expected to be present onsite, as authorized by the SSHO. In addition to the challenge examination, the SSHO may also exempt experienced health physics technicians from the practical demonstration portion of Radiation Worker Training.

6.4.4 Initial Site Safety Training

Site-specific health and safety training will be conducted at the commencement of field activities for all project personnel to address the requirements of the SSHP. All field personnel will be briefed on the Decommissioning Plan and SSHP, ensuring that personnel understand the requirements and responsibilities, as well as the importance of adhering to the site health and safety requirements for the duration of the project. Site safety procedures and emergency protocols will be reviewed, and the field team members will be given an opportunity to ask questions or request clarification. At the conclusion of the training, project personnel will sign a form to acknowledge that they have received and understood this training. A record of the site-specific worker training will be maintained onsite.

6.4.5 Special Training and Qualifications

Other special training and/or qualifications may be required for project personnel, as necessary, to complete the tasks to which they have been assigned.

U.S. Department of Transportation Hazardous Material Training

Field personnel participating in the collection, packaging, handling, storage and/or transportation of hazardous material, as defined by the Department of Transportation, will be trained commensurate with their assigned responsibilities. This training will address the requirements in 49 CFR 172, Subpart H.

For incumbent employees, training will be verified to have been completed within the prior 3 years before assignment of tasks subject to this requirement. For new employees, training required by this section will be completed within 90 days of initial assignment. Prior to completing the required training, a new employee may perform tasks subject to this training requirement provided the employee is supervised by a fully trained and qualified individual. Employees will be retrained every 3 years.

Respiratory Protection Training and Qualification

Personnel requiring the use of respiratory protection against non-radiological airborne hazards will be trained and qualified in accordance with 29 CFR 1910.134. Personnel requiring the use of respiratory protection for radiological airborne hazards will also receive training to address the requirements in 10 CFR 20, Subpart H. Respiratory protection training and qualification will be verified as complete prior to first use of respiratory protection and annually thereafter. Prior completion of training and qualifications (within 12 months of initial work assignment) required by this section may be accepted by the SSHO, with submittal of appropriate training and qualification records.

Site Safety and Health Officer Training and Qualification

The SSHO must be able to identify health, safety, and environmental (HS&E) risks and hazards on site. In order to qualify for the position, the selected individual shall have experience serving as an SSHO, hold a HS&E degree, or possess an advanced certification or license (Certified Safety Professional, Certified Industrial Hygienist, or Certified Health Physicist). Senior Management, the Cabrera Project Manager, the Corporate Health and Safety Manager, and/or client requirements may require additional years of experience for high-risk, high-hazard projects. The appointed SSHO must be knowledgeable of company HS&E policies, procedures and applicable legislation. The selected individual shall have good leadership abilities and communication skills and be able to respond in a calm, controlled and organized manner in the event of an emergency. The SSHO shall be able to interface with clients, emergency providers, and agency representatives as directed by the Cabrera Project Manager or Site Supervisor. The SSHO shall be willing and able to correct violations of established HS&E procedures involving Cabrera employees and contract personnel. When necessary, particularly in situations involving imminent danger, the SSHO shall be knowledgeable of, and willing to, issue a Stop Work order until the potential HS&E violations are corrected.

Health Physics Technician Training and Qualification

Senior health physics technicians supporting the decommissioning will be required to meet certain minimum qualification requirements, such as certification by the National Registry of Radiation Protection Technologists, or demonstrate a pre-determined level of experience and knowledge that allow them to perform and supervise a wide range of radiological tasks in the field. Other health physics personnel will perform duties in support of health physics activities, as assigned and qualified by the SSHO or designee. Prior to initial assignment, health physics personnel will become familiar with the radiation protection requirements, including procedures applicable to the decommissioning of Site WR111. This training may include review of applicable procedures; oral instruction; and, for new health physics personnel, hands-on application of procedure requirements under the supervision of a qualified, veteran field staff member. Ongoing training may include the annual review of procedures and additional training when an existing procedure is revised or a new procedure is introduced.

FSS Technicians and Support Personnel

Personnel supporting the FSS will be trained in FSSP (Appendix D) requirements and implementation, FSS instrumentation and procedures, FSS surveys and sampling, data collection and management, and QA. This training may include review of applicable procedures, oral instruction, and, for new FSS technicians and support personnel, hands-on application of procedure requirements under the supervision of a qualified, veteran staff member.

6.4.6 Daily Tailgate Safety Meetings

Daily tailgate safety meetings will be conducted to review the day's work plan, associated activities, and any anticipated hazards. This safety meeting will be required for all individuals scheduled to work that day. Records of attendee names and topics of discussion will be documented and maintained onsite.

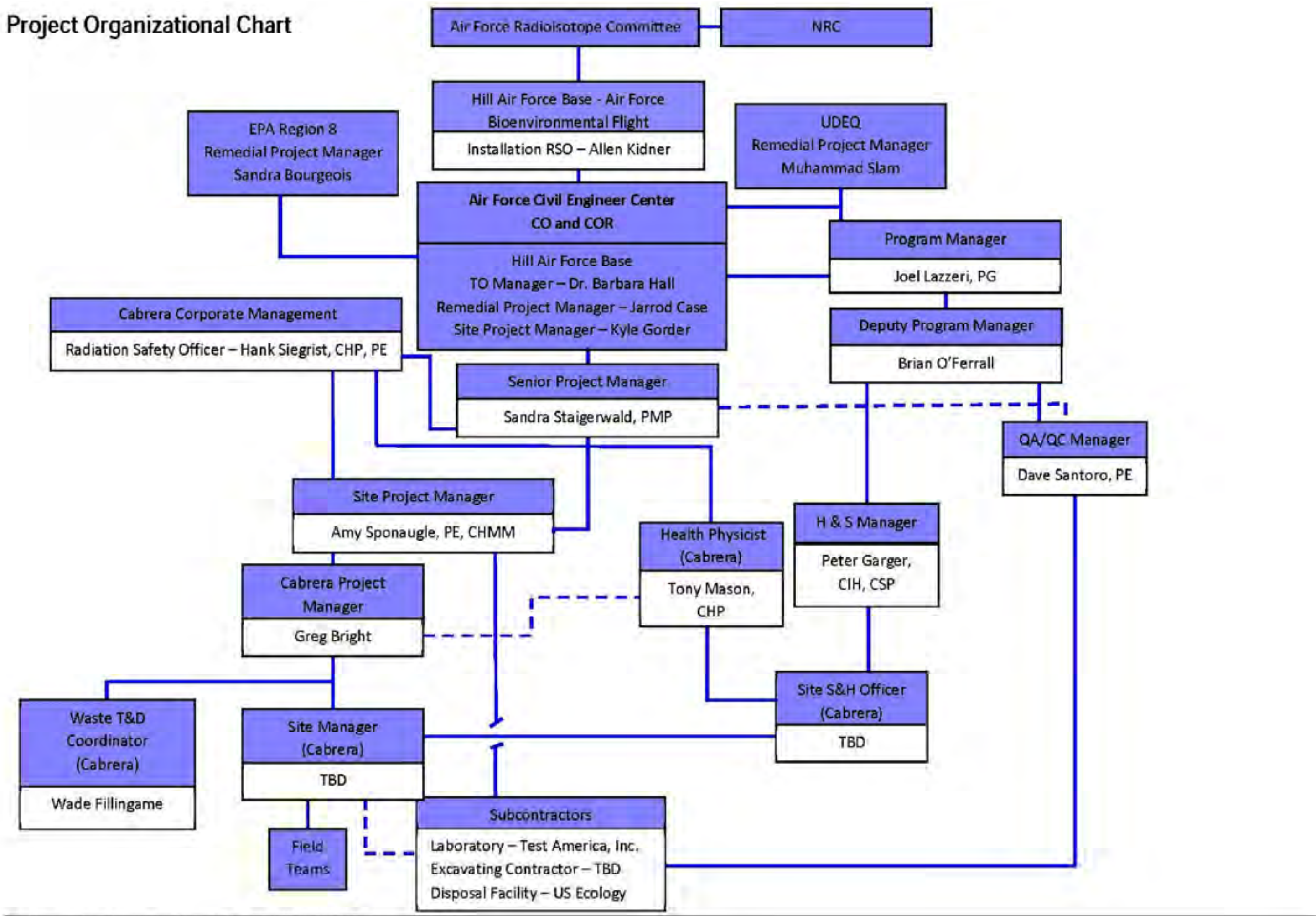
Daily tailgate safety meetings will provide supplemental training, as necessary, and ensure that personnel are given clear direction and the proper tools for performing their respective tasks. These meetings will also provide a forum for the field personnel to relate any potential safety or quality concerns that have arisen on the job. Meeting notes and attendance sheets will be maintained onsite and included in the project file.

6.4.7 Subcontractor Support

Subcontractor specialty services necessary to complete certain aspects of the plan (e.g., waste transportation and disposal, analytical testing, equipment rental, equipment operation, etc.) may be subcontracted to firms with the appropriate skills, resources, and experience.

Each subcontractor will designate a Task Manager and, as necessary, a health and safety and/or QC contact. For subcontractors providing onsite field services, the subcontractor Task Manager will report directly to the Field Site Manager. Other subcontractors such as analytical laboratories, whose activities are conducted primarily at offsite locations, will coordinate their activities with the EA Site Project Manager.

The SSHO will verify that subcontractor personnel are adequately trained and qualified as specified in Section 6.4.5, and that subcontractor personnel perform their assigned activities in accordance with all NRC license commitments and requirements; Decommissioning Plan requirements; and the programs, plans, and procedures applicable to the decommissioning of Site WR111.



Source: June 2013, Supplemental Site Work Plan

FIGURE 6-1
PROJECT ORGANIZATIONAL CHART
WR111 DECOMMISSIONING PLAN
HILL AIR FORCE BASE, UTAH

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7.0 Health and Safety Program During Decommissioning

Decommissioning activities will be completed in a manner that is protective to workers, the environment, and the public. It is U.S. Air Force's policy to maintain minimal human and environmental exposure to known or suspected radioactive and/or hazardous material. The contractor will accomplish this by following the guidance of SOPs, encompassing both administrative procedures and operating procedures presented in the Radiation Safety Program. Administrative procedures will address the following:

- Record Retention
- Radiological Conditions Awareness Reports
- Radiological Compliance Audits
- Radiation Work Permits
- ALARA
- Bioassay
- Dosimetry Program
- Radiological Training
- Personal Protective Equipment
- Emergency Response.

The Radiation Safety Program may also include additional administrative and operational procedures that will be used by management to guide the conduct of all relevant decommissioning activities. Copies of procedures pertinent to decommissioning activities will be maintained onsite for reference and regulatory review. Deviations from procedures must have prior approval of the Corporate RSO.

Cabrera and EA will ensure that a workplace is provided in which employees, visitors, and subcontractors are adequately protected from hazards, including the hazards associated with exposure to radiation and radioactive material. While the expected exposures associated with the planned decommissioning operations are low, all exposures are assumed to entail some risk to employees, visitors, and contractors. The ALARA requirement will be communicated to all employees and subcontractors at the outset of this project so that all individuals entering the job site understand their personal responsibilities in maintaining radiation exposure ALARA. Methods to be used in reducing exposure potential will be reviewed during initial site-specific training and tailgate meetings. Monitoring and surveillance information will be available for personnel review, and will be summarized and discussed with the workforce on a periodic basis.

A SSHP will be developed to describe the practices to be used in minimizing employee exposure to occupational and industrial hazards that may be present during decommissioning activities. Sufficient documentation will be maintained to demonstrate the effectiveness of the health and safety program. The SSHO, or designee, will monitor onsite health and safety during decommissioning activities. The SSHO will coordinate occupational and radiation safety requirements and issues to ensure comprehensive protection of the decommissioning work force from potential hazards. The SSHO or designee, will conduct tailgate safety training, implement the individual monitoring and surveillance programs, and maintain all health and safety records generated during the decommissioning efforts.

7.1 Radiation Safety Controls and Monitoring for Workers

During remediation, the Radiation Safety Program shall be implemented to control exposure to ionizing radiation through approved SOPs. The SOPs will reference and provide instructions to ensure compliance with applicable federal regulatory documents, including 10 CFR Parts 19 and 20, and will ensure that occupational exposure limits are not exceeded as set forth in 10 CFR Part 20. Radioactive materials and sources of radiation will be controlled in such a manner that radiation exposures to workers do not exceed limits specified in 10 CFR Part 20, Subpart C.

Radiation safety personnel assigned to the project will assess the effectiveness of posted warning signs during the conduct of these surveys. Surveys will be conducted using survey instrumentation and equipment suitable for the nature and range of hazards anticipated. Equipment and instrumentation will be calibrated and, where applicable, operationally tested prior to use in accordance with procedural requirements. Routine surveys will be conducted at a specified frequency to ensure that contamination and radiation levels in unrestricted areas do not exceed license, or federal, state, or site limits. The SSHO or designee will also perform surveys during decommissioning whenever work activities create a potential to impact radiological conditions. The frequency, type, and location of routine contamination surveys are provided in Radiation Protection Plan, which is attached as Appendix C of the Remedial Design/Remedial Action Work Plan.

As required in 10 CFR 20.1502, the need for individual monitoring for internal and external exposures will be determined and documented prior to the start of work based on existing data. Potential exposures to personnel working at the site during decommissioning include direct contact and airborne dusts that may be contaminated (inhalation exposure pathway). Personnel will perform routine monitoring for radioactive contamination to minimize the spread of contamination and consequently minimize the exposure to the external gamma, ingestion, and inhalation pathways.

Radiation monitoring (external and/or internal) shall be conducted continuously when it is likely that any individual will exceed 10 percent of the annual limit. If air samples detect the presence of radiation in excess of 10 percent of the derived air concentration, the SSHO will evaluate the need for a bioassay program. Occupationally exposed workers who have received radiation exposure prior to employment with the contractor are required to provide their radiation exposure history records or names and addresses of previous employers and locations where they have received exposures. Copies will be sent to the individual and maintained in the individual's personnel radiological exposure file.

7.2 Air Sampling Program

Radiological air sampling surveys and monitoring will be performed in accordance with written procedures, and in compliance with 10 CFR Parts 20.1204 and 20.1501(a)-(b). Air samples will be collected under known physical conditions (e.g., sample time, flow rate). The flowmeters of air samplers will be calibrated prior to each mobilization and following repair and/or modification.

Both breathing zone and general area air samples will be collected from areas where there is the potential for generation of airborne radioactive material. **Breathing zone air samples will be the primary method of monitoring the worker's intake of radioactive material and will be collected from the workers' breathing zones at work locations where there are most expected to be known or suspected release points.** General area air samples will also be collected from general and localized areas, especially concentrated in areas downwind from excavation and other areas with the greatest likelihood of the presence of airborne dust. Appropriate air sampling equipment will be selected. The type of sampling that is desired will determine the appropriate collection media required to collect the contaminant. The frequency at which air filters will be changed will be determined based on the radiological and physical condition of the work location, worker stay times, and the type of air sampling performed. Effluent air sampling will also be performed as described in Section 8.1.

Air sampling will be performed prior to initiating construction activities in order to document background radioactive airborne particulate activities. Air sampling will be performed to monitor airborne particulate activity when excavation activities commence, routinely during decommissioning activities, and after any significant changes in operating conditions. Sampling durations will be determined prior to the commencement of sample collection based on required action levels, counting instrument sensitivities, and other conditions as warranted.

Following air sample collection, the filter media will be stored for at least 24 hours in order for short-lived radon progeny to be allowed to decay. Air samples will then be counted with sufficient time to achieve required minimum detectable concentration goals for each specific radionuclide. Air sample analysis results will be compared with the derived air concentration for radionuclides. Breathing zone air samples are collected using personal lapel (or equivalent) air samplers or grab samplers. If the breathing zone concentration exceeds 10 percent of derived air concentration, the Corporate Health and Safety Manager should be notified so appropriate actions can be taken and exposures received by workers evaluated and included in their personal exposure file.

If gross alpha activity significantly in excess of (i.e., three times greater than) background is identified, then the air samples will be shipped to an accredited analytical laboratory for determination of the presence of the isotopes present.

7.3 Respiratory Protection Program

Respiratory protection shall be maintained by the application of practicable engineering controls such as process, containment, and ventilation equipment and the concurrent monitoring of airborne dusts. The respiratory protection program is outlined in the SSHP and includes monitoring in the breathing zone (in the area of the excavation) and at the perimeter of the work area. The onsite SSHO is responsible for monitoring site condition and implementation of the respiratory protection program.

Emergency conditions are unplanned events characterized by the need for rapid and aggressive actions to prevent or mitigate the effects of rapidly deteriorating conditions. The use of respirators during such an event is often a reasonable substitute for engineering controls that must be assumed to be nonfunctional or ineffective. Personnel who are physically and psychologically capable and properly trained must use appropriate respirators when directed by the SSHO. Only respirators certified by the National Institute for Occupational Safety and Health will be used. Employees shall not wear respirators until a physician or other licensed health care professional has determined that they are physically and psychologically able to use a respirator and they have been trained and fit-tested.

Use of respirators during the Site WR111 decommissioning activities is highly unlikely. Ambient air monitoring will be conducted during remedial activities to determine if respiratory protection is necessary. The SSHO will monitor the results as well as overall conditions in accordance with the SSHP and make the necessary decisions in coordination with Field Site Manager and U.S. Air Force personnel.

7.4 Internal Exposure Determination

Internal exposure determination will be determined through analysis of breathing zone air samples in compliance with written procedure(s) and, as necessary, bioassay results. The assessment of a workers' Committed Effective Dose Equivalent will be limited to less than 10 percent of the allowable limit on intake as specified in Table I, Columns 1 and 2, of Appendix B of 10 CFR Part 20, providing the total effective dose to the individual is maintained ALARA. The SSHO will determine the validity of bioassay and air monitoring results prior to their inclusion in the internal dose assessment process.

7.5 External Exposure Determination

External exposure potential will be routinely monitored through the use of microrem or equivalent meters in order to assess the level of external exposures to ionizing radiation. Based on the site's current radiological conditions, personnel dosimetry devices are not warranted. However, if it is determined that personnel may likely receive within 1 year, a dose in excess of 10 percent of the applicable limits from radiation sources external to the body, such persons will be monitored by personnel dosimetry such as themoluminescent dosimeters. The personnel dosimetry devices will indicate the amount of ionizing radiation to which the wearer was exposed. The personnel dosimeter will normally be worn on the upper front torso. Personnel are responsible for wearing dosimetry as directed by the SSHO. If a personnel dosimeter is lost, misplaced, or indicates an off-scale reading, the employee is required to notify his/her supervisor, health physics personnel, and/or the SSHO immediately.

7.6 Contamination Control Program

Radioactive material will be controlled as specified in the project Radiation Work Permit and in such a manner that the surface contamination does not exceed the levels specified in NRC guidelines for the decontamination of facilities and equipment prior to release for unrestricted use as presented in the NRC's Policy and Guidance Directive FC 83-23 (NRC 1983). These limits are presented in Table 7-1.

Routine surveys will be performed throughout the decommissioning process, with each survey being planned in advance with regard to the specific radiation type, the predetermined radiation levels, the location where radiation is expected, and any special condition warranting a survey. The initial level of protection for the intrusive tasks of this decommissioning operation (i.e., where residual radioactivity may be encountered) will be Level D modified personal protective equipment, including hard hats, Tyvek© coveralls, safety glasses with side shields, steel-toed boots, and gloves. Upgrading or downgrading the level of protection will be based on ambient conditions as work proceeds. The SSHO will determine if it is necessary to upgrade to a higher level of protection.

To ensure that radioactive materials remain under the control of the contractor, each worker involved in this decommissioning effort and working in a contaminated area will be frisked using calibrated, hand-held instruments prior to leaving the contaminated work area. Equipment and materials will be frisked and decontaminated, as necessary, prior to exiting the controlled area. Records of release surveys will be maintained on standardized forms and maps and will be placed in the decommissioning records. Release criteria will be consistent with those contained in the Radiation Safety Program. In the event that a sealed radioactive source is used at the site, the SSHO will verify the conditions of the license, which regulates the use of the sealed source, and notify the Hill AFB RSO regarding its arrival. This will include verifying the training of the operators and the frequency of wipe tests.

7.6.1 Exposure Control

Application of engineering, administrative, and personnel protection provisions will control personnel exposure to radioactive material. The priority of application will be descending with respect to their order of description below.

1. ***Engineering***—Engineering controls will be used, as practicable, to minimize or prevent the presence of uncontained radioactive material. Engineering controls will predominantly be comprised of containment, isolation, ventilation, and decontamination.

2. ***Administrative***—Administrative controls will be used to control work conditions and work practices. Administrative controls will predominantly be comprised of the following:

    - ***Access Control***—Routine access to work areas will be limited to personnel necessary to accomplish tasks or activities. Access will also be controlled with respect to training and use of specified personnel protection equipment.

    - ***Postings and Barriers***—Postings will be used to inform personnel of relevant hazards or conditions and associated access requirements. Barriers may be used to prevent unauthorized access.

    - ***Procedures***—Written procedures may be used to describe specific radiation protection requirements necessary for tasks that involve radioactive material.

    - ***Radiation Work Permits***—Radiation Work Permits will be used to describe specific or special worker protection requirements for activities involving radioactive material and not covered by a procedure. Radiation Work Permits may also be used in conjunction with a procedure.

    - ***Contamination Control***—Action levels and limits for radiation surveys, described later in this section, will be used to control the levels of radioactivity on equipment and in areas.

3. ***Personal Protective Equipment***—Personal protective equipment will be used to control personnel exposure to radioactive material when administrative controls are not sufficient and engineering controls are not practicable. Personal protective equipment may include head covering, eye protection, respiratory protection, impervious outerwear, gloves, and/or protective shoes or shoe covers. The decommissioning contractor will perform Job Hazard Analysis to determine personal protective equipment selection.

7.6.2 Radiation Surveys

Radiation surveys will be performed to describe the radiation types and levels in an area or during a task, to identify or quantify radioactive material, and to evaluate potential and known radiological hazards. The types of radiation surveys and their frequency are described in the following subsections:

1. ***Contamination Measurements***—Measurements will be made of removable alpha, beta, and beta-gamma radiation, as applicable. The measurements will be made by wiping an area with cloth, paper, or tape. The radiation levels will be measured on the wipe.

2. ***Radiation***—Exposure rate measurements will be performed using an ion chamber or equivalent. Measurements will be made at approximately 30 centimeters. Measurements may also be made at contact.

3. ***Personnel***—Personnel will be frisked prior to leaving access-controlled areas.

4. ***Action Levels***—Action levels are established to inform site personnel when a situation needs to be evaluated so that corrective actions can be taken. Action levels are set so that corrective actions can be made before a regulatory limit is exceeded. Based on information collected during the Supplemental Site Characterization Survey, action levels as outlined in regulatory requirements (e.g., 10 CFR 20) will be sufficient to ensure worker protection.

In cases where an action level is exceeded, an investigation will be conducted that includes evaluation of preventative and/or corrective action. The investigation and documentation of such is completed commensurate with the significance of the condition.

7.7 Instrumentation Program

Instruments used for radiation detection and measurement will be operated in compliance with contractor Radiation Safety Program SOPs. SOPs will contain instructions on the proper use of the instrument, as well as calibration instructions for those instruments, which are calibrated by a certified calibration facility. Radiation detection instruments are calibrated in manner and frequency as per license and manufacturer requirements and after each repair that would affect the accuracy of the instrument. Only personnel trained in accordance with the procedures will use radiation detection instruments. A calibration sticker shall be attached to the instrument to allow the operator to verify the instrument is within current calibration prior to use. Instruments shall be visually inspected, battery checked, and source checked prior to use. Radiation survey equipment and instrumentation suitable for detecting and quantifying the radiological hazards to workers and the public will be present onsite throughout decommissioning activities. The selection of equipment and instrumentation to be utilized will be based upon knowledge of the radiological contaminants as well as concentrations, chemical forms, and chemical behaviors that are expected to exist as demonstrated during radiological characterization activities. Equipment and instrumentation selection will also take into account the working conditions, contamination levels, and source terms encountered during the performance of decommissioning work, as presented in this Decommissioning Plan. In all cases, the program will be consistent with the requirements set forth in the Radiation Safety Program.

7.8 Nuclear Criticality Safety

Available historical records show that radioactive soils are not expected to meet the definition of Special Nuclear Material per 10 CFR 70.4. Therefore, nuclear criticality safety measures will not be necessary.

7.9 Health Physics Audits, Inspections, and Recordkeeping Program

The Radiation Safety Program shall be subject to an audit as well as periodic inspections. Each are performed to determine if radiological operations are being conducted in accordance with regulations, license conditions, and written procedures.

An audit of the program shall be conducted at least once during the execution of the project. The audit shall be conducted by the Corporate RSO or designee. The audit will consider the basic functional areas of the program; e.g., Radiation Work Permits, radiation protection procedures, radiological surveys and air monitoring, ALARA program, individual and area monitoring results, access controls, respiratory protection program, and training, and final status surveys.

The audit shall be conducted in accordance with a specific audit plan developed by the auditor. A written report describing the results shall be generated upon completion of the audit. The report shall be distributed to site management. As necessary, a written corrective action plan shall be prepared to address non-compliance issues. All corrective actions shall be tracked to completion. Once corrective actions have been completed, a written closeout report shall be distributed to management documenting the completion of corrective actions.

The Health and Safety staff shall conduct the periodic inspections. These inspections shall be routine reviews performed of operations and activities. The inspections shall normally be completed against a pre-established checklist. Checklists may be developed independently for differing periods; e.g., daily, weekly, monthly, etc. The checklist items shall usually be comprised of routine procedural requirements. Any findings discovered during the routine inspection shall be recorded on a tracking log. The log shall be maintained by the SSHO or designee. The log shall include a description of planned corrective action and date of completion of corrective action.

7.9.1 Personnel Records

A personnel file is maintained for each employee assigned work duties involving radioactive materials. The content of these files include at a minimum:

- A record of radiation exposure received by the individual during previous employment is maintained by requesting personal exposure information from previous employers where the individual worked with radioactive materials.

- A record of personnel dosimeter measurements is recorded in the personnel file to provide a permanent record of radiation exposure received during the course of work assignments.

- If a personal dosimeter is lost or damaged, an exposure investigation will be performed and an exposure will be assigned for the monitoring period. A report detailing the exposure estimate will be included in the personnel record.

- If the air concentration in the work area exceeds 10 percent of derived air concentration values, air samples and bioassay samples will be used to estimate internal exposures received by the worker and included into their personal exposure file.

- If a worker finds contamination on their person above the limits specified in Table 6-3 of the Radiation Protection Plan (Appendix C of the Remedial Design/Remedial Action Work Plan), a report of the incident will be placed in the personnel file to determine exposure from the incident.

- The personnel records will be maintained indefinitely and personnel may review their file or request copies of information within their files. The licensee for which work is performed will be provided individual exposure information as required by their license or applicable regulations.

Personnel records will be maintained in a secured location, typically a locked fire-proof file cabinet, when not continuously attended by authorized personnel. The SSHO or designee will ensure that individual records are protected from unauthorized review or distribution. Only the SSHO or designee, individual's supervisor, and individual will have access to an individual's personnel records. Personnel records will be maintained indefinitely and personnel may review their file or request copies of information within their files at any time during normal working hours.

7.9.2 Radiation and Contamination Records

Radiation and contamination survey records collected during site surveys, remediation/decontamination activities, and other decommissioning activities shall be stored in project-specific files at the contractor office. Duplicate copies of the records are also supplied to the licensee where the work was performed.

7.9.3 Records of Waste Disposal

Radiation Survey Records, contamination survey records, shipping manifests, and certifications generated for a licensee's shipment of radioactive materials to a licensed disposal site shall be stored in specific shipment files in the contractor's office. Duplicate copies of the records are supplied to the licensee for the work performed.

TABLE 7-1
Acceptable Surface Contamination Levels
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench Decommissioning Plan, Hill Air Force Base, Utah

Radionuclide[a]	Acceptable Surface Contamination Levels (Disintegrations per Minute/100 Square Centimeters)		
	Removable [b,c]	**Average** [d]	**Maximum** [e]
Transuranics, ^{226}Ra, ^{228}Ra, ^{230}Th, ^{228}Th, ^{231}Pa, ^{227}Ac, ^{125}I, ^{129}I	20	100	300
Th-natural, ^{232}Th, ^{90}Sr, ^{223}Ra, ^{224}Ra, ^{232}U, ^{126}I, ^{131}I, ^{133}I	200	1,000	3,000
U-natural, ^{235}U, ^{238}U, and associated decay products	1,000 α	5,000 α	15,000 α
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except ^{90}Sr and others noted above.	1,000 β-γ	5,000 β-γ	15,000 β-γ

NOTES:

a. Where surface contamination by both alpha- and beta-gamma emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides should apply independently.

b. As used in this table, disintegrations per minute means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

c. The amount of removable radioactive material per 100 square centimeters of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionately and the entire surface should be wiped.

d. Measurements of average contaminant should not be averaged over more than 1 square meters. For objects of less surface area, the average should be derived for each object.

e. The maximum contamination level applies to an area of not more than 100 square centimeters.

Transuranic = Radium-226, radium-228, thorium-228, thorium-232, actinium-227, protactinium-231, iodine-125, iodine-129.
Th-natural = Thorium-232, strontium-90, radium-223, uranium-232, iodine-126, iodine-131, iodine-133.
U-natural = Uranium-235, uranium-238.
α = Alpha.
β = Beta.
γ = Gamma.

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8.0 Environmental Monitoring and Control Programs

The decommissioning project management team will ensure that exposure of ionizing radiation to workers, the public, and the environment will be maintained ALARA, and that decommissioning activities will be conducted in a manner that supports this commitment. Engineering and administrative controls will be utilized to the maximum extent practical to minimize the potential for air and liquid effluents and to ensure that any releases to the environment comply with 10 CFR Part 20 requirements, as well as with applicable regulatory guides.

8.1 Effluent Monitoring Program

The primary routes of contaminant transport in effluents during the onsite decommissioning activities are anticipated to be airborne dust from soil excavation. While concentrations of radionuclides in site effluents may increase slightly during decommissioning activities, the effluents will be closely monitored to ensure the effectiveness of engineering and administrative controls in maintaining radioactivity concentrations ALARA.

Effluent air samplers will be positioned at locations along the perimeter of the site that present the greatest likelihood of airborne effluent releases (i.e. downwind of the WR111 site). A total of two effluent air samplers will be used to monitor effluent releases. In addition, general area samplers will be positioned downwind of work locations as described in Section 7.2 to ensure that the samples collected within the immediate work area are representative of actual releases. The positions of the air samplers will be evaluated frequently by the SSHO to take into account any shifts in prevailing wind direction and any movement in the locations of dust-generating operations. Consideration will be given to more frequent filter change-outs during periods of high dust conditions, as determined based on professional judgment.

Air samples collected during decommissioning will be analyzed for airborne radioactivity concentrations. Air samples will be analyzed onsite for gross alpha and gross beta radioactivity, and a portion (five percent) of the samples will be sent to an accredited offsite laboratory for confirmatory analysis. Air effluents will be maintained ALARA and not greater than 20 percent of the limits in 10 CFR 20, Appendix B, Table 2, Column 1. Background air samples will be collected prior to the commencement of site activities in order to establish a baseline for background radionuclide concentrations.

Liquid effluent is not expected to be generated as a result of decommissioning activities. Potentially contaminated liquids, such as stormwater runoff from contaminated areas, shall be collected, sampled, and analyzed before disposition is determined with the concurrence of Hill AFB.

NOTE: The air effluent limits in 10 CFR 20, Appendix B, Table 2, are annual average limits. Short term air effluents may be higher, provided that the annual average does not exceed 20 percent of the 10 CFR 20, Appendix B, Table 2, Column 1 limits for air effluents.

8.2 Effluent Control Program

Effluent control will be performed to address other environmental plans and permitting requirements on the installation. This may include the development of a stormwater pollution prevention plan and measures to avoid potential runoff of oil and fuel from construction equipment.

If visible dust is generated during decommissioning activities, controls will be implemented to moisten the excavation areas, as necessary, to reduce the potential for generating airborne radioactivity. Any soil or other material that is staged in piles, containers, or vehicles will be covered as practical to prevent dispersion by wind and precipitation. If radiological air monitoring results indicate the presence of airborne contaminants in excess of the effluent limits specified in Section 5.1, then work will be stopped, appropriate personnel including the SSHO will be informed, dose evaluations will be performed, and corrective measures will be implemented, as necessary, to control the additional spread of contamination.

Construction activities and equipment shall be monitored closely to ensure that there are no adverse impacts to the environment. This is to prevent the spread of radiological and chemical contamination. Although there are no chemical constituents for the site, there is still a low potential of oil and fuel runoff from construction equipment. The only foreseeable source of contaminated liquid effluents is the accumulation of rain water in open excavations and stormwater runoff. Stormwater that collects in open excavations prior to the completion of final status surveys will be collected, sampled, and analyzed prior to disposition. Runoff shall be controlled through the use of berms, silt fencing, absorbent materials, solidifying agents, or by other means, as necessary.

9.0 Radioactive Waste Management Program

The solid and liquid radioactive waste generated during decommissioning of Site WR111 will be managed as described in this section.

9.1 Solid Radioactive Waste

Material to be removed from Site WR111 is expected to contain soil and residual solids from the in-place burning of waste. The estimated in situ volume of material in the disposal pits is 1,100 cubic yards. Waste materials exhumed from the disposal trench will be transferred to a designated storage area within the fence of Site WR111. Materials will be loaded into dump trucks and tarped before transport to the US Ecology in Grand View, Idaho. A detailed description of excavation, transportation, and disposal of waste materials is provided in Section 4.3 of the Remedial Design/Remedial Action Work Plan.

The spread of potentially contaminated soil and silt materials will be controlled through the use of covers, silt fencing and berms, as necessary, to limit the spread of contamination by means of erosion. It should be noted that, during the supplemental characterization, three soil samples were submitted to TestAmerica for Waste Acceptance Criteria specified by US Ecology. The analyses included toxicity characteristic leaching procedure for EPA-regulated analytes, polychlorinated biphenyls, ignitability, corrosivity, and reactivity. The laboratory results are presented in Appendix B and indicate that the soils at Site WR111 are not considered Resource Conservation and Recovery Act hazardous waste.

9.2 Liquid Radioactive Waste

Generation of liquid radioactive waste is expected to be minimal during the decommissioning of Site WR111. There is no surface water within Site WR111 and with groundwater being absent in the vadose zone, the only foreseeable source of contaminated liquid is the accumulation of rain water in open excavations and stormwater runoff. If potentially contaminated liquid is generated as a result of excessive rainfall, runoff will be controlled through the use of berms, silt fencing, absorbent materials, solidifying agents, or by other means, as necessary. Stormwater that collects in open excavations prior to the completion of final status surveys will be sampled and analyzed prior to release.

In order to minimize potential liquid waste, equipment decontamination is anticipated to be performed on a dry basis through the use of MASSLINN decontamination wipes. Should the use of water during the decontamination be necessary, a temporary decontamination pad will be constructed and any liquid collected and containerized. Accordingly, any accumulated liquids during decontamination activities will be handled, stored, sampled, and analyzed prior to release.

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10.0 Quality Assurance Program

Field surveys will be performed in a manner that ensures the quality and accuracy of data and provides auditable documentation of activities. Details of the field QA and QC requirements are described in this section. Additional QC procedures, which are addressed in the Contractor's corporate QA program and SOPs, include instructions on the following subjects:

- Daily instrument background and source check measurements to confirm that equipment operation is within acceptable tolerances
- Training of all individuals executing SOPs
- Periodic internal audits
- Implementation of split and duplicate sampling, as well as blind spike sample analysis to evaluate the adequacy and accuracy of laboratory performance.

10.1 Organization

Only qualified and trained personnel will operate the equipment and instrumentation used in the field activities specified in this Decommissioning Plan. Personnel will be trained in the technical, QC, and health and safety aspects of the project, as well as in the calibration, maintenance, and SOPs for their assigned equipment.

Daily tailgate safety meetings will provide supplemental training and ensure that personnel are given clear direction and the proper tools for performing their respective tasks. These meetings will also provide a forum for the field personnel to relate any potential safety or quality concerns that may require attention from the Corporate RSO or EA Site Project Manager. Tailgate meeting notes and attendance sheets will be maintained onsite and included in the project file.

Persons responsible for ensuring that the QA Program has been established and for verifying that activities affecting quality are being correctly performed will have sufficient authority, access to work areas, and organizational freedom to accomplish the following:

- Identify quality concerns
- Ensure that further decommissioning activities are controlled until proper resolution of a non-conformance or deficiency has occurred
- Initiate, recommend, or provide solutions to quality problems through designated channels
- Verify implementation of solutions.

The Contractor QCM will maintain responsibility for ensuring that the decommissioning quality objectives are met. This person will have direct access to responsible management at a level appropriate for implementing corrective actions, as necessary, and thus, will report directly to the EA Site Project Manager, or designee, to ensure the required authority and organizational freedom to perform this function. The Contractor QCM may designate others, as appropriate, to implement specific elements of the QA Program.

10.2 Quality Assurance Program

Activities associated with this Decommissioning Plan shall be 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 Decommissioning Plan is described in the sections below.

10.3 Document Control

Data will be recorded and documented in accordance with the Contractor's data management system. Radiation survey maps will identify the location being surveyed, as well as the name of the surveyor, date and time of survey performance, and signatures of those who review and approve the survey data. To the extent practical, State plane coordinates will be used to define the locations of soil samples. If not available, site-specific references will be used to describe sample locations.

Data management personnel will ensure that chain-of-custody and data management procedures are strictly followed for samples related to the FSS. Established protocols will be used to ensure the proper collection, documentation, handling, preparation, storage, and shipment of samples. Field data related to sample collection will be recorded in field logbooks and/or on field data sheets at the time of sample collection and reviewed on a daily basis. Other sample documentation (e.g., labels, chain-of-custodies, log sheets, etc.) will be checked for consistency with the field documentation prior to shipping samples offsite.

Both radiation measurements and analytical results will be documented. The results for each survey measurement and/or each sample will be listed in tabular form along with the corresponding grid block location or coordinate. Radiation survey data will be recorded in a verifiable manner and reviewed for accuracy and consistency. Each of the major phases of the decommissioning process will be documented in a manner that is suitable for audits or assessments.

Substantive changes to the Decommissioning Plan will be submitted to the NRC for review and approval before they are implemented. The records discussed in the preceding paragraphs will be maintained until the completion of remedial action.

10.4 Control of Measuring and Test Equipment

The SSHO, or designee, is responsible for determining the radiological instrumentation necessary to execute the Decommissioning Plan. Only radiological instrumentation approved by the SSHO will be used to collect radiological data. The SSHO is responsible for ensuring that individuals are appropriately trained to use project instrumentation and other equipment, and that instrumentation meets the required detection sensitivities. Instrumentation will be operated in accordance with either a written procedure or manufacturers' manual. The procedure and/or manual will provide guidance to field personnel on the proper use and limitations of the instrument.

Instruments used during the decommissioning activities will have current calibration and maintenance records kept on the site for review and inspection. The records will include, at a minimum, the following:

- Name of the equipment
- Equipment identification (model and serial number)
- Manufacturer
- Date of calibration
- Calibration due date.

Instrumentation shall be maintained and calibrated to manufacturers' specifications to ensure that required traceability, sensitivity, accuracy, and precision of the equipment/instruments are maintained. Instruments will be under current calibration, from a facility possessing appropriate NRC and/or Agreement State licenses for performing calibrations using National Institute of Standards and Technology traceable sources.

Prior to daily use, project instrumentation will be QC checked by comparing instrument response to a benchmark response. Prior to the commencement of field operations, site reference locations shall be selected for performance of these checks; subsequent QC checks will be performed at these locations. QC source checks will consist of a 1-minute integrated count, or other count time designated by the Project Health Physicist, or designee, with the designated source positioned in a reproducible geometry, performed at the reference location. Prior to the start of initial surveys, this procedure will be repeated at least 10 times to establish average instrument response. Equipment should also be inspected for physical damage, current calibration, and erroneous readings in accordance with applicable procedures and/or protocols. Instrumentation that does not meet the specified requirements of calibration, inspection, or response check will be removed from operation.

10.5 Corrective Action

The Contractor QCM has overall responsibility for reporting contract, procedure, and regulatory violations identified to the EA Site Project Manager. The EA Site Project Manager will notify the Air Force RSO of any violations, and the RSO will determine whether the violation requires notification of the appropriate regulatory agency.

Any deficiency or nonconforming conditions will be documented on a Corrective Action Request Form. This form is typically completed by the individual identifying or reporting the nonconformance, and then submitted to the Contractor QCM. The completed form provides a detailed description of the nonconforming condition and references the affected documents, if any, that apply.

The Contractor QCM will review the Corrective Action Request and initiate appropriate corrective action. Following implementation of the action, the QCM will re-evaluate the situation to verify that the response successfully addressed the original concern. The QCM may also initiate preventive action to avoid future occurrences, if necessary. If the re-evaluation indicates that the corrective action has achieved satisfactory results, the Contractor QCM will accept the response and close the Corrective Action Request. The Contractor QCM will maintain a log of all Corrective Action Requests, indicating the current status of each. After corrective action has been verified complete, the closed Corrective Action Request (original) will be maintained in the project file.

10.6 Quality Assurance Records

QA records will be maintained in a centralized project file throughout the decommissioning project. Analytical data reduction, QC review, and reporting will be the responsibility of the analytical laboratory. The laboratory will provide a data package for each set of analyses, which will include a copy of the raw data in electronic format, as well as any other information needed to verify and/or reproduce the analytical results. The data packages will serve as basic reference sheets for data validation, as well as for project data end use.

The generation, handling, computations, evaluation, and reporting of final status survey data will be conducted as specified in the FSSP and implementing procedures. Included in these procedures will be a system for data review and validation to ensure consistency, thoroughness, and acceptability of the data. Some data points will be chosen for evaluation and examined to determine compliance with QA requirements and other factors that determine the quality of the data. Any rejected sample data or data omissions identified during the data validation will be evaluated to determine their impact on the project. Other corrective actions may include resampling and/or reanalysis; evaluating and amending sampling and analytical procedures; and accepting data as reported, with an acknowledgment of the level of uncertainty.

The individual(s) responsible for sample collection will initiate chain-of-custody records. A copy of the chain-of-custody form will accompany the samples throughout transportation and analyses, and any breach in custody or evidence of tampering will be appropriately documented.

10.7 Audits and Surveillances

Periodic audits will be performed to verify that decommissioning activities comply with the Decommissioning Plan, established decommissioning procedures, and to evaluate the overall effectiveness of the QA Program. The EA Site Project Manager and QA Officer will verify that qualified personnel are employed to conduct audits to ensure that the applicable procedures are being properly implemented. The audits will be conducted on at least a quarterly basis for the duration of decommissioning activities. Health and safety personnel will also conduct audits in their area of concern during the decommissioning activities. External program audits may also be used at the discretion of the contractor.

Audit results will be reported to EA Site Project Manager and Contractor QCM in writing, and actions to resolve identified deficiencies will be tracked and appropriately documented. The audit information will become part of the decommissioning record for the site.

11.0 Facility Radiation Surveys

There are no facilities that require radiation surveys to support the decommissioning of Site WR111.

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12.0 Financial Assurance

Financial assurance and funding for the decommissioning activities as described in this plan are provided by AFCEC.

12.1 Cost Estimate Summary

EA is currently contracted to obtain site closeout for Site WR111 under Hill AFB PBR Contract No. FA8903-09-D-8560, Task Order 0006.

12.2 Remedial Action for Soil

The remedial action for impacted soil selected in this Decommissioning Plan is necessary to protect the public health or welfare or the environment from actual or threatened releases of hazardous substances into the environment. Therefore, excavation and offsite disposal of contaminated soil at a permitted or licensed disposal facility was selected. This remedial action provides a high level of protection to human health and the environment by removing contaminated materials, and is consistent with the very conservative unrestricted land use assumptions for the property.

12.3 Soil Volume and Schedule

The estimated volume of contaminated soil for the site was calculated based on the area and depth of the contaminated soil above the cleanup criterion for ^{232}Th. In Section 4.0, the DCGL for ^{232}Th was calculated to 1.9 pCi/g. By adding the background concentration, the cleanup criterion for ^{232}Th was calculated to be 3.5 pCi/g. A computer contouring software, Surfer, was utilized to determine the in situ soil volume of 1,862 cubic yards. The *ex situ* volume of 2,420 cubic yards was then calculated by applying a 130 percent swelling factor to the in situ soil volume.

12.4 Cost Elements

The remedial action cost typically includes both capital and operation and maintenance costs. The selected cleanup criterion for the site was based on an unrestricted land use scenario; therefore, no post-remedial action operation and maintenance costs for monitoring were included.

Capital costs are those expenditures required to implement a remedial action and consist of both direct and indirect costs. Indirect capital costs consist of engineering, supervision, management, administration, financial, and other services necessary to implement a remedial action. These costs are not incurred as part of actual remedial actions but are ancillary to direct or construction costs. However, no indirect capital costs are estimated for this project. Indirect costs include:

- Remedial design
- Project management
- Construction management
- Program management cost
- Prime contractor and subcontractor markups.

Direct capital costs include equipment, labor, and materials necessary for implementing the remedial action. These typically include costs for:

- Mobilization and demobilization
- Monitoring, sampling, and analysis during remedial action
- Excavation of soil
- FSS
- Site work (backfilling)
- Sediment and surface water collection/controls
- Transportation and disposal
- Site restoration.

12.5 Certification

U.S. Air Force Radioisotope Committee will coordinate with NRC and provide a statement regarding its intent to fund the remedial action at Site WR111. The estimated cost is reasonable and funding is available through existing PBR contracts.

13.0 References

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Appendix A
Field Logs

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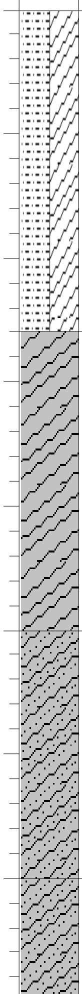
Parsons Engineering Science, Inc
406 West South Jordan Parkway, Suite 300
South Jordan, Utah 84095

Log of Well: LM-060

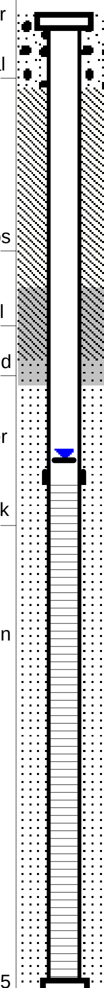
Project: LMTA OU A

Date: 1-3 August 2006

Geologist: TM Jensen



Depth	Lithologic Description	Moisture	Drill Speed/ Density	PID	Sample ID	Remarks
0	Ground Surface				NA	above ground 2.5 in. PVC riser
0–13	**Colluvium/Slate** Slaty argillite, rounded pebbles, 5Y 4/1 olive gray to grayish brown, possible overburden			0.0		concrete seal; bentonite chips; coated pellet bentonite seal; medium (16-40) barrier sand
13–25	**Slate** Slaty argillite, dk. grayish brown to dk. gray, some oxidized pyrite, clay balls in drilling cuttings, moist @ 14 feet	moist		0.0		2.5 in. schedule 40 PVC riser; coarse (10-20) sand pack
25–35	**Tillite** dark gray, slightly coarse grained, clastic?, weak rock and more blocky, less slaty, clay balls from moisture. Note: near contact of fault that juxtaposes slate against tillite	wet		0.0		2.5 in. sch. 40 PVC screen 0.020 slot
35–40	SAA, med dark gray to dark gray to olive gray, blocky rock fragments, quartz clasts, mortar-like cuttings, mostly rock pulverized to soil, some graphite			0.0		6 in. sump; TD=39.5
40	TD= 40 ft bgs					



Driller: Layne

Drill Rig: Schramm DH

Drill Method: Air Rotary w/ Odex casing

Ground Surface Elevation: 4231.94

Top of Casing Elevation: 4234.02

Borehole Diameter: 8.0 inches

Parsons Engineering Science, Inc
406 West South Jordan Parkway, Suite 300
South Jordan, Utah 84095

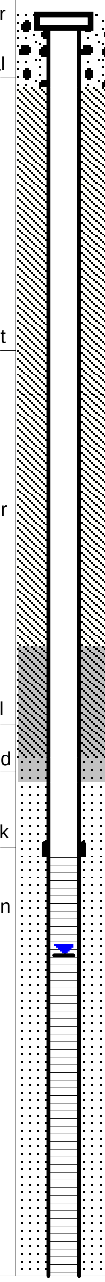
Log of Well: LM-061

Project: LMTA OU A

Date: 3 and 9 August 2006

Geologist: TM Jensen

Depth	Lithologic Description	Moisture	Drill Speed/ Density	PID	Sample ID	Remarks
0	Ground Surface				NA	above ground 2.5 in. PVC riser
0–2	**Colluvium** topsoil, silt, sand, and rock fragments					concrete seal
2–12	**Slate** argillitic, slaty cleavage, platy rock fragments, med. gray (N4) to med. dark gray (N5) to brownish gray 5YR 4/1, weak rock, easily pulverized w/ drill hammer					
12–25	SAA, no apparent hard zones or quartz zones indicative of fractures			0.0 (20)		cement-bentonite grout; 2.5 in. schedule 40 PVC riser
25–33	SAA, medium to medium dark gray, harder rock, small platy rock fragments, not much oxidation		slower			coated pellet bentonite seal; medium (16-40) barrier sand; coarse (10-20) sand pack
33–46	SAA, no apparent water	dry		0.0 (36)		2.5 in. sch. 40 PVC screen 0.020 slot
46–50	SAA, slate, med to med dark gray, N4-N5, platy rock fragments, some thin laminae, more oxidation staining on parting surfaces, no apparent pyrite or oxidized pyrite as normally seen in this formation					



Driller: Layne

Drill Rig: Schramm DH

Drill Method: Air Rotary w/ Odex casing

Ground Surface Elevation: 4245.00

Top of Casing Elevation: 4247.34

Borehole Diameter: 8.0 inches

Parsons Engineering Science, Inc
406 West South Jordan Parkway, Suite 300
South Jordan, Utah 84095

Log of Well: LM-061

Project: LMTA OU A

Date: 3 and 9 August 2006

Geologist: TM Jensen

Depth	Lithologic Symbol	Lithologic Description	Moisture	Drill Speed/ Density	PID	Sample ID	Remarks	Well	Depth
54.5							6 in. sump; TD=54.5		
55		SAA, slate, some quartz, more competent rock and slower drilling from 55-57, some pyrite @ 58 feet, terminate at 63 feet bgs and allow water to equlilibrate in open hole, not much water during drilling or recharge into borehole							55
63		TD= 63 ft bgs							

Depth scale: 55, 60, 65, 70, 75, 80, 85, 90, 95, 100

Driller: Layne

Drill Rig: Schramm DH

Drill Method: Air Rotary w/ Odex casing

Ground Surface Elevation: 4245.00

Top of Casing Elevation: 4247.34

Borehole Diameter: 8.0 inches

Parsons Engineering Science, Inc
406 West South Jordan Parkway, Suite 300
South Jordan, Utah 84095

Log of Well: LM-062

Project: LMTA OU A

Date: 8 and 11 August 2006

Geologist: TM Jensen

Depth	Lithologic Symbol	Lithologic Description	Moisture	Drill Speed/ Density	PID	Sample ID	Remarks	Well	Depth
		Ground Surface							
0		**Colluvium** topsoil, silt, sand, and rock fragments				NA	above ground 2.5 in. PVC riser; concrete seal		0
5		**Slate** argillitic, slaty cleavage, med. gray (N4) to med. dark gray (N5), relatively hard, oxidation on parting surfaces, very fine dust from drilling							5
10							bentonite chips		10
15		SAA, hard, slight schistocity, no apparent pyrite or LAP, some oxidation,					coated pellet bentonite seal		15
20				slower	0.0		medium (16-40) barrier sand; 2.5 in. schedule 40 PVC riser		20
25		SAA, hematized zone from 35 tom 40; rock is rust to red brown in this zone							25
30							coarse (10-20) sand pack		30
35					0.0		2.5 in. sch. 40 PVC screen 0.020 slot		35
40		SAA, slate, med to med dark gray, N4-N5, oxidation staining on parting surfaces, no apparent pyrite or oxidized pyrite					6 in. sump; TD=44.5		40
45									45
50									50

Driller: Layne

Drill Rig: Schramm DH

Drill Method: Air Rotary w/ Odex casing

Ground Surface Elevation: 4234.27

Top of Casing Elevation: 4236.52

Borehole Diameter: 8.0 inches

Parsons Engineering Science, Inc
406 West South Jordan Parkway, Suite 300
South Jordan, Utah 84095

Log of Well: LM-062

Project: LMTA OU A

Date: 8 and 11 August 2006

Geologist: TM Jensen

Depth	Lithologic Symbol	Lithologic Description	Moisture	Drill Speed/ Density	PID	Sample ID	Remarks	Well	Depth
55									55
60									60
65									65
70									70
75									75
80									80
85									85
90									90
95									95
100									100

Driller: Layne

Drill Rig: Schramm DH

Drill Method: Air Rotary w/ Odex casing

Ground Surface Elevation: 4234.27

Top of Casing Elevation: 4236.52

Borehole Diameter: 8.0 inches

Parsons Engineering Science, Inc
406 West South Jordan Parkway, Suite 300
South Jordan, Utah 84095

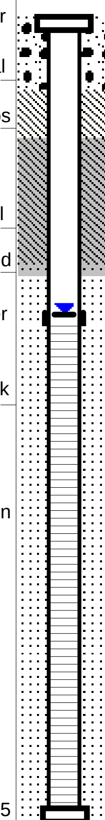
Log of Well: LM-063

Project: LMTA OU A

Date: 4 & 9 August 2006

Geologist: TM Jensen

Depth	Lithologic Description	Moisture	Drill Speed/ Density	PID	Sample ID	Remarks
0	Ground Surface				NA	above ground 2.5 in. PVC riser
0–13	**Colluvium/Alluvium** unconsolidated with rock fragments, moist					concrete seal; bentonite chips; coated pellet bentonite seal; medium (16-40) barrier sand; 2.5 in. schedule 40 PVC riser
13–16	**Tillite** med. dk. gray, milky quartz broken clasts, blocky to angular rock fragments, pulverized mortar-like soil, moist	moist		0.0		coarse (10-20) sand pack
16–25	SAA, less quartz, easy drilling		fast	0.0		2.5 in. sch. 40 PVC screen 0.020 slot
25–30	SAA, more quartz, gritty texture, pulverized rock forms sandy soil,			0.0		
30–36	SAA, dark gray (N5), little water in borehole			0.0		6 in. sump; TD=32.5
36	TD=36 feet bgs					



Driller: Layne

Drill Rig: Schramm DH

Drill Method: Air Rotary w/ Odex casing

Ground Surface Elevation: 4225.14

Top of Casing Elevation: 4227.30

Borehole Diameter: 8.0 inches

	CABRERA SERVICES 1106 N. CHARLES STREET SUITE 300 BALTIMORE, MD 21201	**SOIL BORING LOG**	**BORING No:** WR-700	
		PROJECT: Hill AFB - WR111	**DATE:** 7/2/2013	**PAGE:** 1 of 1
Comments		**PROJECT No:** 13-1013.00	**TIME:** 0845	**LOGGED:** S. Owe
DHG Surface measurement = 4,186 cpm Boring cave-in at 10.5 Ft. bgs The instrument was lowered into the borehole to the target depth and one-minute static measurements were collected at half a foot intervals proceeding upward until the top of the borehole was reached.		**DRILLING METHOD:** Geoprobe	**CORE SCAN INSTUMENT:** Ludlum 2221/ 44-20	
		BORING DEPTH (Ft. bgs): 12.0	**Serial No:** 161580 / PR324757	
		WATER DEPTH (Ft. bgs): None	**BACKGROUND (cpm):** 36,105	
		COORDINATES (N/E) : 4566631.57 / 396224.75	**DHG INSTRUMENT:** Ludlum 2221/ 44-2	
		COORDINATE SYSTEM: WGS1984 UTM Zone 12 N (meters)	**Serial No:** 138356 / PR228325	
		ELEVATION (MSL): 1296.15 meters	**BACKGROUND (cpm):** 2,806	

Depth (Ft. bgs)	Soil Texture	DHG (cpm)	Core Scan (cpm)	Recovery Ft. (4 Ft. Core)	Soil Description: Texture, color, firmness, etc.
	ML	5,246	38,300	FULL	SILT, some Sand, fine to med, light brown, med density, no plasticity, very dry
1		5,855			
		5,469	38,400		SILT, with Sand, fine, light brown/ white, some Gravel, angular, small to med, hard, dry, No plasticity
2		5,640			
		5,990	38,600		
3		5,995			
		6,167	38,300		
4		5,925			COBBLE, crushed
	ML	6,606	38,200	FULL	Clayey SILT, with Sand, fine to med, and Gravel, angular, small to med, med density, dark brown, med plasticity
5		6,908			
		7,196	37,800		
6		6,759			
		6,830	37,400		
7		6,897			
		6,992	37,400		hard
8		7,410			
	ML	8,310	37,900	FULL	Clayey SILT, with Sand, fine to med, some Gravel, small to med, dark brown, med plasticity
9		10,333			
		8,699	37,469		
10		7,550			
		7,430	37,500		
11		NA			
		NA	37,221		
12		NA			
13					**TD @ 12.0 Ft. bgs**
14					
15					
16					
17					
18					
19					
20					

Samples Collected	**Time**	**Depth Interval**
WR111-SB-WR700-SS-P-00	0845	(Surface)
WR111-SB-WR700-BS-P-09	0900	(9-10 Ft)

	CABRERA SERVICES 1106 N. CHARLES STREET SUITE 300 BALTIMORE, MD 21201	**SOIL BORING LOG**	**BORING No:** WR-701	
		PROJECT: Hill AFB - WR111	**DATE:** 7/2/2013	**PAGE:** 1 of 1
Comments		**PROJECT No:** 13-1013.00	**TIME:** 0945	**LOGGED:** S. Owe
DHG Surface measurement = 4,055 cpm Boring cave-in at 8.5 Ft. bgs The instrument was lowered into the borehole to the target depth and one-minute static measurements were collected at half a foot intervals proceeding upward until the top of the borehole was reached.		**DRILLING METHOD:** Geoprobe	**CORE SCAN INSTUMENT:** Ludlum 2221/ 44-20	
		BORING DEPTH (Ft. bgs): 12.0	**Serial No:** 161580 / PR324757	
		WATER DEPTH (Ft. bgs): None	**BACKGROUND (cpm):** 36,105	
		COORDINATES (N/E) : 4566631.89 / 396230.28	**DHG INSTRUMENT:** Ludlum 2221/ 44-2	
		COORDINATE SYSTEM: WGS1984 UTM Zone 12 N (meters)	**Serial No:** 138356 / PR228325	
		ELEVATION (MSL): 1295.95 meters	**BACKGROUND (cpm):** 2,806	

Depth (Ft. bgs)	Soil Texture	DHG (cpm)	Core Scan (cpm)	Recovery Ft. (4 Ft. Core)	Soil Description: Texture, color, firmness, etc.
	ML	6,152	37,600	3.5 Ft	
1		6,834			SILT, with Sand, fine, some Gravel, angular, small to med, light brown, med density, dry,
		8,603	37,600		No plasticity
2		80,414			
		133,534	35,360		
3		355,733			
		716,895	35,300		
4		818,907			SILT, dark brown, loose, no plasticity
	ML	820,809	145,000	2.0 Ft	Burned ASH MATERIAL, brittle, flakey, white/gray
5		806,590			
	GP	753,004	145,000		GRAVEL, angular, reddish brown
6		649,563			Clayey SILT, with Sand, F to M, some, angular Gravel, small to med, light brown, med plasticity
	ML	457,638	NR		
7		131,943			No Recovery
		50,518	NR		
8		29,837			
	ML	30,171	120,000	FULL	SILT, with Sand, fine, light brown, loose, no plasticity
9		NA			
		NA	90,000		Burned ASH MATERIAL, brittle, flakey, white/gray
10		NA			Clayey SILT, with Sand, F to M, some, angular Gravel, small to med, brown, med plasticity
		NA	44,000		
11		NA			
		NA	43,000		
12		NA			
13					TD @ 12.0 Ft. bgs
14					
15					
16					
17					
18					
19					
20					

Samples Collected	Time	Depth Interval	
WR111-SB-WR701-SS-P-00	0945	(Surface)	
WR111-SB-WR701-BS-P-05	0950	(5-6 Ft)	
WR111-SB-WR701-SS-D-00	0955	(Surface)	(DUP)

CABRERA SERVICES 1106 N. CHARLES STREET SUITE 300 BALTIMORE, MD 21201	**SOIL BORING LOG**	**BORING No:** WR-702	
	PROJECT: Hill AFB - WR111	**DATE:** 7/2/2013	**PAGE:** 1 of 1
Comments	**PROJECT No:** 13-1013.00	**TIME:** 1545	**LOGGED:** S. Owe
Boring refusal at 3.0 Ft. bgs Offset boring 5 Ft, refusal at 3.0 Ft. bgs	**DRILLING METHOD:** Geoprobe	**CORE SCAN INSTUMENT:** Ludlum 2221/ 44-20	
No DHG measurements	**BORING DEPTH (Ft. bgs):** 3.0 (Refusal)	**Serial No:** 161580 / PR324757	
The instrument was lowered into the borehole to the target depth and one-minute static measurements were collected at half a foot intervals proceeding upward until the top of the borehole was reached.	**WATER DEPTH (Ft. bgs):** None	**BACKGROUND (cpm):** 36,105	
	COORDINATES (N/E) : 4566618.93 / 396186.20	**DHG INSTRUMENT:** Ludlum 2221/ 44-2	
	COORDINATE SYSTEM: WGS1984 UTM Zone 12 N (meters)	**Serial No:** 138356 / PR228325	
	ELEVATION (MSL): 1297.84 meters	**BACKGROUND (cpm):** 2,806	

Depth (Ft. bgs)	Soil Texture	DHG (cpm)	Core Scan (cpm)	Recovery Ft. (4 Ft. Core)	Soil Description: Texture, color, firmness, etc.
	ML	NA	38,500	2.7 Ft	SILT, some fine Sand, and angular Gravel, small, brown/gray, no plasticity
1		NA			
		NA	39,200		Sandy SILT, fine, some coarse sand and Gravel, angular, small, light brown/gray, no plasticity
2		NA			
		NA	38,700		
3		NA			No Recovery (2.7 - 3.0 Ft.)
4					**TD @ 3.0 Ft. bgs (Refusal)**
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

Samples Collected	**Time**	**Depth Interval**
WR111-SB-WR702-BS-P-02	1600	(2 - 2.5 Ft)

CABRERA SERVICES 1106 N. CHARLES STREET SUITE 300 BALTIMORE, MD 21201	**SOIL BORING LOG**	**BORING No:** WR-703	
	PROJECT: Hill AFB - WR111	**DATE:** 7/2/2013	**PAGE:** 1 of 1
Comments	**PROJECT No:** 13-1013.00	**TIME:** 1555	**LOGGED:** S. Owe
Boring refusal at 4.5 Ft. bgs Offset boring 5 Ft, refusal at 4.5 Ft. bgs No DHG measurements The instrument was lowered into the borehole to the target depth and one-minute static measurements were collected at half a foot intervals proceeding upward until the top of the borehole was reached.	**DRILLING METHOD:** Geoprobe	**CORE SCAN INSTUMENT:** Ludlum 2221/ 44-20	
	BORING DEPTH (Ft. bgs): 4.5 (Refusal)	**Serial No:** 161580 / PR324757	
	WATER DEPTH (Ft. bgs): None	**BACKGROUND (cpm):** 36,105	
	COORDINATES (N/E) : 4566615.32 / 396202.34	**DHG INSTRUMENT:** Ludlum 2221/ 44-2	
	COORDINATE SYSTEM: WGS1984 UTM Zone 12 N (meters)	**Serial No:** 138356 / PR228325	
	ELEVATION (MSL): 1298.45 meters	**BACKGROUND (cpm):** 2,806	

Depth (Ft. bgs)	Soil Texture	DHG (cpm)	Core Scan (cpm)	Recovery Ft. (4 Ft. Core)	Soil Description: Texture, color, firmness, etc.
	ML	NA	37,500	3.25 Ft	SILT, some fine Sand, and angular Gravel, small, gray, dry, no plasticity
1		NA			
		NA	38,300		
2		NA			
		NA	37,200		
3		NA			(2.7 - 3.0) Clayey SILT, some fine Sand, dark brown, med plasticity
		NA	NR		
4		NA			No Recovery
		NA	36,000	0.5 Ft	SILT, some fine Sand, and angular Gravel, small, gray, dry, no plasticity
5					**TD @ 4.5 Ft. bgs (Refusal)**
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

Samples Collected	**Time**	**Depth Interval**
WR111-SB-WR703-BS-P-04	1605	(4 - 4.5 Ft)

	CABRERA SERVICES 1106 N. CHARLES STREET SUITE 300 BALTIMORE, MD 21201	**SOIL BORING LOG**	**BORING No:** WR-704

PROJECT: Hill AFB - WR111		**DATE:** 7/2/2013	**PAGE:** 1 of 1
PROJECT No: 13-1013.00		**TIME:** 0800	**LOGGED:** S. Owe
DRILLING METHOD: Geoprobe		**CORE SCAN INSTUMENT:** Ludlum 2221/ 44-20	
BORING DEPTH (Ft. bgs): 7.0 (Refusal)		**Serial No:** 161580 / PR324757	
WATER DEPTH (Ft. bgs): None		**BACKGROUND (cpm):** 36,105	
COORDINATES (N/E) : 4566617.12 / 396213.28		**DHG INSTRUMENT:** Ludlum 2221/ 44-2	
COORDINATE SYSTEM: WGS1984 UTM Zone 12 N (meters)		**Serial No:** 138356 / PR228325	
ELEVATION (MSL): 1296.21 meters		**BACKGROUND (cpm):** 2,806	

Comments

DHG Surface measurement = 4,276 cpm

Boring cave-in at 6.5 Ft. bgs

Boring Refusal at 7.0 Ft bgs

The instrument was lowered into the borehole to the target depth and one-minute static measurements were collected at half a foot intervals proceeding upward until the top of the borehole was reached.

Depth (Ft. bgs)	Soil Texture	DHG (cpm)	Core Scan (cpm)	Recovery Ft. (4 Ft. Core)	Soil Description: Texture, color, firmness, etc.
	ML	5,506	35,800	FULL	SILT, with Sand, fine to med, light brown, med density, no plasticity, very dry
1		5,891			(0.5 - 0.8 Ft) Crushed ROCK
		6,009	37,500		
2		6,294			SILT, with Gravel, angular, small to med, trace sand, F-M, light brown, med density, very dry, No plasticity
		6,138	36,400		
3		6,251			
		6,361	38,600		
4		6,562			
	ML	6,666	38,200	FULL	
5		6,961			SILT and GRAVEL, angular, small to med, some sand, F-M, light brown, med density, very dry, No plasticity
		7,245	37,200		
6		7,821			
		8,271	38,400		
7		NA			SILT, some angular Gravel, small to med, light gray, med density, very dry, no plasticity
					TD @ 7.0 Ft. bgs (Refusal)
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

Samples Collected	**Time**	**Depth Interval**
WR111-SB-WR704-SS-P-00	0800	(Surface)
WR111-SB-WR704-BS-P-06	0815	(6-7 Ft)

	CABRERA SERVICES 1106 N. CHARLES STREET SUITE 300 BALTIMORE, MD 21201	SOIL BORING LOG	BORING No: WR-705	
		PROJECT: Hill AFB - WR111	DATE: 7/2/2013	PAGE: 1 of 1
Comments		PROJECT No: 13-1013.00	TIME: 0800	LOGGED: S. Owe
Boring refusal at 3.0 Ft. bgs Offset boring 5 Ft, refusal at 3.0 Ft. bgs No DHG measurements The instrument was lowered into the borehole to the target depth and one-minute static measurements were collected at half a foot intervals proceeding upward until the top of the borehole was reached.		DRILLING METHOD: Geoprobe	CORE SCAN INSTUMENT: Ludlum 2221/ 44-20	
		BORING DEPTH (Ft. bgs): 3.0 (Refusal)	Serial No: 161580 / PR324757	
		WATER DEPTH (Ft. bgs): None	BACKGROUND (cpm): 36,105	
		COORDINATES (N/E) : 4566603.43 / 396202.34	DHG INSTRUMENT: Ludlum 2221/ 44-2	
		COORDINATE SYSTEM: WGS1984 UTM Zone 12 N (meters)	Serial No: 138356 / PR228325	
		ELEVATION (MSL): 1297.02 meters	BACKGROUND (cpm): 2,806	

Depth (Ft. bgs)	Soil Texture	DHG (cpm)	Core Scan (cpm)	Recovery Ft. (4 Ft. Core)	Soil Description: Texture, color, firmness, etc.
	ML	NA	37,200	1.75 Ft	Sandy SILT, fine, hard, with Gravel, angular, small to med, light brown, no plasticity
1		NA			
		NA	38,300		
2		NA			
		NA	NR		No Recovery (1.75 - 3.0 Ft.)
3		NA			
4					TD @ 3.0 Ft. bgs (Refusal)
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

Samples Collected	Time	Depth Interval
WR111-SB-WR705-BS-P-01	0820	(1 - 1.5 Ft)

	CABRERA SERVICES 1106 N. CHARLES STREET SUITE 300 BALTIMORE, MD 21201	SOIL BORING LOG	BORING No: WR-706	
		PROJECT: Hill AFB - WR111	DATE: 7/2/2013	PAGE: 1 of 1
		PROJECT No: 13-1013.00	TIME: 1430	LOGGED: S. Owe

Comments

DHG Surface measurement = 5,107 cpm

Boring cave-in at 5.5 Ft. bgs

Boring Refusal at 7.0 Ft bgs

The instrument was lowered into the borehole to the target depth and one-minute static measurements were collected at half a foot intervals proceeding upward until the top of the borehole was reached.

DRILLING METHOD: Geoprobe	CORE SCAN INSTUMENT: Ludlum 2221/ 44-20
BORING DEPTH (Ft. bgs): 7.0 (Refusal)	Serial No: 161580 / PR324757
WATER DEPTH (Ft. bgs): None	BACKGROUND (cpm): 36,105
COORDINATES (N/E) : 4566605.66 / 396220.72	DHG INSTRUMENT: Ludlum 2221/ 44-2
COORDINATE SYSTEM: WGS1984 UTM Zone 12 N (meters)	Serial No: 138356 / PR228325
ELEVATION (MSL): 1294.73 meters	BACKGROUND (cpm): 2,806

Depth (Ft. bgs)	Soil Texture	DHG (cpm)	Core Scan (cpm)	Recovery Ft. (4 Ft. Core)	Soil Description: Texture, color, firmness, etc.
	ML	4,916	37,800	3.4 Ft	SILT, some Sand, fine, some angular gravel, bown/ gray, no plasticity
1		5,528			
		5,169	38,500		SILT, with Sand, fine, some Gravel, angular, brown/ gray, no plasticity
2		5,387			
		6,187	38,600		
3		6,421			
		6,529	37,900		
4		6,651			No Recovery
	ML	5,953	37,600	2.0 Ft	SILT, with Sand, fine, some Gravel, angular, brown/ gray, no plasticity
5		6,061			
		6,095	37,500		
6		NA			
		NA	NR		No Recovery
7		NA			
8					**TD @ 7.0 Ft. bgs (Refusal)**
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

Samples Collected	**Time**	**Depth Interval**	
WR111-SB-WR706-SS-P-00	1500	(Surface)	
WR111-SB-WR706-BS-P-05	1515	(5-6 Ft)	
WR111-SB-WR706-BS-D-05	1515	(5-6 Ft)	(DUP)

CABRERA SERVICES
1106 N. CHARLES STREET
SUITE 300
BALTIMORE, MD 21201

SOIL BORING LOG

BORING No:	WR-707
PROJECT:	Hill AFB - WR111
DATE:	7/2/2013
PAGE:	1 of 1
PROJECT No:	13-1013.00
TIME:	1430
LOGGED:	S. Owe
DRILLING METHOD:	Geoprobe
CORE SCAN INSTUMENT:	Ludlum 2221/ 44-20
BORING DEPTH (Ft. bgs):	12.0
Serial No:	161580 / PR324757
WATER DEPTH (Ft. bgs):	None
BACKGROUND (cpm):	36,105
COORDINATES (N/E) :	4566607.25 / 396232.61
DHG INSTRUMENT:	Ludlum 2221/ 44-2
COORDINATE SYSTEM:	WGS1984 UTM Zone 12 N (meters)
Serial No:	138356 / PR228325
ELEVATION (MSL):	1282.98 meters
BACKGROUND (cpm):	2,806

Comments

DHG Surface measurement = 5,176 cpm

Boring cave-in at 11.5 Ft. bgs

The instrument was lowered into the borehole to the target depth and one-minute static measurements were collected at half a foot intervals proceeding upward until the top of the borehole was reached.

Depth (Ft. bgs)	Soil Texture	DHG (cpm)	Core Scan (cpm)	Recovery Ft. (4 Ft. Core)	Soil Description: Texture, color, firmness, etc.
	ML	5,290	38,300	FULL	SILT, with SAND, fine, and Gravel, small to med, angular, brown, firm, no plasticity
1		5,791			
		5,794	38,100		
2		4,876			gray
		3,620	37,400		
3		3,122			Sandy SILT, with Gravel, small to med, angular, brown/ orange, med density, no plasticity
		3,096	37,500		
4		3,821			
	SM	4,471	37,500	FULL	
5		5,369			Silty SAND, fine, some coarse, with Gravel, angular, small to med, brown/ gray, no plasticity
		4,756	38,200		
6		3,587			
	GP	1,601	37,900		
7		1,354			Sandy GRAVEL, small to med, fine sand, trace coarse sand, brown/ gray, no plasticity
		1,668	38,100		
8		3,317			
	ML	5,794	37,600	FULL	
9		6,565			Sandy SILT, with Gravel, small to med, angular, gray/ brown, firm, no plasticity
		6,785	38,300		
10		6,517			
		6,627	38,700		
11		6,761			
		7,722	38,600		
12		NA			
13					**TD @ 12.0 Ft. bgs**
14					
15					
16					
17					
18					
19					
20					

Samples Collected	**Time**	**Depth Interval**
WR111-SB-WR707-SS-P-00	1600	(Surface)
WR111-SB-WR707-BS-P-08	1645	(8-9 Ft)

CABRERA SERVICES 1106 N. CHARLES STREET SUITE 300 BALTIMORE, MD 21201	**SOIL BORING LOG**	**BORING No:** WR-708	
	PROJECT: Hill AFB - WR111	**DATE:** 7/2/2013	**PAGE:** 1 of 1
Comments	**PROJECT No:** 13-1013.00	**TIME:** 1300	**LOGGED:** S. Owe

Comments

DHG Surface measurement = 3,637 cpm

The instrument was lowered into the borehole to the target depth and one-minute static measurements were collected at half a foot intervals proceeding upward until the top of the borehole was reached.

DRILLING METHOD: Geoprobe	**CORE SCAN INSTUMENT:** Ludlum 2221/ 44-20
BORING DEPTH (Ft. bgs): 12.0	**Serial No:** 161580 / PR324757
WATER DEPTH (Ft. bgs): None	**BACKGROUND (cpm):** 36,105
COORDINATES (N/E) : 4566631.89 / 396233.32	**DHG INSTRUMENT:** Ludlum 2221/ 44-2
COORDINATE SYSTEM: WGS1984 UTM Zone 12 N (meters)	**Serial No:** 138356 / PR228325
ELEVATION (MSL): 1292.73 meters	**BACKGROUND (cpm):** 2,806

Depth (Ft. bgs)	Soil Texture	DHG (cpm)	Core Scan (cpm)	Recovery Ft. (4 Ft. Core)	Soil Description: Texture, color, firmness, etc.
1	ML	5,234 5,831	39,400	3.0 Ft	SILT, with Sand, fine-med, some Gravel, small to large, angular, light brown, loose, dry, No plasticity
2		5,691 5,636	39,000		
3		5,834 6,067	38,700		Clayey SILT, with sand, F-M, some Gravel, angular, small to med, dark brown, hard, medium plasticity
4		6,898 9,671	NR		No Recovery
5	ML	15,777 42,680	39,800	2.0 Ft	Clayey SILT, with sand, F-M, some Gravel, angular, small to med, dark brown, hard, medium plasticity
6		240,418 370,344	40,000		
7		497,287 523,745	NR		No recovery
8		524,217 516,448	NR		
9	ML	250,053 236,900	153,000	FULL	Burned ASH MATERIAL, brittle fibers, gray
10		149,882 31,325	52,000		Clayey SILT, with Sand and Gravel, angular, small to large, brown, medium density, med plasticity
11		12,784 9,544	38,000		
12		7,267 7,756	39,000		
13					**TD @ 12.0 Ft. bgs**
14					
15					
16					
17					
18					
19					
20					

Samples Collected	**Time**	**Depth Interval**	
WR111-SB-WR708-SS-P-00	1315	(Surface)	
WR111-SB-WR708-BS-P-08	1330	(8-9 Ft)	
WR111-SB-WR708-BS-D-08	1335	(8-9 Ft)	(DUP)

	CABRERA SERVICES 1106 N. CHARLES STREET SUITE 300 BALTIMORE, MD 21201	**SOIL BORING LOG**	**BORING No:** WR-709
		PROJECT: Hill AFB - WR111	**DATE:** 7/2/2013 / **PAGE:** 1 of 1
Comments		**PROJECT No:** 13-1013.00	**TIME:** 1700 / **LOGGED:** S. Owe
DHG Surface measurement = 3,478 cpm Boring cave-in at 9.0 Ft. bgs		**DRILLING METHOD:** Geoprobe	**CORE SCAN INSTUMENT:** Ludlum 2221/ 44-20
The instrument was lowered into the borehole to the target depth and one-minute static measurements were collected at half a foot intervals proceeding upward until the top of the borehole was reached.		**BORING DEPTH (Ft. bgs):** 12.0	**Serial No:** 161580 / PR324757
		WATER DEPTH (Ft. bgs): None	**BACKGROUND (cpm):** 36,105
		COORDINATES (N/E) : 4566631.84 / 396238.02	**DHG INSTRUMENT:** Ludlum 2221/ 44-2
		COORDINATE SYSTEM: WGS1984 UTM Zone 12 N (meters)	**Serial No:** 138356 / PR228325
		ELEVATION (MSL): 1291.56 meters	**BACKGROUND (cpm):** 2,806

Depth (Ft. bgs)	Soil Texture	DHG (cpm)	Core Scan (cpm)	Recovery Ft. (4 Ft. Core)	Soil Description: Texture, color, firmness, etc.
	ML	3,311	37,300	3.0 Ft	Sandy SILT, with Gravel, fine Sand, angular gravel, small to med, gray/ brown, No plasticity
1		4,821			
		5,128	37,400		
2		4,825			SILT, with Sand, fine, some Gravel, small, angular, gray/ white, loose, no plasticity
	SM	4,252	38,200		Silty SAND, fine, with Gravel, small to med, angular, hard, light brown, no plasticity
3		4,541			
		5,474	NR		No Recovery
4		6,882			
	ML	7,886	38,100	FULL	
5		8,249			
		8,481	37,500		Clayey SILT, with Sand, med to fine, some coarse, dark brown, firm, med plasticity
6		8,781			
		7,706	37,200		
7		7,186			
		6,930	36,900		
8		7,122			
	ML	6,557	37,300	FULL	
9		6,838			
		NA	37,200		
10		NA			
		NA	37,500		
11		NA			
		NA	38,300		
12		NA			
13					**TD @ 12.0 Ft. bgs**
14					
15					
16					
17					
18					
19					
20					

Samples Collected	**Time**	**Depth Interval**
WR111-SB-WR709-SS-P-00	1720	(Surface)
WR111-SB-WR709-BS-P-07	1745	(7-8 Ft)

	CABRERA SERVICES 1106 N. CHARLES STREET SUITE 300 BALTIMORE, MD 21201	**SOIL BORING LOG**	**BORING No:** WR-710	
		PROJECT: Hill AFB - WR111	**DATE:** 7/3/2013	**PAGE:** 1 of 1
Comments		**PROJECT No:** 13-1013.00	**TIME:** 0730	**LOGGED:** S. Owe
DHG Surface measurement = 3,364 cpm Boring cave-in at 6.5 Ft. bgs The instrument was lowered into the borehole to the target depth and one-minute static measurements were collected at half a foot intervals proceeding upward until the top of the borehole was reached.		**DRILLING METHOD:** Geoprobe	**CORE SCAN INSTUMENT:** Ludlum 2221/ 44-20	
		BORING DEPTH (Ft. bgs): 12.0	**Serial No:** 161580 / PR324757	
		WATER DEPTH (Ft. bgs): None	**BACKGROUND (cpm):** 33,809	
		COORDINATES (N/E) : 4566635.16 / 396233.27	**DHG INSTRUMENT:** Ludlum 2221/ 44-2	
		COORDINATE SYSTEM: WGS1984 UTM Zone 12 N (meters)	**Serial No:** 138356 / PR228325	
		ELEVATION (MSL): 1294.38 meters	**BACKGROUND (cpm):** 2,695	

Depth (Ft. bgs)	Soil Texture	DHG (cpm)	Core Scan (cpm)	Recovery Ft. (4 Ft. Core)	Soil Description: Texture, color, firmness, etc.
1	ML	4,514 5,559	37,000	2.75 Ft	Sandy SILT, fine to med, with Gravel, angular, small, light brown, gray, no plasticity
2		6,646 6,191	38,500		Sandy SILT, fine to coarse, with Gravel, angular, small-med, brown, no plasticity
3		6,383 7,327	39,000		(2.5-2.75) Clayey SILT, with Sand and Gravel, F-M, S-M gravel, angular, dk brown, med plasticity
4		11,121 22,558	NR		No Recovery
5	ML	37,861 46,782	45,000	2.25 Ft	Clayey SILT, with Sand and Gravel, F-M, S-M gravel, angular, dk brown, med plasticity
6		146,731 361,531	70,000		
7		473,853 NA	109,000		No Recovery
8		NA NA	NR		
9	ML	NA NA	43,000	FULL	Clayey SILT, with Sand and Gravel, F-M, S-M gravel, angular, dk brown, med plasticity, Some wood debris
10		NA NA	41,000		
11		NA NA	37,000		
12		NA NA	35,000		
13					**TD @ 12.0 Ft. bgs**
14					
15					
16					
17					
18					
19					
20					

Samples Collected	**Time**	**Depth Interval**
WR111-SB-WR710-SS-P-00	0830	(Surface)
WR111-SB-WR710-BS-P-05	0835	(5-6 Ft)

	CABRERA SERVICES 1106 N. CHARLES STREET SUITE 300 BALTIMORE, MD 21201	**SOIL BORING LOG**	**BORING No:** WR-711
		PROJECT: Hill AFB - WR111	**DATE:** 7/3/2013 — **PAGE:** 1 of 1
Comments		**PROJECT No:** 13-1013.00	**TIME:** 0845 — **LOGGED:** S. Owe
DHG Surface measurement = 3,294 cpm Boring cave-in at 6.0 Ft. bgs		**DRILLING METHOD:** Geoprobe	**CORE SCAN INSTUMENT:** Ludlum 2221/ 44-20
The instrument was lowered into the borehole to the target depth and one-minute static measurements were collected at half a foot intervals proceeding upward until the top of the borehole was reached.		**BORING DEPTH (Ft. bgs):** 12.0	**Serial No:** 161580 / PR324757
		WATER DEPTH (Ft. bgs): None	**BACKGROUND (cpm):** 33,809
		COORDINATES (N/E) : 4566628.75 / 396233.31	**DHG INSTRUMENT:** Ludlum 2221/ 44-2
		COORDINATE SYSTEM: WGS1984 UTM Zone 12 N (meters)	**Serial No:** 138356 / PR228325
		ELEVATION (MSL): 1293.71 meters	**BACKGROUND (cpm):** 2,695

Depth (Ft. bgs)	Soil Texture	DHG (cpm)	Core Scan (cpm)	Recovery Ft. (4 Ft. Core)	Soil Description: Texture, color, firmness, etc.
1	ML	3,766 4,772	36,500	3.5 Ft	SILT, with Sand, fine, some Gravel, small, angular, brown, no plasticity
2		4,877 5,241	37,000		Sandy SILT, with Gravel, fine Sand, small, angular, light brown, no plasticity
3		4,929 5,194	37,000		Clayey SILT, with sand, fine, some GRAVEL, small to med, angular, med plasticity
4		5,155 5,890	36,800		No Recovery
5	ML	6,598 6,622	37,000	FULL	Clayey SILT, with sand, fine, some GRAVEL, small to med, angular, med plasticity
6		6,511 6,582	36,500		
7		NA NA	38,000		
8		NA NA	38,000		
9	ML	NA NA	37,000	FULL	
10		NA NA	38,000		
11		NA NA	37,500		
12		NA NA	37,500		
13					**TD @ 12.0 Ft. bgs**
14					
15					
16					
17					
18					
19					
20					

Samples Collected	**Time**	**Depth Interval**
WR111-SB-WR711-SS-P-00	0915	(Surface)
WR111-SB-WR711-BS-P-07	0930	(7-8 Ft)

	CABRERA SERVICES 1106 N. CHARLES STREET SUITE 300 BALTIMORE, MD 21201	**SOIL BORING LOG**	**BORING No:** WR-712
		PROJECT: Hill AFB - WR111	**DATE:** 7/3/2013 / **PAGE:** 1 of 1
Comments		**PROJECT No:** 13-1013.00	**TIME:** 1015 / **LOGGED:** S. Owe
DHG instrument out of service		**DRILLING METHOD:** Geoprobe	**CORE SCAN INSTUMENT:** Ludlum 2221/ 44-20
The instrument was lowered into the borehole to the target depth and one-minute static measurements were collected at half a foot intervals proceeding upward until the top of the borehole was reached.		**BORING DEPTH (Ft. bgs):** 12.0	**Serial No:** 161580 / PR324757
		WATER DEPTH (Ft. bgs): None (moist at 9.2 Ft)	**BACKGROUND (cpm):** 33,809
		COORDINATES (N/E) : 4566639.59 / 396233.10	**DHG INSTRUMENT:** Ludlum 2221/ 44-2
		COORDINATE SYSTEM: WGS1984 UTM Zone 12 N (meters)	**Serial No:** 138356 / PR228325
		ELEVATION (MSL): 1285.31 meters	**BACKGROUND (cpm):** 2,695

Depth (Ft. bgs)	Soil Texture	DHG (cpm)	Core Scan (cpm)	Recovery Ft. (4 Ft. Core)	Soil Description: Texture, color, firmness, etc.
		NA	37,500	2.75 Ft	
1	ML	NA			SILT, with Sand, fine, some Gravel, small-med, angular, light brown, dry, no plasticity
		NA	38,000		
2		NA			Clayey SILT, some fine Sand, and Gravel, small to med, angular, brown, low plasticity
		NA	38,000		
3		NA			
		NA	NR		No Recovery
4		NA			
		NA	37,000	3.5 Ft	
5	ML	NA			Clayey SILT, some fine Sand, and Gravel, small to med, angular, brown, low plasticity, hard
		NA	37,500		
6		NA			
		NA	39,000		
7		NA			
		NA	60,000		Burned ASH MATERIAL, brittle fibers, gray, white
8		NA			No Recovery
		NA	43,000	3.75 Ft	
9	ML	NA			Clayey SILT, some fine Sand, and Gravel, small to med, angular, brown, med plasticity, hard moist at 9.2 Ft
		NA	38,000		
10		NA			
		NA	38,000		
11		NA			
		NA	38,000		
12		NA			(11.75 - 12 Ft) No Recovery
13					**TD @ 12.0 Ft. bgs**
14					
15					
16					
17					
18					
19					
20					

Samples Collected	**Time**	**Depth Interval**
WR111-SB-WR712-SS-P-00	1030	(Surface)
WR111-SB-WR712-BS-P-07	1045	(7-7.5 Ft)

CABRERA SERVICES
1106 N. CHARLES STREET
SUITE 300
BALTIMORE, MD 21201

SOIL BORING LOG

BORING No: WR-713

PROJECT: Hill AFB - WR111

DATE: 7/3/2013

PAGE: 1 of 1

PROJECT No: 13-1013.00

TIME: 1015

LOGGED: S. Owe

DRILLING METHOD: Geoprobe

CORE SCAN INSTUMENT: Ludlum 2221/ 44-20

BORING DEPTH (Ft. bgs): 8.0

Serial No: 161580 / PR324757

WATER DEPTH (Ft. bgs): None

BACKGROUND (cpm): 33,809

COORDINATES (N/E) : 4566642.80 / 396233.04

DHG INSTRUMENT: Ludlum 2221/ 44-2

COORDINATE SYSTEM: WGS1984 UTM Zone 12 N (meters)

Serial No: 138356 / PR228325

ELEVATION (MSL): 1285.51 meters

BACKGROUND (cpm): 2,695

Comments

DHG instrument out of service

The instrument was lowered into the borehole to the target depth and one-minute static measurements were collected at half a foot intervals proceeding upward until the top of the borehole was reached.

Depth (Ft. bgs)	Soil Texture	DHG (cpm)	Core Scan (cpm)	Recovery Ft. (4 Ft. Core)	Soil Description: Texture, color, firmness, etc.
	ML	NA	37,500	3.5 Ft	Sandy SILT, fine, with some coarse Sand and Gravel, small to med, angular, light brown, dry, No plasticity
1		NA			
		NA	37,000		
2		NA			
		NA	38,000		
3		NA			
		NA	37,500		
4		NA			No Recovery
	ML	NA	38,000	FULL	Clayey SILT, with Sand, fine-med, and Gravel, small to med, angular, brown, low plasticity
5		NA			
		NA	37,500		
6		NA			
		NA	38,000		Clayey SILT, with Gravel, small, angular, some Sand, F-C, hard, med plasticity, dense, brown
7		NA			
		NA	37,500		
8		NA			
9					TD @ 8.0 Ft. bgs
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

Samples Collected	Time	Depth Interval
WR111-SB-WR713-BS-P-07	1115	(7-8 Ft)
WR111-SB-WR713-BS-P-04	1130	(4-5 Ft)

DAILY QUALITY CONTROL REPORT		Date:	7/1/2013
		Day:	Monday
Project:	Hill AFB – WR111	Report No.:	DQCR-WR111-070113
Contract No.:	FA8903-09-D-8560	Wind:	Light
Task Order No.:	0006	Humidity:	Low
Cabrera Project No.:	13-1013.00	Weather:	Sunny, 100+ deg

Hill AFB Project Manager:	*Kyle Gorder*
Cabrera Personnel On Site:	*Katharine Arzate*
Subcontractors On Site:	*Porta-John Contractor and Earth Probe Geoprobe Contractor*
Hill AFB Personnel On Site:	*John Monk-EA 0700-0800 and 1200-1500*
Visitors On Site:	*None*
Equipment On Site:	*Geoprobe*
Work Performed:	• *Received equipment from EA office* • *Obtained Base pass from Hill AFB* • *Conducted Radworker Training at EA office for Drilling Contractor* • *Purchased field equipment from Home Depot* • *Rented Generator from Sunbelt* • *Onsite at WR111 at 1100. Staged Porta-John at WR111* • *Performed Instrument QC* • *Trouble-shot GPS/GWS equipment* • *Performed incoming Rad survey on Geoprobe* • *Offsite at 1700*
Quality Control Activities:	*Completed radiological instrument QC and GPS QC.*
Health And Safety Levels And Activities:	*Modified Level D* *Conducted 'tailgate' health and safety meeting*
Problems Encountered/ Corrective Action Taken:	*GPS unit not communicating with NaI detector. Purchased new serial cable from RadioShack. GWS equipment is now working correctly.*
Special Notes:	*None*
Tomorrow's Expectations:	*Complete Gamma Walkover Survey and begin DPT subsurface investigation/ Sampling*
By: *Stephan Owe*	**TITLE: Field Site Manager**

DAILY QUALITY CONTROL REPORT		Date:	7/2/2013
		Day:	Tuesday
Project:	Hill AFB – WR111	Report No.:	DQCR-WR111-070213
Contract No.:	FA8903-09-D-8560	Wind:	Light
Task Order No.:	0006	Humidity:	Low
Cabrera Project No.:	13-1013.00	Weather:	Sunny, 100+ deg

Hill AFB Project Manager:	*Kyle Gorder*
Cabrera Personnel On Site:	*Katharine Arzate, Stephan Owe*
Subcontractors On Site:	*Earth Probe Geoprobe Contractor – Pat Casey*
Hill AFB Personnel On Site:	*None*
Visitors On Site:	*John Monk-EA1200-1400*
Equipment On Site:	*Geoprobe*
Work Performed:	• Onsite at 0630. Performed radiological instrument/GPS QC • Completed GWS of AOI – Sent Data offsite for processing • Marked Pre-determined Sample locations #1-8 with GPS • Completed Soil Boring/ Core Scan/ DHG/ Soil Sampling of location # - 1,2,3,4,5,6,7, 8, 9, 10 (WR-700 thru WR-709) • Collected 3 – TCLP/ WAC Samples. Location # 7,8,10 (WR-706, 707,709) • Had Call with Project Team to discuss Bias Geoprobe locations. Decided on Offset locations from Sample #2 (Radiologically Elevated) • Bias Soil Borings were advanced at locations #9 and #10. #9 was 10 Ft east of location #2. #10 was 15 Ft east of #9 (25 Ft east of #2)
Quality Control Activities:	*Completed radiological instrument QC and GPS QC.*
Health And Safety Levels And Activities:	*Modified Level D* *Conducted 'tailgate' health and safety meeting*
Problems Encountered/ Corrective Action Taken:	*Geoprobe Refusal at following locations – Location #3 @ 3ft bgs, Location #4 @4ft bgs and Location #6 @ 3ft bgs. Visual rock outcrops at surface in vicinity, appears this area has solid rock at few feet bgs. Offset locations, refusal at same depth. Collected 1 subsurface sample from each location.*
Special Notes:	*GWS worked correctly after purchasing new Serial Cable from Radio Shack. (Defective cable)*
Tomorrow's Expectations:	*Complete Geoprobe soil borings/ soil sampling. Complete radiological release surveys. Package WAC samples. Ship Samples.*
By: *Stephan Owe*	**TITLE: Field Site Manager**

DAILY QUALITY CONTROL REPORT

		Date:	*7/3/2013*
		Day:	*Wednesday*
Project:	*Hill AFB – WR111*	**Report No.:**	*DQCR-WR111-070313*
Contract No.:	*FA8903-09-D-8560*	**Wind:**	*Light*
Task Order No.:	*0006*	**Humidity:**	*Low*
Cabrera Project No.:	*13-1013.00*	**Weather:**	*Sunny, 100+ deg*

Hill AFB Project Manager:	*Kyle Gorder*
Cabrera Personnel On Site:	*Katharine Arzate, Stephan Owe*
Subcontractors On Site:	*Earth Probe Geoprobe Contractor – Pat Casey*
Hill AFB Personnel On Site:	*None*
Visitors On Site:	*John Monk-EA 1300-1700*
Equipment On Site:	*Geoprobe*
Work Performed:	• *Onsite at 0700. Performed radiological instrument/GPS QC* • *Completed Bias Soil Boring/ Core Scan/ DHG/ Soil Sampling of location # - 11, 12, 13, (WR-710 thru WR-712)* • *Bias Soil Borings were advanced at locations #11, #12 and #13. #11 was 10 Ft north of location #9. #12 was 10 Ft south of #9. #13 was 10 Ft north of #11. #14 was 10 Ft north of #13.* • *Collected surface soil samples #14 and #15 (WR-713 thru 714). #14 was mid-way between location #4 and #6. #15 was directly west of #14 (just outside fence)* • *Collected GPS coordinates and Elevation (MSL) for all sample locations* • *Performed release surveys of Geoprobe and other field equipment* • *Plastic sheeting used under soil core cutting tables was elevated. Some macrocores were elevated and difficult to survey due to shape. Decided to package all in Contaminated drum (1 drum used for contaminated material). Drum was staged on pallet immediately inside WR111 fence* • *Offsite at 1700. Drove to EA office to package equipment and samples for shipment*
Quality Control Activities:	*Completed radiological instrument QC and GPS QC.*
Health And Safety Levels And Activities:	*Modified Level D* *Conducted 'tailgate' health and safety meeting*
Problems Encountered/ Corrective Action Taken:	*Noticed 44-9 instrument was out of calibration, took out of service. All scanning/ surveys were performed with 43-93. No data was collected with the 44-9 instrument (i.e., core scan/ DHG)*

Special Notes:	*None*
Tomorrow's Expectations:	*None. Offsite.*
By: *Stephan Owe*	***TITLE: Field Site Manager***

Appendix B
Offsite Laboratory Radiological Analytical Results and Data Quality Assessment

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Appendix B-1
2013 Radiological Site Characterization Sampling Results

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Table B-1: 2013 Radiological Site Characterization Sampling Results

Parent Radionuclides	Parent and Daughter Radionuclides	WR111-SB-WR700-BS-P-09				WR111-SB-WR700-SS-P-00				WR111-SB-WR701-BS-P-05				WR111-SB-WR701-SS-D-00			
		Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier
Potassium-40	Potassium-40	24.40	3.97	1.50		20.32	3.77	1.53		5.70	8.18	13.50	U	22.90	3.18	0.85	
Thorium-232	Thorium-232	3.04	0.57	0.28		2.71	0.57	0.42		563	122	3.26		2.51	0.40	0.23	
	Thallium-208	1.05	0.21	0.11		1.01	0.22	0.13		239.00	24.90	1.49		0.83	0.14	0.07	
	Bismuth-212	3.31	1.13	0.73		3.00	1.57	2.21		692.00	73.80	15.70		2.36	0.81	0.87	
	Lead-212	3.08	0.48	0.16		3.09	0.64	0.24		767.00	99.40	2.19		2.40	0.39	0.18	
	Actinium-228	3.04	0.57	0.28		2.71	0.57	0.42		658.00	67.60	3.24		2.51	0.40	0.23	
	Radium-228	3.04	0.57	0.28		2.71	0.57	0.42		658.00	67.60	3.24		2.51	0.40	0.23	
	Thorium-228									560	122	4.55					
Radium-226	Lead-210	2.10	2.15	3.07	U[b]	1.03	2.26	3.85	U	10.50	20.30	33.40	U	1.27	1.81	2.99	U
	Bismuth-214	1.26	0.35	0.30		1.26	0.34	0.26		11.00	2.41	2.31		0.99	0.21	0.16	
	Lead-214	1.11	0.24	0.19		1.29	0.34	0.27		11.20	2.61	2.64		1.22	0.24	0.20	
Uranium-235	Uranium-235	0.30	0.48	0.71	U	0.48	0.55	0.83	U	0.0079	0.026	0.062	U	0.01	0.30	0.52	U
	Actinium-227	0.22	1.00	2.94	U	0.22	2.23	3.73	U	-4.39	21.60	35.60	U	0.19	0.39	0.68	U
Uranium-238	Uranium-238	1.41	1.11	3.27	U	2.10	2.57	3.64	U	0.397	0.132	0.054		1.02	0.81	2.70	U
	Thorium-234	1.41	1.11	3.27	U	2.10	2.57	3.64	U	2.69	20.30	33.50	U	1.02	0.81	2.70	U
Americium-241	Americium-241																
Cesium-137	Cesium-137																
Cobalt-60	Cobalt-60																
Thorium-230[a]	Thorium-230									373	89	1.81					
Uranium-233/234[a]	Uranium-233/234									0.425	0.139	0.077					

Footnote:

[a] = Sample analyzed by alpha spectroscopy

[b] U = Analyte was analyzed for, but not detected above the minimum detectable concentration (MDC)

Table B-1: 2013 Radiological Site Characterization Sampling Results

Parent Radionuclides	Parent and Daughter Radionuclides	WR111-SB-WR701-SS-P-00				WR111-SB-WR702-BS-P-02				WR111-SB-WR703-BS-P-04				WR111-SB-WR704-BS-P-06			
		Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier
Potassium-40	Potassium-40	22.50	3.40	0.86		22.20	3.27	0.88		26.70	3.89	1.37		27.90	4.02	0.89	
Thorium-232	Thorium-232	2.14	0.40	0.34		1.83	0.33	0.12		3.17	0.49	0.12		2.29	0.42	0.13	
	Thallium-208	0.74	0.15	0.08		0.62	0.13	0.08		0.57	0.18	0.23		0.66	0.14	0.11	
	Bismuth-212	2.86	1.08	0.85		2.65	0.89	0.59		5.51	1.42	0.76		2.66	1.04	0.96	
	Lead-212	2.39	0.37	0.16		1.60	0.29	0.18		3.24	0.49	0.21		2.25	0.36	0.17	
	Actinium-228	2.14	0.40	0.34		1.83	0.33	0.12		3.17	0.49	0.12		2.29	0.42	0.13	
	Radium-228	2.14	0.40	0.34		1.83	0.33	0.12		3.17	0.49	0.12		2.29	0.42	0.13	
	Thorium-228																
Radium-226	Lead-210	1.98	1.61	2.25	U	1.16	2.00	3.02	U	0.97	2.47	4.29	U	1.86	2.09	2.95	U
	Bismuth-214	1.10	0.21	0.05		1.19	0.27	0.21		2.08	0.38	0.22		1.45	0.29	0.19	
	Lead-214	1.33	0.25	0.15		1.13	0.26	0.21		1.91	0.33	0.27		1.73	0.29	0.22	
Uranium-235	Uranium-235	0.10	0.25	0.51	U	0.23	0.35	0.63	U	0.07	0.29	0.71	U	0.16	0.42	0.63	U
	Actinium-227	0.09	0.17	2.24	U	0.30	0.32	2.19	U	-2.51	1.31	2.03	U	0.06	1.35	2.27	U
Uranium-238	Uranium-238	2.86	1.97	2.41		0.35	0.82	2.37	U	1.36	1.17	3.42	U	1.31	0.91	2.97	U
	Thorium-234	2.86	1.97	2.41		0.35	0.82	2.37	U	1.36	1.17	3.42	U	1.31	0.91	2.97	U
Americium-241	Americium-241																
Cesium-137	Cesium-137																
Cobalt-60	Cobalt-60																
Thorium-230[a]	Thorium-230																
Uranium-233/234[a]	Uranium-233/234																

Footnote:

[a] = Sample analyzed by alpha spectroscopy

[b] U = Analyte was analyzed for, but not detected above the minimum detectable concentration (MDC)

Table B-1: 2013 Radiological Site Characterization Sampling Results

Parent Radionuclides	Parent and Daughter Radionuclides	WR111-SB-WR704-SS-P-00				WR111-SB-WR705-BS-P-01				WR111-SB-WR706-BS-D-05				WR111-SB-WR706-BS-P-05			
		Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier
Potassium-40	Potassium-40	21.30	3.17	1.04		24.70	3.70	0.83		23.40	3.55	1.26		26.70	3.71	1.14	
Thorium-232	Thorium-232	2.61	0.44	0.25		1.50	0.39	0.21		1.91	0.42	0.35		1.95	0.40	0.25	
	Thallium-208	0.84	0.16	0.11		0.58	0.13	0.08		0.69	0.14	0.09		0.69	0.13	0.08	
	Bismuth-212	2.82	0.96	1.03		2.18	0.86	0.65		1.28	1.00	1.52	U	3.52	1.16	0.84	
	Lead-212	2.39	0.42	0.25		1.40	0.26	0.19		1.79	0.31	0.20		1.70	0.29	0.17	
	Actinium-228	2.61	0.44	0.25		1.50	0.39	0.21		1.91	0.42	0.35		1.95	0.40	0.25	
	Radium-228	2.61	0.44	0.25		1.50	0.39	0.21		1.91	0.42	0.35		1.95	0.40	0.25	
	Thorium-228																
Radium-226	Lead-210	0.14	2.02	3.62	U	2.11	2.47	3.07	U	2.92	2.16	2.88		0.16	1.77	3.16	U
	Bismuth-214	0.91	0.24	0.22		1.03	0.24	0.16		1.42	0.32	0.23		1.34	0.29	0.23	
	Lead-214	1.28	0.28	0.22		1.25	0.23	0.16		1.56	0.29	0.20		1.43	0.29	0.24	
Uranium-235	Uranium-235	0.14	0.39	0.68	U	0.27	0.44	0.65	U	0.17	0.41	0.70	U	0.48	0.43	0.55	U
	Actinium-227	0.05	0.30	2.02	U	-0.11	1.15	1.92	U	6.14	1.07	0.62		0.33	0.32	0.46	U
Uranium-238	Uranium-238	0.45	0.63	3.43	U	0.86	0.82	2.90	U	2.03	1.79	2.54	U	2.09	1.66	2.76	U
	Thorium-234	0.45	0.63	3.43	U	0.86	0.82	2.90	U	2.03	1.79	2.54	U	2.09	1.66	2.76	U
Americium-241	Americium-241																
Cesium-137	Cesium-137																
Cobalt-60	Cobalt-60																
Thorium-230[a]	Thorium-230																
Uranium-233/234[a]	Uranium-233/234																

Footnote:

[a] = Sample analyzed by alpha spectroscopy

[b] U = Analyte was analyzed for, but not detected above the minimum detectable concentration (MDC)

Table B-1: 2013 Radiological Site Characterization Sampling Results

Parent Radionuclides	Parent and Daughter Radionuclides	WR111-SB-WR706-SS-P-00				WR111-SB-WR707-BS-P-08				WR111-SB-WR707-SS-P-00				WR111-SB-WR708-BS-P-08			
		Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier
Potassium-40	Potassium-40	19.20	2.90	0.88		21.80	3.71	1.02		18.70	3.94	1.73		30.80	6.33	4.58	
Thorium-232	Thorium-232	1.65	0.38	0.18		2.11	0.61	0.41		1.93	0.50	0.28		190.00	55.10	2.83	
	Thallium-208	0.62	0.12	0.07		0.73	0.18	0.13		0.64	0.18	0.13		62.80	6.66	0.82	
	Bismuth-212	2.82	1.19	0.99		3.88	1.50	1.07		0.98	1.44	2.41	U	181.00	21.60	8.55	
	Lead-212	1.57	0.27	0.17		2.15	0.38	0.20		1.87	0.38	0.23		198.00	25.70	1.08	
	Actinium-228	1.65	0.38	0.18		2.11	0.61	0.41		1.93	0.50	0.28		175.00	18.20	1.50	
	Radium-228	1.65	0.38	0.18		2.11	0.61	0.41		1.93	0.50	0.28		175.00	18.20	1.50	
	Thorium-228													212.00	59.60	5.24	
Radium-226	Lead-210	-0.09	1.82	3.12	U	1.52	2.13	3.28	U	-0.37	3.58	4.66	U	0.78	11.80	19.70	U
	Bismuth-214	0.96	0.24	0.19		0.98	0.27	0.22		0.80	0.31	0.38		2.24	0.88	1.25	
	Lead-214	1.07	0.22	0.14		1.33	0.30	0.26		1.39	0.33	0.37		1.68	0.95	1.17	
Uranium-235	Uranium-235	0.22	0.35	0.56	U	0.09	0.39	0.69	U	0.27	0.43	0.84	U	0.03	0.04	0.04	U
	Actinium-227	0.11	0.25	0.42	U	0.14	0.89	2.69	U	0.42	0.52	3.22	U	1.56	10.30	17.10	U
Uranium-238	Uranium-238	2.06	1.57	2.27	U	1.29	1.89	2.83	U	1.35	2.34	4.05	U	0.55	0.16	0.05	
	Thorium-234	2.06	1.57	2.27	U	1.29	1.89	2.83	U	1.35	2.34	4.05	U	9.52	13.80	22.80	U
Americium-241	Americium-241																
Cesium-137	Cesium-137																
Cobalt-60	Cobalt-60																
Thorium-230[a]	Thorium-230													58.00	26.90	4.13	
Uranium-233/234[a]	Uranium-233/234													0.63	0.17	0.07	

Footnote:

[a] = Sample analyzed by alpha spectroscopy

[b] U = Analyte was analyzed for, but not detected above the minimum detectable concentration (MDC)

Table B-1: 2013 Radiological Site Characterization Sampling Results

Parent Radionuclides	Parent and Daughter Radionuclides	WR111-SB-WR708-SS-P-00				WR111-SB-WR709-BS-P-07				WR111-SB-WR709-SS-P-00				WR111-SB-WR710-BS-P-05			
		Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier
Potassium-40	Potassium-40	22.00	3.49	1.24		23.90	3.49	0.93		19.00	2.82	0.91		36.30	7.50	9.11	
Thorium-232	Thorium-232	2.30	0.38	0.28		2.69	0.43	0.12		2.04	0.36	0.18		222.00	59.40	1.64	
	Thallium-208	0.74	0.15	0.09		0.91	0.18	0.11		0.70	0.14	0.08		140.00	14.70	1.30	
	Bismuth-212	2.80	1.12	0.97		1.77	1.03	1.48		2.72	1.06	0.86		393.00	42.80	12.70	
	Lead-212	2.29	0.37	0.17		2.68	0.42	0.22		2.07	0.33	0.16		432.00	56.00	1.93	
	Actinium-228	2.30	0.38	0.28		2.69	0.43	0.12		2.04	0.36	0.18		390.00	40.00	2.79	
	Radium-228	2.30	0.38	0.28		2.69	0.43	0.12		2.04	0.36	0.18		390.00	40.00	2.79	
	Thorium-228													262.00	67.00	4.16	
Radium-226	Lead-210	2.86	2.05	2.66		1.70	2.07	3.21	U	1.48	1.55	2.50	U	1.84	18.10	30.00	U
	Bismuth-214	1.11	0.23	0.10		1.01	0.23	0.18		0.84	0.23	0.20		15.47	3.39	2.97	
	Lead-214	1.30	0.25	0.17		0.93	0.22	0.19		1.14	0.24	0.16		11.10	2.12	2.07	
Uranium-235	Uranium-235	0.35	0.27	0.40	U	0.08	0.24	0.50	U	-0.01	0.01	0.64	U	0.03	0.04	0.04	U
	Actinium-227	0.08	0.66	2.36	U	0.15	0.22	2.78	U	0.12	0.20	1.62	U	1.31	1.21	35.90	U
Uranium-238	Uranium-238	1.66	1.54	2.54	U	0.73	1.07	2.98	U	1.49	0.87	2.60	U	0.33	0.13	0.05	
	Thorium-234	1.66	1.54	2.54	U	0.73	1.07	2.98	U	1.49	0.87	2.60	U	32.00	22.60	28.50	
Americium-241	Americium-241																
Cesium-137	Cesium-137																
Cobalt-60	Cobalt-60																
Thorium-230[a]	Thorium-230													448.00	100.00	2.59	
Uranium-233/234[a]	Uranium-233/234													0.38	0.14	0.06	

Footnote:

[a] = Sample analyzed by alpha spectroscopy

[b] U = Analyte was analyzed for, but not detected above the minimum detectable concentration (MDC)

Table B-1: 2013 Radiological Site Characterization Sampling Results

Parent Radionuclides	Parent and Daughter Radionuclides	WR111-SB-WR710-SS-P-00				WR111-SB-WR711-BS-P-07				WR111-SB-WR711-SS-P-00				WR111-SB-WR712-BS-P-07			
		Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier
Potassium-40	Potassium-40	17.70	2.79	1.19		23.60	3.67	1.49		22.90	3.46	1.04		29.70	5.26	2.78	
Thorium-232	Thorium-232	1.86	0.37	0.11		2.85	0.49	0.35		2.14	0.37	0.25		63.90	6.83	1.15	
	Thallium-208	0.58	0.12	0.06		1.11	0.21	0.12		0.64	0.15	0.11		22.70	2.52	0.52	
	Bismuth-212	3.27	1.00	0.61		2.67	1.15	1.47		2.20	0.90	0.77		68.20	10.20	5.75	
	Lead-212	1.85	0.32	0.17		2.58	0.42	0.22		1.76	0.30	0.17		71.00	9.28	0.68	
	Actinium-228	1.86	0.37	0.11		2.85	0.49	0.35		2.14	0.37	0.25		63.90	6.83	1.15	
	Radium-228	1.86	0.37	0.11		2.85	0.49	0.35		2.14	0.37	0.25		63.90	6.83	1.15	
	Thorium-228																
Radium-226	Lead-210	1.90	2.03	2.72	U	2.16	2.05	2.99	U	2.21	2.08	3.18	U	-0.12	9.01	12.60	U
	Bismuth-214	0.89	0.21	0.17		1.16	0.30	0.23		1.24	0.33	0.25		2.28	0.88	0.85	
	Lead-214	0.94	0.19	0.16		1.26	0.27	0.22		1.34	0.27	0.22		1.11	0.64	1.04	
Uranium-235	Uranium-235	0.11	0.30	0.53	U	0.16	0.25	0.83	U	0.23	0.37	0.65	U	0.90	1.27	2.10	U
	Actinium-227	0.06	0.31	0.36	U	0.31	0.36	2.93	U	0.12	0.26	2.28	U	0.32	0.86	15.00	U
Uranium-238	Uranium-238	0.67	1.67	2.88	U	1.36	1.05	2.94	U	2.23	1.86	2.77	U	3.10	3.96	11.00	U
	Thorium-234	0.67	1.67	2.88	U	1.36	1.05	2.94	U	2.23	1.86	2.77	U	3.10	3.96	11.00	U
Americium-241	Americium-241																
Cesium-137	Cesium-137																
Cobalt-60	Cobalt-60																
Thorium-230[a]	Thorium-230																
Uranium-233/234[a]	Uranium-233/234																

Footnote:

[a] = Sample analyzed by alpha spectroscopy

[b] U = Analyte was analyzed for, but not detected above the minimum detectable concentration (MDC)

Table B-1: 2013 Radiological Site Characterization Sampling Results

Parent Radionuclides	Parent and Daughter Radionuclides	WR111-SB-WR712-SS-P-00				WR111-SB-WR713-BS-P-04				WR111-SB-WR713-BS-P-07				WR111-SB-WR714-SS-P-00			
		Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier	Result	Uncertainty	MDC	Qualifier
Potassium-40	Potassium-40	21.00	3.21	1.35		23.50	3.59	1.17		23.30	3.55	0.94		22.50	3.28	1.01	
Thorium-232	Thorium-232	2.38	0.42	0.19		1.93	0.36	0.19		1.88	0.45	0.28		3.63	0.58	0.31	
	Thallium-208	0.88	0.16	0.09		0.83	0.17	0.09		0.79	0.17	0.10		1.48	0.23	0.10	
	Bismuth-212	3.93	0.97	0.36		2.39	0.98	0.88		0.61	1.00	1.68	U	2.37	1.08	1.45	
	Lead-212	2.41	0.39	0.19		2.09	0.33	0.14		2.00	0.34	0.23		4.51	0.65	0.18	
	Actinium-228	2.38	0.42	0.19		1.93	0.36	0.19		1.88	0.45	0.28		3.63	0.58	0.31	
	Radium-228	2.38	0.42	0.19		1.93	0.36	0.19		1.88	0.45	0.28		3.63	0.58	0.31	
	Thorium-228																
Radium-226	Lead-210	1.57	1.84	2.73	U	2.27	1.75	2.41	U	0.36	1.87	3.19	U	3.26	2.54	3.09	
	Bismuth-214	1.01	0.26	0.21		1.03	0.23	0.19		1.03	0.24	0.15		1.38	0.32	0.25	
	Lead-214	0.99	0.22	0.18		1.12	0.22	0.16		1.16	0.24	0.16		1.62	0.28	0.25	
Uranium-235	Uranium-235	-0.04	0.15	0.69	U	0.24	0.33	0.50	U	0.18	0.39	0.67	U	0.38	0.46	0.75	U
	Actinium-227	0.33	0.33	2.47	U	-0.14	1.26	2.11	U	0.02	0.37	0.64	U	-1.95	1.03	1.59	U
Uranium-238	Uranium-238	2.88	2.07	2.80		1.27	0.79	2.66	U	2.85	2.25	2.77		1.62	2.16	3.55	U
	Thorium-234	2.88	2.07	2.80		1.27	0.79	2.66	U	2.85	2.25	2.77		1.62	2.16	3.55	U
Americium-241	Americium-241																
Cesium-137	Cesium-137																
Cobalt-60	Cobalt-60																
Thorium-230[a]	Thorium-230																
Uranium-233/234[a]	Uranium-233/234																

Footnote:

[a] = Sample analyzed by alpha spectroscopy

[b] U = Analyte was analyzed for, but not detected above the minimum detectable concentration (MDC)

Table B-1: 2013 Radiological Site Characterization Sampling Results

Parent Radionuclides	Parent and Daughter Radionuclides	WR111-SB-WR715-SS-P-00			
		Result	Uncertainty	MDC	Qualifier
Potassium-40	Potassium-40	24.00	3.50	0.91	
Thorium-232	Thorium-232	3.64	0.59	0.22	
	Thallium-208	1.30	0.21	0.12	
	Bismuth-212	3.58	1.56	1.44	
	Lead-212	3.94	0.58	0.21	
	Actinium-228	3.64	0.59	0.22	
	Radium-228	3.64	0.59	0.22	
	Thorium-228				
Radium-226	Lead-210	2.67	2.72	3.76	U
	Bismuth-214	1.44	0.29	0.20	
	Lead-214	1.61	0.33	0.26	
Uranium-235	Uranium-235	0.23	0.45	0.82	U
	Actinium-227	0.31	1.99	3.31	U
Uranium-238	Uranium-238	2.79	1.93	2.80	U
	Thorium-234	2.79	1.93	2.80	U
Americium-241	Americium-241				
Cesium-137	Cesium-137				
Cobalt-60	Cobalt-60				
Thorium-230[a]	Thorium-230				
Uranium-233/234[a]	Uranium-233/234				

Footnote:

[a] = Sample analyzed by alpha spectroscopy

[b] U = Analyte was analyzed for, but not detected above the minimum detectable concentration (MDC)

Appendix B-2
2013 Waste Characterization Sample Results

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Table B-2: 2013 Waste Characterization Sample Results

			Sample Location	WR706	WR707	WR709
			Sample Type	TCLP	TCLP	TCLP
			Sample Name	WR111-SB-WR706-SS-P-00	WR111-SB-WR707-BS-P-07	WR111-SB-WR709-BS-P-04
			Lab Sample ID	280-44030-3	280-44030-2	280-44030-1
			Sample Date	7/2/2013	7/2/2013	7/2/2013
CAS	Analyte	Unit	RCRA Criteria	Result	Result	Result
SW6010C						
7439-92-1	Lead	mg/l	5	< 0.035	< 0.035	< 0.035
7440-22-4	Silver	mg/l	5	< 0.015	< 0.015	< 0.015
7440-38-2	Arsenic	mg/l	5	< 0.065	< 0.065	< 0.065
7440-39-3	Barium	mg/l	100	0.66	0.038	0.38
7440-43-9	Cadmium	mg/l	1	< 0.007	< 0.007	0.003
7440-47-3	Chromium	mg/l	5	< 0.0045	0.0049	< 0.0045
7782-49-2	Selenium	mg/l	1	< 0.075	< 0.075	< 0.075
SW7470A						
7439-97-6	Mercury	mg/l	0.2	< 0.00008	< 0.00008	< 0.00008
SW8081B						
1024-57-3	Heptachlor epoxide	mg/l	0.008	< 0.000099	< 0.0001	< 0.000099
12789-03-6	Chlordane, Technical	mg/l		< 0.0048	< 0.0048	< 0.0048
58-89-9	Gamma-BHC (Lindane)	mg/l	0.4	< 0.000099	< 0.0001	< 0.000099
72-20-8	Endrin	mg/l	0.02	< 0.000099	< 0.0001	< 0.000099
72-43-5	Methoxychlor	mg/l	10	< 0.0002	< 0.0002	< 0.0002
76-44-8	Heptachlor	mg/l	0.008	< 0.000099	< 0.0001	< 0.000099
8001-35-2	Toxaphene	mg/l	0.5	< 0.0079	< 0.008	< 0.0079
SW8082A						
11096-82-5	Aroclor 1260	ug/kg		< 11	< 10	< 11
11097-69-1	Aroclor 1254	ug/kg		< 11	< 10	< 11
11104-28-2	Aroclor 1221	ug/kg		< 22	< 20	< 22
11141-16-5	Aroclor 1232	ug/kg		< 11	< 10	< 11
12672-29-6	Aroclor 1248	ug/kg		< 11	< 10	< 11
12674-11-2	Aroclor 1016	ug/kg		< 11	< 10	< 11
53469-21-9	Aroclor 1242	ug/kg		< 11	< 10	< 11
SW8260B						
107-06-2	1,2-dichloroethane	ug/l	500	< 2	< 2	< 2
108-90-7	Chlorobenzene	ug/l	100000	< 2	< 2	< 2
127-18-4	Tetrachloroethene	ug/l	700	< 4	< 4	< 4
56-23-5	Carbon tetrachloride	ug/l	500	< 4	< 4	< 4
67-66-3	Chloroform	ug/l	6000	< 2	< 2	< 2
71-43-2	Benzene	ug/l	500	< 2	< 2	< 2
75-01-4	Vinyl chloride	ug/l	200	< 8	< 8	< 8
75-35-4	1,1-dichloroethene	ug/l	700	< 2	< 2	< 2
78-93-3	2-butanone	ug/l	200000	< 32	< 32	< 32
79-01-6	Trichloroethene	ug/l	500	< 2	< 2	< 2
SW8270D						
106-44-5	4-methylphenol	mg/l	200	< 0.005	< 0.005	< 0.005
106-46-7	1,4-dichlorobenzene	mg/l	7.5	< 0.005	< 0.005	< 0.005
110-86-1	Pyridine	mg/l	5	< 0.01	< 0.01	< 0.01
118-74-1	Hexachlorobenzene	mg/l	0.13	< 0.005	< 0.005	< 0.005
121-14-2	2,4-dinitrotoluene	mg/l	0.13	< 0.02	< 0.02	< 0.02
67-72-1	Hexachloroethane	mg/l	3	< 0.02	< 0.02	< 0.02
87-68-3	Hexachloro-1,3-butadiene	mg/l	0.5	< 0.05	< 0.05	< 0.05
87-86-5	Pentachlorophenol	mg/l	100	< 0.2	< 0.2	< 0.2
88-06-2	2,4,6-trichlorophenol	mg/l	2	< 0.005	< 0.005	< 0.005
95-48-7	2-methylphenol	mg/l	200	< 0.02	< 0.02	< 0.02

Table B-2: 2013 Waste Characterization Sample Results

			Sample Location	WR706	WR707	WR709
			Sample Type	TCLP	TCLP	TCLP
			Sample Name	WR111-SB-WR706-SS-P-00	WR111-SB-WR707-BS-P-07	WR111-SB-WR709-BS-P-04
			Lab Sample ID	280-44030-3	280-44030-2	280-44030-1
			Sample Date	7/2/2013	7/2/2013	7/2/2013
CAS	Analyte	Unit	RCRA Criteria	Result	Result	Result
95-95-4	2,4,5-trichlorophenol	mg/l	400	< 0.005	< 0.005	< 0.005
98-95-3	Nitrobenzene	mg/l	2	< 0.01	< 0.01	< 0.01
SW846 8151A						
93-72-1	2,4,5-TP (silvex)	mg/l	1	< 0.0028	< 0.0028	< 0.0028
94-75-7	2,4-D	mg/l	10	< 0.0092	< 0.0091	< 0.0092
SW846 9012B						
57-12-5	Cyanide	mg/kg		0.17	0.11	0.18
SW846 9045						
PH	pH	pH units	2 - 12.5	8.57	9.75	9.68
SW846 ASTM D93						
IGNITB	Ignitability	none		0	0	0
SW9034						
18496-25-8	Sulfide	mg/kg		< 5.3	< 4.8	< 5.3

Appendix B-3
Data Quality Assessment Report

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1.0 Introduction

A data quality assessment was performed to assess the quality of the offsite laboratory soil sampling results collected during July 2013 as part of the supplemental site characterization survey. The purpose of this survey was to confirm existing assumptions regarding impacted soil and to further define the nature and extent of contamination while specifically filling data gaps along the eastern and southeastern boundaries of Site WR111. The objectives for this assessment were to demonstrate whether environmental data generated during the sampling events could withstand scientific scrutiny, are appropriate for their intended purpose, are technically defensible, and are of known and acceptable precision and accuracy.

A total of 29 soil characterization samples, including 2 field duplicate samples, were collected; submitted to TestAmerica; and analyzed for natural radium, thorium, and uranium isotopes using gamma spectroscopy via U.S. Environmental Protection Agency Method 901.1. Three of the samples had reported results of elevated Radium-226 (^{226}Ra) and Thorium-232 (^{232}Th). The three samples were re-analyzed for ^{226}Ra via U.S. Environmental Protection Agency Method 901.1M, which measures the ^{226}Ra daughter progeny (bismuth-214 [^{214}Bi], and lead-214 [^{214}Pb]) at equilibrium. The three samples were also analyzed for isotopic thorium (including thorium-228 [^{228}Th], thorium-230 [^{230}Th], and ^{232}Th]) by the alpha spectroscopy method EML HASL 300 Modified (Department of Energy 1997). One of the three elevated activity samples (analyzed by gamma spectroscopy) also had an elevated uranium concentration with high uncertainty. Therefore, all three samples were analyzed by Isotopic Uranium (including Uranium-234 [^{234}U], Uranium-235 [^{235}U], and Uranium-238 [^{238}U]) by EML HASL 300 Modified (Department of Energy 1997). Alpha spectroscopy is more accurate with a higher confidence level for reporting the activity of alpha emitting radionuclides. For this reason, the alpha spectroscopy results for the three reanalyzed samples were used during the data quality assessment.

As a part of project requirements, quality indicator samples (QIS) were also collected and analyzed at an offsite laboratory. The QIS are used to evaluate the usability of data. The identity of duplicate quality control samples is held blind to the analysts and the purpose of these samples is to provide activity-specific, field-originated information regarding the homogeneity of the sampled matrix and the consistency of the sampling effort. These samples were collected concurrently with the primary environmental samples and equally represent the medium at a given time and location. QIS consisted of the following types: laboratory control sample (LCS), laboratory duplicate, field duplicate (FDUP), and method blank (MB). They were usually analyzed at a rate of 1 per 20 samples or per batch for each analysis performed.

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2.0 Data Quality Assessment for Offsite Laboratory Sample Results

The analytical sampling results were evaluated to verify the data usability for project-specific data quality objectives (DQOs). As a part of the DQO, a review of the analytical data was performed with regard to its usability and quality. The purpose of the analytical data review is to identify analytical methods and compounds for which the quality assurance objectives are not satisfied. The following sections summarize the data evaluation process conducted for this report.

2.1 Sample Receipt

All samples were received at TestAmerica St. Louis on 6 July 2013; the samples arrived in good condition, were properly preserved, and placed on ice. The temperature of the cooler at receipt was 32.1 degrees Celsius; however, three issues were resulted during the shipment.

- The container for sample WR111-SB-WR700-BS-P-09 was received broken. The sample was transferred to a new container.
- The container for sample WR111-SB-WR708-BS-D-08 was received broken. The sample volume was lost and the sample was not logged.
- A sample identification discrepancy was noted between the information listed on the chain-of-custody and the container labels. The chain-of-custody lists a sample identification of WR111-SB-WR701-SS-D-00, while the container labels list the identification as WR111-SB-WR700-SS-D-00. The laboratory was able to determine the identity of the sample by comparing the sample collection time with the sample collection time on the container labels. The sample identification was logged as WR111-SB-WR701-SS-D-00 per the information on the chain-of-custody.

2.2 Analytical Holding Times

All samples were extracted and analyzed within 180 days from time of sample collection. Therefore, <u>all sample results are acceptable</u>.

2.3 Sample Preservation

No chemical preservatives were added to samples.

2.4 Quality Indicator Samples

Quality indicator samples (QIS) are used to evaluate the usability of data. When reporting the sample data, the laboratory also provides the results of associated quality control sample analyses. The following section of the report summarized quality control processes that were conducted in order to verify and review the analytical data generated in the laboratory. Attachment 1 presents the results of data evaluation for each QIS. The following sections summarize the evaluation procedures for each QIS:

2.4.1 Laboratory Control Sample

The purpose of the LCS is to monitor the accuracy of sample preparation and analysis. LCS evaluation was performed for Am-241, Cs-137, and Co-60. Preparation and analysis were performed under the same conditions as a regular project sample. Two primary and one secondary acceptance criteria were considered during this evaluation as follows:

1. The LCS concentration should be at 20 times of the laboratory's Minimum Detectable Activity – *Passed.*

2. The primary acceptance criterion for LCS percent recovery is 75-125 percent – *Passed.*

3. The secondary criterion for LCS is based of MARLAP Z-statistics (Z_{LCS}) statistic as follows:

$$Z_{LCS} = \frac{x - d}{\sqrt{u_c^2(x) + u_c^2(d)}}$$

where

x	=	Measured result from the spiked sample.
d	=	Spike concentration added.
$u_c(x)$	=	Combined Standard Uncertainty (spike sample).
$u_c(d)$	=	Combined Standard Uncertainty (spike).

The calculated ZLCS statistic(s) should be between -1.96 and +1.96. Calculated ZLCS within the performance range are considered acceptable. Calculated ZLCS outside the performance range require further evaluation. The calculated Z_{LCS} values for all radiological parameters are within the secondary acceptable limits; therefore, all results are acceptable.

2.4.2 Laboratory Duplicate/Replicates

The purpose of the LDUP/LREP is to monitor the precision of the analytical method, provided the sample is fully homogenized prior to preparation and analysis. For sample and LDUP/LREP result pairs, a Duplicate Error Ratio (DER), which is functionally equivalent to the normalized absolute difference, was calculated by using the following equation:

$$DER = \frac{|(x_1 - x_2)|}{\sqrt{ku_c^2(x_1) + ku_c^2(x_2)}}$$

where

x_1	=	First sample value (REG)
x_2	=	Second sample value (DUP/REP)
$u_c(x_1)$	=	Combined Standard Uncertainty (REG)

$u_c(x_2)$ = Combined Standard Uncertainty (DUP/REP)
k = Coverage Factor representing the 95 percent Uncertainty Level.

The calculated DER results were compared to an acceptable performance range of from -1.96 to +1.96. Calculated DER results within the performance range are considered acceptable. Calculated DER results outside the performance range are investigated for possible discrepancies in analytical precision. The calculated DER results for all samples are within acceptable performance range. Therefore, all results are acceptable.

2.4.3 Method Blank

The purpose of the MB is to monitor the presence of external sources of contamination for parameters of interest in the sample preparation and analysis process. The MB is a laboratory-generated sample of the same matrix as the analytical samples but in absence of the parameters of interest. Primary Acceptance Criteria for MB are <minimal detectable concentration (MDC) or $<1.96 u_c^2(x)$. If either primary acceptance criterion is met, the MB is considered acceptable.

When both primary criteria fail, a secondary MB acceptance evaluation is performed by calculation of a Z-blank (Z_{BLANK}) statistic with Warning and Control Limits of +/-2sigma and +/-3sigma, respectively. The formula for calculation of the Z_{BLANK} is as follows:

$$Z_{BLANK} = \frac{x}{u_c^2(x)}$$

where

x = Reported MB Result.
$u_c(x_1)$ = Combined Standard Uncertainty.

All MB results for parameters included in this report met both primary and secondary acceptance criteria. Therefore, all results are acceptable.

2.4.4 Field Duplicate/Replicate

The purpose of the FDUP/FREP is to monitor the precision of the entire sampling and analysis process, provided the sample is fully homogenized prior to preparation and analysis. The criteria selected for initial evaluation is the relative percent difference (RPD) with an acceptance criteria of ≤ 50 percent and a formula presented as follows:

$$\%RPD = \left| \frac{(x_1 - x_2)}{0.5(x_1 + x_2)} \right| * 100$$

where

x_1 = First sample value (REG)
x_2 = Second sample value (FDUP/FREP).

The calculated percent RPD values for all RCOCs are within the primary acceptable criterion. For samples that fail to meet primary acceptance criteria, the DER ratio is calculated with an acceptance criterion of ≤1.96 by using the following equation:

$$DER = \frac{|(x_1 - x_2)|}{\sqrt{ku_c^2(x_1) + ku_c^2(x_2)}}$$

where

x_1 = First sample value (REG).
x_2 = Second sample value (DUP/REP).
$u_c(x_1)$ = Combined Standard Uncertainty (REG).
$u_c(x_2)$ = *Combined Standard Uncertainty (DUP/REP).*
k = *Coverage Factor representing the 95 percent Uncertainty Level.*

The purpose of the DER calculation in this case is to assess whether a discrepancy identified by the RPD is primarily attributable to normal analysis uncertainties. Result uncertainty is not a consideration in the RPD calculation. The calculated DER results are compared to an acceptable performance criterion of ≤1.96. Calculated DER results within the performance range are considered acceptable. Calculated DER results outside the performance range are investigated for possible discrepancies in analytical precision. All calculated DER results are within the secondary acceptance criteria. Therefore, all results are acceptable.

2.5 Data Usability

The overall quality of the sampling information meets or exceeds the established project objectives. Data, as presented, have been qualified as usable, but estimated when necessary. Except for one sampling result for Ac-227, no reported parameter results were rejected. For sample WR111-SB-WR706-BS-D-05 (280-44050-13), Ac-227 is reported above the sample-specific minimal detectable concentration. In the “first pass,” the GammaVision software did not see a peak at the most abundant energy for Th-227 at 236 keV (12.3 percent abundance). However, the software “forced” a Th-227/Ac-227 result based upon an interference peak at 238.6 keV (the main peak for Pb-212 in the Th-232/Ra-228/Ac-228 decay chain). Minor peaks for Th-227 are not present to support its presence. The laboratory does not believe Ac-227 to be present in this sample.

Data produced for this project demonstrate that they can withstand scientific scrutiny, are appropriate for their intended purpose, are technically defensible, and are of known and acceptable precision and accuracy. Data integrity has been documented through proper implementation of quality assurance and quality control measures.

Attachment 1

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QUALITY INDICATOR SAMPLE EVALUATION												
LABORATORY CONTROL SAMPLE/STANDARD												
Laboratory Identification	Parameter	Spiked Sample Result (x)	TPU [2uc(x)]	CSU [$u_c(x)$]	MDC	Spike (d)	Percent TPU (Percent $2u_c[d]$)	CSU ($u_c[d]$)	Spike >20xMDC	Z_{LCS}	Percent Recovery
LCS 160-60383/2-A	Americium-241	101.3	10.6	5.30	1.15	97.6	3.50	1.71	PASS	0.66	103.8
LCS 160-60383/2-A	Cesium-137	31.37	3.34	1.67	0.305	31.7	4.00	0.63	PASS	-0.18	99.0
LCS 160-60383/2-A	Cobalt-60	24.57	2.52	1.26	0.168	25.1	4.00	0.50	PASS	-0.39	97.9
LCS 160-60392/2-A	Americium-241	100	10.5	5.25	1.14	97.6	3.50	1.71	PASS	0.43	102.5
LCS 160-60392/2-A	Cesium-137	32.16	3.43	1.72	0.28	31.7	4.00	0.63	PASS	0.25	101.5
LCS 160-60392/2-A	Cobalt-60	24.67	2.54	1.27	0.141	25.1	4.00	0.50	PASS	-0.31	98.3
LCS 160-69145/2-A	Americium-241	103.1	10.9	5.45	1.48	97.6	3.50	1.71	PASS	0.96	105.6
LCS 160-69145/2-A	Cesium-137	31.41	3.43	1.72	0.424	31.6	4.00	0.63	PASS	-0.10	99.4
LCS 160-69145/2-A	Cobalt-60	23.02	2.53	1.27	0.0869	24.7	4.00	0.49	PASS	-1.24	93.2

Criteria (*Source*)				
Z_{LCS} Limits:	Warning ±	1.96	Control ±	1.96
Percent Recovery Limits:	75%	to	125%	

GENERAL NOTES

1. All result, uncertainty, and spike concentrations are reported in units of pCi/g
2. The analytical laboratory reports all uncertainty values as total propagated uncertainty (TPU[2σ]). This is functionally equivalent to the MARLAP combined "expanded" uncertainty at the 95.4% uncertainty level (2uc).
3. The blue shaded cells represent conversion of reported TPU (2σ) to combined "standard" uncertainty equivalent (uc), where necessary, to perform "Z-based" statistical evaluations. ZREP calculations for DUP/REP are based on the lab reported TPU (2σ) values.
4. Spike uncertainties are reported as a percentage in Section 8 (Standards Traceability Documents) of the Level IV Lab Report at a level equivalent to their 2σ TPU [%2uc(d)].

LABORATORY DUPLICATE/REPLICATE (LDUP/LREP)						
Laboratory Sample Identification	**Parameter**	**Sample Result (x)**	**TPU [$2u_c(x)$]**	**Rep/Dup Result (y)**	**Lab TPU [$2u_c(y)$]**	**DER**
280-44050-1/ 280-44050-1 DU	Bismuth-214	1.26	0.344	1.145	0.278	**0.26**
	Thorium-232	2.71	0.567	2.509	0.479	**0.27**
280-44050-4/ 280-44050-4 DU	Thorium-232	563	122	761.3	160	**0.99**
280-44050-22/ 280-44050-22 DU	Radium-226	13.9	2.06	15.47	3.39	**0.40**
Criteria (*Source*)						
Z_{REP} Limits:	**Warning ±**	**1.96**	**Control ±**	**1.96**		

FIELD DUPLICATE/REPLICATE (FDUP/FREP)							
Field Sample Identification	**Parameter**	**Sample Result (x)**	**TPU [$2u_c(x)$]**	**Rep/Dup Result (y)**	**Lab TPU [$2u_c(y)$]**	**RPD**	**DER**
WR111-SB-WR701-SS-P-00/	Bismuth-214	1.1	0.212	0.988	0.211	**10.7%**	**0.37**
WR111-SB-WR701-SS-D-00	Thorium-232	2.14	0.396	2.51	0.4	**15.9%**	**0.66**
WR111-SB-WR706-BS-P-05/	Bismuth-214	1.34	0.294	1.42	0.322	**5.8%**	**0.18**
WR111-SB-WR706-BS-D-05	Thorium-232	1.95	0.4	1.91	0.418	**2.1%**	**0.07**
Criteria (*Source*)							
RPD<	**50.0%**						
Z_{REP} Limits:	**Warning ±**	**1.96**	**Control ±**	**1.96**			

METHOD BLANK							
Laboratory Identification	**Parameter**	**Sample Result (x)**	**TPU [$2u_c(x)$]**	**CSU [$u_c(x)$]**	**MDC**	**<$2u_c(x)$ or <MDC**	**Z_{BLANK}**
MB 160-60383/1-A	Bismuth-214	-0.01884	0.0693	0.035	0.169	**PASS**	**-0.54**
MB 160-60383/1-A	Thorium-232	0.01254	0.0173	0.009	0.282	**PASS**	**1.45**
MB 160-60392/1-A	Bismuth-214	-0.06334	0.703	0.352	0.165	**PASS**	**-0.18**
MB 160-60392/1-A	Thorium-232	0.0231	0.146	0.073	0.272	**PASS**	**0.32**
MB 160-69145/1-A	Radium-226	0.1222	0.0887	0.044	0.138	**PASS**	**2.76**
MB 160-70744/1-A	Thorium-232	0	0.0109	0.005	0.0392	**PASS**	**0.00**
Criteria (*Source*)							
Primary Criteria:		**<$2u_c(x)$ OR <MDC**					
Z_{MB} Limits:	**Warning ±**	**2**	**Control ±**	**3**			

GENERAL NOTES

1. All result, uncertainty, and spike concentrations are reported in units of pCi/g
2. The analytical laboratory reports all uncertainty values as total propagated uncertainty (TPU[2σ]). This is functionally equivalent to the MARLAP combined "expanded" uncertainty at the 95.4% uncertainty level (2uc).

3. The blue shaded cells represent conversion of reported TPU (2σ) to combined "standard" uncertainty equivalent (uc), where necessary, to perform "Z-based" statistical evaluations. ZREP calculations for DUP/REP are based on the lab reported TPU (2σ) values.
4. Spike uncertainties are reported as a percentage in Section 8 (Standards Traceability Documents) of the Level IV Lab Report at a level equivalent to their 2σ TPU [%2uc(d)].

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Appendix B-4
Data Quality Assessment Report Waste Acceptance Criteria

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1.0 Laboratory Data Quality Summary

This laboratory data quality summary report describes the findings of the data verification activities conducted for the three waste characterization soil samples collected in support of the Supplemental Site Characterization at WR111, Hill Air Force Base, Utah, and is provided to document the quality of the analytical data used to determine disposition of the remediated soil for site. Sampling procedures and overall quality control and quality assurance protocols associated with the waste sampling are presented in the *Supplemental Site Characterization WR111 Little Mountain Test Annex/Magnesium–Thorium Disposal Trench Work Plan, Hill Air Force Base, Utah* (U.S. Air Force 2013).

Three soil samples were collected on 2 July 2013 and shipped to TestAmerica Laboratories, Arvada, Colorado, for waste characterization analyses. The laboratory holds a current U.S. Department of Defense (DoD) Environmental Laboratory Accreditation Program certification to perform the listed analyses.

Soil samples were analyzed for the following list of parameters:

- Toxicity characteristic leaching procedure (TCLP) volatile organic compounds – U.S. Environmental Protection Agency (EPA) Method 1311/ SW8260B
- TCLP semivolatile organic compounds – EPA Method 1311/SW8270D
- TCLP organochlorine pesticides – EPA Method 1311/SW8081B
- TCLP herbicides – EPA Methods 1311/SW8151A
- TCLP metals – EPA Methods 1311/SW6010C and 7470A
- Polychlorinated biphenyls – EPA Method 8082A
- Total cyanide – EPA Method 9012B
- Total sulfide – EPA Method 9034
- Ignitability – EPA SW846 Chapter 7.1.2
- Corrosivity pH – EPA Method 9045D.

The analytical results for the three waste characterization samples are included in the sample delivery group 280-44030. Data verification review was performed for the analytical results in this sample delivery group. The review was performed in accordance with the guidelines and control criteria specified in the following documents:

- *Supplemental Site Characterization WR111 Little Mountain Test Annex/Magnesium – Thorium Disposal Trench Work Plan, Hill Air Force Base, Utah* (U.S. Air Force 2013)
- *DoD Quality Systems Manual(QSM) for Environmental Laboratories, Version 4.2* (DoD 2010)

- *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (2006), SW-846* (EPA 1996 and updates)

- *Environmental Quality – Guidance for Evaluating Performance-Based Chemical Data, Engineer Manual 200-1-10* (U.S. Army Corps of Engineers 2005)

- *EPA Contract Laboratory Program, National Functional Guidelines for Superfund Organic Methods Data Review* (EPA 2008)

- *EPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Data Review, Final* (EPA 2010).

The following criteria were included in the data verification:

- Review of chain-of-custody documentation for signatures, sample condition upon receipt, and sample preservation

- Sample extraction and analysis holding times

- Review of blank data for laboratory contamination (no field blank data)

- Review of quality control summaries and case narrative regarding sample analysis

- Review of laboratory detection limits to verify conformance with project data objectives and screening criteria

- Review of the data and deliverables for completeness.

Analytical data were reviewed in terms of accuracy, precision, representativeness, comparability, and completeness as follows:

- Accuracy or bias is demonstrated by recovery of target analytes from fortified blank and sample matrices, laboratory control sample (LCS) and LCS duplicate (LCSD), and matrix spike (MS) and MS duplicate (MSD), respectively. For organic methods, bias is also demonstrated through recovery of surrogates from field and quality control samples. The recovery of target analytes from fortified samples is compared with the acceptance criteria defined in the Work Plan/Quality Assurance Project Plan (U.S. Air Force 2013) and DoD QSM. When the acceptance criteria are not available in the Quality Assurance Project Plan or DoD QSM, results are compared with the laboratory in-house control limits. When these criteria are not met, the data are qualified accordingly.

- Precision is expressed as the relative percent difference (RPD) between the results of replicate sample analyses: sample duplicates, LCSDs, and MSDs. When analyte RPDs exceed the acceptance criteria, the data are qualified accordingly.

- Representativeness of the samples submitted for analysis is ensured by adherence to standard sampling techniques and protocols.

- Comparability of sample results is ensured through the use of approved sampling and analysis methods.

  — Completeness of the data set is determined based on review of final deliverables, and percent of data that meets the data quality objectives.

1.1 Validation Results

1.1.1 Chain-of-Custody and Sample Receipt

Three samples were received on 5 July 2013 in good condition. The sample coolers and samples contained within were received intact at the laboratory and were within the required 0-6 degrees Celsius, in compliance with EPA preservation requirements. There were no discrepancies between the chain-of-custody form and the sample container labels. Appropriate signatures were included on the chain-of-custody documentation.

1.1.2 Sample Extraction and Analysis Holding Times

Sample holding times were evaluated by comparing the sample collection dates to the sample extraction and analysis dates. Extraction and analysis holding times were reviewed for all samples to determine compliance to EPA recommended holding times. Holding time requirements were met for method-specific extraction and analysis for all project samples.

1.1.3 Blank Data Results

1.1.3.1 Laboratory Method Blank Data

The field sample results were evaluated with respect to the laboratory method blank prepared and analyzed with the analytical batch for each analytical method. A low-level detection of barium was reported in the method blank sample for the TCLP metals analysis. No other target analytes were detected in laboratory method blanks for all other parameters.

Based on the DoD QSM requirements, laboratory method blank concentrations are considered acceptable when contaminant levels in the blank are less than one-half the limit of quantitation (LOQ) for target analytes and less than the LOQ for common laboratory contaminants. The method blank concentration for barium was less than one-half the LOQ and thus met the blank acceptance criteria. Barium data were qualified accordingly by the laboratory.

1.1.3.2 Field Blank Data

There were no field blank, trip blank, or equipment rinse blank samples collected for this sample delivery group since the samples in this sample delivery group are investigation-derived waste samples used for the purpose of waste characterization and disposal and not project samples used for investigative purposes.

1.1.4 Quality Control Sample Summary

1.1.4.1 Surrogate Recoveries

Surrogate standards are organic compounds added to field and laboratory quality control samples for organic analysis to evaluate matrix effect and method performance on an individual sample basis. Surrogate recoveries were within the method control criteria for volatile organic compounds, semivolatile organic compounds, pesticide, herbicide, and polychlorinated biphenyl analyses.

1.1.4.2 Laboratory Control Sample Recoveries and Precision Results

The LCS is an aliquot of analyte-free matrix spiked with target analytes that is prepared with each analytical batch for each analytical method. The recovery of target analytes from the LCS analysis is a measurement of method performance in an interference-free sample matrix. LCS and LCSD sample recoveries and precision between the LCS and LCSD were within the control criteria for all analytical methods.

1.1.4.3 Matrix Spike Sample Recoveries and Precision Results

The MS and MSD samples are a portion of a field sample spiked with target analytes that are prepared with each analytical method. The MS and MSD results are used to evaluate any bias introduced to the method due to matrix interference and to measure bias and precision for each analytical batch.

MS and MSD samples were not required to be analyzed on project-specific samples due to nature of the samples (waste characterization); however, the laboratory did spike project sample WR111-SB-WR709-BS-P-04 and analyze for MS and MSD recoveries. Except as noted below, the MS and MSD recoveries and precision were within method-specific control criteria.

- One pesticide and two herbicide compounds exceeded the RPD criteria between the MS and MSD recoveries. All other spiked pesticide and herbicide compounds were within control criteria for the MS and MSD samples.

- One sulfide recovery was outside of the control criteria for the MS and resulted in exceedance of the RPD criteria.

Although 3 analytes exceeded the control criteria for either the MS or RPD, the LCS and LCSD recoveries and RPD for the same analytes were within acceptable control limits, indicating minor interferences with sample matrix. Data were qualified by the laboratory accordingly and do not impact usability of the data results.

1.1.4.4 Field Duplicate Samples

Field duplicate samples were not required to be collected for this set of waste characterization samples.

1.2 Data Comparability

Comparability of data is achieved through the use of industry standard analytical method protocols and conformance to project required detection limits to achieve DOQs. Data verification indicates that project-specific methods and detection limits were used for analysis of the waste characterization samples in accordance with the Work Plan and Quality Assurance Project Plan.

1.3 Data Completeness

Project deliverables were reviewed for accuracy and completeness. Based on the data verification results the completeness of deliverables is 100 percent. Technical completeness is a quantitative measure of the data usability based on the number of rejected data compared to the total number of sample results. The project-specific technical completeness goal is equal to or greater than 90 percent. Since no data were qualified as rejected or unusable to achieve project data quality objectives, the data completeness is 100 percent for all methods for the waste characterization sample data.

1.4 Conclusions

The analytical data reported for this project have been reviewed for accuracy, precision, representativeness, comparability, and completeness. Data quality criteria exceedances consist of one MS recovery for sulfide, the MS/MSD RPD control criteria for one pesticide and two herbicide compounds, and one low level detection of barium in the method blank sample. The affected data were qualified as estimated or non-detect data results. Estimated data are still usable to achieve project data quality objectives. All data in this SDG are usable for the intended purpose of waste characterization for soil disposal.

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Appendix C
Derived Concentration Guideline Level Evaluation

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Hill Air Force Base Performance-Based Remediation

WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench

Appendix C, Derived Concentration Guideline Level Evaluation

Contract No: FA8903-09-D-8560
Task Order 0006

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Executive Summary

This document presents the derived concentration guideline levels (DCGLs) for radioactive contaminants that may be present in soil at the Little Mountain Test Annex (LMTA) Magnesium-Thorium Disposal Trench Site in Utah. Hereinafter, the LMTA Magnesium-Thorium Disposal Trench Site will be referred to as Site WR111. DCGLs are derived radionuclide-specific activity concentrations that correspond to the site release criteria.

The U.S. Atomic Energy Commission (AEC), the forerunner of the Nuclear Regulatory Commission (NRC), issued Source Material License C-3650 to Marquardt Aircraft Company of Van Nuys, California, for possession of magnesium-thorium (Mg-Th) alloy to be used in the manufacture of controls, accessories, and engine parts. In September 1961, Source Material License C-3650 expired and License STB-434 was issued that included permission to incinerate source material in accordance with AEC regulations associated with treatment or disposal by incineration. Documents show that 500 pounds of scrap Mg-Th were buried in June 1959, 1,500 pounds were buried in February 1960, and 3,600 pounds were incinerated in August 1961. License STB-434 terminated on 12 April 1971. No documentation is in NRC docket files to show that the AEC performed a closeout inspection or survey for this license or facility. In addition, the materials-disposition documentation was incomplete.

A number of investigations conducted at Site WR111 identified both surface and subsurface soil radiological contamination. A previous investigation indicated that groundwater has not been impacted. The radionuclides of concern (ROCs) are radium-226 (^{226}Ra), thorium-230 (^{230}Th), and thorium-232 (^{232}Th).

The NRC is the regulatory authority for establishing the primary limit of 25 millirem (mrem) total effective dose equivalent in any one year, in excess of natural background, for releasing a radiologically contaminated site. *Residual Radioactivity (RESRAD), Version 6.5* was used to derive the soil DCGLs for Site WR111 based on NRC's regulatory dose limit of 25 millirem per year (mrem/yr).

Two receptor scenarios were considered during the derivation of DCGLs for each ROC. A residential farmer was considered as the critical receptor for the base-case exposure scenario at Site WR111. Under the residential farmer scenario, assumptions are that a family moves onto the property after it has been released for unrestricted use (with no radiological restrictions), builds a home, and raises crops and livestock for family consumption. One additional exposure scenario was evaluated to confirm that the base case resident farmer scenario is bounding for the development of soil DCGLs. The site is currently federally owned so a very conservative airman exposure scenario was selected. Under that scenario, the airman would be exposed to the residual contamination being brought to the surface from the bottom of the burial trench.

In the derivation of the soil DCGLs, soil dose assessments were performed by using a unit concentration of 1 picoCurie per gram (1 pCi/g) for each of the ROCs, individually. The output of each RESRAD "run" of the model could then be interpreted as an estimate of the dose per unit activity (in millirem/yr per pCi/g, or mrem/pCi/g), also called a dose-to-source ratio that the receptor would receive in a single year from 1 pCi/g of the radionuclide in soil. The primary dose limit was then divided by this dose-to-source ratio to yield a DCGL for that radionuclide, in units of pCi/g. Among two exposure scenarios, the most conservative DCGL for each ROC was selected as the site-specific DCGL.

Table ES-1 presents the results of the site-specific DCGL for each ROC.

TABLE ES-1
Site-Specific, Radionuclide-Specific, Soil Derived Concentration Guideline Levels
Appendix C: Site-Specific Derived Concentration Guideline Level Report
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench, Hill Air Force Base, Utah

Radionuclides of Concern	**Site-Specific Derived Concentration Guideline Level (picoCurie per gram)**
^{226}Radium	1.6
^{230}Thorium	4.3
^{232}Thorium	1.9

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Acronyms and Abbreviations

AEC	U.S. Atomic Energy Commission
^{214}Bi	Bismuth-214
bgs	Below ground surface
CFR	Code of Federal Regulations
Ci	Curie
DCGL	Derived Concentration Guideline Level
EPA	U.S. Environmental Protection Agency
ft	Feet(foot)
^{40}K	Potassium 40
LMTA	Little Mountain Test Annex
Mg-Th	Magnesium-thorium
mrem	Millirem
mrem/yr	Millirem per year
NRC	Nuclear Regulatory Commission
NUREG	Nuclear Regulatory Commission Guidance
Parsons	Parsons Infrastructure and Technology Group, Inc.
^{214}Pb	Lead-214
pCi/g	PicoCurie per gram
^{226}Ra	Radium-226
RESRAD	Residual radioactivity
ROC	Radionuclide of concern
ROPC	Radionuclide of potential concern
SOR	Sum of the Ratio
SOR_G	Sum of the Ratio based on gross concentration
SOR_N	Sum of the Ratio based on net concentration
SSV	Soil screening value
^{228}Th	Thorium-228
^{230}Th	Thorium-230
^{232}Th	Thorium-232
TEDE	Total Effective Dose Equivalent

^{234}U	Uranium-234
^{235}U	Uranium-235
^{238}U	Uranium-238

1.0 Introduction

This document presents site-specific derived concentration guideline levels (DCGLs) for the radionuclides of concern (ROCs) in soil at the Little Mountain Test Annex (LMTA) Magnesium-Thorium Disposal Trench Site in Utah. Hereinafter, the LMTA Magnesium-Thorium Disposal Trench Site will be referred to as Site WR111.

1.1 Purpose

The analyses in this report provide a site-specific DCGL in order to support decisions on whether or not additional remediation is needed for Site WR111 to be released for unrestricted use. Specifically, when the DCGL is applied to the final status survey and the survey data demonstrate that the DCGL has been satisfied with respect to Total Effective Dose Equivalent (TEDE), the following requirements of Title 10, Code of Federal Regulations (CFR), Part 20, Paragraph 1402 (10 CFR 20.1402) are achieved:

> *A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a TEDE to an average member of the critical group that does not exceed 25 millirem per year (mrem/yr), including that from groundwater sources of drinking water, and that the residual radioactivityhas been reduced to levels that are as low as reasonably achievable. Determination of the levels which are as low as reasonably achievable must take into account the consideration of any detriments, such as deaths from transportation accidents, expected to potentially result from decontamination and waste disposal.*

In addition to 10 CFR 20, several Nuclear Regulatory Commission (NRC) and U.S. Environmental Protection Agency (EPA) reference documents were used to derive the site-specific DCGL as presented in this document.

1.2 Scope

The scope of this document is limited to soils that may have been impacted by radionuclides of concern (ROCs). This document addressed the following ROCs:

- Radium-226 (^{226}Ra)
- Thorium-230 (^{230}Th)
- Thorium-232 (^{232}Th).

The Residual Radioactivity (RESRAD) Version 6.5 (ANL 2009) was used during the derivation of DCGLs for each ROC. RESRAD is a computer code developed at Argonne National Laboratory for the U.S. Department of Energy to determine site-specific residual radiation guidelines and dose to a future hypothetical onsite receptor at sites that are contaminated with residual radioactive materials.

1.3 Site Description, Radiological History, and Contaminants

The LMTA and Site WR111 are located in a remote area west of Ogden, Utah, which is approximately 15 miles northwest of Hill Air Force Base and adjacent to the Great Salt Lake. The disposal trench is approximately 200 × 150 feet (ft) in area and is enclosed by a chain-link fence in the southeastern corner of the LMTA. The fenced area is referred to as the Radioactive Disposal Area.

Based on review of the *Final Radiological Disposal Sites Characterization for Little Mountain Testing Annex* report (AECOM 2009), material disposed of at Site WR111 originated from the Marquardt Aircraft Ramjet manufacturing plant in Ogden. The U.S. Atomic Energy Commission (AEC), the forerunner of the NRC, issued Source Material License C-3650 to Marquardt Aircraft Company of Van Nuys, California, for possession of magnesium-thorium (Mg-Th) alloy to be used in the manufacture of controls, accessories, and engine parts. The maximum amount of ^{232}Th allowed by this license was 4,600 pounds, or approximately 0.23 curie (Ci) of ^{232}Th.

In April 1959, Marquardt sent a letter to the AEC concerning disposition of Mg-Th scrap material. Apparently, the licensee was having difficulty in finding a supplier who would accept its scrap material. Documents show that 500 pounds of scrap Mg-Th were buried in June 1959 and 1,500 pounds were buried in February 1960. In June 1961, Marquardt requested AEC approval to burn the machine chips and small pieces of Mg-Th scrap material that accumulated at the Ogden facility. The licensee proposed to burn the material in burial/burn trench that was 10 ft deep, 8 ft wide, and 20 ft long. The trench would be located in a remote controlled area on government property.

In September 1961, Source Material License C-3650 expired and License STB-434 was issued for the Marquardt facility in Ogden. This license included permission to incinerate source material in accordance with AEC regulations associated with treatment or disposal by incineration. Documents show that 3,600 pounds were incinerated in August 1961. Historical records indicate that this amount included sludge from the wet collectors from the pickling tanks (containing thorium fluoride) and lathe turnings/milling scraps (possibly containing cutting oil and/or solvents). No other documentation of disposal was identified in the docket files.

License STB-434 was terminated on 12 April 1971. No documentation is in NRC docket files to show that the AEC performed a closeout inspection or survey for this license or facility. In addition, the materials-disposition documentation was incomplete.

1.4 Past and Present Site Investigations

In the early 1990s, a number of investigations were conducted at Site WR111. The results of the investigations were summarized in the *Final Summary Report: Low Level Radioactive Waste Contamination, LMTA* (Jacobs Engineering Group Inc. 1994), and according to the report:

- In 1993, the NRC performed an inspection at the LMTA and identified two disposal pits where the highest exposure rate was about twice the background exposure rate recorded in the vicinity.

- In 1993, the Hill Air Force Base Radiation Safety Officer collected 10 surface soil sample from a potential radioactive disposal area and a background surface soil sample. The result indicated that gross alpha concentrations for all 10 samples were greater than the background concentration.

- The Final Summary Report identified an area in the southeast corner of the LMTA as the radioactive disposal area, which is in the general vicinity of the elevated gamma measurements observed by the NRC. The gamma-scan results for other disposal areas (north of the radioactive disposal area) exhibited elevated count rates; however, these were within 25 percent of the background count.

In 2006, the U.S. Air Force Institute for Operational Health performed a Global Positioning System-referenced gamma radiation survey of various areas of interest at the LMTA (U.S. Air Force Institute for Operational Health 2007). Only the area within the fenced Radioactive Disposal Area showed elevated gamma count rates. The original trench did not show any elevated gamma count rates. Therefore, the U.S. Air Force Institute for Operational Health concluded that areas outside of the fenced Radioactive Disposal Area were not impacted.

In August 2006, four shallow bedrock monitoring wells (LM-060 through LM-063) were installed surrounding Site WR111 by Parsons Infrastructure and Technology Group, Inc. (Parsons). In November 2006, the four wells were sampled and the samples analyzed for volatile and semivolatile organic compounds, metals, water quality parameters, gross alpha and gross beta, specific gamma emitters, and thorium isotopes. Thorium-228 (^{228}Th) and ^{232}Th were not detected in groundwater at any of the wells, indicating that Mg-Th impact is not migrating to groundwater. Low concentrations of thorium-230 (^{230}Th), which is direct progeny of ^{238}U, were identified in groundwater; however, the concentrations were random and less than 1 picocurie per liter, which is indicative of natural uranium decay. Gross alpha radiation was detected in the downgradient well only, but was not considered significant. Low levels of gross beta radiation were detected in all four wells. The Parsons report concluded that the random pattern of low-level detections of ^{230}Th, combined with the absence of ^{232}Th and ^{228}Th, represented radioactive decay of naturally occurring uranium rather than leaching of the scrap metal.

During 2007–2009, AECOM performed a more detailed investigation as part of a site characterization survey of Site WR111. This work included identifying and sampling appropriate background location(s), geophysical survey to define site boundaries, gamma walkover survey measurements with Global Positioning System mapping, characterization survey of soil at surface and depth, and radiological surveys to include sampling and analysis of incidental chemical contaminants (i.e., volatile and semivolatile organic compounds), and disposal of investigative-derived waste.

Twenty-six surface soil samples and 14 subsurface soil samples were collected from radiological disposal area during the 2009 site characterization survey. In addition, AECOM collected 26 background surface soil samples and 14 subsurface soil samples within the background reference area. All soil samples were analyzed via gamma spectroscopy with the 6 samples from the radiological disposal area exhibiting the highest activity also analyzed for isotopic thorium via alpha spectroscopy.

The characterization survey showed that the maximum ^{232}Th concentrations in the Radioactive Disposal Area were 7.1 ± 0.4 and 99 ± 3 picoCuries per gram (pCi/g) for surface soil and subsurface soil, respectively. The ^{232}Th background concentration for surface soils was 1.65 ± 0.03 (pCi/g) and for subsurface soils 1.60 ± 0.04 pCi/g (uncertainties were two standard deviations). Results of the AECOM investigation indicate that site soils within the fenced Radioactive Disposal Area had been impacted with ^{232}Th and decay progeny above background levels (AECOM 2009). The report also indicated that elevated radiological activity may extend beyond the fence line to the south and east. While ^{226}Ra was also detected, the naturally occurring radionuclide was determined to be present at concentrations similar to background levels, and ^{226}Ra was not considered a site contaminant.

In July 2013, Cabrera Services, Inc. performed a supplemental site characterization investigation of potentially impacted soil at Site WR111 to assess conditions at the Radioactive Disposal Area and confirm existing assumptions about the nature and extent of radiological contamination. Samples were also collected for waste characterization analyses to assess disposal requirements. The radiological investigation included the following tasks:

- Performed a limited gamma walkover survey with 3 × 3-inch sodium iodide detector coupled with a Global Positioning System, to identify areas of elevated activities in order to strategically position boring locations in areas beyond those previously identified as radiologically impacted. GWS was performed with the detector 10 centimeters above the ground surface.

- Fourteen soil borings were advanced by direct-push method using as terrain and access permitted. Subsurface soil samples were collected by advancing a steel macro-sampler core barrel (minimum 2-inch outside diameter) with acetate sleeves to a depth of 12-15 ft below ground surface (bgs). Core scans were obtained from each soil boring. Five out of the 14 boreholes did not advance to 12-15 ft bgs due to refusal. An additional two boreholes collapsed before downhole gamma readings could be collected.

- Subsurface soil cores were scanned for radiological contamination using a 3 × 3-inch sodium iodide detector.

- Downhole gamma logging, in conjunction with core scanning, was performed to assist in determining the location of biased subsurface soil samples. Downhole gamma measurements were conducted utilizing a Ludlum 44-2 (1 × 1-inch) sodium iodide detector not collimated with lead shielding. The instrument was lowered into the borehole to the target depth and one-minute static measurements were collected at half a foot intervals proceeding upward until the top of the borehole was reached.

- Surface and subsurface soil from intervals with the highest gross count rates were selected for biased soil sampling.

- Soil samples were submitted to the offsite laboratory for radiological analysis.

Twenty-nine soil characterization samples, including 2 field duplicate samples, were collected in support of characterization survey at Site WR111. These samples were submitted to TestAmerica and analyzed for natural radium, thorium, uranium isotopes, and potassium-40 (^{40}K) using gamma spectroscopy via EPA Method 901.1. Three of those samples had elevated levels of ^{226}Ra and ^{232}Th. In order to obtain a more accurate ^{226}Ra activity value, the 3 samples were re-analyzed for ^{226}Ra via EPA Method 901.1M, which measures the ^{226}Ra daughter progeny (bismuth-214 [^{214}Bi], and lead-214 [^{214}Pb]) at equilibrium. The three samples were also analyzed for isotopic thorium (including ^{228}Th, ^{230}Th, and ^{232}Th) by the alpha spectroscopy method EML HASL 300 Modified (U.S. Department of Energy 1997) in order to determine the source of the elevated ^{226}Ra activity (^{226}Ra is a daughter of ^{230}Th). One of the three elevated activity samples (analyzed by gamma spectroscopy) also had an elevated uranium concentration with high uncertainty. Therefore, all 3 samples were analyzed for Isotopic Uranium (including Uranium-234 [^{234}U], Uranium-235 [^{235}U], and ^{238}U) by EML HASL 300 Modified (U.S. Department of Energy 1997). Alpha spectroscopy is more accurate with a higher confidence level for reporting the activity of alpha emitting radionuclides. For this reason, the alpha spectroscopy results for the three reanalyzed samples (WR111-SB-WR701-BS-P-05, WR111-SB-WR708-BS-P-08, and WR111-SB-WR710-BS-P-05) were used during subsequent data evaluation activities. The results showed that the elevated ^{226}Ra activity is progeny from the elevated ^{230}Th from the site Mg-Th contamination in all 3 samples. In addition, the isotopic uranium results were all representative of background activity levels. Alpha spectroscopy results are provided in Table B-1 (pages 1 through 8) in Appendix B.

1.4.1 Identification of Radionuclides of Potential Concern

Analytical data from the 2009 and 2013 characterization efforts were combined to identify the radionuclides of potential concern (ROPCs) for Site WR111. ROPCs are the radionuclides that have been detected and have gone through the following screening processes. Two different types of screenings were performed to identify ROPCs for the site. Each screening process is summarized below:

- ***Data Reduction***—For radiological constituents, when secular equilibrium exists in the decay series, the activities of all members of the series will be the same. Measurement of the activity of one member of the series then provides the activities for all members of the series. Based on that:

  — ^{232}Th is assumed to be in secular equilibrium with respect to its short-lived daughter products. Therefore, sampling results for ^{232}Th are the same as that for its daughter products (^{228}Th, actinium-228, radium-228, lead-212, bismuth-212, and thallium-208). Therefore, ^{232}Th sampling results were utilized during the data evaluation.

  — ^{226}Ra is assumed to be in secular equilibrium with respect to its short-lived daughter products. Therefore, sampling results for ^{226}Ra are the same as that for its daughter products (^{214}Pb and ^{214}Bi). Therefore, ^{226}Ra sampling results were utilized during the data evaluation.

  — Similarly, ^{238}U is assumed to be in secular equilibrium with respect to its short-lived daughter products. Therefore, sampling results for ^{238}U are the same as that for its daughter product (thorium-234). Therefore, ^{238}U sampling results were utilized during the data evaluation.

- ***Weight-of-Evidence Screening***—The weight-of-evidence screening was performed for each radiological constituent that passed the data reduction screening. If the frequency of detection for a radiological constituent in a medium is 5 percent or less (i.e., a minimum of 1 detection out of 20 analytical results), generally, the radiological constituent is excluded from further evaluation. This rationale is consistent with EPA's Risk Assessment Guidance (EPA 1989). Under this screening, radiological constituents that were detected in less than 5 percent of the samples from a given medium may be artifacts in the data due to sampling, analytical, or other problems, and may not be related to site activities. These constituents (^{235}U and its daughter product) were not included in the data evaluation.

In addition, even though ^{40}K was detected for all samples, it was not considered as a ROPC during the data evaluations. Potassium is an essential nutrient. ^{40}K is naturally present in soil and is the predominant radioactive component in normal foods and human tissues.

1.4.2 Data Evaluation Methodology

Two data evaluations were performed utilizing the sampling results of ROPCs to determine the ROCs at Site WR111. Each evaluation is summarized below.

Data Evaluation Based on Site-Specific Soil Screening Values (SSVs)—During the first evaluation, individual sampling results for each ROPC at a sampling location were compared with respect to its corresponding site-specific SSVs, thus defining ROCs and, therefore, areas where potential radiological contamination may be present. SSV for each ROPC was calculated by adding site-specific soil background values to the surface SSVs provided in NRC Regulatory Guidance (NUREG) 1757, Volume 2, Appendix H (NRC 2006). When the individual sampling result was found to be in excess of a corresponding site-specific SSV, the area associated with that result is potentially contaminated. Mean background values for two ROPCs (^{226}Ra and ^{232}Th) were established during the 2009 characterization survey (AECOM 2009). The surface soil arithmetic average background concentration was considered during the calculation of SSV for each ROPC. It should be noted that site-specific background for ^{230}Th was not calculated during the 2009 site characterization survey. As a conservative approach, the NRC's surface SSV for ^{230}Th was used as its SSV. The results of the site-specific SSVs are presented in Tables 3-1 and 3-2 of the Decommissioning Plan. A comparison for each ROPC with respect to its SSV was performed for the sampling results from 2009 and 2013, and exceedances are presented in Tables 3-1 and 3-2 of the Decommissioning Plan, respectively.

Data Evaluation Based on the Sum-of-the-Ratios (SORs)—When there are multiple ROCs present in the soil, the allowed soil concentration levels must follow the SORs. This will ensure that the sum of the individual fractions for each isotope to its individual site-specific SSV fraction does not exceed unity. The SOR at Site WR111 is calculated as follows:

$$\mathrm{SOR} = \frac{\mathrm{Ra\text{ - }226_{Conc}}}{\mathrm{Ra\text{ - }226_{SSV}}} + \frac{\mathrm{Th\text{ - }232_{Conc}}}{\mathrm{Th\text{ - }232_{SSV}}} + \frac{\mathrm{Th\text{ - }230_{Conc}}}{\mathrm{Th\text{ - }230_{SSV}}}$$

where

^{226}Ra Conc = Gross activity for ^{226}Ra.
^{232}Th Conc = Gross concentration for ^{232}Th.
^{230}Th Conc = Gross concentration for $^{230\text{Th}}$.
^{226}Ra SSV = Site-Specific SSV for ^{226}Ra.
^{232}Th SSV = Site-Specific SSV for ^{232}Th.
^{230}Th SSV = Site-Specific SSV for $^{230\text{Th}}$.

Two types of ratios were calculated for each sample based on the site and background soil sampling results for ^{226}Ra, $^{230\text{Th}}$, and ^{232}Th and their corresponding site-specific SSVs:

1. Ratio based on gross concentration ($\mathrm{SOR_G}$).
2. Ratio based on net concentration ($\mathrm{SOR_N}$) (Net = [Gross – Background) Concentration]).

When the $\mathrm{SOR_N}$ in excess of one is present in a specific area, radiological contamination may present at that location. If the result of the $\mathrm{SOR_N}$ is below 1, no further evaluation may be required. Table 3-3 of the Decommissioning Plan presents the results of the ratios where the $\mathrm{SOR_N}$ are greater than 1.

Tables 3-1 and 3-2 of the Decommissioning Plan showed that sampling results for ^{226}Ra and/or ^{230}Th and/or ^{232}Th exceeded their corresponding SSVs at 29 sample locations. Table 3-3 of the Decommissioning Plan showed that out of 69 total samples, 32 samples had an $\mathrm{SOR_N}$ exceeding 1. That means, even though sampling results for both ^{226}Ra and ^{232}Th did not exceed their corresponding SSVs, the $\mathrm{SOR_N}$ results for three additional sample locations (RSS07, RSS15, and RSS16) exceeded 1.

Figure 3-3 of the Decommissioning Plan presents the sampling locations for all of above exceedances. Figure 3-3 shows that surface soil contamination is present in the southern portion and subsurface soil contamination is present in the east-central portion of Site WR111. The subsurface soil contamination is present at a depth of 5-10 ft bgs. The figure also showed that two elevated locations for ^{226}Ra and three elevated locations for ^{230}Th are co-located with respect to the highest concentrations for ^{232}Th. Therefore, remedial action for one ROC will remediate the other ROCs.

1.4.3 Site WR111 Radionuclides of Concern

Results of data evaluations were utilized to determine the ROCs in the soil. ROCs are ROPCs and their sampling results exceeded their corresponding site-specific SSVs.

As mentioned in Section 1.4.2, sampling results for ^{226}Ra and/or ^{230}Th and/or ^{232}Th exceeded their corresponding SSVs at 29 sample locations and the SOR_N results exceeded 1 at three locations. All three ROPCs (^{226}Ra, ^{230}Th, and ^{232}Th) were considered as the soil ROCs for Site WR111. Therefore, DCGLs were calculated for all three ROCs.

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2.0 General Environmental and Physical Site Characteristics

Site WR111 is located in the far southeast corner of the LMTA property. The site is bounded by private land to the east, Great Salt Lake to the south, and a paved Air Force road to the north. The adjacent property to the east is owned by Weber County. Approximately 350 ft south of Site WR111 is the railroad right-of-way and marsh land associated with the Great Salt Lake.

The disposal trench area is roughly 0.5 acres in size and is situated between two small mounds of soil. The terrain in the area of Site WR111 is gently sloping at with surface elevations ranging from 4,225 to 4,245 ft above mean sea level. The terrain drops steeply to the northeast toward the city of Weber.

2.1 Current/Future Land Use

The current land use of Site WR111 is considered military and industrial with a large amount of rangeland. Land use at LMTA is not expected to change in the future. LMTA is surrounded by the communities of South Weber, Riverdale, Sunset, Clearfield, Clinton, Roy, and Layton. Adjacent land use is residential and mixed agricultural, commercial, and residential.

2.2 Meteorology

Based on the climatological data for this area from 1981 through 2010, Ogden and the surrounding area experience a dry summer continental climate where the summers are hot and dry, with temperatures typically reaching 95 degrees Fahrenheit. Annual rainfall is typically less than 16 inches. During the summer months, infrequent thunderstorms result in average monthly rainfall totaling:

- 1.54 inches in June
- 0.83 inches in July
- 0.92 inches in August
- 1.67 inches in September.

2.3 Geology

Bedrock at Site WR111 occurs at depths ranging from 2 to 13 ft bgs and is highly fractured. The bedrock surface has an apparent downward slope trending from west to east.

The bedrock in the area of Site WR111 consists of two lithological units: slate argillite, and tillite. These units contact along a fault line to the south that continues in a northwesterly direction. The bedrock stratigraphic sequence at the LMTA consists of the slate overlain by a relatively thin clastic, calcareous unit, loosely-termed calcareous phyllite that transitions upward to a greenstone. The thick tillite overlays the calcareous phyllite and greenstone sequence. Tillite juxtaposed against the slate suggests a large offset along this fault with an apparent strike-slip component to the offset. Low water yield during drilling, development, and sampling of the site monitoring wells indicates low permeability of the bedrock at all well locations and limited groundwater flow.

2.4 Hydrogeology

Both shallow and deep aquifers are present in this region. The uppermost water bearing zone is encountered at an approximate depth of 30 ft bgs, corresponding to an elevation of approximately 4,208 ft above mean sea level. The site-specific groundwater flow direction is southerly with a southwest component. In 2006, four monitoring wells were installed in the vicinity of Site WR111 and are screened in bedrock. Low water yield during drilling, development, and sampling of the site monitoring wells indicates low permeability of the bedrock at all well locations and limited groundwater flow. Low permeability is also consistent with the relatively steep hydraulic gradient.

2.5 Surface Water Hydrology

Site WR111 is located within the Weber River Watershed. The Weber River Basin is a flat, fertile plain, which was formed by alluvial deposits from the former Lake Bonneville. The Ogden River is a major tributary to the Weber River and drains the Ogden Valley and the eastern portion of Weber County. The flow of the Weber River and its tributaries is controlled by reservoirs that have a great effect on water quality. The Willard Reservoir, commonly known as Williard Bay, is the last major reservoir in the Weber River Basis. Closest to Site WR111is the Williard Reservoir, which is located on the shores of the Great Salt Lake, and used for irrigation in the lower basin and some fishing and boating. There are no known wetlands in the immediate vicinity of Site WR111.

2.6 Natural Resources

Ogden, Utah is at the foot of the Wasatch Mountains and is the largest city in Weber County. Located within the Great Salt Basin, the natural resources and benefits are many. However, there are no known significant mineral deposits, water resources, coal deposits, or other natural resources at Site WR111.

3.0 Determination of Derived Concentration Guideline Level

The three soil ROCs for Site WR111 are ^{226}Ra, ^{230}Th, and ^{232}Th. Therefore, a DCGL was calculated for each ROC based on acceptable dose limit and post-remediation site conceptual model. The following sections of the report summarize the procedures for calculating the DCGLs for ROCs present at the site.

3.1 Annual Public Dose Limit

The NRC annual dose limit for a member of the public is 100 mrem TEDE associated with licensed activities and exclusive of background (and other) sources, as specified in 10 CFR 20.1301. As described in Section 1.1, 10 CFR 20.1402, *Radiological Criteria for Unrestricted Use*, specifies that an average member of the critical population group may not receive a TEDE in excess of 25 mrem, including groundwater sources of drinking water. The RESRAD model uses this required input parameter (25 mrem) for the applicable dose limit to establish the resulting DCGLs for a site.

3.2 Conceptual Site Model

The conceptual site model identifies the relationship between the sources of contamination, source areas, transport mechanisms, exposure routes, and receptors. The conceptual side model provides a description of how contaminants enter into the environment, how they are transported within the environment, and the routes of exposures to humans. In this section, the conceptual site model presented both existing and expected post-remediation site conditions. However, the conceptual site model representing post-remediation or as-left conditions will be used for the DCGL modeling.

Based on historical records of previous burial activities and results of data evaluations performed for both historical and newly-collected surface and subsurface soil samples, existing surface and subsurface radiological soil contamination is present at Site WR111. As mentioned in Section 1.4.2, radiological surface soil contamination is present in the southern portion and radiological subsurface contamination is present in the east-central portion of the site. Most of the subsurface contamination is present at a depth of 5-10 ft bgs. The estimated aerial extent of impact soil in the east-central portion and southern portions is approximately 4,500 and 4,100 square ft, respectively; therefore, remedial action will be initiated in those areas. As a part of the decommissioning activities, it is anticipated that radiologically contaminated soil will be excavated from approximately 0 to 10 ft bgs in the east-central portion of the site, and approximately 1 ft of radiological contaminated soil will be excavated from the southern portion of Site WR111. Radiologically impacted soil will be disposed at an offsite facility licensed to accept the waste stream. The excavated areas will be backfilled with clean backfill material. Under post-remediation conditions, residual radiological activity will be present in the excavation floor and wall surfaces; and, due to the persistence (longevity) of the ROCs, there is potential exposure to current and future receptors. The residual radiological activity is anticipated to be present in the remaining soils at the walls of the excavation area and at the bottom of the excavation area, from 10 to 20 ft below the excavation floor surfaces.

Natural thorium is not typically mobile in the environment and, therefore, is unlikely to leach into groundwater. At Site WR111, the lack of thorium mobility is confirmed based on a review of groundwater quality data that were obtained from four monitoring wells (LM-060 through LM-063) at the site, as summarized in the *Final North Disposal Area, Thorium Site, Oil Emulsion Disposal Area Data*

Summary Report Little Mountain Test Annex Operable Unit A Remedial Investigation Report 2006 Program (Parsons 2007). In Table C.2 of the Parsons report, upgradient, sidegradient, and downgradient radionuclide sampling results show no detection of ^{232}Th and ^{228}Th in groundwater at any of the wells, indicating that Mg-Th impact is not migrating to groundwater. Low concentrations of ^{230}Th (progeny of ^{238}U) were identified in groundwater at all wells but the concentrations are random and less than 1 picoCurie per liter, which is indicative of natural uranium decay. The remaining ROC, ^{226}Ra, is typically more mobile in the environment, and low concentrations of ^{226}Ra progeny were also detected in the wells. However, the upgradient and downgradient groundwater concentrations are statistically equal. Based on the groundwater data, and consistent with the conclusions provided in the Parsons report, radiological concentrations in groundwater are due to natural uranium decay and are not associated with the Mg-Th alloy.

Groundwater quality parameters which were measured during well sampling indicate that the conductivity of the groundwater varies from 2,000 to 19,000 microSiemens per centimeter (µS/cm), which equates to salinity ranging from approximately 1,100 to over 10,000 milligrams per liter (mg/L). The average, expressed as salinity, is 7,250 µS/cm (Parsons 2007). Utah's groundwater quality classes are based mostly on total dissolved solids concentrations as follows: Class 1A (Pristine), less than 500 mg/L; Class 2 (Drinking Water Quality), 500 to less than 3,000 mg/L; Class 3 (Limited Use), 3,000 to less than 10,000 mg/L; and Class 4 (Saline), 10,000 mg/L and greater. Three of the wells in the WR111 area were tested for hydraulic conductivity and values averaging 2.1 ft/day were obtained (Parsons 2007). The flow rate would be very low for domestic use and of low quality due to its salinity.

The water-table aquifer is in slate and tillite rock formation at depths averaging approximately 30 feet deep. These conditions would make it very unlikely for the use of the area for aquiculture. The more likely potential use of the water table aquifer would be for watering cattle, which are more tolerant of salinity than humans. The low anticipated flow rate from a well in this aquifer would be sufficient to supply a stock tank.

The Delta aquifer is the primary source of drinking water for the region and is located southeast of WR111. The top of the aquifer is located around 500 to 700 feet bgs. The shallow Sunset aquifer is another source of drinking water and it is located above the Delta aquifer at a depth of approximately 400 ft bgs. Both aquifers are under confined conditions except at their recharge areas. The deeper Delta aquifer is separated from the shallower Sunset aquifer by numerous clay layers which prevent downward migration. Groundwater at WR111 is between 34 and 57 ft bgs and within low-permeability bedrock. There is no apparent communication between groundwater at WR111 and the regional aquifer.

Due to existing groundwater data indicating that water quality and yield are poor for domestic use, a complete groundwater pathway does not exist for the site.

There are no surface water bodies present within the site boundaries. Although the major surface water body in the area, the Great Salt Lake, is located approximately 1,000 ft from Site WR111, there is no evidence of contaminant migration from the Mg-Th disposal area in the direction of the lake. As such, a complete surface water pathway does not exist for the site.

The NRC guidance document, *Decision Methods for Dose Assessment to Comply with Radiological Criteria for License Termination* (NRC 1998), recommends the use of a residential farmer scenario as the basis for the DCGLs for residual contamination in site-wide soils. Hence, a resident farmer scenario was utilized as the base case exposure scenario for the derivation of soil DCGLs. Under a resident farmer scenario, a family is assumed to move onto the site after it has been released for use without radiological restrictions, build a home, and raise crops and livestock for family consumption. The resident farmer is exposed through different exposure pathways to residual radioactivity present in the site soil after unrestricted release of the site. To be conservative during modeling, the areal extent of residual radioactivity is assumed to be within the site boundaries of Site WR111 60,500 square feet (5,620 square meters), and the thickness interval is assumed to be 10 feet (3.05 meters). As a conservative approach, no soil cover was assumed for the Site. Members of the resident farmer critical group can incur a radiation dose via the following pathways:

- Direct radiation from radionuclides in the soil
- Inhalation of re-suspended dust (if the contaminated area is exposed at the ground surface)
- Ingestion of food from crops grown in contaminated soil
- Ingestion of milk from livestock raised in the contaminated area
- Ingestion of meat from livestock raised in the contaminated area
- Direct ingestion of contaminated soil.

A complete groundwater pathway does not exist. Therefore, the groundwater pathway was not considered for the residential farmer.

The aquatic foods pathway is not considered in the Site WR111 model since a complete surface water pathway does not exist.

The radon pathway is suppressed in this assessment due to its inapplicability. In a Federal Register Notice (NRC 1994), issued as a result of comments received from a radon workshop, the NRC noted that "radon would not be evaluated when developing release criteria due to: the ubiquitous nature of radon in the general environment, the large uncertainties in the models used to predict radon concentrations; and the inability to distinguish between naturally occurring radon and that which occurs due to licensed activities."

The exposure pathways are depicted in Figure 3-1 of this report.

In addition to the base case scenario, an additional exposure scenario was evaluated to confirm that the base case resident farmer scenario is bounding for the development of soil DCGLs. Site WR111 is currently federally owned so a very conservative airman (soldier) exposure scenario was selected. Under this scenario, the airman will be exposed to residual radioactivity being brought to the surface from the bottom of the burial trench.

Based on the nature and extent of radiological contamination currently present in soil, the area of the impacted soil during remedial activities is approximately 5,670 square feet (527 square meters). Approximately 1,860 cubic yards of soil will be excavated from the Site WR111. As a conservative modeling approach for the airman scenario, it was assumed that all excavated soil will be uniformly spread over the entire ground surface (60,500 square feet or 5,620 square meters) of Site WR111. The thickness of the contaminated soil zone was calculated to be 0.83 feet (0.253 meters).

The airman is modeled as a typical outdoor site worker who spends most of the work day outdoors. The airman will be at the site for 25 years (EPA 1991). A typical industrial worker usually spends 250 days per year at the site. As a conservative approach, the airman will spend 300 days per year at this site, with a 10-hour work day. During the 10-hour working day, the airman is assumed to spend 2 hours indoors and 8 hours outdoors.

Complete exposure pathways applicable to the airman scenario include:

1. Direct radiation from radionuclides in the soil

2. Inhalation of re-suspended contaminated dust
3. Ingestion of contaminated soil.

These exposure pathways are shown in the schematic representation of residual radioactivity pathways in Figure 3-2 of this report.

3.3 Recommended Values for Residual Radioactivity Parameters

The following hierarchy was implemented in assigning values for RESRAD input parameters for both the residential farmer and airman scenarios. In general, the preference was to use site-specific information first, followed by EPA recommended values, then NRC recommended values, and finally the RESRAD defaults:

- ***First Preference – Site-Specific Parameter***—Site-specific information is the first preference for selection of values for RESRAD input parameters.

- ***Second Preference – NRC Documents***—When site-specific data values are not available, the values provided in NRC documents were chosen for the RESRAD input parameters. Between the applicable NRC documents, NUREG/CR-5512 (Volume 4) (NRC 1999a) defines the residential farmer scenario, and was given first preference. The remaining NRC documents define the values for a residential scenario.
    - — *Comparison of the Models and Assumptions used in DandD 1.0, RESRAD 5.61, and RESRAD-Build 1.50 Computer Codes with Respect to the Resident Farmer and Industrial Occupant Scenarios*; NUREG/CR-5512 Volume 4 (NRC 1999a)
    - — *Residual Radioactive Contamination from Decommissioning – Parameter Analysis, Draft Report for Comments*; NUREG/CR-5512 Volume 3 (NRC 1999b)
    - — *Residual Radioactive Contamination from Decommissioning: Technical Basis for Translating Contamination Levels to Annual TEDE* NUREG/CR-5512 Volume 1 (NRC 1999c)
    - — *Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes* NUREG/CR-6697 (NRC 2000).
    - —

- ***Third Preference – EPA's Guidance Documents***—The following EPA documents were mainly used for selection of conservative values for intake parameters.
    - — *Exposure Factors Handbook* (EPA 2011 Edition).
    - — *Soil Screening Guidance Document for Radionuclides: User's Guide* (EPA 2000).

- ***Fourth Preference – RESRAD Default***—When no site-specific, NRC, and EPA values for the RESRAD parameters are available, the following document was used for selection of RESRAD default values:
    - — *Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil, Environmental Assessment and Information Sciences Division, Argonne National Laboratory* (Argonne National Laboratory 1993).

Attachment A presents the assigned values and justification for the RESRAD input parameters under a residential farmer scenario. Attachment B presents the assigned values and justification for the RESRAD input parameters under an airman scenario.

3.4 Methodologies to Determine Soil Derived Concentration Guideline Levels

The RESRAD model was used to calculate DCGLs from exposure to direct and indirect pathways. Direct pathways include soil ingestion, dust inhalation, and external gamma. Indirect pathways include plant ingestion. The dose from all complete exposure pathways was included in the soil DCGLs.

RESRAD Version 6.5 was used to perform the dose assessments for soil sources. The actual fractional concentrations activities of the ROCs for the site are not currently available. Therefore, a unit concentration of 1 pCi/g for ROC and the recommended model input parameters provided in Attachments A and B were used during the dose assessments. The dose resulting from a unit concentration for a given ROC is defined as the dose-to-source ratio. Attachment C includes the output summary reports of dose assessments for both exposure case scenarios. The maximum dose-to-source ratio (in units mrem/yr per pCi/g) over the 1,000-year evaluation period for each ROC was then divided into the 25 mrem/yr primary limit to determine the soil DCGLs for each ROC, in units that can be applied to the net soil sample results.

3.4.1 Determination of Soil Derived Concentration Guideline Level for Base Case Residential Farmer Scenario

The base case soil DCGL for each ROC was determined for the residential farmer scenario. Selected exposure pathways in Figure 3-1 of this report and recommended assigned values for site and exposure parameters in Attachment A were utilized during the determination of soil DCGL for each ROC. Report C-1 of Attachment C presents the results of output summary report for base case residential farmer scenario.

3.4.2 Determination of Soil Derived Concentration Guideline Level under Airman Scenario

Alternative case soil DCGL for each ROC was determined for the airman scenario. Selected exposure pathways in Figure 3-2 of this report and recommended assigned values for site and exposure parameters in Attachment B were utilized during the determination of soil DCGL for each ROC. Report C-2 of Attachment C presents the results of output summary report for the alternative case airman scenario.

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FIGURE 3-1
Schematic of Residual Radioactivity Pathways for Resident Farmer
Appendix C: Site-Specific Derived Concentration Guideline Level Report
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench, Hill Air Force Base, Utah

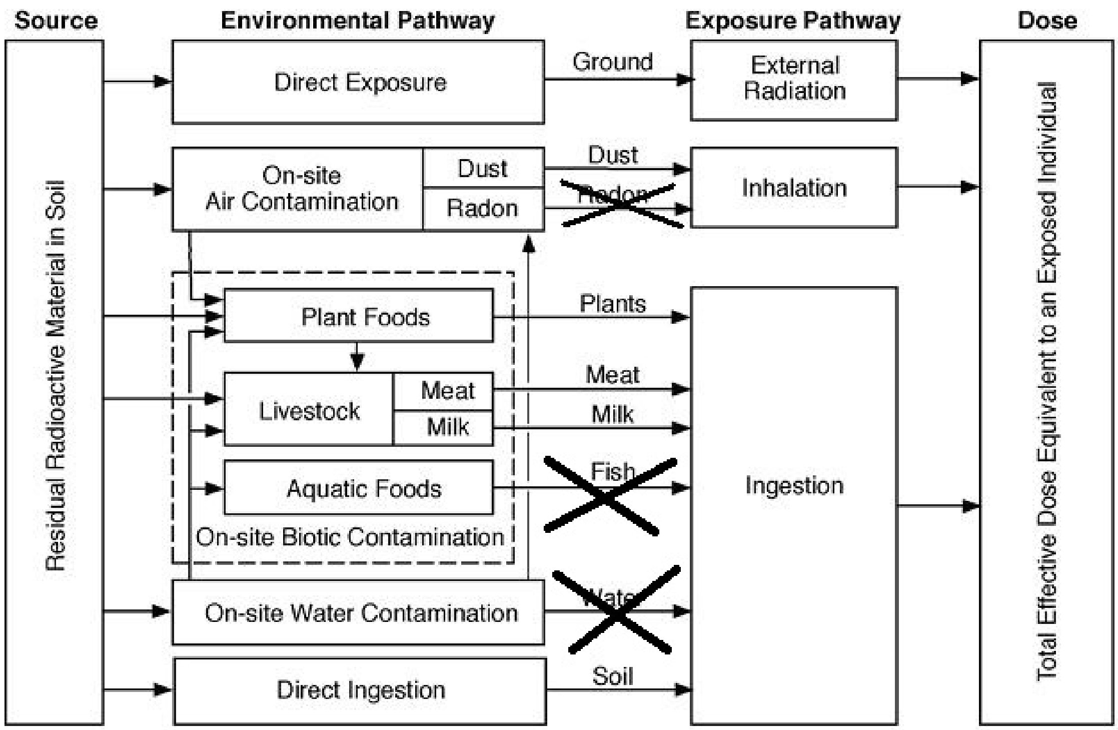

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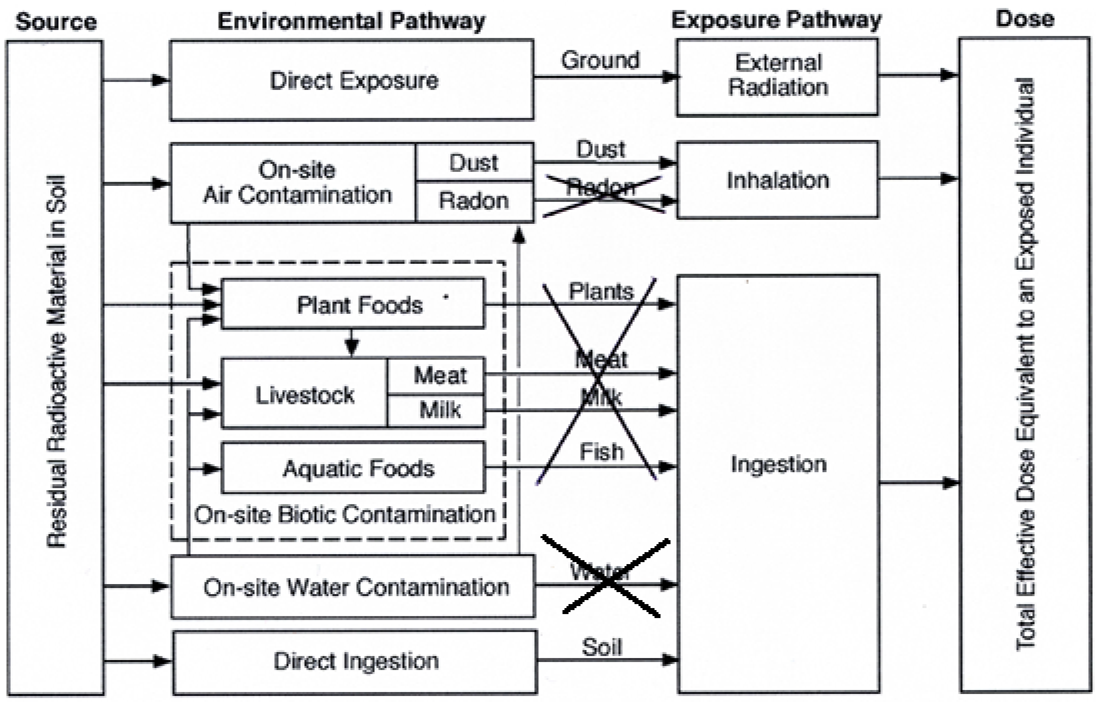
FIGURE 3-2
Schematic of Residual Radioactivity Pathways for Resident Airman
Appendix C: Site-Specific Derived Concentration Guideline Level Report
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench, Hill Air Force Base, Utah



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4.0 Results

The summary DCGL results from the RESRAD computer runs are provided in Attachment C. The DCGLs are based on conservative assumptions with a dose criteria limit of 25 mrem/yr peak annual TEDE over a 1,000-year time period as provided by 10 CFR Part 20 Subpart E. As mentioned in Section 3.4, the maximum dose-to-source ratio over the 1,000-year evaluation period for each ROC was then divided into the 25 mrem/yr primary limit to determine the soil DCGLs for each ROC. Pages C-1-25 and C-2-25 of Attachment C presented the results of maximum dose-to-source ratio for residential farmer and airman scenario, respectively.

The report shows the dose conversion factors, a summary of the site-specific parameters, summary of the pathway selections, summary of the contaminated zone and total dose, total dose components by time, the single radionuclide soil guideline DCGL, the dose by nuclide summed over all pathways, and the soil concentration by nuclide.

Table 4-1 of this report presents the results of ROC-specific DCGL under base case residential farmer scenario and airman scenario. The most conservative DCGL for each ROC was selected as the site-specific DCGL for the site. The table also presents NRC SSVs for each ROC. The NRC screening levels are listed in 64 CFR 68395 and further detailed in NUREG 1757.

The results in Table 4-1 of this report show that the site-specific DCGL is greater than the NRC SSV for all ROCs. This is due to differences between the DandD and RESRAD models and how they handle certain soil-to-plant bioaccumulation factors and associated animal and human food consumption factors for those plant foodstuffs.

Due to the presence of multiple ROCs in the soil, the allowed soil concentration levels must follow the SOR. This will ensure that the sum of the individual fractions for each isotope to its individual DCGL fraction does not exceed unity.

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TABLE 4-1
Results of Derived Concentration Guideline Level for Each Radionuclide of Concern
Appendix C: Site-Specific Derived Concentration Guideline Level Report
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench, Hill Air Force Base, Utah

Radionuclide of Concern	**Receptor Specific Derived Concentration Guideline Levels (picoCurie per gram)**		**Site-Specific Derived Concentration Guideline Level (picoCurie per gram)**	**Nuclear Regulatory Commission Screening Values**
	Base Case Scenario	**Airman Scenario**		
^{226}Ra	1.6	7.5	1.6	0.7
^{230}Th	4.3	135.2	4.3	1.8
^{232}Th	1.9	5.5	1.9	1.1

NOTES:
^{226}Ra = Radium-226
^{230}Th = Thorium-230
^{232}Th = Thorium-232

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5.0 Uncertainty Analysis

Uncertainty is inherent in all dose and risk assessment calculations and should be considered in determining whether a selected DCGL concentration will satisfy the regulatory decision-making criteria. In general, there are three primary sources of uncertainty in a dose/risk assessment (Bonano 1988). The following sections explain each of the sources of uncertainty and summarize how the associated uncertainties were handled.

5.1 Uncertainty in the Models

A number of computer software models are available to characterize the site-specific fate and transport mechanisms of contaminants in the environment, and to assess the residual dose presented by contamination from licensed activities at the site. Models are simplifications of reality and, in general, are not able to fully characterize the physical condition of the site. During this project, the RESRAD code was used for estimating the dose to human receptors from exposure to soil contaminated with residual radioactivity. The U.S. Department of Energy and NRC have approved the use of RESRAD for dose evaluation and waste disposal at licensed nuclear facilities. EPA also used the computer code in rule making for sites contaminated with radioactivity. Therefore, the uncertainty associated with the RESRAD model is considered to be acceptable.

5.2 Uncertainty in the Scenario

Uncertainty due to the selected scenario results from lack of absolute knowledge about the future uses of the site. During this evaluation, a residential farmer scenario was chosen for determining the soil DCGLs at the site. This is the most conservative receptor scenario. However, it is important to recognize that the model evaluation time period (next 1,000 years) is not intended to predict the future scenarios in these 1,000 years. It is intended to evaluate the continued protectiveness of a given DCGL for 1,000 years into the future given the reasonable and plausible future uses of the site in today’s social and economic conditions. Since the residential farmer receptor is considered the most conservative scenario, the uncertainty associated with this scenario is considered to be acceptable.

5.3 Uncertainty in the Parameters

Uncertainty in parameters was limited by using, whenever possible, site-specific values. However, there are no site-specific values for many of the parameters; thus, conservative EPA/NRC reference values were used to ensure that doses would be overestimated rather than underestimated. The selection of prudently conservative parameters was conducted based on the hierarchy presented in Section 3.3 and was designed to utilize broadly accepted values while adhering to the conceptual site model and particular nuances of the RESRAD code. Because of the established hierarchy and tendency toward prudently conservative parameters values that tend to overestimate doses, the uncertainties associated with parameter selection are considered to be acceptable.

$DCGL_W$s for Site WR111 were calculated using the deterministic and not the probabilistic approach. RESRAD allows users to consider parameters as point estimates (deterministic) or as distributions (probabilistic). A sensitivity analysis on point estimate may be used to determine which parameters have the largest impact of dose results. Knowledge of sensitivity analysis results helps modelers limit uncertainty by focusing on the most sensitive parameters. As a part of sensitivity analysis, a review of the output summary report for the resident farmer scenario was performed to identify exposure pathways and RESRAD input parameters that contribute significantly to the DCGL for three ROCs. Plant ingestion and external gamma pathways are the two most significant exposure pathways (contribute more than 95% of the total dose) for the resident farmer scenario. Five exposure parameters - Fruits, vegetable and grain consumption, leafy vegetable consumption, external gamma shielding factor, outdoor and indoor time fraction are directly related to those exposure pathways. Table 5-1 presents the RESRAD default value, NRC and EPA's standard default values for those exposure parameters.

The table shows that NRC's standard default values for all five intake parameters are either the most conservative or equivalent as compared to the same for RESRAD and EPA. Therefore, no additional sensitivity analysis was performed.

By utilizing the probabilistic module, modelers can used representative distributions (e.g., with a mean and standard deviation) for those sensitive parameters to limit the conservatism in using NRC/EPA reference values. The $DCGL_W$s in this report are calculated using the deterministic approach based upon a number of conservative assumptions. The tendency to be conservative is an effort toward protecting health. The report uses conservative assumptions to ensure that the outcome will be protective to human health and the environment.

TABLE 5-1
RESRAD, NRC, and EPA Standard Default Values for Exposure Parameters Under Resident Farmer Scenario
Appendix C: Site-Specific Derived Concentration Guideline Level Report
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench, Hill Air Force Base, Utah

Exposure Parameter	Units	RESRAD Default	NRC	EPA
			Resident Farmer	**Resident**
Shielding factor, external gamma	unitless	0.7	0.5512	0.4
Fraction of time spent indoors	unitless	0.5	0.6571	0.655
Fraction of time spent outdoors (on site)	unitless	0.25	0.1181	0.08
Fruits, vegetables and grain consumption	kg/yr	160	166	161
Leafy vegetable consumption	kg/yr	14	11	10.3

NOTES:
kg/yr = kilograms per year

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6.0 Summary and Conclusions

Site-specific DCGLs for various ROCs in soil have been developed for remediation planning and/or verification that applicable regulatory dose requirements have been achieved at the LMTA Site WR111. In determining the DCGL, several conservative and reasonable factors were utilized in the dose modeling assessments. The DCGL for each ROC was determined for the base case residential farmer scenario. One additional exposure scenario, the airman scenario, was evaluated to confirm that the base case resident farmer scenario is bounding for the development of soil DCGLs.

Among the two scenarios, the most conservative DCGL for each ROC was selected as the site-specific DCGL for the Site. Table 4-1 presents the results of the individual DCGL for each ROC.

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Attachment A
Assigned Values for Exposure Parameters Used in RESRAD Model under Resident Farmer Scenario

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DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS

RESRAD Version 6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
PATHWAY SELECTIONS						
External Gamma	NA	Active	Active	NA	NA	NA
Inhalation (without radon)	NA	Active	Active	NA	NA	NA
Plant Ingestion	NA	Active	Active	NA	NA	NA
Meat Ingestion	NA	Active	Active	NA	NA	NA
Milk Ingestion	NA	Active	Active	NA	NA	NA
Aquatic Foods	NA	Active	**Inactive**	NA	NA	NA
Drinking Water'	NA	Active	**Inactive**	NA	NA	NA
Soil Ingestion	NA	Active	Active	NA	NA	NA
Radon	NA	Inactive	Inactive	NA	NA per Federal Register, 1994, p. 43210	NRC 1994
CONTAMINATED ZONE PARAMETERS						
Area of contaminated zone	AREA	10,000	5,620	m^2	Site-Specific Value.	
Thickness of contaminated zone	THICK0	2	**3.048**	m	The residual contamination was assumed to be uniformly distributed to the depth of 10 feet below from the bottom of the burial trench	
Length parallel to the aquifer	LCZPAQ	100	**75**	m	For all cases, the length parallel to the aquifer was calculated as the square root of the contaminated zone area.	ANL 1993 (Section 16)
Times for calculations	TI	1, 3, 10, 30, 100, 300, 1000	1, 3, 10, 30, 100, 300, 1000	yr	RESRAD defaults for calculation times.	ANL 2009
COVER AND CONTAMINATED ZONE HYDROLOGICAL DATA						
Cover depth	COVER	0	**0**	M	As a conservative approach, no soil cover is assumed.	
Density of cover material	DENSCV	1.5	**NA**	g/cm^3	Not applicable due to no soil cover	
Cover erosion rate	VCV	0.001	**0.0042**	m/yr	Not applicable due to no soil cover	
Density of contaminated zone	DENSCZ	1.5	1.431	g/cm^3	Based on Silty Soil	ANL 1993 (Section 2)
Contaminated zone erosion rate	VCZ	0.001	0.001	m/yr	RESRAD default used	ANL 2009
Contaminated zone total porosity	TPCZ	0.4	0.46	unitless	Based on Silty Soil	ANL 1993 (Section 3)
Contaminated zone field capacity	FCCZ	0.2	0.2	unitless	RESRAD default used	ANL 2009
Contaminated zone hydraulic conductivity	HCCZ	10	10	m/yr	RESRAD default used.	ANL 1993 (Section 5)

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS

RESRAD Version 6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
Contaminated zone b parameter	BCZ	5.3	**10.4**	unitless	The contaminated zone b parameter was selected from Table 13.1 of the reference for silty sand.	ANL 1993 (Section 13)
Humidity in air	HUMID	8	**NA**	g/m^3	Humidity input is only required in RESRAD when tritium is a radionuclide of concern.	
Evapotranspiration coefficient	EVAPTR	0.5	0.5	unitless	No site-specific data available. RESRAD default used.	ANL 1993 (Section 12)
Wind speed	WIND	2	2	m/sec	RESRAD default used.	ANL 1993 (Section 21)
Precipitation	PRECIP	1	**0.406**	m/yr	Site-specific value based on reported 16 inches per year	ANL 1993 (Section 9) AECOM (2009)
Irrigation	RI	0.2	0.2	m/yr	No site-specific data available. RESRAD default used.	ANL 1993 (Section 11)
Irrigation mode	IDITCH	Overhead	Overhead	unitless	The “Overhead” and “Ditch” designations are independent of the depth of contaminated zone and have no significant impact on the RESRAD evaluation. The RESRAD default designation was selected.	ANL 2009
Runoff coefficient	RUNOFF	0.2	0.2	unitless	The RESRAD default value was selected.	ANL 1993 (Section 10)
Watershed area for nearby stream or pond	WAREA	1.00E6	1.00E6	m^2	RESRAD default used.	ANL 1993 (Section 17)
Accuracy for water/soil computations	EPS	0.001	0.001	Unitless	RESRAD default used.	ANL 1993
SATURATED ZONE HYDROLOGICAL DATA						
Density of saturated zone	DENSAQ	1.5	**1.431**	g/cm^3	Based on Silty Soil	ANL 1993 (Section 2)
Saturated zone total porosity	TPSZ	0.4	**0.46**	unitless	Based on Silty Soil	ANL 1993 (Section 3)
Saturated zone effective porosity	EPSZ	0.2	0.2	unitless	RESRAD default used	ANL 2009
Saturated zone field capacity	FCSZ	0.2	0.2	unitless	RESRAD default used	ANL 2009
Saturated zone hydraulic conductivity	HCSZ	100	100	m/yr	RESRAD default used.	ANL 1993 (Section 5)
Saturated zone hydraulic gradient	HGWT	0.02	0.02	unitless	RESRAD default used. Potable water at the Site is obtained via public water supply.	ANL 1993 (Section 15)
Saturated zone b parameter	BSZ	5.3	**10.4**	unitless	The contaminated zone b parameter was selected from Table 13.1 of the reference for silty sand.	ANL 1993 (Section 13)
Water table drop rate	VWT	0.001	0.001	m/yr	RESRAD default used.	ANL 1993 (Section 18)

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS

RESRAD Version 6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
Well pump intake depth (meters below water table)	DWIBWT	10	10	m	RESRAD default used.	ANL 1993 (Section 19)
Model for Water Transport Parameters [Non-dispersion (ND) or Mass-Balance (MB)]	MODEL	ND	ND	unitless	RESRAD default used	ANL 1993
Well pumping rate	UW	250	250	m^3/yr	RESRAD default used	ANL 2009
UNCONTAMINATED UNSATURATED ZONE PARAMETERS						
Number of unsaturated zone strata	NS	1	1	unitless	RESRAD default used	ANL 2009
Unsaturated zone thickness	H(1)	4	4	m	The thickness of the unsaturated zone varies from 12 to 15 feet below ground surface. Therefore, RESRAD default value was chosen.	NA
Unsaturated zone soil density	DENSUZ(1)	1.5	**1.431**	g/cm^3	Based on Silty Soil	ANL 1993 (Section 2)
Unsaturated zone total porosity	TPUZ(1)	0.4	**0.46**	unitless	Based on Silty Soil	ANL 1993 (Section 3)
Unsaturated zone effective porosity	EPSZ(1)	0.2	0.2	unitless	RESRAD default used	ANL 2009
Unsaturated zone field capacity	FCSZ(1)	0.2	0.2	unitless	RESRAD default used	ANL 2009
Unsaturated zone hydraulic conductivity	HCSZ(1)	10	10	m/yr	RESRAD default used.	ANL 1993 (Section 5)
Unsaturated zone b parameter	BSZ	5.3	**10.4**	unitless	The contaminated zone b parameter was selected from Table 13.1 of the reference for silty sand.	ANL 1993 (Section 13)
ELEMENTAL DISTRIBUTION (PARTITION) COEFFICIENTS AND LEACH RATES: RADIUM						
Contaminated zone	DCNUCC(1)	70	11,207	cm^3/g	Based on NUREG-1757, Vol. 2, Section I.6.4.4, in the absence of site-specific values, 3rd quartile values presented in NUREG/CR-5512, Vol. 3, Table 6.86 were used.	NUREG-1757; NUREG/CR-5512, Vol.3
Unsaturated zone	DCNUCU(1, 1)	70	11,207	cm^3/g		
Saturated zone	DCNUCS(1)	70	11,207	cm^3/g		
LEMENTAL DISTRIBUTION (PARTITION) COEFFICIENTS AND LEACH RATES: THORIUM						
Contaminated zone	DCNUCC(1)	60000	67,569	cm^3/g	Based on NUREG-1757, Vol. 2, Section I.6.4.4, in the absence of site-specific values, 3rd quartile values presented in NUREG/CR-5512, Vol. 3, Table 6.86 were used.	NUREG-1757; NUREG/CR-5512, Vol.3
Unsaturated zone	DCNUCU(1, 1)	60000	67,569	cm^3/g		
Saturated zone	DCNUCS(1)	60000	67,569	cm^3/g		

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS

RESRAD Version 6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
OCCUPANCY, INHALATION AND EXTERNAL GAMMA DATA						
Inhalation rate	INHALR	8,400	6650 (footnote)	m^3/y	Site-specific value for this parameter is not available. Hence, time-weighted inhalation rate was calculated based on NRC defined inhalation rates for different activities, and the time, receptor will spend for each activity. Indoor = 0.9; Outdoor = 1.4 ; Gardening = 1.7 (m^3/hr)	NUREG/CR-5512
Mass loading for inhalation	MLINH	0.0001	4.6E-6 (footnote)	g/m^3	Site-specific value for this parameter is not available. Hence, time-weighted mass loading for inhalation rate was calculated based on NRC defined mass loading factor for different activities, and the time, receptor will spend for each activity. Indoor = 1.4E-6; Outdoor=3.14E-6; Gardening = 4E-4; (g/m^3)	NUREG/CR-5512
Exposure duration	ED	30	**26**	yr	Residential	EPA 2014
Inhalation shielding factor	SHF3	0.4	0.2448	unitless	No site-specific value is available. Hence, NRC value was assigned.	NUREG/CR-5512
External gamma shielding factor	SHF1	0.7	0.5512	unitless	No site-specific value is available. Hence, NRC value was assigned.	NUREG/CR-5512
Indoor time fraction	FIND	0.5	0.6571	unitless	No site-specific value is available. Hence, NRC value was assigned.	NUREG/CR-5512
Outdoor time fraction	FOTD	0.25	0.1181	unitless	No site-specific value is available. Hence, NRC value was assigned.	NUREG/CR-5512
Shape of the contaminated zone (circular or non-circular)	FS	Circular	Circular	unitless	RESRAD default used.	ANL 1993 (Section 50)
INGESTION PATHWAY (DIETARY DATA)						
Fruits, vegetables and grain consumption	DIET(1)	160	**166**	kg/yr	No site-specific value is available. NUREG/CR-5512 default value was chosen for this parameter. The value is almost equal to the most likely value defined in NUREG/CR-6697. This value is more conservative than EPA value. (Fruits = 51; Grains = 69; Vegetables = 51; kg/yr)	NUREG/CR-5512
Leafy vegetable consumption	DIET(2)	14	**11**	kg/yr	No site-specific value is available. Hence, NRC value was used for this parameter.	NUREG/CR-5512
Milk consumption	DIET(3)	92	**100**	L/yr	No site-specific value is available. NUREG/CR-5512 default value was chosen for this parameter. The value is almost equal to the most likely value defined in NUREG/CR-6697.	NUREG/CR-5512
Meat and poultry consumption	DIET(4)	63	**65.1**	kg/yr	No site-specific value is available. NRC value was used.	NUREG/CR-5512

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS

RESRAD Version 6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
					(Beef = 59; Poultry = 6; kg./yr)	
Fish consumption	DIET(5)	5.4	**NA**	kg/yr	Pathway not active	NA
Other seafood consumption	DIET(6)	0.9	**NA**	kg/yr	Pathway not active	NA
Soil ingestion rate	SOIL	36.5	**18.25**	g/yr	No site-specific value is available. Hence, NRC value was assigned.	NUREG/CR-5512
Drinking water intake	DW1	510	**NA**	kg/yr	Pathway not active	NA
Contamination fraction of drinking water	FDW	1	**NA**	kg/yr	Pathway not active	NA
Contamination fraction of household water	FHHW	1	**NA**	kg/yr	Pathway not active	NA
Contamination fraction of livestock water	FLW	1	1	unitless	Pathway active	ANL 1993
Contamination fraction of irrigation water	FIRW	1	1	unitless	Pathway active	ANL 1993
Contamination fraction of aquatic food	FR9	0.5	**NA**	unitless	Pathway not active	NA
Contaminated fraction of plant food	FPLANT	-1	-1	unitless	RESRAD default used. This is also consistent with the assigned value for resident gardener scenario.	ANL 1993 USEPA 2000
Contaminated fraction of meat	FMEAT	-1	-1	unitless	RESRAD default used.	ANL 1993
Contaminated fraction of milk	FMILK	-1	-1	unitless	RESRAD default used.	ANL 1993
INGESTION PATHWAY (NON-DIETARY DATA)						
Livestock fodder intake for meat	LP15	68	68	kg/day	RESRAD default used.	ANL 1993
Livestock fodder intake for milk	LP16	55	55	kg/day	RESRAD default used.	ANL 1993
Livestock water intake for meat	LW15	50	50	L/day	RESRAD default used.	ANL 1993
Livestock water intake for milk	LW15	160	160	L/day	RESRAD default used.	ANL 1993
Livestock intake of soil	LS1	0.5	0.5	kg/day	RESRAD default used.	ANL 1993
Mass loading for foliar deposition	MLFD	0.0001	0.0001	g/m^3	RESRAD default used.	ANL 1993
Depth of soil mixing layer	DM	0.15	0.15	m	RESRAD default used.	ANL 1993
Depth of roots	DROOT	0.9	0.9	m	RESRAD default used.	ANL 1993
Groundwater fractional usage: Drinking water	FGWDW	1	**NA**	unitless	Pathway not active	NA
Groundwater fractional usage: Household water	FGWHH	1	**NA**	unitless	Pathway not active	NA
Groundwater fractional usage: Livestock water	FGWLW	1	1	unitless	RESRAD default used.	ANL 1993
Groundwater fractional usage: Irrigation water	FGWIR	1	1	unitless	RESRAD default used.	ANL 1993
PLANT TRANSPORT FACTORS						

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS

RESRAD Version 6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
Wet weight crop yield: non-leafy vegetables	YV(1)	0.7	0.7	kg/m^2	RESRAD default used.	ANL 1993
Wet weight crop yield: leafy vegetables	YV(2)	1.5	1.5	kg/m^2	RESRAD default used.	ANL 1993
Wet weight crop yield: fodder	YV(3)	1.1	1.1	kg/m^2	RESRAD default used.	ANL 1993
Length of growing season: non-leafy vegetables	TE(1)	0.17	0.17	years	RESRAD default used.	ANL 1993
Length of growing season: leafy vegetables	TE(2)	0.25	0.25	years	RESRAD default used.	ANL 1993
Length of growing season: fodder	TE(3)	0.08	0.08	years	RESRAD default used.	ANL 1993
Translocation factor: non-leafy vegetables	TIV(1)	0.1	0.1	unitless	RESRAD default used.	ANL 1993
Translocation factor: leafy vegetables	TIV(2)	1	1	unitless	RESRAD default used.	ANL 1993
Translocation factor: fodder	TIV(3)	1	1	unitless	RESRAD default used.	ANL 1993
Weathering removal constant	WLAM	20	20	y^{-1}	RESRAD default used.	ANL 1993
Wet foliar interception fraction: non-leafy vegetables	RWET(1)	0.25	0.25	unitless	RESRAD default used.	ANL 1993

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS

RESRAD Version 6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
Wet foliar interception fraction: leafy vegetables	RWET(2)	0.25	0.25	unitless	RESRAD default used.	ANL 1993
Wet foliar interception fraction: fodder	RWET(3)	0.25	0.25	unitless	RESRAD default used.	ANL 1993
Dry foliar interception fraction: non-leafy vegetables	RDRY(1)	0.25	0.25	unitless	RESRAD default used.	ANL 1993
Dry foliar interception fraction: leafy vegetables	RDRY(2)	0.25	0.25	unitless	RESRAD default used.	ANL 1993
Dry foliar interception fraction: fodder	RDRY(3)	0.25	0.25	unitless	RESRAD default used.	ANL 1993
STORAGE TIMES BEFORE USE						
Fruits, non-leafy vegetables and grain	STOR_T(1)	14	14	days	RESRAD default used.	ANL 1993
Leafy vegetables	STOR_T(2)	1	1	days	RESRAD default used.	ANL 1993
Milk	STOR_T(3)	1	1	days	RESRAD default used.	ANL 1993
Meat	STOR_T(4)	20	20	days	RESRAD default used.	ANL 1993
Fish	STOR_T(5)	7	**NA**	days	Pathway not active	NA
Crustacea and mollusks	STOR_T(6)	7	**NA**	days	Pathway not active	NA
Well water	STOR_T(7)	1	1	days	RESRAD default used.	ANL 1993
Surface water	STOR_T(8)	1	1	days	RESRAD default used.	ANL 1993
Livestock fodder	STOR_T(9)	45	45	days	RESRAD default used.	ANL 1993

NOTE:
NA = Not applicable.

Inhalation Rate =((0.9 m^3/hr x 15.77 hrs/day) + (1.4 m^3/hr x 2.64 hrs/day) + (1.7 m^3/hr x 0.20 hrs/day)) x 8760 hrs/yr / (24 hrs/day) = 6650 m^3/yr, where 15.77, 2.64, and 0.2 hrs/day are indoor, outdoor, and gardening activities for the receptor
Mass loading for inhalation =((1.4 E-6 g/m^3 x 15.77 hrs/day) + (3.14E-06 g/m^3 x 2.64 hrs/day) + (4E-04 g/m^3 x 0.20 hrs/day)) /24 hrs/day = 4.6E-06 g/m^3

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Attachment B
Assigned Values for Exposure Parameters Used in RESRAD Model under Airman Scenario

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DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS UNDER AIRMAN SCENARIO

RESRAD Version 6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
PATHWAY SELECTIONS						
External Gamma	NA	Active	Active	NA	NA	NA
Inhalation (without radon)	NA	Active	Active	NA	NA	NA
Plant Ingestion	NA	Active	**Inactive**	NA	NA for Airman	NA
Meat Ingestion	NA	Active	**Inactive**	NA	NA for Airman	NA
Milk Ingestion	NA	Active	**Inactive**	NA	NA for Airman	NA
Aquatic Foods	NA	Active	**Inactive**	NA	NA for Airman	NA
Drinking Water	NA	Active	**Inactive**	NA	NA for Airman	NA
Soil Ingestion	NA	Active	Active	NA	NA	NA
Radon	NA	Inactive	Inactive	NA	NA per Federal Register, 1994, p. 43210	NRC 1994
CONTAMINATED ZONE PARAMETERS						
Area of contaminated zone	AREA	10,000	5,620	m^2	Site-Specific Value.	
Thickness of contaminated zone	THICK0	2	**0.25**	m		
Length parallel to the aquifer	LCZPAQ	100	**NA**	m	NA due to inactive exposure pathway	
Times for calculations	TI	1, 3, 10, 30, 100, 300, 1000	1, 3, 10, 30, 100, 300, 1000	yr	RESRAD defaults for calculation times.	ANL 2009
COVER AND CONTAMINATED ZONE HYDROLOGICAL DATA						
Cover depth	COVER)	0	0	m	No soil cover	
Density of cover material	DENSCV	1.5	**NA**	g/cm^3	NA due to no soil cover	
Cover erosion rate	VCV	0.001	**NA**	m/yr	NA due to no soil cover	
Density of contaminated zone	DENSCZ	1.5	1.431	g/cm^3	Based on Silty Soil	ANL 1993 (Section 2)
Contaminated zone erosion rate	VCZ	0.001	**0.001**	m/yr	RESRAD default value	ANL 2009
Contaminated zone total porosity	TPCZ	0.4	0.46	unitless	Based on Silty Soil	ANL 1993

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS UNDER AIRMAN SCENARIO

RESRAD Version 6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
						(Section 3)
Contaminated zone field capacity	FCCZ	0.2	0.2	unitless	RESRAD default used as an estimate of field capacity	ANL 2009
Contaminated zone hydraulic conductivity	HCCZ	10	10	m/yr	RESRAD default used.	ANL 1993 (Section 5)
Contaminated zone b parameter	BCZ	5.3	**10.4**	unitless	The contaminated zone b parameter was selected from Table 13.1 of the reference for silty sand.	ANL 1993 (Section 13)
Humidity in air	HUMID	8	**NA**	g/m^3	Humidity input is only required in RESRAD when tritium is a radionuclide of concern.	
Evapotranspiration coefficient	EVAPTR	0.5	0.5	unitless	No site-specific data available. RESRAD default used.	ANL 1993 (Section 12)
Wind speed	WIND	2	2	m/sec	RESRAD default used.	ANL 1993 (Section 21)
Precipitation	PRECIP	1	**0.406**	m/yr	Site-specific value based on reported 16 inches per year	ANL 1993 (Section 9) AECOM (2009)
Irrigation	RI	0.2	0.2	m/yr	No site-specific data available. RESRAD default used.	ANL 1993 (Section 11)
Irrigation mode	IDITCH	Overhead	Overhead	unitless	The “Overhead” and “Ditch” designations are independent of the depth of contaminated zone and have no significant impact on the RESRAD evaluation. The RESRAD default designation was selected.	ANL 2009
Runoff coefficient	RUNOFF	0.2	0.2	unitless	The RESRAD default value was selected.	ANL 1993 (Section 10)
Watershed area for nearby stream or pond	WAREA	1.00E6	**NA**	m^2	NA due to inactive water exposure pathway	NA
Accuracy for water/soil computations	EPS	0.001	**NA**	unitless	NA due to inactive water exposure pathway	NA
SATURATED ZONE HYDROLOGICAL DATA						

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS UNDER AIRMAN SCENARIO

RESRAD Version 6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
Density of saturated zone	DENSAQ	1.5	**NA**	g/cm^3	NA due to inactive water exposure pathway	NA
Saturated zone total porosity	TPSZ	0.4	**NA**	unitless	NA due to inactive water exposure pathway	NA
Saturated zone effective porosity	EPSZ	0.2	**NA**	unitless	NA due to inactive water exposure pathway	NA
Saturated zone field capacity	FCSZ	0.2	**NA**	unitless	NA due to inactive water exposure pathway	NA
Saturated zone hydraulic conductivity	HCSZ	100	**NA**	m/yr	NA due to inactive water exposure pathway	NA
Saturated zone hydraulic gradient	HGWT	0.02	**NA**	unitless	NA due to inactive water exposure pathway	NA
Saturated zone b parameter	BSZ	5.3	**NA**	unitless	NA due to inactive water exposure pathway	NA
Water table drop rate	VWT	0.001	**NA**	m/yr	NA due to inactive water exposure pathway	NA
Well pump intake depth (meters below water table)	DWIBWT	10	**NA**	m	NA due to inactive water exposure pathway	NA
Model for Water Transport Parameters [Non-dispersion (ND) or Mass-Balance (MB)]	MODEL	ND	**MB**	unitless	Per NRC guidance, the MB model is an acceptable approach and provides a potentially more conservative dose estimate relative to the ND model. The MB model assumes a well is located at the center of the site rather than on the down gradient side of the Site boundary.	NUREG-1757, Vo. 2, App. I, page I-40
Well pumping rate	UW	250	**NA**	m^3/yr	NA due to inactive water exposure pathway	
UNCONTAMINATED UNSATURATED ZONE PARAMETERS						
Number of unsaturated zone strata	NS	1	**NA**	unitless	NA due to inactive water exposure pathway	NA
Unsaturated zone thickness	H(1)	4	**NA**	m	NA due to inactive water exposure pathway	NA
Unsaturated zone soil density	DENSUZ(1)	1.5	**NA**	g/cm^3	NA due to inactive water exposure pathway	NA
Unsaturated zone total porosity	TPUZ(1)	0.4	**NA**	unitless	NA due to inactive water exposure pathway	NA
Unsaturated zone effective porosity	EPSZ(1)	0.2	**NA**	unitless	NA due to inactive water exposure pathway	NA
Unsaturated zone field capacity	FCSZ(1)	0.2	**NA**	unitless	NA due to inactive water exposure pathway	NA
Unsaturated zone hydraulic conductivity	HCSZ(1)	100	**NA**	m/yr	NA due to inactive water exposure pathway	NA

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS UNDER AIRMAN SCENARIO

RESRAD Version 6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
Unsaturated zone b parameter	BSZ	5.3	**NA**	unitless	NA due to inactive water exposure pathway	NA
NATURAL THORIUM						
ELEMENTAL DISTRIBUTION (PARTITION) COEFFICIENTS AND LEACH RATES: THORIUM						
Contaminated zone	DCNUCC(2 & 3)	60,000	67,569	cm^3/g	Based on NUREG-1757, Vol. 2, Section I.6.4.4, in the absence of site-specific values, 3rd quantile values presented in NUREG/CR-5512, Vol. 3, Table 6.86 were used.	NUREG-1757; NUREG/CR-5512, Vol. 3
Unsaturated zone	DCNUCU(2 & 3,1)	60,000	67,569	cm^3/g		
Saturated zone	DCNUCS(2 & 3)	60,000	67,569	cm^3/g		
Leach rate	ALEACH(2 & 3)	0	0	y^{-1}	RESRAD default used.	ANL 2009
Solubility constant	SOLUBK(2 & 3)	0	0	unitless	RESRAD default used.	ANL 2009
ELEMENTAL DISTRIBUTION (PARTITION) COEFFICIENTS AND LEACH RATES: RADIUM						
Contaminated zone	DCNUCC(1)	70	11,207	cm^3/g	Based on NUREG-1757, Vol. 2, Section I.6.4.4, in the absence of site-specific values, 3rd quantile values presented in NUREG/CR-5512, Vol. 3, Table 6.86 were used.	NUREG-1757; NUREG/CR-5512, Vol. 3
Unsaturated zone	DCNUCU(1,1)	70	11,207	cm^3/g		
Saturated zone	DCNUCS(1)	70	11,207	cm^3/g		
Leach rate	ALEACH(1)	0	0	y^{-1}	RESRAD default used.	ANL 2009
Solubility constant	SOLUBK(1)	0	0	unitless	RESRAD default used.	ANL 2009

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS UNDER AIRMAN SCENARIO

RESRAD Version 6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
OCCUPANCY, INHALATION AND EXTERNAL GAMMA DATA						
Inhalation rate	INHALR	8,400	**11,388**	m^3/y	Based on time-weighted inhalation rate as calculated as below. = ((0.9 m^3/hr x 2 hrs/day + 1.4 m^3/hr x 8 hrs/day) x 8,760 hrs/year) / 10 hrs/day)	NRC 1999
Mass loading for inhalation	MLINH	0.0001	**2.79E-6**	g/m^3	Based on time –weighted mass loading for inhalation as below: = (1.41 g/m^3 x 2 hrs/day + 3.14 g/m^3 x 8 hrs/day) / 10 hrs/day	ANL 1993 (Section 35)
Exposure duration	ED	30	**25**	yr	EPA RAGS value in reference was used.	EPA 1991
Inhalation shielding factor	SHF3	0.4	0.4	unitless	RESRAD default used.	ANL 1993 (Section 36)
External gamma shielding factor	SHF1	0.7	**0.4**	unitless	60% shielding per EPA, cited reference used for all indoor receptors.	EPA, 2000
Indoor time fraction	FIND	0.5	**0.068**	unitless	2 hours per day was assumed.	
Outdoor time fraction	FOTD	0.25	**0.274**	unitless	8 hours per day was assumed.	
Shape of the contaminated zone (circular or non-circular)	FS	Circular	Circular	unitless	RESRAD default used.	ANL 1993 (Section 50)

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS UNDER AIRMAN SCENARIO

RESRAD Version 6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
INGESTION PATHWAY (DIETARY DATA)						
Fruits, vegetables and grain consumption	DIET(1)	160	**NA**	kg/yr	Pathway not active	NA
Leafy vegetable consumption	DIET(2)	14	**NA**	kg/yr	Pathway not active	NA
Milk consumption	DIET(3)	92	**NA**	L/yr	Pathway not active	NA
Meat and poultry consumption	DIET(4)	63	**NA**	kg/yr	Pathway not active	NA
Fish consumption	DIET(5)	5.4	**NA**	kg/yr	Pathway not active	NA
Other seafood consumption	DIET(6)	0.9	**NA**	kg/yr	Pathway not active	NA
Soil ingestion rate	SOIL	36.5	**143.8**	g/yr	This value was calculated based on time-weighted soil ingestion rates: (50 mg/day x 2 hrs/day + 480 mg/day x 8 hrs/day) x 1 g/ 1000 mg / 10 hrs/day	EPA 1991
Drinking water intake	DWI	510	**NA**	L/yr	Pathway not active	NA
Contamination fraction of drinking water	FDW	1	**NA**	unitless	Pathway not active	NA
Contamination fraction of household water	FHHW	1	**NA**	unitless	Radon pathway is not selected; hence this parameter is not applicable	NA
Contamination fraction of livestock water	FLW	1	**NA**	unitless	Pathway not active.	NA
Contamination fraction of irrigation water	FIRW	1	**NA**	unitless	Pathway not active	NA
Contamination fraction of aquatic food	FR9	0.5	**NA**	unitless	Pathway not active.	NA
Contaminated fraction of plant food	FPLANT	-1	**NA**	unitless	Pathway not active	NA
Contaminated fraction of meat	FMEAT	-1	**NA**	unitless	Pathway not active	NA
Contaminated fraction of milk	FMILK	-1	**NA**	unitless	Pathway not active	NA

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS UNDER AIRMAN SCENARIO

RESRAD Version 6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
INGESTION PATHWAY (NON-DIETARY DATA)						
Livestock fodder intake for meat	LP15	68	**NA**	kg/day	Pathway not active	NA
Livestock fodder intake for milk	LP16	55	**NA**	kg/day	Pathway not active	NA
Livestock water intake for meat	LW15	50	**NA**	L/day	Pathway not active	NA
Livestock water intake for milk	LW15	160	**NA**	L/day	Pathway not active	NA
Livestock intake of soil	LS1	0.5	**NA**	kg/day	Pathway not active	NA
Mass loading for foliar deposition	MLFD	0.0001	**NA**	g/m^3	Pathway not active	NA
Depth of soil mixing layer	DM	0.15	0.15	m	RESRAD default used.	ANL 1993 (Section 35)
Depth of roots	DROOT	0.9	NA	m	Pathway not active	NA
Groundwater fractional usage: Drinking water	FGWDW	1	**NA**	unitless	Pathway not active	NA
Groundwater fractional usage: Household water	FGWHH	1	**NA**	unitless	Radon pathway not active	NA
Groundwater fractional usage: Livestock water	FGWLW	1	**NA**	unitless	Pathway not active	NA
Groundwater fractional usage: Irrigation water	FGWIR	1	NA	unitless	Pathway not active	NA
PLANT TRANSPORT FACTORS						
Wet weight crop yield: non-leafy vegetables	YV(1)	0.7	**NA**	kg/m^2	Pathway not active	NA
Wet weight crop yield: leafy vegetables	YV(2)	1.5	**NA**	kg/m^2	Pathway not active	NA
Wet weight crop yield: fodder	YV(3)	1.1	**NA**	kg/m^2	Pathway not active.	NA
Length of growing season: non-leafy vegetables	TE(1)	0.17	**NA**	years	Pathway not active	NA

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS UNDER AIRMAN SCENARIO

RESRAD Version 6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
Length of growing season: leafy vegetables	TE(2)	0.25	**NA**	years	Pathway not active	NA
Length of growing season: fodder	TE(3)	0.08	**NA**	years	Pathway not active	NA
Translocation factor: non-leafy vegetables	TIV(1)	0.1	**NA**	unitless	Pathway not active	NA
Translocation factor: leafy vegetables	TIV(2)	1	**NA**	unitless	Pathway not active	NA
Translocation factor: fodder	TIV(3)	1	**NA**	unitless	Pathway not active	NA
Weathering removal constant	WLAM	20	**NA**	y^{-1}	Pathway not active	NA
Wet foliar interception fraction: non-leafy vegetables	RWET(1)	0.25	**NA**	unitless	Pathway not active	NA
Wet foliar interception fraction: leafy vegetables	RWET(2)	0.25	**NA**	unitless	Pathway not active	NA
Wet foliar interception fraction: fodder	RWET(3)	0.25	**NA**	unitless	Pathway not active.	NA
Dry foliar interception fraction: non-leafy vegetables	RDRY(1)	0.25	**NA**	unitless	Pathway not active	NA
Dry foliar interception fraction: leafy vegetables	RDRY(2)	0.25	**NA**	unitless	Pathway not active	NA
Dry foliar interception fraction: fodder	RDRY(3)	0.25	**NA**	unitless	Pathway not active.	NA

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS UNDER AIRMAN SCENARIO

RESRAD Version 6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
STORAGE TIMES BEFORE USE						
Fruits, non-leafy vegetables and grain	STOR_T(1)	14	NA	days	Pathway not active	NA
Leafy vegetables	STOR_T(2)	1	NA	days	Pathway not active	NA
Milk	STOR_T(3)	1	**NA**	days	Pathway not active.	NA
Meat	STOR_T(4)	20	**NA**	days	Pathway not active.	NA
Fish	STOR_T(5)	7	**NA**	days	Pathway not active.	NA
Crustacea and mollusks	STOR_T(6)	7	**NA**	days	Pathway not active.	NA
Well water	STOR_T(7)	1	**NA**	days	Pathway not active	NA
Surface water	STOR_T(8)	1	**NA**	days	Pathway not active	NA
Livestock fodder	STOR_T(9)	45	**NA**	days	Pathway not active.	NA

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(U.S.) Environmental Protection Agency (EPA). 2000. *Soil Screening Guidance for Radionuclides: User's Guide*. EPA/540-R-00-007. Washington, D.C.

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Attachment C
RESRAD Output Summary Reports

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REPORT C-1

CALCULATION AND OUTPUT DOSE SUMMARY REPORT FOR BASE CASE RESIDENTIAL FARMER SCENARIO

Calculation of Soil DCGL for Base Case Residential Farmer Scenario

Nuclide (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)	Maximum DSR	**Calculated DCGL (pCi/g)**
Ra-226	1	109.4± 0.2	1.57E+01	1.59E+00	1.50E+01	1.67E+00	1.57E+01	1.6
Th-230	1	1.00E+03	5.80E+00	4.31E+00	1.64E+00	1.53E+01	5.80E+00	4.3
Th-232	1	98.3± 0.2	1.29E+01	1.95E+00	1.29E+01	1.95E+00	1.29E+01	1.9

Footnotes:
tmin (years) = time of minimum single radionuclide soil guideline
tmax(years) = time of maximum total dose
DSR (i, tmin) = Dose to source Ratio at tmin
G (i, tmin) = Single Radionuclide Soil Guidelines at tmin
DSR (i, tmax) = Dose to source Ratio at tmax
G (i, tmax) = Single Radionuclide Soil Guidelines at tmin
Maximum DSR = Maximum (DSR (i, tmin), DSR (i, tmax))
Calculated DCGL = 25 mrem/yr / Maximum DSR

```
RESRAD, Version 6.5      T« Limit = 180 days        07/16/2015  14:17  Page   1
 Summary : DCGL under Resident Farmer Scenario based on 3rd Quantile Kd Values
 File    : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\DCGL_HAFB_RESIDENT_FARMER_3RDQNTLKD.RAD
```

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Part I: Mixture Sums and Single Radionuclide Guidelines

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Summary : DCGL under Resident Farmer Scenario based on 3rd Quantile Kd Values
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                          Dose Conversion Factor (and Related) Parameter Summary
                                      Dose Library: FGR 12 & FGR 11
                                                                             Current     Base      Parameter
Menu                          Parameter                                       Value#     Case*       Name
------------------------------------------------------------------------------------------------------------------------
A-1   DCF's for external ground radiation, (mrem/yr)/(pCi/g)
A-1   Ac-228   (Source: FGR 12)                                     5.978E+00  5.978E+00  DCF1(  1)
A-1   At-218   (Source: FGR 12)                                     5.847E-03  5.847E-03  DCF1(  2)
A-1   Bi-210   (Source: FGR 12)                                     3.606E-03  3.606E-03  DCF1(  3)
A-1   Bi-212   (Source: FGR 12)                                     1.171E+00  1.171E+00  DCF1(  4)
A-1   Bi-214   (Source: FGR 12)                                     9.808E+00  9.808E+00  DCF1(  5)
A-1   Pb-210   (Source: FGR 12)                                     2.447E-03  2.447E-03  DCF1(  6)
A-1   Pb-212   (Source: FGR 12)                                     7.043E-01  7.043E-01  DCF1(  7)
A-1   Pb-214   (Source: FGR 12)                                     1.341E+00  1.341E+00  DCF1(  8)
A-1   Po-210   (Source: FGR 12)                                     5.231E-05  5.231E-05  DCF1(  9)
A-1   Po-212   (Source: FGR 12)                                     0.000E+00  0.000E+00  DCF1( 10)
A-1   Po-214   (Source: FGR 12)                                     5.138E-04  5.138E-04  DCF1( 11)
A-1   Po-216   (Source: FGR 12)                                     1.042E-04  1.042E-04  DCF1( 12)
A-1   Po-218   (Source: FGR 12)                                     5.642E-05  5.642E-05  DCF1( 13)
A-1   Ra-224   (Source: FGR 12)                                     5.119E-02  5.119E-02  DCF1( 14)
A-1   Ra-226   (Source: FGR 12)                                     3.176E-02  3.176E-02  DCF1( 15)
A-1   Ra-228   (Source: FGR 12)                                     0.000E+00  0.000E+00  DCF1( 16)
A-1   Rn-220   (Source: FGR 12)                                     2.298E-03  2.298E-03  DCF1( 17)
A-1   Rn-222   (Source: FGR 12)                                     2.354E-03  2.354E-03  DCF1( 18)
A-1   Th-228   (Source: FGR 12)                                     7.940E-03  7.940E-03  DCF1( 19)
A-1   Th-230   (Source: FGR 12)                                     1.209E-03  1.209E-03  DCF1( 20)
A-1   Th-232   (Source: FGR 12)                                     5.212E-04  5.212E-04  DCF1( 21)
A-1   Tl-208   (Source: FGR 12)                                     2.298E+01  2.298E+01  DCF1( 22)
A-1   Tl-210   (Source: no data)                                    0.000E+00 -2.000E+00  DCF1( 23)

B-1   Dose conversion factors for inhalation, mrem/pCi:
B-1   Pb-210+D                                                      2.320E-02  1.360E-02  DCF2(  1)
B-1   Ra-226+D                                                      8.594E-03  8.580E-03  DCF2(  2)
B-1   Ra-228+D                                                      5.078E-03  4.770E-03  DCF2(  3)
B-1   Th-228+D                                                      3.454E-01  3.420E-01  DCF2(  4)
B-1   Th-230                                                        3.260E-01  3.260E-01  DCF2(  5)
B-1   Th-232                                                        1.640E+00  1.640E+00  DCF2(  6)

D-1   Dose conversion factors for ingestion, mrem/pCi:
D-1   Pb-210+D                                                      7.276E-03  5.370E-03  DCF3(  1)
D-1   Ra-226+D                                                      1.321E-03  1.320E-03  DCF3(  2)
D-1   Ra-228+D                                                      1.442E-03  1.440E-03  DCF3(  3)
D-1   Th-228+D                                                      8.086E-04  3.960E-04  DCF3(  4)
D-1   Th-230                                                        5.480E-04  5.480E-04  DCF3(  5)
D-1   Th-232                                                        2.730E-03  2.730E-03  DCF3(  6)
```

```
D-34  Food transfer factors:
D-34  Pb-210+D  , plant/soil concentration ratio, dimensionless    1.000E-02  1.000E-02  RTF(  1,1)
D-34  Pb-210+D  , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)    8.000E-04  8.000E-04  RTF(  1,2)
D-34  Pb-210+D  , milk/livestock-intake ratio, (pCi/L)/(pCi/d)     3.000E-04  3.000E-04  RTF(  1,3)
D-34
D-34  Ra-226+D  , plant/soil concentration ratio, dimensionless    4.000E-02  4.000E-02  RTF(  2,1)
D-34  Ra-226+D  , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)    1.000E-03  1.000E-03  RTF(  2,2)
D-34  Ra-226+D  , milk/livestock-intake ratio, (pCi/L)/(pCi/d)     1.000E-03  1.000E-03  RTF(  2,3)
D-34
```

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                    Dose Conversion Factor (and Related) Parameter Summary (continued)
                                      Dose Library: FGR 12 & FGR 11
                                                                     Current     Base      Parameter
Menu                           Parameter                              Value#     Case*       Name
-----------------------------------------------------------------------------------------------------------
D-34  Ra-228+D  , plant/soil concentration ratio, dimensionless    4.000E-02  4.000E-02  RTF(  3,1)
D-34  Ra-228+D  , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)    1.000E-03  1.000E-03  RTF(  3,2)
D-34  Ra-228+D  , milk/livestock-intake ratio, (pCi/L)/(pCi/d)     1.000E-03  1.000E-03  RTF(  3,3)
D-34
D-34  Th-228+D  , plant/soil concentration ratio, dimensionless    1.000E-03  1.000E-03  RTF(  4,1)
D-34  Th-228+D  , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)    1.000E-04  1.000E-04  RTF(  4,2)
D-34  Th-228+D  , milk/livestock-intake ratio, (pCi/L)/(pCi/d)     5.000E-06  5.000E-06  RTF(  4,3)
D-34
D-34  Th-230    , plant/soil concentration ratio, dimensionless    1.000E-03  1.000E-03  RTF(  5,1)
D-34  Th-230    , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)    1.000E-04  1.000E-04  RTF(  5,2)
D-34  Th-230    , milk/livestock-intake ratio, (pCi/L)/(pCi/d)     5.000E-06  5.000E-06  RTF(  5,3)
D-34
D-34  Th-232    , plant/soil concentration ratio, dimensionless    1.000E-03  1.000E-03  RTF(  6,1)
D-34  Th-232    , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)    1.000E-04  1.000E-04  RTF(  6,2)
D-34  Th-232    , milk/livestock-intake ratio, (pCi/L)/(pCi/d)     5.000E-06  5.000E-06  RTF(  6,3)

D-5   Bioaccumulation factors, fresh water, L/kg:
D-5   Pb-210+D  , fish                                             3.000E+02  3.000E+02  BIOFAC(  1,1)
D-5   Pb-210+D  , crustacea and mollusks                           1.000E+02  1.000E+02  BIOFAC(  1,2)
D-5
D-5   Ra-226+D  , fish                                             5.000E+01  5.000E+01  BIOFAC(  2,1)
D-5   Ra-226+D  , crustacea and mollusks                           2.500E+02  2.500E+02  BIOFAC(  2,2)
D-5
D-5   Ra-228+D  , fish                                             5.000E+01  5.000E+01  BIOFAC(  3,1)
D-5   Ra-228+D  , crustacea and mollusks                           2.500E+02  2.500E+02  BIOFAC(  3,2)
D-5
D-5   Th-228+D  , fish                                             1.000E+02  1.000E+02  BIOFAC(  4,1)
D-5   Th-228+D  , crustacea and mollusks                           5.000E+02  5.000E+02  BIOFAC(  4,2)
D-5
D-5   Th-230    , fish                                             1.000E+02  1.000E+02  BIOFAC(  5,1)
D-5   Th-230    , crustacea and mollusks                           5.000E+02  5.000E+02  BIOFAC(  5,2)
D-5
D-5   Th-232    , fish                                             1.000E+02  1.000E+02  BIOFAC(  6,1)
D-5   Th-232    , crustacea and mollusks                           5.000E+02  5.000E+02  BIOFAC(  6,2)
-----------------------------------------------------------------------------------------------------------
#For DCF1(xxx) only, factors are for infinite depth & area.  See ETFG table in Ground Pathway of Detailed Report.
*Base Case means Default.Lib w/o Associate Nuclide contributions.
```

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```

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	5.620E+03	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	3.048E+00	2.000E+00	---	THICK0
R011	Fraction of contamination that is submerged	0.000E+00	0.000E+00	---	SUBMFRACT
R011	Length parallel to aquifer flow (m)	7.500E+01	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	2.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Ra-226	1.000E+00	0.000E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Th-230	1.000E+00	0.000E+00	---	S1(5)
R012	Initial principal radionuclide (pCi/g): Th-232	1.000E+00	0.000E+00	---	S1(6)
R012	Concentration in groundwater (pCi/L): Ra-226	not used	0.000E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L): Th-230	not used	0.000E+00	---	W1(5)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W1(6)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.431E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.600E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity	2.000E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	1.040E+01	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	2.000E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	5.000E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	4.060E-01	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	2.000E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	1.000E-03	1.000E-03	---	EPS

R014	Density of saturated zone (g/cm**3)	1.430E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	4.600E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	2.000E-01	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	2.000E-02	2.000E-02	---	HGWT
R014	Saturated zone b parameter	1.040E+01	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT

```
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                                          Site-Specific Parameter Summary (continued)
                                                          User                           Used by RESRAD          Parameter
Menu                      Parameter                       Input      Default   (If different from user input)     Name
----------------------------------------------------------------------------------------------------------------------------------
R014  Well pump intake depth (m below water table)      1.000E+01  1.000E+01              ---                DWIBWT
R014  Model: Nondispersion (ND) or Mass-Balance (MB)    ND         ND                     ---                MODEL
R014  Well pumping rate (m**3/yr)                       2.500E+02  2.500E+02              ---                UW

R015  Number of unsaturated zone strata                 1          1                      ---                NS
R015  Unsat. zone 1, thickness (m)                      4.000E+00  4.000E+00              ---                H(1)
R015  Unsat. zone 1, soil density (g/cm**3)             1.431E+00  1.500E+00              ---                DENSUZ(1)
R015  Unsat. zone 1, total porosity                     4.600E-01  4.000E-01              ---                TPUZ(1)
R015  Unsat. zone 1, effective porosity                 2.000E-01  2.000E-01              ---                EPUZ(1)
R015  Unsat. zone 1, field capacity                     2.000E-01  2.000E-01              ---                FCUZ(1)
R015  Unsat. zone 1, soil-specific b parameter          1.040E+01  5.300E+00              ---                BUZ(1)
R015  Unsat. zone 1, hydraulic conductivity (m/yr)      1.000E+01  1.000E+01              ---                HCUZ(1)

R016  Distribution coefficients for Ra-226
R016    Contaminated zone (cm**3/g)                     1.121E+04  7.000E+01              ---                DCNUCC( 2)
R016    Unsaturated zone 1 (cm**3/g)                    1.121E+04  7.000E+01              ---                DCNUCU( 2,1)
R016    Saturated zone (cm**3/g)                        1.121E+04  7.000E+01              ---                DCNUCS( 2)
R016    Leach rate (/yr)                                0.000E+00  0.000E+00           5.368E-06             ALEACH( 2)
R016    Solubility constant                             0.000E+00  0.000E+00           not used              SOLUBK( 2)

R016  Distribution coefficients for Th-230
R016    Contaminated zone (cm**3/g)                     6.757E+04  6.000E+04              ---                DCNUCC( 5)
R016    Unsaturated zone 1 (cm**3/g)                    6.757E+04  6.000E+04              ---                DCNUCU( 5,1)
R016    Saturated zone (cm**3/g)                        6.757E+04  6.000E+04              ---                DCNUCS( 5)
R016    Leach rate (/yr)                                0.000E+00  0.000E+00           8.903E-07             ALEACH( 5)
R016    Solubility constant                             0.000E+00  0.000E+00           not used              SOLUBK( 5)

R016  Distribution coefficients for Th-232
R016    Contaminated zone (cm**3/g)                     6.757E+04  6.000E+04              ---                DCNUCC( 6)
R016    Unsaturated zone 1 (cm**3/g)                    6.757E+04  6.000E+04              ---                DCNUCU( 6,1)
R016    Saturated zone (cm**3/g)                        6.757E+04  6.000E+04              ---                DCNUCS( 6)
R016    Leach rate (/yr)                                0.000E+00  0.000E+00           8.903E-07             ALEACH( 6)
R016    Solubility constant                             0.000E+00  0.000E+00           not used              SOLUBK( 6)

R016  Distribution coefficients for daughter Pb-210
R016    Contaminated zone (cm**3/g)                     1.549E+04  1.000E+02              ---                DCNUCC( 1)
R016    Unsaturated zone 1 (cm**3/g)                    1.549E+04  1.000E+02              ---                DCNUCU( 1,1)
R016    Saturated zone (cm**3/g)                        1.549E+04  1.000E+02              ---                DCNUCS( 1)
R016    Leach rate (/yr)                                0.000E+00  0.000E+00           3.884E-06             ALEACH( 1)
R016    Solubility constant                             0.000E+00  0.000E+00           not used              SOLUBK( 1)

R016  Distribution coefficients for daughter Ra-228
```

R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(3)
R016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCU(3,1)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	8.561E-04	ALEACH(3)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for daughter Th-228				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(4)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(4,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(4)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.003E-06	ALEACH(4)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(4)
R017	Inhalation rate (m**3/yr)	6.650E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	4.600E-06	1.000E-04	---	MLINH
R017	Exposure duration	2.600E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	2.248E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	5.512E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	6.571E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	1.181E-01	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows circular AREA.	FS
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)

R018	Fruits, vegetables and grain consumption (kg/yr)	1.660E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.100E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	1.000E+02	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	6.510E+01	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	1.825E+01	3.650E+01	---	SOIL

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Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R018	Drinking water intake (L/yr)	not used	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	not used	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	1.000E+00	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	1.000E+00	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	5.000E-01	-1	---	FPLANT
R018	Contamination fraction of meat	-1	-1	0.281E+00	FMEAT
R018	Contamination fraction of milk	-1	-1	0.281E+00	FMILK
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	5.500E+01	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	1.600E+02	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	5.000E-01	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	not used	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	1.000E+00	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	7.000E-01	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	1.500E+00	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	1.100E+00	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	1.700E-01	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	2.500E-01	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	8.000E-02	8.000E-02	---	TE(3)
R19B	Translocation Factor for Non-Leafy	1.000E-01	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	1.000E+00	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	1.000E+00	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	2.000E+01	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ

C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.000E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)
TITL	Number of graphical time points	32	---	---	NPTS
TITL	Maximum number of integration points for dose	17	---	---	LYMAX
TITL	Maximum number of integration points for risk	257	---	---	KYMAX

```
           Summary of Pathway Selections

          Pathway               User Selection
---------------------------------------------------
   1 -- external gamma              active
   2 -- inhalation (w/o radon)      active
   3 -- plant ingestion             active
   4 -- meat ingestion              active
   5 -- milk ingestion              active
   6 -- aquatic foods             suppressed
   7 -- drinking water            suppressed
   8 -- soil ingestion              active
   9 -- radon                     suppressed
   Find peak pathway doses        suppressed
---------------------------------------------------
```

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Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	5620.00 square meters	Ra-226	1.000E+00
Thickness:	3.05 meters	Th-230	1.000E+00
Cover Depth:	0.00 meters	Th-232	1.000E+00

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 2.500E+01 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	1.081E+01	1.202E+01	1.439E+01	2.055E+01	2.655E+01	2.923E+01	2.950E+01	2.942E+01
M(t):	4.323E-01	4.809E-01	5.756E-01	8.221E-01	1.062E+00	1.169E+00	1.180E+00	1.177E+00

Maximum TDOSE(t): 2.950E+01 mrem/yr   at t =   243.9 ñ 0.5 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2.439E+02 years
Water Independent Pathways (Inhalation excludes radon)

Radio- Nuclide	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	4.488E+00	0.1521	3.742E-05	0.0000	0.000E+00	0.0000	1.008E+01	0.3418	1.856E-01	0.0063	1.491E-01	0.0051	1.105E-01	0.0037
Th-230	5.015E-01	0.0170	4.257E-04	0.0000	0.000E+00	0.0000	1.084E+00	0.0367	1.951E-02	0.0007	1.577E-02	0.0005	1.863E-02	0.0006
Th-232	7.182E+00	0.2434	2.579E-03	0.0001	0.000E+00	0.0000	5.396E+00	0.1829	8.751E-02	0.0030	1.077E-01	0.0036	7.022E-02	0.0024
Total	1.217E+01	0.4126	3.042E-03	0.0001	0.000E+00	0.0000	1.656E+01	0.5614	2.926E-01	0.0099	2.725E-01	0.0092	1.994E-01	0.0068

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2.439E+02 years
Water Dependent Pathways

Radio- Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.502E+01	0.5090
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.639E+00	0.0556
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.285E+01	0.4354
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.950E+01	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Ra-226	4.992E+00	0.4619	1.161E-05	0.0000	0.000E+00	0.0000	4.793E+00	0.4435	8.088E-02	0.0075	1.016E-01	0.0094	2.027E-02	0.0019
Th-230	1.632E-03	0.0002	4.230E-04	0.0000	0.000E+00	0.0000	4.952E-02	0.0046	5.826E-04	0.0001	6.094E-05	0.0000	7.757E-03	0.0007
Th-232	1.843E-01	0.0171	2.131E-03	0.0002	0.000E+00	0.0000	5.214E-01	0.0482	6.463E-03	0.0006	5.429E-03	0.0005	3.988E-02	0.0037
Total	5.178E+00	0.4791	2.566E-03	0.0002	0.000E+00	0.0000	5.364E+00	0.4963	8.792E-02	0.0081	1.071E-01	0.0099	6.790E-02	0.0063

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.988E+00	0.9242
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.998E-02	0.0055
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.597E-01	0.0703
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.081E+01	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	4.990E+00	0.4151	1.251E-05	0.0000	0.000E+00	0.0000	4.988E+00	0.4149	8.482E-02	0.0071	1.035E-01	0.0086	2.336E-02	0.0019
Th-230	3.794E-03	0.0003	4.230E-04	0.0000	0.000E+00	0.0000	5.163E-02	0.0043	6.177E-04	0.0001	1.047E-04	0.0000	7.766E-03	0.0006
Th-232	6.212E-01	0.0517	2.147E-03	0.0002	0.000E+00	0.0000	1.070E+00	0.0890	1.546E-02	0.0013	1.694E-02	0.0014	4.244E-02	0.0035
Total	5.615E+00	0.4671	2.582E-03	0.0002	0.000E+00	0.0000	6.110E+00	0.5082	1.009E-01	0.0084	1.206E-01	0.0100	7.356E-02	0.0061

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.019E+01	0.8476
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.433E-02	0.0054
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.768E+00	0.1471
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.202E+01	1.0000

*Sum of all water independent and dependent pathways.

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Summary : DCGL under Resident Farmer Scenario based on 3rd Quantile Kd Values
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\DCGL_HAFB_RESIDENT_FARMER_3RDQNTLKD.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	4.986E+00	0.3465	1.423E-05	0.0000	0.000E+00	0.0000	5.354E+00	0.3720	9.198E-02	0.0064	1.071E-01	0.0074	2.926E-02	0.0020
Th-230	8.116E-03	0.0006	4.230E-04	0.0000	0.000E+00	0.0000	5.611E-02	0.0039	6.943E-04	0.0000	1.960E-04	0.0000	7.789E-03	0.0005
Th-232	1.636E+00	0.1137	2.201E-03	0.0002	0.000E+00	0.0000	1.997E+00	0.1387	3.092E-02	0.0021	3.650E-02	0.0025	4.743E-02	0.0033
Total	6.630E+00	0.4607	2.638E-03	0.0002	0.000E+00	0.0000	7.407E+00	0.5147	1.236E-01	0.0086	1.438E-01	0.0100	8.448E-02	0.0059

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.057E+01	0.7344
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.333E-02	0.0051
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.750E+00	0.2606
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.439E+01	1.0000

*Sum of all water independent and dependent pathways.

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RESRAD, Version 6.5      T« Limit = 180 days       07/16/2015  14:17  Page  13
Summary : DCGL under Resident Farmer Scenario based on 3rd Quantile Kd Values
File    : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\DCGL_HAFB_RESIDENT_FARMER_3RDQNTLKD.RAD

                       Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
                                    As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years
                                       Water Independent Pathways (Inhalation excludes radon)
             Ground           Inhalation           Radon              Plant              Meat               Milk               Soil
Radio-  ----------------  ----------------  ----------------  ----------------  ----------------  ----------------  ----------------
Nuclide  mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.
------- --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------
Ra-226  4.971E+00 0.2419  1.946E-05 0.0000  0.000E+00 0.0000  6.465E+00 0.3146  1.137E-01 0.0055  1.181E-01 0.0057  4.719E-02 0.0023
Th-230  2.321E-02 0.0011  4.230E-04 0.0000  0.000E+00 0.0000  7.409E-02 0.0036  1.007E-03 0.0000  5.381E-04 0.0000  7.905E-03 0.0004
Th-232  4.587E+00 0.2232  2.395E-03 0.0001  0.000E+00 0.0000  3.940E+00 0.1917  6.329E-02 0.0031  7.726E-02 0.0038  5.992E-02 0.0029
------- --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------
Total   9.581E+00 0.4662  2.838E-03 0.0001  0.000E+00 0.0000  1.048E+01 0.5099  1.780E-01 0.0087  1.959E-01 0.0095  1.150E-01 0.0056

                       Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
                                    As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years
                                                      Water Dependent Pathways
              Water              Fish              Radon              Plant              Meat               Milk          All Pathways*
Radio-  ----------------  ----------------  ----------------  ----------------  ----------------  ----------------  ----------------
Nuclide  mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.
------- --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------
Ra-226  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  1.172E+01 0.5700
Th-230  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  1.072E-01 0.0052
Th-232  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  8.729E+00 0.4248
------- --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------
Total   0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  2.055E+01 1.0000
*Sum of all water independent and dependent pathways.
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RESRAD, Version 6.5 T« Limit = 180 days 07/16/2015 14:17 Page 14
Summary : DCGL under Resident Farmer Scenario based on 3rd Quantile Kd Values
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\DCGL_HAFB_RESIDENT_FARMER_3RDQNTLKD.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	4.929E+00	0.1856	2.929E-05	0.0000	0.000E+00	0.0000	8.549E+00	0.3220	1.545E-01	0.0058	1.385E-01	0.0052	8.100E-02	0.0031
Th-230	6.609E-02	0.0025	4.231E-04	0.0000	0.000E+00	0.0000	1.401E-01	0.0053	2.188E-03	0.0001	1.659E-03	0.0001	8.475E-03	0.0003
Th-232	6.950E+00	0.2617	2.563E-03	0.0001	0.000E+00	0.0000	5.268E+00	0.1984	8.539E-02	0.0032	1.050E-01	0.0040	6.932E-02	0.0026
Total	1.194E+01	0.4499	3.015E-03	0.0001	0.000E+00	0.0000	1.396E+01	0.5257	2.421E-01	0.0091	2.451E-01	0.0092	1.588E-01	0.0060

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.385E+01	0.5217
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.189E-01	0.0082
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.248E+01	0.4700
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.655E+01	1.0000

*Sum of all water independent and dependent pathways.

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Summary : DCGL under Resident Farmer Scenario based on 3rd Quantile Kd Values
File   : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\DCGL_HAFB_RESIDENT_FARMER_3RDQNTLKD.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	4.781E+00	0.1636	3.853E-05	0.0000	0.000E+00	0.0000	1.046E+01	0.3578	1.921E-01	0.0066	1.560E-01	0.0053	1.132E-01	0.0039
Th-230	2.132E-01	0.0073	4.239E-04	0.0000	0.000E+00	0.0000	4.395E-01	0.0150	7.663E-03	0.0003	6.235E-03	0.0002	1.160E-02	0.0004
Th-232	7.183E+00	0.2458	2.579E-03	0.0001	0.000E+00	0.0000	5.396E+00	0.1846	8.752E-02	0.0030	1.077E-01	0.0037	7.023E-02	0.0024
Total	1.218E+01	0.4166	3.042E-03	0.0001	0.000E+00	0.0000	1.629E+01	0.5575	2.873E-01	0.0098	2.699E-01	0.0092	1.950E-01	0.0067

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.570E+01	0.5372
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.787E-01	0.0232
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.285E+01	0.4396
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.923E+01	1.0000

*Sum of all water independent and dependent pathways.

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RESRAD, Version 6.5      T« Limit = 180 days       07/16/2015  14:17  Page  16
Summary : DCGL under Resident Farmer Scenario based on 3rd Quantile Kd Values
File    : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\DCGL_HAFB_RESIDENT_FARMER_3RDQNTLKD.RAD

                       Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
                                    As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years
                                       Water Independent Pathways (Inhalation excludes radon)
             Ground           Inhalation           Radon              Plant              Meat               Milk               Soil
Radio-  ----------------  ----------------  ----------------  ----------------  ----------------  ----------------  ----------------
Nuclide  mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.
------- --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------
Ra-226  4.379E+00 0.1485  3.653E-05 0.0000  0.000E+00 0.0000  9.842E+00 0.3336  1.811E-01 0.0061  1.455E-01 0.0049  1.079E-01 0.0037
Th-230  6.090E-01 0.0206  4.264E-04 0.0000  0.000E+00 0.0000  1.325E+00 0.0449  2.395E-02 0.0008  1.935E-02 0.0007  2.127E-02 0.0007
Th-232  7.182E+00 0.2434  2.579E-03 0.0001  0.000E+00 0.0000  5.395E+00 0.1829  8.751E-02 0.0030  1.077E-01 0.0036  7.022E-02 0.0024
------- --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------
Total   1.217E+01 0.4125  3.042E-03 0.0001  0.000E+00 0.0000  1.656E+01 0.5615  2.926E-01 0.0099  2.725E-01 0.0092  1.994E-01 0.0068

                       Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
                                    As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years
                                                      Water Dependent Pathways
              Water              Fish              Radon              Plant              Meat               Milk          All Pathways*
Radio-  ----------------  ----------------  ----------------  ----------------  ----------------  ----------------  ----------------
Nuclide  mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.
------- --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------
Ra-226  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  1.466E+01 0.4968
Th-230  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  1.999E+00 0.0678
Th-232  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  1.284E+01 0.4354
------- --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------
Total   0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  2.950E+01 1.0000
*Sum of all water independent and dependent pathways.
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RESRAD, Version 6.5 T« Limit = 180 days 07/16/2015 14:17 Page 17
Summary : DCGL under Resident Farmer Scenario based on 3rd Quantile Kd Values
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\DCGL_HAFB_RESIDENT_FARMER_3RDQNTLKD.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	3.222E+00	0.1095	2.687E-05	0.0000	0.000E+00	0.0000	7.241E+00	0.2461	1.332E-01	0.0045	1.070E-01	0.0036	7.937E-02	0.0027
Th-230	1.744E+00	0.0593	4.329E-04	0.0000	0.000E+00	0.0000	3.877E+00	0.1318	7.091E-02	0.0024	5.707E-02	0.0019	4.919E-02	0.0017
Th-232	7.177E+00	0.2440	2.577E-03	0.0001	0.000E+00	0.0000	5.392E+00	0.1833	8.745E-02	0.0030	1.076E-01	0.0037	7.018E-02	0.0024
Total	1.214E+01	0.4128	3.037E-03	0.0001	0.000E+00	0.0000	1.651E+01	0.5612	2.916E-01	0.0099	2.717E-01	0.0092	1.987E-01	0.0068

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.078E+01	0.3665
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.799E+00	0.1971
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.284E+01	0.4364
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.942E+01	1.0000

*Sum of all water independent and dependent pathways.

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RESRAD, Version 6.5      T« Limit = 180 days        07/16/2015  14:17  Page  18
Summary : DCGL under Resident Farmer Scenario based on 3rd Quantile Kd Values
File    : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\DCGL_HAFB_RESIDENT_FARMER_3RDQNTLKD.RAD

                                  Dose/Source Ratios Summed Over All Pathways
                       Parent and Progeny Principal Radionuclide Contributions Indicated
0  Parent    Product    Thread                       DSR(j,t) At Time in Years   (mrem/yr)/(pCi/g)
   (i)        (j)      Fraction   0.000E+00 1.000E+00 3.000E+00 1.000E+01 3.000E+01 1.000E+02 3.000E+02 1.000E+03
---------- ---------- ---------  --------- --------- --------- --------- --------- --------- --------- ---------
Ra-226+D   Ra-226+D   1.000E+00  9.864E+00 9.860E+00 9.851E+00 9.821E+00 9.735E+00 9.441E+00 8.648E+00 6.362E+00
Ra-226+D   Pb-210+D   1.000E+00  1.236E-01 3.299E-01 7.170E-01 1.894E+00 4.117E+00 6.259E+00 6.008E+00 4.420E+00
Ra-226+D   -DSR(j)               9.988E+00 1.019E+01 1.057E+01 1.172E+01 1.385E+01 1.570E+01 1.466E+01 1.078E+01
Th-230     Th-230     1.000E+00  5.789E-02 5.789E-02 5.789E-02 5.788E-02 5.787E-02 5.783E-02 5.772E-02 5.732E-02
Th-230     Ra-226+D   1.000E+00  2.068E-03 6.328E-03 1.487E-02 4.469E-02 1.294E-01 4.199E-01 1.201E+00 3.443E+00
Th-230     Pb-210+D   1.000E+00  1.951E-05 1.187E-04 5.740E-04 4.599E-03 3.166E-02 2.009E-01 7.399E-01 2.298E+00
Th-230     -DSR(j)               5.998E-02 6.433E-02 7.333E-02 1.072E-01 2.189E-01 6.787E-01 1.999E+00 5.799E+00
Th-232     Th-232     1.000E+00  2.859E-01 2.859E-01 2.859E-01 2.859E-01 2.859E-01 2.859E-01 2.858E-01 2.857E-01
Th-232     Ra-228+D   1.000E+00  4.417E-01 1.292E+00 2.719E+00 5.690E+00 7.713E+00 7.908E+00 7.907E+00 7.902E+00
Th-232     Th-228+D   1.000E+00  3.202E-02 1.903E-01 7.450E-01 2.753E+00 4.481E+00 4.653E+00 4.652E+00 4.649E+00
Th-232     -DSR(j)               7.597E-01 1.768E+00 3.750E+00 8.729E+00 1.248E+01 1.285E+01 1.284E+01 1.284E+01
---------- ---------- ---------  --------- --------- --------- --------- --------- --------- --------- ---------
The DSR includes contributions from associated (half-life ó 180 days) daughters.

                           Single Radionuclide Soil Guidelines G(i,t) in pCi/g
                              Basic Radiation Dose Limit = 2.500E+01 mrem/yr
0Nuclide
  (i)    t= 0.000E+00   1.000E+00   3.000E+00   1.000E+01   3.000E+01   1.000E+02   3.000E+02   1.000E+03
-------     ---------   ---------   ---------   ---------   ---------   ---------   ---------   ---------
Ra-226      2.503E+00   2.453E+00   2.366E+00   2.134E+00   1.805E+00   1.592E+00   1.706E+00   2.319E+00
Th-230      4.168E+02   3.886E+02   3.409E+02   2.333E+02   1.142E+02   3.684E+01   1.251E+01   4.311E+00
Th-232      3.291E+01   1.414E+01   6.667E+00   2.864E+00   2.003E+00   1.946E+00   1.946E+00   1.948E+00
-------     ---------   ---------   ---------   ---------   ---------   ---------   ---------   ---------

            Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
            and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
         at tmin = time of minimum single radionuclide soil guideline
     and at tmax = time of maximum total dose =   243.9 ñ 0.5 years
Nuclide  Initial        tmin       DSR(i,tmin) G(i,tmin) DSR(i,tmax) G(i,tmax)
  (i)    (pCi/g)       (years)                  (pCi/g)              (pCi/g)
------- ---------  ----------------  ---------  ---------  ---------  ---------
Ra-226  1.000E+00    109.4 ñ 0.2     1.571E+01  1.591E+00  1.502E+01  1.665E+00
Th-230  1.000E+00     1.000E+03      5.799E+00  4.311E+00  1.639E+00  1.525E+01
Th-232  1.000E+00     98.3 ñ 0.2     1.285E+01  1.946E+00  1.285E+01  1.946E+00
------- ---------  ----------------  ---------  ---------  ---------  ---------
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Summary : DCGL under Resident Farmer Scenario based on 3rd Quantile Kd Values
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\DCGL_HAFB_RESIDENT_FARMER_3RDQNTLKD.RAD

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

0Nuclide (j)	Parent (i)	THF(i)	DOSE(j,t), mrem/yr t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-226	Ra-226	1.000E+00	9.864E+00	9.860E+00	9.851E+00	9.821E+00	9.735E+00	9.441E+00	8.648E+00	6.362E+00
Ra-226	Th-230	1.000E+00	2.068E-03	6.328E-03	1.487E-02	4.469E-02	1.294E-01	4.199E-01	1.201E+00	3.443E+00
Ra-226	-DOSE(j)		9.866E+00	9.866E+00	9.866E+00	9.866E+00	9.865E+00	9.861E+00	9.849E+00	9.805E+00
Pb-210	Ra-226	1.000E+00	1.236E-01	3.299E-01	7.170E-01	1.894E+00	4.117E+00	6.259E+00	6.008E+00	4.420E+00
Pb-210	Th-230	1.000E+00	1.951E-05	1.187E-04	5.740E-04	4.599E-03	3.166E-02	2.009E-01	7.399E-01	2.298E+00
Pb-210	-DOSE(j)		1.236E-01	3.300E-01	7.176E-01	1.899E+00	4.149E+00	6.460E+00	6.748E+00	6.718E+00
0Th-230	Th-230	1.000E+00	5.789E-02	5.789E-02	5.789E-02	5.788E-02	5.787E-02	5.783E-02	5.772E-02	5.732E-02
0Th-232	Th-232	1.000E+00	2.859E-01	2.859E-01	2.859E-01	2.859E-01	2.859E-01	2.859E-01	2.858E-01	2.857E-01
0Ra-228	Th-232	1.000E+00	4.417E-01	1.292E+00	2.719E+00	5.690E+00	7.713E+00	7.908E+00	7.907E+00	7.902E+00
0Th-228	Th-232	1.000E+00	3.202E-02	1.903E-01	7.450E-01	2.753E+00	4.481E+00	4.653E+00	4.652E+00	4.649E+00

THF(i) is the thread fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

0Nuclide (j)	Parent (i)	THF(i)	S(j,t), pCi/g t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-226	Ra-226	1.000E+00	1.000E+00	9.996E-01	9.987E-01	9.956E-01	9.869E-01	9.571E-01	8.767E-01	6.449E-01
Ra-226	Th-230	1.000E+00	0.000E+00	4.331E-04	1.299E-03	4.322E-03	1.291E-02	4.236E-02	1.216E-01	3.489E-01
Ra-226	-S(j):		1.000E+00	1.000E+00	1.000E+00	9.999E-01	9.998E-01	9.995E-01	9.983E-01	9.938E-01
0Pb-210	Ra-226	1.000E+00	0.000E+00	3.060E-02	8.897E-02	2.665E-01	6.018E-01	9.254E-01	8.891E-01	6.541E-01
Pb-210	Th-230	1.000E+00	0.000E+00	6.663E-06	5.873E-05	6.077E-04	4.523E-03	2.947E-02	1.092E-01	3.398E-01
Pb-210	-S(j):		0.000E+00	3.060E-02	8.903E-02	2.671E-01	6.063E-01	9.548E-01	9.983E-01	9.939E-01
0Th-230	Th-230	1.000E+00	1.000E+00	1.000E+00	1.000E+00	9.999E-01	9.997E-01	9.990E-01	9.970E-01	9.902E-01
0Th-232	Th-232	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	9.999E-01	9.997E-01	9.991E-01
0Ra-228	Th-232	1.000E+00	0.000E+00	1.135E-01	3.031E-01	6.980E-01	9.669E-01	9.929E-01	9.927E-01	9.921E-01
0Th-228	Th-232	1.000E+00	0.000E+00	1.864E-02	1.242E-01	5.628E-01	9.538E-01	9.929E-01	9.927E-01	9.921E-01

THF(i) is the thread fraction of the parent nuclide.
RESCALC.EXE execution time = 0.88 seconds

REPORT C-2

CALCULATION AND OUTPUT SUMMARY REPORT
FOR THE AIRMAN EXPOSURE SCENARIO

Calculation of Soil DCGL under the Airman Scenario

Nuclide	**Initial** (pCi/g)	**tmin** (years)	**DSR(i,tmin**	**G(i,tmin)** (pCi/g)	**DSR(i,tmax)**	**G(i,tmax)** (pCi/g)	**Maximum** DSR	**Calculated DCGL (pCi/g)**
Ra-226	1	31.69 ±0.06	3.33E+00	7.50E+00	3.33E+00	7.52E+00	3.33	**7.5**
Th-230	1	153.3 ± 0.3	1.85E-01	1.35E+02	8.70E-02	2.88E+02	0.185	**135.2**
Th-232	1	41.44 ±0.08	4.57E+00	5.47E+00	4.57E+00	5.47E+00	4.57	**5.5**

Footnotes:
tmin (years) = time of minimum single radionuclide soil guideline
tmax(years) = time of maximum total dose
DSR (i, tmin) = Dose to source Ratio at tmin
G (i, tmin) = Single Radionuclide Soil Guidelines at tmin
DSR (i, tmax) = Dose to source Ratio at tmax
G (i, tmax) = Single Radionuclide Soil Guidelines at tmin
Maximum DSR = Maximum (DSR (i, tmin), DSR (i, tmax))
Calculated DCGL = 25 mrem/yr / Maximum DSR

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 Summary : Determination of DCGL under Airman Scenario
 File    : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\DCGL HILL AFB-AIRMAN.RAD

                        Table of Contents
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    Part I: Mixture Sums and Single Radionuclide Guidelines
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RESRAD, Version 6.5      T« Limit = 180 days        08/09/2015  13:41  Page   2
Summary : Determination of DCGL under Airman Scenario
File    : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\DCGL HILL AFB-AIRMAN.RAD

                          Dose Conversion Factor (and Related) Parameter Summary
                                      Dose Library: FGR 12 & FGR 11
                                                                     Current     Base      Parameter
Menu                           Parameter                              Value#     Case*       Name
-----------------------------------------------------------------------------------------------------------
A-1   DCF's for external ground radiation, (mrem/yr)/(pCi/g)
A-1   Ac-228   (Source: FGR 12)                                     5.978E+00  5.978E+00  DCF1(  1)
A-1   At-218   (Source: FGR 12)                                     5.847E-03  5.847E-03  DCF1(  2)
A-1   Bi-210   (Source: FGR 12)                                     3.606E-03  3.606E-03  DCF1(  3)
A-1   Bi-212   (Source: FGR 12)                                     1.171E+00  1.171E+00  DCF1(  4)
A-1   Bi-214   (Source: FGR 12)                                     9.808E+00  9.808E+00  DCF1(  5)
A-1   Pb-210   (Source: FGR 12)                                     2.447E-03  2.447E-03  DCF1(  6)
A-1   Pb-212   (Source: FGR 12)                                     7.043E-01  7.043E-01  DCF1(  7)
A-1   Pb-214   (Source: FGR 12)                                     1.341E+00  1.341E+00  DCF1(  8)
A-1   Po-210   (Source: FGR 12)                                     5.231E-05  5.231E-05  DCF1(  9)
A-1   Po-212   (Source: FGR 12)                                     0.000E+00  0.000E+00  DCF1( 10)
A-1   Po-214   (Source: FGR 12)                                     5.138E-04  5.138E-04  DCF1( 11)
A-1   Po-216   (Source: FGR 12)                                     1.042E-04  1.042E-04  DCF1( 12)
A-1   Po-218   (Source: FGR 12)                                     5.642E-05  5.642E-05  DCF1( 13)
A-1   Ra-224   (Source: FGR 12)                                     5.119E-02  5.119E-02  DCF1( 14)
A-1   Ra-226   (Source: FGR 12)                                     3.176E-02  3.176E-02  DCF1( 15)
A-1   Ra-228   (Source: FGR 12)                                     0.000E+00  0.000E+00  DCF1( 16)
A-1   Rn-220   (Source: FGR 12)                                     2.298E-03  2.298E-03  DCF1( 17)
A-1   Rn-222   (Source: FGR 12)                                     2.354E-03  2.354E-03  DCF1( 18)
A-1   Th-228   (Source: FGR 12)                                     7.940E-03  7.940E-03  DCF1( 19)
A-1   Th-230   (Source: FGR 12)                                     1.209E-03  1.209E-03  DCF1( 20)
A-1   Th-232   (Source: FGR 12)                                     5.212E-04  5.212E-04  DCF1( 21)
A-1   Tl-208   (Source: FGR 12)                                     2.298E+01  2.298E+01  DCF1( 22)
A-1   Tl-210   (Source: no data)                                    0.000E+00 -2.000E+00  DCF1( 23)

B-1   Dose conversion factors for inhalation, mrem/pCi:
B-1   Pb-210+D                                                      2.320E-02  1.360E-02  DCF2(  1)
B-1   Ra-226+D                                                      8.594E-03  8.580E-03  DCF2(  2)
B-1   Ra-228+D                                                      5.078E-03  4.770E-03  DCF2(  3)
B-1   Th-228+D                                                      3.454E-01  3.420E-01  DCF2(  4)
B-1   Th-230                                                        3.260E-01  3.260E-01  DCF2(  5)
B-1   Th-232                                                        1.640E+00  1.640E+00  DCF2(  6)

D-1   Dose conversion factors for ingestion, mrem/pCi:
D-1   Pb-210+D                                                      7.276E-03  5.370E-03  DCF3(  1)
D-1   Ra-226+D                                                      1.321E-03  1.320E-03  DCF3(  2)
D-1   Ra-228+D                                                      1.442E-03  1.440E-03  DCF3(  3)
D-1   Th-228+D                                                      8.086E-04  3.960E-04  DCF3(  4)
D-1   Th-230                                                        5.480E-04  5.480E-04  DCF3(  5)
D-1   Th-232                                                        2.730E-03  2.730E-03  DCF3(  6)
```

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D-34  Food transfer factors:
D-34  Pb-210+D  , plant/soil concentration ratio, dimensionless    1.000E-02  1.000E-02  RTF(  1,1)
D-34  Pb-210+D  , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)    8.000E-04  8.000E-04  RTF(  1,2)
D-34  Pb-210+D  , milk/livestock-intake ratio, (pCi/L)/(pCi/d)     3.000E-04  3.000E-04  RTF(  1,3)
D-34
D-34  Ra-226+D  , plant/soil concentration ratio, dimensionless    4.000E-02  4.000E-02  RTF(  2,1)
D-34  Ra-226+D  , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)    1.000E-03  1.000E-03  RTF(  2,2)
D-34  Ra-226+D  , milk/livestock-intake ratio, (pCi/L)/(pCi/d)     1.000E-03  1.000E-03  RTF(  2,3)
D-34
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RESRAD, Version 6.5      T« Limit = 180 days        08/09/2015  13:41  Page   3
Summary : Determination of DCGL under Airman Scenario
File    : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\DCGL HILL AFB-AIRMAN.RAD

                    Dose Conversion Factor (and Related) Parameter Summary (continued)
                                  Dose Library: FGR 12 & FGR 11
                                                                             Current     Base      Parameter
Menu                           Parameter                                      Value#     Case*       Name
---------------------------------------------------------------------------------------------------------------
D-34  Ra-228+D  , plant/soil concentration ratio, dimensionless    4.000E-02  4.000E-02  RTF(  3,1)
D-34  Ra-228+D  , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)    1.000E-03  1.000E-03  RTF(  3,2)
D-34  Ra-228+D  , milk/livestock-intake ratio, (pCi/L)/(pCi/d)     1.000E-03  1.000E-03  RTF(  3,3)
D-34
D-34  Th-228+D  , plant/soil concentration ratio, dimensionless    1.000E-03  1.000E-03  RTF(  4,1)
D-34  Th-228+D  , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)    1.000E-04  1.000E-04  RTF(  4,2)
D-34  Th-228+D  , milk/livestock-intake ratio, (pCi/L)/(pCi/d)     5.000E-06  5.000E-06  RTF(  4,3)
D-34
D-34  Th-230    , plant/soil concentration ratio, dimensionless    1.000E-03  1.000E-03  RTF(  5,1)
D-34  Th-230    , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)    1.000E-04  1.000E-04  RTF(  5,2)
D-34  Th-230    , milk/livestock-intake ratio, (pCi/L)/(pCi/d)     5.000E-06  5.000E-06  RTF(  5,3)
D-34
D-34  Th-232    , plant/soil concentration ratio, dimensionless    1.000E-03  1.000E-03  RTF(  6,1)
D-34  Th-232    , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)    1.000E-04  1.000E-04  RTF(  6,2)
D-34  Th-232    , milk/livestock-intake ratio, (pCi/L)/(pCi/d)     5.000E-06  5.000E-06  RTF(  6,3)

D-5   Bioaccumulation factors, fresh water, L/kg:
D-5   Pb-210+D  , fish                                             3.000E+02  3.000E+02  BIOFAC(  1,1)
D-5   Pb-210+D  , crustacea and mollusks                           1.000E+02  1.000E+02  BIOFAC(  1,2)
D-5
D-5   Ra-226+D  , fish                                             5.000E+01  5.000E+01  BIOFAC(  2,1)
D-5   Ra-226+D  , crustacea and mollusks                           2.500E+02  2.500E+02  BIOFAC(  2,2)
D-5
D-5   Ra-228+D  , fish                                             5.000E+01  5.000E+01  BIOFAC(  3,1)
D-5   Ra-228+D  , crustacea and mollusks                           2.500E+02  2.500E+02  BIOFAC(  3,2)
D-5
D-5   Th-228+D  , fish                                             1.000E+02  1.000E+02  BIOFAC(  4,1)
D-5   Th-228+D  , crustacea and mollusks                           5.000E+02  5.000E+02  BIOFAC(  4,2)
D-5
D-5   Th-230    , fish                                             1.000E+02  1.000E+02  BIOFAC(  5,1)
D-5   Th-230    , crustacea and mollusks                           5.000E+02  5.000E+02  BIOFAC(  5,2)
D-5
D-5   Th-232    , fish                                             1.000E+02  1.000E+02  BIOFAC(  6,1)
D-5   Th-232    , crustacea and mollusks                           5.000E+02  5.000E+02  BIOFAC(  6,2)
---------------------------------------------------------------------------------------------------------------
#For DCF1(xxx) only, factors are for infinite depth & area.  See ETFG table in Ground Pathway of Detailed Report.
*Base Case means Default.Lib w/o Associate Nuclide contributions.
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RESRAD, Version 6.5 T« Limit = 180 days 08/09/2015 13:41 Page 4
Summary : Determination of DCGL under Airman Scenario
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\DCGL HILL AFB-AIRMAN.RAD

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	5.620E+03	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	2.530E-01	2.000E+00	---	THICK0
R011	Fraction of contamination that is submerged	0.000E+00	0.000E+00	---	SUBMFRACT
R011	Length parallel to aquifer flow (m)	not used	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	2.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Ra-226	1.000E+00	0.000E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Th-230	1.000E+00	0.000E+00	---	S1(5)
R012	Initial principal radionuclide (pCi/g): Th-232	1.000E+00	0.000E+00	---	S1(6)
R012	Concentration in groundwater (pCi/L): Ra-226	not used	0.000E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L): Th-230	not used	0.000E+00	---	W1(5)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W1(6)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.431E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.600E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity	2.000E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	1.040E+01	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	2.000E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	5.000E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	4.060E-01	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	2.000E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	not used	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	not used	1.000E-03	---	EPS

R014	Density of saturated zone (g/cm**3)	not used	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	not used	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	not used	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	not used	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	not used	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	not used	2.000E-02	---	HGWT
R014	Saturated zone b parameter	not used	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	not used	1.000E-03	---	VWT

```
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                                  Site-Specific Parameter Summary (continued)
                                                          User                           Used by RESRAD          Parameter
Menu                      Parameter                       Input     Default   (If different from user input)    Name
--------------------------------------------------------------------------------------------------------------------------------
R014  Well pump intake depth (m below water table)      not used   1.000E+01              ---                DWIBWT
R014  Model: Nondispersion (ND) or Mass-Balance (MB)    not used   ND                     ---                MODEL
R014  Well pumping rate (m**3/yr)                       not used   2.500E+02              ---                UW

R015  Number of unsaturated zone strata                 not used   1                      ---                NS
R015  Unsat. zone 1, thickness (m)                      not used   4.000E+00              ---                H(1)
R015  Unsat. zone 1, soil density (g/cm**3)             not used   1.500E+00              ---                DENSUZ(1)
R015  Unsat. zone 1, total porosity                     not used   4.000E-01              ---                TPUZ(1)
R015  Unsat. zone 1, effective porosity                 not used   2.000E-01              ---                EPUZ(1)
R015  Unsat. zone 1, field capacity                     not used   2.000E-01              ---                FCUZ(1)
R015  Unsat. zone 1, soil-specific b parameter          not used   5.300E+00              ---                BUZ(1)
R015  Unsat. zone 1, hydraulic conductivity (m/yr)      not used   1.000E+01              ---                HCUZ(1)

R016  Distribution coefficients for Ra-226
R016    Contaminated zone (cm**3/g)                     1.121E+04  7.000E+01              ---                DCNUCC( 2)
R016    Unsaturated zone 1 (cm**3/g)                    not used   7.000E+01              ---                DCNUCU( 2,1)
R016    Saturated zone (cm**3/g)                        not used   7.000E+01              ---                DCNUCS( 2)
R016    Leach rate (/yr)                                0.000E+00  0.000E+00           6.467E-05             ALEACH( 2)
R016    Solubility constant                             0.000E+00  0.000E+00           not used              SOLUBK( 2)

R016  Distribution coefficients for Th-230
R016    Contaminated zone (cm**3/g)                     6.757E+04  6.000E+04              ---                DCNUCC( 5)
R016    Unsaturated zone 1 (cm**3/g)                    not used   6.000E+04              ---                DCNUCU( 5,1)
R016    Saturated zone (cm**3/g)                        not used   6.000E+04              ---                DCNUCS( 5)
R016    Leach rate (/yr)                                0.000E+00  0.000E+00           1.073E-05             ALEACH( 5)
R016    Solubility constant                             0.000E+00  0.000E+00           not used              SOLUBK( 5)

R016  Distribution coefficients for Th-232
R016    Contaminated zone (cm**3/g)                     6.757E+04  6.000E+04              ---                DCNUCC( 6)
R016    Unsaturated zone 1 (cm**3/g)                    not used   6.000E+04              ---                DCNUCU( 6,1)
R016    Saturated zone (cm**3/g)                        not used   6.000E+04              ---                DCNUCS( 6)
R016    Leach rate (/yr)                                0.000E+00  0.000E+00           1.073E-05             ALEACH( 6)
R016    Solubility constant                             0.000E+00  0.000E+00           not used              SOLUBK( 6)

R016  Distribution coefficients for daughter Pb-210
R016    Contaminated zone (cm**3/g)                     1.549E+04  1.000E+02              ---                DCNUCC( 1)
R016    Unsaturated zone 1 (cm**3/g)                    not used   1.000E+02              ---                DCNUCU( 1,1)
R016    Saturated zone (cm**3/g)                        not used   1.000E+02              ---                DCNUCS( 1)
R016    Leach rate (/yr)                                0.000E+00  0.000E+00           4.680E-05             ALEACH( 1)
R016    Solubility constant                             0.000E+00  0.000E+00           not used              SOLUBK( 1)

R016  Distribution coefficients for daughter Ra-228
```

R016	Contaminated zone (cm**3/g)	1.121E+04	7.000E+01	---	DCNUCC(3)
R016	Unsaturated zone 1 (cm**3/g)	not used	7.000E+01	---	DCNUCU(3,1)
R016	Saturated zone (cm**3/g)	not used	7.000E+01	---	DCNUCS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	6.467E-05	ALEACH(3)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)

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R016	Distribution coefficients for daughter Th-228				
R016	Contaminated zone (cm**3/g)	6.757E+04	6.000E+04	---	DCNUCC(4)
R016	Unsaturated zone 1 (cm**3/g)	not used	6.000E+04	---	DCNUCU(4,1)
R016	Saturated zone (cm**3/g)	not used	6.000E+04	---	DCNUCS(4)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.073E-05	ALEACH(4)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(4)
R017	Inhalation rate (m**3/yr)	1.139E+04	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	2.790E-06	1.000E-04	---	MLINH
R017	Exposure duration	2.500E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	5.512E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	6.800E-02	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	2.740E-01	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows circular AREA.	FS
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)

R018	Fruits, vegetables and grain consumption (kg/yr)	not used	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	not used	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	1.438E+02	3.650E+01	---	SOIL

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Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R018	Drinking water intake (L/yr)	not used	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	not used	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	not used	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	not used	-1	---	FPLANT
R018	Contamination fraction of meat	not used	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	not used	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	not used	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	not used	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	not used	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	not used	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	not used	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	not used	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	not used	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	not used	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	not used	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	not used	8.000E-02	---	TE(3)
R19B	Translocation Factor for Non-Leafy	not used	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	not used	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	not used	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	not used	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ

C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5

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Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.000E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)
TITL	Number of graphical time points	32	---	---	NPTS
TITL	Maximum number of integration points for dose	17	---	---	LYMAX
TITL	Maximum number of integration points for risk	257	---	---	KYMAX

```
     Summary of Pathway Selections

          Pathway                User Selection
---------------------------------------------------
   1 -- external gamma              active
   2 -- inhalation (w/o radon)      active
   3 -- plant ingestion           suppressed
   4 -- meat ingestion            suppressed
   5 -- milk ingestion            suppressed
   6 -- aquatic foods             suppressed
   7 -- drinking water            suppressed
   8 -- soil ingestion              active
   9 -- radon                     suppressed
   Find peak pathway doses        suppressed
---------------------------------------------------
```

```
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     Contaminated Zone Dimensions            Initial Soil Concentrations, pCi/g
     ----------------------------            ----------------------------------
       Area:   5620.00 square meters                Ra-226     1.000E+00
  Thickness:      0.25 meters                       Th-230     1.000E+00
Cover Depth:      0.00 meters                       Th-232     1.000E+00

                              Total Dose TDOSE(t), mrem/yr
                        Basic Radiation Dose Limit = 2.500E+01 mrem/yr
             Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)
             --------------------------------------------------------------------------
   t (years):  0.000E+00  1.000E+00  3.000E+00  1.000E+01  3.000E+01  1.000E+02  3.000E+02  1.000E+03
    TDOSE(t):  3.513E+00  3.806E+00  4.474E+00  6.394E+00  7.906E+00  7.467E+00  0.000E+00  0.000E+00
        M(t):  1.405E-01  1.522E-01  1.790E-01  2.557E-01  3.162E-01  2.987E-01  0.000E+00  0.000E+00
Maximum TDOSE(t):  7.979E+00 mrem/yr   at t =   41.46 ñ 0.08 years

                       Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
                                    As mrem/yr and Fraction of Total Dose At t = 4.146E+01 years
                                       Water Independent Pathways (Inhalation excludes radon)
             Ground          Inhalation          Radon             Plant              Meat              Milk              Soil
Radio-  ----------------  ----------------  ----------------  ----------------  ----------------  ----------------  ----------------
Nuclide  mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.
Nuclide
------- --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------
Ra-226  3.004E+00 0.3765  3.832E-05 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  3.209E-01 0.0402
Th-230  5.551E-02 0.0070  4.979E-04 0.0001  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  3.094E-02 0.0039
Th-232  4.320E+00 0.5414  3.033E-03 0.0004  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  2.440E-01 0.0306
------- --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------
Total   7.379E+00 0.9249  3.569E-03 0.0004  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  5.958E-01 0.0747

                       Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
                                    As mrem/yr and Fraction of Total Dose At t = 4.146E+01 years
                                                      Water Dependent Pathways
              Water             Fish              Radon             Plant              Meat              Milk          All Pathways*
Radio-  ----------------  ----------------  ----------------  ----------------  ----------------  ----------------  ----------------
Nuclide  mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.   mrem/yr  fract.
Nuclide
------- --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------
Ra-226  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  3.325E+00 0.4167
Th-230  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  8.695E-02 0.0109
Th-232  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  4.567E+00 0.5724
------- --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------
Total   0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  7.979E+00 1.0000
*Sum of all water independent and dependent pathways.
```

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	3.156E+00	0.8983	1.367E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.045E-02	0.0201
Th-230	1.044E-03	0.0003	4.978E-04	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.697E-02	0.0077
Th-232	1.170E-01	0.0333	2.508E-03	0.0007	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.386E-01	0.0395
Total	3.274E+00	0.9319	3.020E-03	0.0009	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.360E-01	0.0672

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.226E+00	0.9184
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.851E-02	0.0081
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.581E-01	0.0735
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.513E+00	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	3.152E+00	0.8283	1.473E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.119E-02	0.0213
Th-230	2.410E-03	0.0006	4.978E-04	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.700E-02	0.0071
Th-232	3.922E-01	0.1030	2.526E-03	0.0007	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.475E-01	0.0388
Total	3.547E+00	0.9320	3.039E-03	0.0008	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.557E-01	0.0672

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.234E+00	0.8497
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.990E-02	0.0079
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.422E-01	0.1425
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.806E+00	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years
Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Ra-226	3.146E+00	0.7032	1.675E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.017E-01	0.0227
Th-230	5.135E-03	0.0011	4.978E-04	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.708E-02	0.0061
Th-232	1.026E+00	0.2293	2.590E-03	0.0006	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.649E-01	0.0369
Total	4.177E+00	0.9337	3.105E-03	0.0007	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.937E-01	0.0656

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years
Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.248E+00	0.7259
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.271E-02	0.0073
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.194E+00	0.2668
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.474E+00	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years
Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Ra-226	3.123E+00	0.4885	2.289E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.640E-01	0.0256
Th-230	1.460E-02	0.0023	4.978E-04	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.748E-02	0.0043
Th-232	2.853E+00	0.4462	2.820E-03	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.085E-01	0.0326
Total	5.990E+00	0.9369	3.340E-03	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.000E-01	0.0626

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years
Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.287E+00	0.5141
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.258E-02	0.0067
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.064E+00	0.4792
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.394E+00	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years
Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Ra-226	3.051E+00	0.3859	3.442E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.811E-01	0.0356
Th-230	4.096E-02	0.0052	4.978E-04	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.945E-02	0.0037
Th-232	4.259E+00	0.5387	3.018E-03	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.415E-01	0.0305
Total	7.350E+00	0.9297	3.550E-03	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.521E-01	0.0698

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years
Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.332E+00	0.4214
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.090E-02	0.0090
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.503E+00	0.5696
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.906E+00	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	2.686E+00	0.3597	4.510E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.913E-01	0.0524
Th-230	1.201E-01	0.0161	4.984E-04	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.023E-02	0.0054
Th-232	3.981E+00	0.5332	3.036E-03	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.446E-01	0.0328
Total	6.787E+00	0.9090	3.579E-03	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.762E-01	0.0906

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.077E+00	0.4121
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.609E-01	0.0215
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.229E+00	0.5664
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.467E+00	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

*Sum of all water independent and dependent pathways.

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RESRAD, Version 6.5      T« Limit = 180 days        08/09/2015  13:41  Page  18
Summary : Determination of DCGL under Airman Scenario
File    : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\DCGL HILL AFB-AIRMAN.RAD

                                  Dose/Source Ratios Summed Over All Pathways
                       Parent and Progeny Principal Radionuclide Contributions Indicated
  Parent    Product    Thread                       DSR(j,t) At Time in Years   (mrem/yr)/(pCi/g)
   (i)        (j)     Fraction   0.000E+00 1.000E+00 3.000E+00 1.000E+01 3.000E+01 1.000E+02 3.000E+02 1.000E+03
---------- ---------- ---------  --------- --------- --------- --------- --------- --------- --------- ---------
Ra-226+D   Ra-226+D   1.000E+00  3.220E+00 3.217E+00 3.211E+00 3.187E+00 3.113E+00 2.746E+00 0.000E+00 0.000E+00
Ra-226+D   Pb-210+D   1.000E+00  5.532E-03 1.637E-02 3.703E-02 9.986E-02 2.183E-01 3.312E-01 0.000E+00 0.000E+00
Ra-226+D   -DSR(j)               3.226E+00 3.234E+00 3.248E+00 3.287E+00 3.332E+00 3.077E+00 0.000E+00 0.000E+00
Th-230     Th-230     1.000E+00  2.781E-02 2.781E-02 2.781E-02 2.780E-02 2.779E-02 2.775E-02 0.000E+00 0.000E+00
Th-230     Ra-226+D   1.000E+00  6.976E-04 2.091E-03 4.872E-03 1.453E-02 4.144E-02 1.225E-01 0.000E+00 0.000E+00
Th-230     Pb-210+D   1.000E+00  8.009E-07 5.556E-06 2.878E-05 2.398E-04 1.672E-03 1.063E-02 0.000E+00 0.000E+00
Th-230     -DSR(j)               2.851E-02 2.990E-02 3.271E-02 4.258E-02 7.090E-02 1.609E-01 0.000E+00 0.000E+00
Th-232     Th-232     1.000E+00  1.369E-01 1.369E-01 1.369E-01 1.369E-01 1.369E-01 1.368E-01 0.000E+00 0.000E+00
Th-232     Ra-228+D   1.000E+00  1.028E-01 2.927E-01 6.096E-01 1.268E+00 1.702E+00 1.607E+00 0.000E+00 0.000E+00
Th-232     Th-228+D   1.000E+00  1.837E-02 1.126E-01 4.471E-01 1.659E+00 2.665E+00 2.485E+00 0.000E+00 0.000E+00
Th-232     -DSR(j)               2.581E-01 5.422E-01 1.194E+00 3.064E+00 4.503E+00 4.229E+00 0.000E+00 0.000E+00
---------- ---------- ---------  --------- --------- --------- --------- --------- --------- --------- ---------
The DSR includes contributions from associated (half-life ó 180 days) daughters.

                           Single Radionuclide Soil Guidelines G(i,t) in pCi/g
                              Basic Radiation Dose Limit = 2.500E+01 mrem/yr
Nuclide
  (i)    t= 0.000E+00   1.000E+00   3.000E+00   1.000E+01   3.000E+01   1.000E+02   3.000E+02   1.000E+03
-------     ---------   ---------   ---------   ---------   ---------   ---------   ---------   ---------
Ra-226      7.750E+00   7.731E+00   7.698E+00   7.606E+00   7.504E+00   8.124E+00  *9.885E+11  *9.885E+11
Th-230      8.770E+02   8.360E+02   7.643E+02   5.872E+02   3.526E+02   1.554E+02  *2.018E+10  *2.018E+10
Th-232      9.685E+01   4.611E+01   2.094E+01   8.159E+00   5.551E+00   5.912E+00  *1.097E+05  *1.097E+05
-------     ---------   ---------   ---------   ---------   ---------   ---------   ---------   ---------
*At specific activity limit

            Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
            and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
         at tmin = time of minimum single radionuclide soil guideline
     and at tmax = time of maximum total dose =   41.46 ñ 0.08 years
Nuclide  Initial         tmin       DSR(i,tmin) G(i,tmin) DSR(i,tmax) G(i,tmax)
  (i)    (pCi/g)       (years)                   (pCi/g)               (pCi/g)
------- ---------  ----------------  ---------  ---------  ---------  ---------
Ra-226  1.000E+00    31.69 ñ 0.06    3.332E+00  7.503E+00  3.325E+00  7.519E+00
Th-230  1.000E+00    153.3 ñ 0.3     1.849E-01  1.352E+02  8.695E-02  2.875E+02
Th-232  1.000E+00    41.44 ñ 0.08    4.567E+00  5.474E+00  4.567E+00  5.474E+00
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RESRAD, Version 6.5 T« Limit = 180 days 08/09/2015 13:41 Page 19
Summary : Determination of DCGL under Airman Scenario
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Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

0Nuclide (j)	Parent (i)	THF(i)	DOSE(j,t), mrem/yr t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-226	Ra-226	1.000E+00	3.220E+00	3.217E+00	3.211E+00	3.187E+00	3.113E+00	2.746E+00	0.000E+00	0.000E+00
Ra-226	Th-230	1.000E+00	6.976E-04	2.091E-03	4.872E-03	1.453E-02	4.144E-02	1.225E-01	0.000E+00	0.000E+00
Ra-226	-DOSE(j)		3.221E+00	3.219E+00	3.216E+00	3.202E+00	3.155E+00	2.868E+00	0.000E+00	0.000E+00
Pb-210	Ra-226	1.000E+00	5.532E-03	1.637E-02	3.703E-02	9.986E-02	2.183E-01	3.312E-01	0.000E+00	0.000E+00
Pb-210	Th-230	1.000E+00	8.009E-07	5.556E-06	2.878E-05	2.398E-04	1.672E-03	1.063E-02	0.000E+00	0.000E+00
Pb-210	-DOSE(j)		5.533E-03	1.637E-02	3.706E-02	1.001E-01	2.199E-01	3.418E-01	0.000E+00	0.000E+00
Th-230	Th-230	1.000E+00	2.781E-02	2.781E-02	2.781E-02	2.780E-02	2.779E-02	2.775E-02	0.000E+00	0.000E+00
Th-232	Th-232	1.000E+00	1.369E-01	1.369E-01	1.369E-01	1.369E-01	1.369E-01	1.368E-01	0.000E+00	0.000E+00
Ra-228	Th-232	1.000E+00	1.028E-01	2.927E-01	6.096E-01	1.268E+00	1.702E+00	1.607E+00	0.000E+00	0.000E+00
Th-228	Th-232	1.000E+00	1.837E-02	1.126E-01	4.471E-01	1.659E+00	2.665E+00	2.485E+00	0.000E+00	0.000E+00

THF(i) is the thread fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

0Nuclide (j)	Parent (i)	THF(i)	S(j,t), pCi/g t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-226	Ra-226	1.000E+00	1.000E+00	9.995E-01	9.985E-01	9.950E-01	9.852E-01	9.514E-01	8.613E-01	6.078E-01
Ra-226	Th-230	1.000E+00	0.000E+00	4.331E-04	1.299E-03	4.321E-03	1.290E-02	4.222E-02	1.204E-01	3.376E-01
Ra-226	-S(j):		1.000E+00	9.999E-01	9.998E-01	9.994E-01	9.981E-01	9.936E-01	9.816E-01	9.454E-01
Pb-210	Ra-226	1.000E+00	0.000E+00	3.060E-02	8.896E-02	2.664E-01	6.009E-01	9.203E-01	8.738E-01	6.168E-01
Pb-210	Th-230	1.000E+00	0.000E+00	6.662E-06	5.872E-05	6.075E-04	4.518E-03	2.937E-02	1.081E-01	3.287E-01
Pb-210	-S(j):		0.000E+00	3.060E-02	8.902E-02	2.670E-01	6.054E-01	9.497E-01	9.819E-01	9.455E-01
Th-230	Th-230	1.000E+00	1.000E+00	1.000E+00	9.999E-01	9.998E-01	9.994E-01	9.980E-01	9.941E-01	9.805E-01
Th-232	Th-232	1.000E+00	1.000E+00	1.000E+00	1.000E+00	9.999E-01	9.997E-01	9.989E-01	9.968E-01	9.893E-01
Ra-228	Th-232	1.000E+00	0.000E+00	1.136E-01	3.034E-01	7.002E-01	9.724E-01	9.985E-01	9.963E-01	9.889E-01
Th-228	Th-232	1.000E+00	0.000E+00	1.864E-02	1.243E-01	5.642E-01	9.590E-01	9.985E-01	9.963E-01	9.889E-01

THF(i) is the thread fraction of the parent nuclide.
RESCALC.EXE execution time = 0.91 seconds

Appendix D
Final Status Survey Plan

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FINAL

Hill Air Force Base
Performance-Based Remediation

WR111 Little Mountain Test Annex
Magnesium-Thorium Disposal Trench

Appendix D, Final Status Survey Plan

Contract No: FA8903-09-D-8560
Task Order 0006

Air Force Civil Engineer Center
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SEPTEMBER 2015

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Acronyms and Abbreviations

AEC	Atomic Energy Commission
AFB	Air Force Base
AFIOH	U.S. Air Force Institute of Occupational Health
ALARA	as low as (is) reasonably achievable
^{137}Cs	Cesium-137
Cabrera	Cabrera Services, Inc.
CFR	Code of Federal Regulations
Ci	Curie
cm	Centimeter
cm^2/g	Square centimeter per gram
cpm	Counts per minute
DCGL	Derived Concentration Guideline Level
$DCGL_{EMC}$	Derived Concentration Guideline Level used for elevated measurement comparison
$DCGL_w$	Derived Concentration Guideline Level used for Non-Parametric Statistical Test
DER	Duplicate Error Ratio
EA	EA Engineering, Science, and Technology, Inc.
EPA	U.S. Environmental Protection Agency
FDUP	Field duplicate
FREP	Field replicate
FSS	Final Status Survey
FSSP	Final Status Survey Plan
GIS	Geographic Information System
GPS	Global Positioning System
GWS	Gamma Walkover Survey
H_a	Alternative Hypothesis
HASL	Health and Safety Laboratory
H_o	Null Hypothesis
LBGR	Lower Bound of the Grey Region
LCS	Laboratory control sample
LDUP	Laboratory duplicate
LMTA	Little Mountain Test Annex
LREP	Laboratory replicate
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MB	Method blank
MDC	Minimum Detectable Concentration
MDCR	Minimum Detectable Count Rate
MDL	Method detection limit
Mg-Th	Magnesium-thorium
mrem/yr	Millirem per year

MS	Matrix spike
MSD	Matrix spike duplicate
NaI	Sodium Iodide
NIST	National Institute of Standards and Technology
NRC	Nuclear Regulatory Commission
NUREG	Nuclear Regulatory Commission Guidance
Parsons	Parsons Infrastructure and Technology Group, Inc.
pCi/g	PicoCuries per gram
QC	Quality control
QIS	Quality indicator sample
^{226}Ra	Radium-226
RESRAD	Residual radioactivity
ROC	Radionuclide of concern
SOR	Sum of the Ratio
SU	Survey unit
^{230}Th	Thorium-230
^{232}Th	Thorium-232
TestAmerica	Test America, Inc.
^{238}U	Uranium-238
WRS	Wilcoxon Rank Sum

1.0 Introduction

EA Engineering, Science, and Technology, Inc. (EA) is currently contracted under the Hill Air Force Base (AFB) Performance-Based Remediation Contract No. FA8903-09-D-8560 to obtain site closeout at the Little Mountain Test Annex (LMTA) Magnesium-Thorium Disposal Trench Site (hereinafter referred to as Site WR111). Cabrera Services, Inc. (Cabrera) is providing health physics services to support EA's investigation, remediation, and closure of the site. EA and Cabrera will conduct a Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (Department of Defense, U.S. Department of Energy, U.S. Environmental Protection Agency [EPA], and Nuclear Regulatory Commission [NRC] 2000) compliant final status survey (FSS) as part of a Decommissioning Plan for Site WR111. All remedial action activities, including the FSS at Site WR111, are being conducted in coordination with the NRC via the U.S. Air Force Radioisotope Committee (U.S. Air Force Radioisotope Committee).

1.1 Purpose

The purpose of this FSS Plan (FSSP) is to provide the basis for conducting an FSS at Site WR111 to assess site radiological conditions and document compliance with radiological cleanup criteria to achieve unrestricted release. This FSSP addresses post-removal action surveys for radiological contaminants at Site WR111. Cleanup activities will be accomplished in accordance with a Remedial Design/Remedial Action Work Plan, which will be prepared under separate cover. The expected outcome of the selected remedy is that Site WR111 will not present an unacceptable risk to future land users via exposure to soil and would be suitable for a resident farmer.

The objective of this FSSP is to provide a consistent approach for planning, performing, and assessing radionuclides of concern (ROCs) present in site surface soils through FSS in order to demonstrate compliance with established dose-based criteria, Derived Concentration Guideline Level (DCGLs). This objective is met when residual soils impacted by past operations have been remediated, and an FSS has verified that any residual radioactivity meets remediation goals.

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2.0 Facility and Site Information

2.1 Facility Location and Description

The LMTA Magnesium-Thorium Disposal Trench Site is located in a remote area west of Ogden, Utah, which is approximately 15 miles northwest of Hill AFB and adjacent to the Great Salt Lake (Figure D-1). The disposal trench is approximately 200 × 150 feet (ft) in area and is enclosed by a chain-link fence in the southeastern corner of the LMTA (Figure D-2). The fenced area is referred to as the Radioactive Disposal Area.

Based on the review of *Final Radiological Disposal Sites Characterization For Little Mountain Testing Annex* report (AECOM 2009), material disposed in the Radioactive Disposal Area originated from the Marquardt Aircraft Ramjet manufacturing plant in Ogden. The U.S. Atomic Energy Commission (AEC), the predecessor agency to the U.S. NRC, issued Source Material License C-3650 to Marquardt Aircraft Company of Van Nuys, California, for possession of magnesium-thorium (Mg-Th) alloy to be used in the manufacture of controls, accessories, and engine parts. The maximum amount of Thorium-232 (^{232}Th) allowed by this license was 4,600 pounds, or approximately 0.23 curie (Ci) of ^{232}Th.

In April 1959, Marquardt sent a letter to the AEC concerning disposition of Mg-Th scrap material. Apparently, the licensee was having difficulty in finding a supplier who would accept its scrap material. Documents show that 500 pounds of scrap Mg-Th were buried in a disposal trench in June 1959, and 1,500 pounds were buried in February 1960. In June 1961, Marquardt requested AEC approval to burn the machine chips and small pieces of Mg-Th scrap material accumulated at the Ogden facility. The licensee proposed to burn the material in burial/burn trench that was 10 feet deep, 8 feet wide, and 20 feet long. The trench would be located in a remote controlled area on government property. In September 1961, Source Material License C-3650 expired and License STB-434 was issued for the Marquardt facility in Ogden. This license included permission to incinerate source material in accordance with AEC regulations associated with treatment or disposal by incineration. Documents show that 3,600 pounds were incinerated in August 1961. Historical records indicate that this amount included sludge from the wet collectors from the pickling tanks (containing thorium fluoride) and lathe turnings/milling scraps (possibly containing cutting oil and/or solvents). No other documentation of disposal was identified in the docket files.

License STB-434 was terminated on 12 April 1971. No documentation is in NRC docket files to show that the AEC performed a closeout inspection or survey for this license or facility. In addition, the materials-disposition documentation was incomplete.

2.2 Previous Investigations

In the early 1990s, a number of investigations were conducted at Site WR111. The results of the investigations were summarized in the *Final Summary Report: Low Level Radioactive Waste Contamination, LMTA* (Jacobs Engineering Group, Inc. 1994), and according to the report:

- In 1993, the NRC performed an inspection at the LMTA and identified two disposal pits where the highest exposure rate was about twice the background exposure rate recorded in the vicinity.

- In 1993, the Hill AFB Radiation Safety Officer collected 10 surface soil samples from a potential radioactive disposal area and a background surface soil sample. The result indicated that gross alpha concentrations for all 10 samples were greater than the background concentration.

- The Final Summary Report identified an area in the southeast corner of the LMTA as the Radioactive Disposal Area, which is in the general vicinity of the elevated gamma measurements observed by the NRC. The gamma-scan results for other disposal areas (north of the radioactive disposal area) exhibited elevated count rates; however, these were reported as within 25 percent of the background count.

In 2006, the U.S. Air Force Institute for Operational Health (AFIOH) performed a Global Positioning System (GPS)-referenced gamma radiation survey of surface soil for various areas of interest at the LMTA (AFIOH 2007). Only the radioactive disposal area showed elevated gamma count rates. The initial area thought to be the location of the trench (northeast portion of the site) did not show any elevated gamma count rates. Therefore, AFIOH concluded that areas outside of the fenced Radioactive Disposal Area were not impacted.

In Summer and Fall 2006, Parsons Infrastructure and Technology Group, Inc. (Parsons) conducted a remedial investigation of Operable Unit A at LMTA (Parsons 2007), which included Site WR111. In August 2006, four shallow bedrock monitoring wells (LM-060 through LM-063) were installed in the vicinity of WR111 (upgradient, downgradient, and sidegradient). In November 2006, the four wells were sampled and the samples were analyzed for volatile and semivolatile organic compounds, metals, water quality parameters, gross alpha and gross beta, select gamma emitters, and thorium isotopes. Thorium-232 (^{232}Th) and Thorium-228 (^{228}Th) were not detected in groundwater at any of the wells, indicating that Mg-Th impact is not migrating to groundwater. Low concentrations of U-238 progeny (Thorium-230 [^{230}Th] and Radium-226 [^{226}Ra]) were identified in groundwater, but the concentrations were random and less than 1 picocurie per liter, which is indicative of natural uranium decay. Gross alpha radiation was detected in the downgradient well only. Low levels of gross beta radiation were detected at all four wells. The Parsons report concluded that the seemingly random pattern of low-level detections of ^{230}Th and ^{226}Ra, combined with the absence of ^{232}Th and ^{228}Th, represented radioactive decay of naturally occurring uranium rather than leaching from scrap metal in the Mg-Th disposal area. Volatile and semivolatile organic compounds were not detected in the groundwater, indicating that organic compounds were not disposed in the trench or, if present in the trench, have not migrated to the monitoring well locations. Metal detections in groundwater were considered to be consistent with background.

From 2007 to 2009, AECOM performed a more detailed investigation to assess site conditions at Site WR111. Investigative work included identifying and sampling appropriate background location(s); geophysical surveying to define site boundaries; performing gamma walkover survey (GWS) measurements with GPS mapping; and collection of surface and subsurface soil samples for radiological and chemical analytes (i.e., volatile and semivolatile organic compounds).

The characterization survey showed that the maximum ^{232}Th concentrations in the Radioactive Disposal Area were 7.1 ± 0.4 and 99 ± 3 picocuries per gram (pCi/g) for surface soil and subsurface soil, respectively. The ^{232}Th background concentration for surface soils was 1.65 ± 0.03 (pCi/g) and for subsurface soils 1.60 ± 0.04 pCi/g (uncertainties were two standard deviations). Results of the AECOM investigation indicate that site soils within the fenced Radioactive Disposal Area were impacted with ^{232}Th and decay progeny above background levels (AECOM 2009). The report also indicated that elevated radiological activity may extend beyond the fence line to the south and east. While radium-226 (^{226}Ra) was also detected in the soil samples, the concentrations appeared to be consistent with background, and ^{226}Ra was not considered to be a site ROC.

Sampling results from the investigation also showed that no volatile or semivolatile organic compounds were detected above reportable limits in soil.

2.3 Current Site Investigation

In July 2013, EA and Cabrera performed a supplemental site characterization survey of potentially impacted soil at WR111 to assess conditions at the Radioactive Disposal Area, confirm existing assumptions about the nature and extent of radiological contamination in soil, and to collect samples for waste disposal characterization. Investigative activities included the following tasks:

- Limited GWS of the central and southeastern portions of WR111 was performed with a Ludlum 44-20 sodium iodide (NaI) detector coupled with GPS, to identify areas of elevated activities in order to strategically position boring locations in areas beyond those previously identified as radiologically impacted. GWS was performed with the detector 10 centimeters above the ground surface.

- Fourteen soil borings were advanced by direct-push method as terrain and access permitted. Subsurface soil samples were collected by advancing a steel macro-sampler core barrel (minimum 2-inch outside diameter) with acetate sleeves to a depth of 12-15 feet below ground surface. Core scans were obtained from each soil boring. Five out of the 14 boreholes did not advance to the investigational depth due to refusal and an additional two boreholes collapsed. As a result, downhole gamma readings were not collected from each soil boring.

- Subsurface soil cores were scanned for radiological contamination using a Ludlum 44-20 NaI detector.

- Downhole gamma loggings, in conjunction with core scanning, were performed to assist in determining the location of biased subsurface soil samples. Downhole gamma measurements were conducted utilizing a Ludlum 44-2 (1×1-inch) sodium iodide detector not collimated with lead shielding. The instrument was lowered into the borehole to the target depth and one-minute static measurements were collected at half a foot intervals proceeding upward until the top of the borehole was reached.

- Surface and subsurface soil from boring intervals with the highest gross count rates were selected for biased soil sampling. A total of 29 soil samples, including 2 duplicate samples, were submitted to the offsite laboratory for radiological analysis. In addition, 3 samples were submitted to the offsite laboratory for chemical analyses to support future disposal activities, including toxicity characteristic leaching procedure for EPA-regulated analytes, polychlorinated biphenyls, ignitability, corrosivity, and reactivity.

A total of 29 soil samples were submitted to Test America, Inc. (TestAmerica) and analyzed for natural radium, thorium and uranium isotopes using gamma spectroscopy via EPA Method 901.1. Three samples had elevated levels of ^{226}Ra and ^{232}Th. In order to obtain a more accurate ^{226}Ra activity value, the three samples were re-analyzed for ^{226}Ra via EPA Method 901.1M, which measures the ^{226}Ra daughter progeny (Lead-214 and Bismuth-214) at equilibrium. The 3 samples were also analyzed for isotopic thorium (including thorium-228, ^{230}Th, and ^{232}Th) by the alpha spectroscopy method EML Health and Safety Laboratory (HASL) 300 Modified (Department of Energy 1997) in order to determine the source of the elevated ^{226}Ra activity (^{226}Ra is a daughter of Th-230). One of the three elevated activity samples (analyzed by gamma spectroscopy) also had an elevated uranium concentration with high uncertainty. Therefore, all 3 samples were analyzed by Isotopic Uranium (including Uranium-234, Uranium-235, and

^{238}U) by EML HASL 300 Modified (Department of Energy 1997). Alpha spectroscopy is more accurate with a higher confidence level for reporting the activity of alpha emitting radionuclides. For this reason, the alpha spectroscopy results for the three reanalyzed samples (WR111-SB-WR701-BS-P-05, WR111-SB-WR708-BS-P-08, and WR111-SB-WR710-BS-P-05) were used during subsequent data evaluation activities. The results showed that the elevated ^{226}Ra activity is progeny from the elevated ^{230}Th resulting from the site Mg-Th contamination in all 3 samples. In addition, the isotopic uranium results were all representative of background activity levels. Alpha spectroscopy results are provided in Table B-1 (pages 1 through 8) in Appendix B.

Results of the surveys and sample analyses were used to identify specific areas of radiological contamination at Site WR111. A detailed analysis of the analytical results from the 2013 investigation is presented in Section 3.0 of the Decommissioning Plan.

2.4 Radionuclides of Concern

Based on the results of the previous investigations and current site characterization, a number of sample results for the radionuclides ^{226}Ra, ^{230}Th, and ^{232}Th exceeded their corresponding NRC surface soil screening values (NRC Guidance [NUREG]-1757, Vol. 1, Table B-2). Therefore, ^{226}Ra, ^{230}Th, and ^{232}Th are considered as the ROCs for Site WR111.

2.5 Residual Derived Concentration Guideline Limit for Each Radionuclide of Concern

As described by MARSSIM, a DCGL is a derived radionuclide activity concentration within a survey unit (SU) that corresponds to a dose-based release criterion. The DCGLs presented in this document are based on the *Radiological Criteria for Unrestricted Use* requirements set forth by the NRC in 10 Code of Federal Regulations (CFR) Part 20.1402. In accordance with these requirements, a site is considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a Total Effective Dose Equivalent to an average member of the critical group that does not exceed 25 millirem per year (mrem/yr), and the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA).

A detailed evaluation and derivation of DCGLs for WR111 is provided in Appendix C of the Decommissioning Plan (Site- Specific DCGL Evaluation). As identified in Appendix C of the Decommissioning Plan, surface and subsurface soil at Site WR111 is the medium of concern. Two receptor scenarios were considered during the derivation of ROC-specific DCGLs for soil. A residential farmer was considered as the critical receptor for the base case site exposure scenario. One additional exposure scenario was evaluated to confirm that the base-case resident farmer scenario is bounding for the development of soil DCGLs. Site WR111 is currently federally owned and, hence, a very conservative airman exposure scenario was also selected. For each scenario, the receptor is potentially exposed to residual radioactivity in surface and subsurface soil that is remaining after the site has been released for use without radiological restrictions.

The residential farmer receptor is assumed to live onsite for 350 days per year for 30 years (EPA 2000). Under a resident farmer scenario, a family is assumed to move onto the site after it has been released for use without radiological restrictions, build a home, and raise crops and livestock for family consumption. The resident farmer is exposed through different exposure pathways to residual radioactivity present in the site soil. Members of the critical group can incur a radiation dose by:

- Direct radiation from radionuclides in the soil
- Inhalation of resuspended dust
- Ingestion of food from crops grown in the soil
- Ingestion of milk from livestock raised in the area
- Ingestion of meat from livestock raised in the area
- Ingestion of the soil.

As discussed in Appendix C, there is no complete groundwater exposure pathway or surface water exposure pathway; therefore, these pathways were not considered.

Under the airman scenario, the airman is modeled as a typical outdoor site worker who spends most of the time outdoors. The airman is assumed to be onsite for 25 years (EPA 1991). A typical industrial worker usually spends 250 days per year at the site. As a conservative approach, the airman is assumed to spend 300 days per year at this site, with a 10-hour work day. During the 10-hour working day, the airman is assumed to spend 2 hours indoors and 8 hours outdoors.

Complete exposure pathways applicable to the airman scenario include:

- Direct radiation from radionuclides in the soil
- Inhalation of re-suspended dust
- Ingestion of soil.

Table D-1 presents the DCGLs for ROCs in soil at Site WR111. Among the two receptor scenarios, the most conservative DCGL for each ROC was selected as the site-specific DCGL. Each DCGL represents the concentration (based on the presented model) that would produce a 25 mrem/yr exposure.

When there are multiple ROCs present in the soil, the allowed soil concentration levels must follow the sum of the ratio (SOR). This will ensure that the sum of the individual fractions for each isotope to its individual DCGL fraction does not exceed unity. The SOR at Site WR111 is calculated as follows:

$$\mathrm{SOR} = \frac{\mathrm{Ra\text{-}226}_{\mathrm{Conc}}}{\mathrm{Ra\text{-}226}_{\mathrm{DCGLw}}} + \frac{\mathrm{Th\text{-}232}_{\mathrm{Conc}}}{\mathrm{Th\text{-}232}_{\mathrm{DCGLw}}} + \frac{\mathrm{Th\text{-}230}_{\mathrm{Conc}}}{\mathrm{Th\text{-}230}_{\mathrm{DCGLw}}}$$

where

^{226}Ra Conc	=	Measured activity concentration for ^{226}Ra.
^{232}Th Conc	=	Measured activity concentration for ^{232}Th.
^{230}Th Conc	=	Measured activity concentration for ^{230}Th.
^{226}Ra $DCGL_w$	=	Site-Specific $DCGL_w$ for ^{226}Ra.
^{232}Th $DCGL_w$	=	Site-Specific $DCGL_w$ for ^{232}Th.
^{230}Th $DCGL_w$	=	Site-Specific $DCGL_w$ for ^{230}Th.

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3.0 Data Quality Objectives

The first step in designing effective surveys is planning. The Data Quality Objective process provides systematic procedures for defining the criteria that the survey design should satisfy, including what type of measurements to perform, when and where to perform measurements, the level of decision errors for the survey, and how many measurements to perform.

The Data Quality Objective process includes the following seven steps (EPA 2000):

- State the Problem
- Identify the Decision
- Identify Inputs to the Decision
- Define the Study Boundaries
- Develop the Decision Rule
- Specify Tolerable Limits on Decision Error
- Optimize the Design for Obtaining Data.

The Data Quality Objectives are described below as they apply to both soil and surficial contamination FSSs Site WR111.

3.1 Step 1: State the Problem

3.1.1 Problem Description

Characterization data indicate that surface and subsurface soil at Site WR111 are potentially contaminated with ^{226}Ra, ^{230}Th, and ^{232}Th from disposal of Mg-Th waste. As a result, remediation activities are required at the site to address the contamination. The objective of FSS activities is to obtain data of sufficient quality and quantity to support unrestricted release of Site WR111 following remedial activities. The levels of residual radioactivity must be determined by FSS to confirm compliance with the radionuclide-specific DCGLs.

3.1.2 Planning Team Members

FSS planning is being performed by a team of Cabrera and EA personnel, with input from Air Force Civil Engineer Center, Hill AFB, and the NRC via U.S. Air Force Radioisotope Committee.

3.1.3 Primary Decision Maker

The ultimate decision regarding site disposition will rest with the U.S. Air Force Radioisotope Committee. The U.S. Air Force Radioisotope Committee will oversee all decommissioning activities on behalf of the NRC and will work with the NRC to accomplish decommissioning of soils and release for unrestricted use.

3.1.4 Available Resources

Sufficient resources are available through the combined staff of EA, Cabrera, and subcontractors, to perform and complete all work required in achieving the FSS objectives.

3.2 Step 2: Identify the Decision

This plan will be used to demonstrate that the residual radionuclide concentrations on the soil comply with their corresponding DCGL. Compliance will be verified using guidance found in this FSSP, which was prepared in accordance with MARSSIM. Specifically, the compliance will be demonstrated by:

- Collection of systematic surface soil samples consistent with MARSSIM
- Performance of GWS to identify gross contamination and small areas of elevated radiological activity
- Collection of biased measurements in areas of elevated radiological activity
- Comparison of residual soil concentrations for each ROC with respect to their corresponding remediation goals
- Collection of soil samples from background reference area
- Performance of statistical tests to verify that remediation goals are met and, therefore, the soil does not present a current or potential threat to public health, welfare, or the environment
- Review of the data to verify that they are of sufficient quality.

To demonstrate that an SU meets remediation goals, four evaluation questions must be answered:

1. Is the SOR of each sample less than 1?
2. Are small areas of elevated radioactivity below the elevated measurement comparison criteria?
3. Do surface soil sample results satisfy the Wilcoxon Rank Sum (WRS) statistical test as described in MARSSIM?
4. Are the data of sufficient quality to support the conclusions (i.e., have Data Quality Indicators been met)?

If the answer to any one of these evaluation questions is “no” for any SU, then remediation goals are not satisfied. The remediation contractor will be required to remove additional soil and the SU will be reevaluated.

3.3 Step 3: Identify Inputs to the Decision

The Data Quality Assessment process as described in the MARSSIM and in the *Guidance for Data Quality Assessment* (EPA 2000) will be used to determine if data obtained from environmental data operations are of the right type, quality, and quantity to support their intended use.

The "graded approach" concept will also be used to assure that survey efforts are maximized in those areas where there is the highest probability for residual contamination or greatest potential for adverse impacts of residual contamination. Examples of integrating the graded approach into the MARSSIM process include the use of historical site assessments, characterization surveys, site conditions, equipment capabilities, and results as the survey progresses to establish or adjust the degree of scanning coverage of a survey area, SU size, SU classification, sampling frequency, and criteria for the evaluation of elevated measurements.

Field activities for the FSS are summarized below:

- GWSs will be performed to identify elevated area of surface radioactivity at Site WR111.
- Collection of both systematic and biased volumetric samples.
- Collection of samples from areas of background reference area.

3.4 Step 4: Define the Study Boundaries

Study boundaries are defined by both horizontal (areal) and vertical parameters. The horizontal boundaries are defined in this FSSP by the potential for containing contaminated soil. The vertical extent or depth of contamination was determined utilizing down-hole gamma readings and sample results collected from previous Site characterizations. Classification of areas by contamination potential and then grouping areas into SUs is a critical step in the survey design process. An area is Class 1 if, prior to excavation activities, it is known to contain contamination above remediation goals. An area is Class 2 if contamination above remediation goals is not believed to exist. The concentration-based remediation goals are described in Section 4.2. Following the MARSSIM approach, the remediation goal is also referred to as the $DCGL_W$ (the DCGL for average concentrations over a wide area, used with statistical tests).

Division into specific Class 1 or Class 2 SUs will depend on the actual extent of remediation; final designation of SUs will, therefore, be performed after remediation is completed and just prior to initiating post-remediation screening and the FSS. Generally, excavated areas will be Class 1 and the boundary areas surrounding the excavated areas will be Class 2. The SU boundary will be established by Cabrera and EA, in coordination with Air Force Civil Engineer Center, Hill AFB, and U.S. Air Force Radioisotope Committee.

3.4.1 Population of Interest Defining Characteristics

The population of interest for the site is the concentration of the three ROCs and their associated $DCGL_W$ values in surface soils.

3.4.2 Temporal Boundaries of the Decision Statement

Time frame to which the decision applies:

- $DCGL_w$ values are based on risks to an average member of the Critical Group over a 1,000-year period following the study.

Time for data collection:

- Data collection and analysis should be performed as soon as practical, as timely completion of the site restoration is contingent upon the results of the FSS.

3.4.3 Scale of Decision Making

Decisions will be made for small areas in the SU that may exhibit elevated levels of radioactivity, then for the entire SU regarding whether or not it meets the criteria for unrestricted release.

3.4.4 Constraints on Data Collection

Data collection activities can be constrained due to excessive moisture or rain, which can have an adverse effect on field instrumentation. However, the constraint is limited due to the arid climate and minimal rainfall.

3.5 Step 5: State the Decision Rules

Figure D-3 illustrates the sequence of events that are followed in the MARSSIM final status survey evaluation process. This evaluation process will be used to determine whether an SU meets remediation goals or if additional remediation or investigation and data gathering is required.

3.6 Step 6: Define Acceptable Decision Errors

As part of the Data Quality Objective process, the null hypothesis (H_o) for demonstrating compliance of data with cleanup goals must be stated. The H_o is the residual radioactivity surficial contamination that exceeds the acceptance criterion. Measurements or soil sample concentrations in the SU exceed the background by more than the $DCGL_{W.}$ In rejecting the H_o, the alternative hypothesis (H_a) must be accepted, and the finding would be that the SU meets the acceptance criterion. For H_a all measurements or soil sample concentrations in the SU do not exceed the background by more than the DCGLW

Appendix D in *MARSSIM* (NRC, 2000) provides a discussion regarding decision errors. This discussion includes the concept that acceptable error rates must be balanced between the need to make appropriate decisions and the financial costs of achieving high degrees of certainty.

> *"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."*

The non-parametric WRS test will be used to evaluate the residual contamination in the SU relative to the H_o. To enable testing of survey data relative to the acceptance criterion, the acceptable decision errors have been established for Site WR111. These are shown in Table D-2.

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 Type I decision error provides a 95 percent confidence level that the statistical tests will not incorrectly indicate that an SU satisfies acceptance criteria when, in fact, it does not. The Type II decision error provides a 95 percent confidence level that the statistical tests will not incorrectly indicate that an SU does not satisfy acceptance criteria when, in fact, it does. Type II errors are more a function of labor and survey costs and do not adversely impact public safety or health, and thus are subject to adjustment as needed. For the purposes of the FSS, the acceptable error rate for both Type I and Type II errors is 5 percent (i.e., $\alpha = \beta = 0.05$).

A minimum of 10 percent replicate and split samples will be collected for field quality control (QC) purposes. Data quality indicators for precision, accuracy, representativeness, completeness, and comparability have been established.

- The acceptable criteria related to precision and accuracy for the project are presented in Section 8.3.
- Representativeness and comparability are assured through the selection and proper implementation of systematic sampling and measurement techniques.
- Completeness refers to the portion of the data that meets acceptance criteria and is, therefore, useable for statistical testing. The objective is 90 percent for this project.

3.7 Optimize the Design for Obtaining Data

Scoping surveys, field screening techniques (remedial support surveys), surface contamination scans, field QC, and the Data Quality Assessment process are used throughout the characterization, remediation and final status survey process to focus efforts and to optimize costs.

Existing survey data has been reviewed in detail to support the FSS design and may be used as a portion of the FSS data set if the quality is sufficient. If existing data are going to be combined with new data to support a decision, then it should be determined if there are any gaps that can be filled or deficiencies that might be mitigated when designing the new data collection strategy.

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4.0 Survey Instrumentation and Techniques

This section describes the GWS, and volumetric sample collection and analysis instruments and methodology that will be used during the FSS of Site WR111. Specific survey and sampling requirements including percent coverage and types of surveys, numbers and types of samples, and analytical tests to be performed are discussed in the following sections. More detailed descriptions related to design of the SUs are presented in Section 5.0. Minimum detectable concentrations (MDCs) and minimum detectable count rates (MDCRs) required for the GWSs are calculated in accordance with MARSSIM and NUREG-1507, as presented in Attachments A and B.

4.1 Gamma Walkover Surveys

GWSs will be performed in accordance with Cabrera OP-001, Radiological Surveys. Surveys will be performed to measure surface radioactivity on the grounds. Equipment required for performing the GWS survey includes the following:

- Trimble Pathfinder Pro XRS/XH GPS
- Ludlum Model 44-20 NaI gamma scintillation detector (or equivalent) coupled to a Ludlum Model 2221 rate meter, equipped with RS-232 data download port
- Hardware: IBM-compatible Pentium (minimum) personal computer, color printer, large capacity data storage device (e.g., zip drive), modem, and large format plotter (note that some hardware may not be site-based)
- Software: Trimble Pathfinder Office, AutoCAD (or equivalent computer aided drawing software) with coordinate geometry capability.

The survey will be performed following MARSSIM protocol by walking straight parallel lines at a speed of 0.5 meters per second over an area with the detector kept a fixed distance from the ground (≤ 4 inches). A three-wheeled cart may be used for mounting the GPS and rate meter to stabilize the geometry for data collection in flat or open areas. Survey passes will be approximately 0.5 meters apart. Data from the rate meter/scaler will be automatically logged into the GPS unit every second. This system will log the gross gamma reading and position (in State Plane Coordinates) every second. After completion of the survey, the raw data will be downloaded from the GPS and transmitted to a data processing specialist for export into a geospatial software program.

Evaluation of the GWS data includes geospatial imaging for visual trend analysis and comparison of count rates to investigation levels for identification of distribution outliers. Investigation levels will be equal to three sigma (standard deviations) above the mean reference area count rates for the surface soils and trench soils data sets.

The GWS results will be processed and organized and then reviewed by the Data Management Coordinator and evaluated by the Project Health Physicist. The review will combine observation of individual data points that exceed the investigation levels with any identifiable spatial patterns or trends that might indicate areas of relatively elevated activity, particularly those that correspond to the areas where historical data indicated contamination within the particular excavation unit.

Section 5.5.3 in MARSSIM discusses the recommended scanning survey coverage for land areas. The objective of a scanning survey is to identify locations within the SU that exceed the cleanup level. These areas of elevated readings are marked for additional investigation. For Class 1 areas, scanning surveys are designed to detect small areas of elevated activity that are not detected by the soil samples collected using the systematic pattern. To achieve this goal, a 100 percent GWS will be performed over all Class 1 soils. Class 2 SUs have a lower probability for areas of elevated activity than Class 1 SUs, but some portions of the SU may have a higher potential than others based on remediation efforts. The coverage goal for Class 2 areas will be 100 percent as a conservative measure with 50-100 percent considered acceptable, depending on safety and accessibility. If the entire SU has an equal probability for areas of elevated activity, systematic scans along transects of the SU or scanning surveys of randomly selected grid blocks are performed.

Before a detection system is utilized for surveys, it is necessary to perform an a priori calculation of the Scan Minimum Detectable Concentration (Scan MDC) for the system. Attachment A presents the process and calculations for determining this a priori Scan MDC for ^{232}Th. Attachment B presents the process and calculations for determining this a priori Scan MDC for ^{226}Ra. The MDCs for ^{232}Th and ^{226}Ra in soil are provided in terms of pCi/g in Table D-3.

4.2 Volumetric Sample Collection and Analysis

Volumetric samples of soil samples will be collected from Site WR111 and Reference Area and will be sent to TestAmerica for analysis and analyzed in accordance with TestAmerica's standard operating procedure. Samples will be collected in accordance with Cabrera OP-005: Volumetric and Material Sampling. Sample chain-of-custody will be maintained in accordance with Cabrera OP-008: Chain-of-Custody.

Soil samples will be collected using a hand auger or stainless steel trowel, and homogenized in a stainless steel bowl prior to containerization. During the homogenization of soil samples, twigs, stones, and other non-soil items will be removed from the sample material in the field and excluded from the laboratory samples to avoid biasing results low. Samples will not be preserved in the field, as there are no preservation requirements for radiological analyses. One set of QC samples (e.g., field duplicate, matrix spike [MS], and matrix spike duplicate [MSD]) will be collected as required by each test method for each medium sampled.

Samples will be handled, packaged, labeled, sealed, preserved, and shipped as described in the Cabrera OP-062. Utensils and equipment that contact the sample material will be decontaminated between sampling locations, as necessary, to prevent cross-contamination of the samples. A Ludlum 43-93 detector and smear sample will be used to ascertain that no cross-contamination occurs between samples.

Hand augers/hand trowels/shovels, mixing utensils, and homogenizing bowls will be decontaminated between samples in order to avoid cross-contamination. Decontamination will be performed by wiping the tool or bowl with a MASLIN wipe to remove any residual contamination.

Systematic, biased, and field QC soil samples will be numbered, logged, and transferred under applicable chain-of-custody procedures to an offsite laboratory for analyses. Field duplicate samples will be collected at the frequency of 10 percent. Soil samples will be submitted to a TestAmerica. All soil samples will be analyzed for ^{226}Ra (EPA Method 901.1 modified) and isotopic analysis for ^{230}Th and ^{232}Th (method HASL 300 Modified) (Department of Energy 1997).

The analytical test methods used to analyze radionuclides in volumetric samples at the offsite laboratory will be able to achieve MDCs that are 10-50 percent of the soil screening criteria presented in Section 2.5.

4.3 Gamma Dose Rate Measurements

Gamma dose rate measurements may be qualitatively performed during the FSS to ensure worker health and safety and to identify unusual dose rate conditions. Measurements will be performed using a Bicron MicroRem tissue-equivalent scintillation detector, or equivalent, and will be performed in accordance with Cabrera OP-023, Operation of micro-R Meters, Rev 0. Measurements will be performed using the “slow” response time constant setting. The detector will be positioned over the area of interest and allowed to stabilize prior to recording the measurement. The technician will use their judgment to determine when the instrument has stabilized, estimated to take at least 15 seconds. Such measurements will typically be performed at 30 centimeters (cm) from and/or on contact with the surface being evaluated.

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5.0 Final Status Survey Design

The FSS at Site WR111 is designed in accordance with FSS guidance from MARSSIM (NRC 2000). FSS activities will consist of scanning surveys over 100 percent of the reasonably accessible surface soil. Discrete soil sampling will be performed at frequencies based on MARSSIM guidance. Survey activities will also include biased soil sample collection and the performance of gamma dose rate measurements. The FSS is designed such that the radiological background present in the soil will be considered for statistical comparisons to release criteria.

5.1 Classify Areas by Contamination Potential

As discussed in MARSSIM (NRC 2000), areas of sites undergoing an FSS should be classified into SU according to their potential for residual radioactivity. Section 2.2 of MARSSIM provides the following definitions for classifying areas (herein identified as SUs):

Non-Impacted Areas Areas that have no reasonable potential for residual contamination.

Impacted Areas Any area not classified as non-impacted; areas with the possibility of containing residual radioactivity in excess of natural background or fallout levels.

Class 1 Areas Impacted areas that have, or had prior to remediation, a potential for contamination (based on site operating history) or known contamination (based on previous radiological surveys) above the $DCGL_w$.

Class 2 Areas Impacted areas that, prior to remediation, are not likely to have concentrations of residual radioactivity that exceed the DCGLw.

Class 3 Areas Impacted areas that have a low probability of containing residual radioactivity.

Using MARSSIM as guidance, the site will be divided into one Class 1 SU and one Class 2 SU as shown on Figure D-4. The initial SU classifications are based on sample matrix, area, and contamination potential from previous investigations. Actual SU area and location designations will be based on remedial action and support surveys results. MARSSIM suggests that outdoor Class 1 and Class 2 SUs be not more than 2,000 and 10,000 square meters, respectively, in size.

5.2 Select a Background Reference Area Data Set

A background reference set must be identified if the contribution of naturally occurring levels of the ROCs is to be subtracted from survey measurements (through application of the WRS test). The background reference area dataset for the FSS must be pre-approved by Hill AFB and U.S. Air Force Radioisotope Committee in the FSS evaluation process on an area-specific basis.

There are two areas that will require reference area comparison at the conclusion of the remediation: the surface soils underlying the Layback Soils Staging Area, and the subsurface soils at the limits of excavation of the WR111 trench. Therefore, there will be two reference areas for this project: a surface soil reference area and trench reference area. The approved background areas will have a GWS conducted and the data will be reviewed for areas of elevated activity prior to surface soil sampling to establish the background reference data sets. Eighteen total background soil samples will be collected and analyzed by the same offsite laboratory utilized for analysis of survey unit samples from Site WR111.

5.3 Prepare Site for Survey Access

Site WR111 is located on federally-owned land and, therefore, approval from Hill AFB must be obtained before entering the site. Requests for site access will be submitted by EA prior to mobilization.

The site access agreement should include information relative to the following additional topics:

- Security concerns, locking of the facility, and key control, where applicable
- How grids, survey locations, and surface nomenclature may be marked (or not marked) on survey surfaces
- What may and may not be moved, repositioned, or dismantled in order to gain access for survey, and notification requirements for such
- Cleanliness needs for survey execution and responsibilities for achieving this level of cleanliness
- Coordination with Hill AFB personnel for utility mark-out via Red Stakes.

5.4 Establish Survey Location Reference System

An FSS reference coordinate system will be developed and installed early in the FSS process. Coordinates will be referenced to the State Plane Coordinate System (e.g., North American Datum 83 U.S State Plane meters). The reference coordinate system will be established such that the grid spacing satisfies the survey design requirements (and, therefore, the grid intersections correspond to the survey data point locations) for Class 1 and Class 2 SUs.

Measurement locations within Class 1 and Class 2 areas will also be placed on a triangular grid overlaid on the ground surface. The spacing of the grid in each area will depend upon the calculated area since the number of locations will not change.

A Geographic Information System (GIS) program will be used to lay a triangular grid with proper length spacing over the SUs. A random start point for the grid will be established using a computer-generated random coordinate set. The number of sample locations corresponding to the random grid will be determined using GIS.

Each survey will be 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 will be available onsite. Technicians will annotate copies of the base map with information relevant to the survey, as appropriate. Each survey will be assigned an SU number and date of collection.

At a minimum, the boundaries of the SU will be identified and clearly marked. Additionally, to facilitate the GWS, intermediate markings may be installed using pin flags to mark the start and end points of planned survey lines. The use of a GPS obviates the need for marking small grid intervals.

5.5 Number of Systematic Soil Samples

MARSSIM provides a method to determine the number of measurement locations required in a given SU. A minimum number of measurement locations are required in each SU to obtain sufficient statistical confidence that the conclusions drawn from the measurements are correct. The following subsections describe the bases for and derivation of the minimum required measurement locations per SU.

5.5.1 Estimation of Relative Shift

The minimum number of measurement locations required is dependent on the distribution of site residual radionuclide concentrations relative to the $DCGL_w$ and acceptable decision error limits (α and β).
The relative shift describes the relationship of site residual radionuclide concentrations to the $DCGL_w$ and is calculated using the guidance found in Section 5.5.2.3 of MARSSIM. The relative shift is calculated as follows:

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

where

$DCGL_w$	=	Derived Concentration Guideline Level over a wide area.
LBGR	=	Concentration at the lower bound of the gray region. The Lower Bound of the Grey Region (LBGR) is the concentration at which the SU has an acceptable probability of passing the statistical tests.
σ	=	An estimate of the standard deviation of the concentration of residual radioactivity in the survey unit (which includes real spatial variability in the concentration as well as the precision of the measurement system).

MARSSIM recommends that it may be reasonable to assume a sigma on the order of 30 percent, which is equivalent to a sigma value of 0.3 (NRC 2000). Using a $DCGL_w$ equal to an SOR of 1, an LBGR of 0.5 (half the $DCGL_w$), and a sigma equal to 0.3, the relative shift is calculated to be 1.67.

5.5.2 Determination of Systematic Samples (Number of Required Measurement Locations)

The WRS statistical test will be used to determine when SUs are suitable for release for unrestricted use, according to the DCGLs. The minimum number of systematic measurement locations required in each SU for the WRS statistical test can be determined using Table 5.3 in MARSSIM (NRC 2000). Section 4.6 establishes the acceptable decision errors for the SUs as $\alpha = \beta = 0.05$. Based on the relative shift established above and these decision errors, the estimated minimum number of required measurement locations is 15. MARSSIM recommends an additional 20 percent to protect against lost or unusable data. Therefore, a minimum of 18 sample locations is required in Class 1 SU and Class 2 SU, and the reference area.

5.5.3 Systematic Measurement Locations

Field personnel will mark the perimeter of each SU using GPS. Actual SU dimensions will be measured in the field and are contingent upon the extent of excavations performed in the course of remediation. These data will then be transferred into the GIS so that a triangular sampling grid can be established.
A random start point will be generated and systematic sample locations will be calculated in an equilateral

triangular grid pattern using the spacing given by the equation shown below (Equation 5-5 from MARSSIM).

$$L = \sqrt{\frac{A}{0.866 \times N}}$$

where

L = Triangular grid spacing for SU.
A = Area of SU.
N = Number of sample locations.

Measurement spacing results (L) using the equation above are presented in Table D-4. Site SU delineations, reference area, and Class 1 and Class 2 sampling locations are presented in Figure D-4. Actual sample locations will be calculated in the field based on SU size after remediation and will follow the same process as above.

After the systematic sample locations have been established and prior to sample collection, soil sample locations will be marked in the field. Table D-4 lists each SU by matrix type, area, number of samples to be collected in that SU, and the distance between each sample using a triangular grid pattern.

5.5.4 Determination of Biased Samples

Areas exceeding the investigation level will be investigated with hand-held instruments (Ludlum 44-20 NaI detectors) to locate the highest gross gamma activity. Biased samples will be collected within each SU at the location(s) GWS data and the hand-held instrument investigation data indicate elevated radioactivity. Additional biased (or focused) samples may be collected within each area that has historically been shown to have contamination or suspected to be contaminated. The number of biased locations will be determined by the Project Technical Team based on the actual survey results. Examples of where these biased samples may be taken are along the path of buried trenches.

5.6 Gamma Dose Rate Measurements

Gamma dose rate measurements will be performed at locations selected for MARSSIM statistical testing and at biased locations identified during scanning. At soil locations, dose rate measurements will be recorded prior to the collection of any soil samples. Gamma dose rate measurements will be performed to ensure worker safety and to identify unusual dose rate conditions. Gamma dose rate measurements will be performed as described in Section 4-3.

6.0 Data Processing

This section describes how project events and data will be retained for this FSS.

6.1 Field Log

Project data will be recorded in a Field Data Logbook (or other equivalent method of data record) and subsequently transferred to an electronic format. Field Data Logbook records shall be sufficient to allow data transfers to be reconstructed after the project is completed. The Project Manager or Field Site Manager is responsible for ensuring logbook(s) entries are completed appropriately, and in accordance with standard operating procedures. The Project Logbook will be reviewed at least weekly and any significant issues will be relayed to the Project Manager.

Each survey team will maintain a logbook to document their field activities. The following information, at a minimum, will be recorded:

- Instrument (e.g., meter/detector) serial numbers
- Names of field survey personnel
- Identification of area surveyed
- Description of large obstacles or geographic features that limit accessibility to the areas to be surveyed
- Notes regarding equipment performance (e.g., loss of satellite signal, technical malfunction, etc.)
- Notes regarding any issue related to the survey and requiring documentation.

Field Data Logbooks will be permanently bound and the pages will be numbered. Pages may not be removed from logbooks under any circumstances. All entries are to be made in blue or black ink. Entries shall be legible, factual, detailed, and complete and shall be signed and dated by the individual(s) making the entries. If a mistake is made, the error shall be denoted by placing a single line through the erroneous entry and initialing the deletion. Under no circumstances shall any previously entered information be completely obliterated. Use of whiteout in data logbooks is not permitted for any reason.

6.2 Project Logbook

All significant events that occur during this FSS shall be documented and retained for future reference. While many types of project events have specific forms on which they are documented, many events occur on a routine basis during survey field activities that must be documented as they occur. Additionally, project data transfers must also be recorded as they occur. To provide a practical means of capturing this information, a project logbook will be initiated upon project commencement.

Significant project events, including data transfers involving project electronic data, shall be recorded in the Project Logbook. Data transfers are defined as any transfer, download, export, copy, differential correction, sort, or other manipulation performed on project electronic data. Project Logbook records shall be sufficient to allow data transfers to be reconstructed after the project is completed. The Field Site

Manager shall be responsible for maintaining the Project Logbook and will review the Project Logbook at least daily to report significant issues.

The Project Logbook is considered a legal record and will be permanently bound and the pages will be pre-numbered. Pages may not be removed from the logbook under any circumstances. Entries shall be legible, factual, detailed, and complete and shall be signed and dated by the individual(s) making the entries. If a mistake is made, the individual making the entry shall place a single line through the erroneous entry and shall initial and date the deletion. Under no circumstances shall any previously entered information be completely obliterated. Use of whiteout in the Project Logbook is not permitted for any reason. Only one Project Logbook will be maintained. If a Project Logbook is completely filled, another volume shall be initiated. In this case, each volume shall be sequentially numbered.

6.3 Project Electronic Data

Much of this FSS will rely on data collected and stored electronically. Electronic data are subject to damage and/or loss if not properly protected. As such, all project electronic data shall be downloaded from their collection device (e.g., laptop computers, data loggers, etc.) on at least a daily basis. At the conclusion of each day's survey activities, the Field Site Manager shall back up all electronic data collected that day to appropriate removable media (e.g., compact disc, zip disk, or equivalent) and shall ensure the backup is removed from the site. Under no circumstances shall the backup be stored in the same location in which the original project electronic data are stored.

Data files shall be named according to a naming protocol designated by the Field Site Manager. No variations from this protocol shall occur without the prior concurrence of the Field Site Manager. During data download and transfer, the applicable data file name(s) shall be included in Project Logbook entries.

7.0 Data Evaluation and Interpretation of Survey Results

In accordance with MARSSIM guidance, a preliminary data review will be performed to identify patterns, relationships, and potential anomalies present in the survey data. In this review, basic statistics including the mean, standard deviation, maximum, and minimum values will be calculated for each SU. A graphical review of the data will be performed consisting of posting plots and histograms. Posting plots will be used to review the spatial independence of measurements within SUs, while histograms will be employed to review the overall symmetry of the data.

Once the data have been reviewed, systematic soil sample results for each SU will be compared to the respective $DCGL_W$. Due to the presence of multiple ROCs in the soil, the allowed soil concentration levels may be evaluated by employing the 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 at Site WR111 is calculated as follows:

$$\text{SOR} = \frac{\text{Ra - 226}_{\text{Conc}}}{\text{Ra - 226}_{\text{DCGLw}}} + \frac{\text{Th - 232}_{\text{Conc}}}{\text{Th - 232}_{\text{DCGLw}}} + \frac{\text{Th - 230}_{\text{Conc}}}{\text{Th - 230}_{\text{DCGLw}}}$$

where

^{226}Ra Conc = Measured activity concentration for ^{226}Ra.
^{232}Th Conc = Measured activity concentration for ^{232}Th.
^{230}Th Conc = Measured activity concentration for ^{230}Th.
^{226}Ra $DCGL_w$ = Site-Specific $DCGL_w$ for ^{226}Ra.
^{232}Th $DCGL_w$ = Site-Specific $DCGL_w$ for ^{232}Th.
^{230}Th $DCGL_w$ = Site-Specific $DCGL_w$ for ^{230}Th.

For every sample location within an SU where the SOR is greater than 1, the Net SOR for that sample location will be calculated. Net SOR considers the concentration of each radionuclide less its respective background concentration (as established by the reference area soil sample results) divided by the $DCGL_w$ established for the radionuclide, as follows:

$$\text{Net SOR} = \sum_i \left[\frac{(\text{Conc}_\text{i} - \text{B}_\text{i})}{DCGL_{Wi}} \right]$$

where

Conc_i = Concentration of ROC "i" present in the soil sample.
Bi = Average concentration of ROC "i" present in the reference area.
$DCGL_{wi}$ = $DCGL_w$ of ROC "i."

For each biased sample within an SU, individual measurement values that exceed the appropriate action level, an elevated measurement comparison ($DCGL_{EMC}$) is calculated as a release criteria. The $DCGL_{EMC}$ is the DCGL for residual radioactivity evenly distributed over a wide area ($DCGL_w$), modified using a correction factor (i.e., an area dose factor) to account for the difference in area and the change in dose or risk. An area dose factor "is the magnitude by which the concentration within the small area of elevated activity can exceed $DCGL_w$ while maintaining compliance with the release criterion" (NRC 2000). The

$DCGL_{EMC}$ is calculated as follows:

$$DCGL_{EMC} = DCGL_w \times \text{Area Factor}$$

For example, the action level for ^{226}Ra may be modified for a 1 square meter outdoor area using the area dose factor of 54.8 listed in MARSSIM Table 5.6, yielding a $DCGL_{EMC}$ of 109.6 pCi/g (i.e., [2.0 pCi/g] × [54.8]).

The Residual Radioactivity (RESRAD) computer code may be used to calculate the maximum allowable elevated concentrations pertaining to ROCs not listed in MARSSIM Table 5.6 (Illustrative Examples of Outdoor Area Dose Factors) based on SU size for small areas on an as-needed basis.

For every biased sample location within an SU where the Net SOR is greater than 1, an elevated measurement comparison is made.

Net SOR_{EMC} is calculated using the $DCGL_{EMC}$ as follows:

$$\text{Net } SOR_{EMC} = \sum_i \left[\frac{(\text{Conc}_i - B_i)}{DCGL_{EMC}} \right]$$

If the Net SOR results for all samples for an SU are less than 1, the SU meets the release criteria. If the Net SOR result for any sample in an individual SU is greater than 1, the SU does not meet the release criteria.

In addition to Net SOR data evaluation, comparison of reference area (background) radionuclide concentrations with SU concentrations will be performed using the two-sample WRS statistical test. This test is selected because the ROCs also occur naturally (i.e., background). The two-sample WRS statistical test assumes the reference area and SU data distributions are similar except for a possible shift in the medians. It should be noted that biased soil sampling results will be excluded during the WRS statistical test since they violate the random criteria used to establish systematic sampling locations.

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 reference area measurement is 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:

1. ***Null Hypothesis (H_0)***—The median concentration in the survey unit exceeds that in the reference area by more than the $DCGL_w$ versus the alternative.

2. ***Alternative Hypothesis (H_a)***—The median concentration in the survey unit exceeds that in the reference area by less than the $DCGL_w$

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

1. Reduce reference area and SU isotopic data to SOR using the first equation presented in this section.

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

$$Z_i = X_i + 1.0$$

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

$$N = m + n$$

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

5. Sum the ranks of the adjusted SOR from the reference area, W_r. Since the sum of the first *N* integers is $N(N + 1)/2$, one can equivalently sum the ranks of the SOR from the SU, W_s, and calculate

$$W_r = \frac{N(N+1)}{2} - W_s$$

6. Compare W_r with the critical value given in Table I.4 in MARSSIM for the appropriate values of *n*, *m*, and α. If W_r is greater than the tabulated value, then reject the H_0 that the SU exceeds the release criterion.

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8.0 Survey Quality Assurance/Quality Control

Activities associated with this FSSP shall be performed in accordance with written procedures and/or protocols to ensure consistent, repeatable results. Topics covered in project procedures and protocols may include proper use of instrumentation, QC requirements, equipment limitation, etc. Implementations of quality assurance measures for this FSSP are described herein.

8.1 Instrumentation Requirements

The Project Health Physicist is responsible for selecting the instrumentation required to complete the requirements of this FSSP. Only instrumentation approved by the Project Health Physicist will be used to collect radiological data. The Field Site Manager is responsible for ensuring individuals are appropriately trained to use project instrumentation and other equipment, and that instrumentation meets the required detection sensitivities. Instrumentation shall be operated in accordance with either a written procedure or manufacturers' manual, as determined by the Field Site Manager. The procedure and/or manual will provide guidance to field personnel on the proper use and limitations of the instrument.

8.1.1 Calibration Requirements

Instruments used during the FSS shall have current calibration/maintenance records kept onsite for review and inspection. The records will include, at a minimum, the following:

- Name of the equipment
- Equipment identification (model and serial number)
- Manufacturer
- Date of calibration
- Calibration due date.

Instrumentation shall be maintained and calibrated to manufacturers' specifications to ensure that required traceability, sensitivity, accuracy, and precision of the equipment/instruments are maintained. Instruments will be calibrated at a facility possessing appropriate NRC and/or Agreement State licenses for performing calibrations using National Institute of Standards and Technology (NIST) traceable sources.

8.2 Instrument Quality Control Source and Background Checks

The following subsections describe the techniques that will be used to evaluate accuracy and precision of measurements obtained with project instrumentation. Daily instrument response check data and calibration certificates for each instrument will be included in an appendix of the FSS.

8.2.1 Sodium Iodide Gross Gamma Systems

Ludlum Model 44-20 NaI gamma scintillation detectors (or equivalent) coupled to a Ludlum Model 2221 rate meter, equipped with RS-232 data download port coupled to Trimble Pathfinder Pro XRS/XH GPS, will be used to perform GWSs. Instruments will be calibrated at least annually at a facility possessing appropriate NRC and/or Agreement State licenses for performing calibrations using NIST-traceable standards.

Instruments will be response checked daily for QC by comparing the instrument response to a designated Cesium-137 (^{137}Cs) source. Response checks will consist of a 1-minute integrated count of the ^{137}Cs source positioned in a reproducible geometry (i.e., a jig). The acceptance criterion for these instrument response checks is within +/- 20 percent of the mean response generated using 10 initial source checks and 10 measurements of ambient background. A response check outside these criteria will be cause for evaluation of conditions (e.g., instrument operation, source/detector geometry). The response check will be repeated once prior to field use of that instrument. Instruments that fail the second response check will be removed from service. During daily response checks, instruments will be inspected for physical damage, battery voltage levels, current calibration, and erroneous readings.

Background checks will be performed daily for each instrument. These checks will be performed to monitor fluctuations in ambient gamma background that could impact the interpretation of the gross gamma measurements, not to monitor the performance of the instruments. The results of the background measurements will be recorded and presented on a control chart.

8.2.2 MicroRem Meter

A Bicron MicroRem tissue-equivalent scintillation detector or equivalent meter will be used to provide gamma dose rate information during performance of area radiation surveys. The instrument was calibrated at least annually by a facility possessing appropriate NRC and/or Agreement State licenses for performing calibrations using NIST-traceable standards.

Instruments will be checked daily for QC by comparing response to a designated ^{137}Cs source. Response checks will consist of exposing the instrument to a designated ^{137}Cs source positioned in a reproducible geometry and location. The acceptance criterion for these instruments is response within a +/- 20 percent of the mean response generated using 10 initial source checks and 10 measurements of ambient background. A response check outside these criteria is cause for evaluation of conditions (e.g., instrument operation, source/detector geometry). The response check is repeated once prior to field use of that instrument. Instruments that fail the second response check will be removed from service pending evaluation. During daily response checks, the instrument used to obtain radiological data will be inspected for physical damage, battery voltage levels, current calibration, and erroneous readings in accordance with Cabrera procedures.

8.2.3 Global Positioning System

GPS point features will be collected at the beginning and end of the day at a fixed location established at the beginning of the FSS. Results of these feature counts will be compared to the mean of a series of sequential initial positions. These data will be entered into a spreadsheet and examined to ensure no more than 1-meter variability occurs. A feature count outside these criteria is cause for notification of the Field Site Manager and evaluation of conditions prior to further counts and/or removal of the GPS from service. GPS units must pass a feature count prior to field use. During daily feature counts, GPS will also be inspected for physical damage, battery voltage levels and erroneous readings in accordance with standard operating procedures.

8.3 Quality Indicator Sample Measurements

As a part of project requirements, quality indicator samples (QIS) will be collected as part of field and laboratory QC measures and submitted to an offsite laboratory for analysis. The QIS will be used to evaluate the usability of data. The identity of duplicate QC samples is held blind to the analysts, and the purpose of these samples is to provide activity-specific, field-originated information regarding the homogeneity of the sampled matrix and consistency of the sampling effort. These samples will be collected (and/or analyzed by the offsite laboratory) with the primary environmental samples and equally represent the medium at a given time and location. QIS consist of the following types: laboratory control sample (LCS), field duplicate (FDUP), method blank (MB), MS/MSD, and tracer samples. They will be analyzed at a rate of 1 per 10 samples or per batch for each analysis performed. The following sections summarize QC processes that will be used to evaluate the usability of the sampling results.

8.3.1 Standard Traceability

Calibration/LCS standards must be traceable to a reliable source (e.g., NIST). The offsite laboratory utilizes a traceable reliable source (e.g., NIST, International Atomic Energy Agency) for calibration, daily QC, LCS, MS, and tracer evaluations.

8.3.2 Laboratory Control Sample

The purpose of the LCS is to monitor the accuracy of sample preparation and analysis. LCS evaluation was performed for ^{226}Ra, ^{230}Th and ^{232}Th. Preparation and analysis will be performed under the same conditions as a regular project sample. Three primary and one secondary acceptance criteria will be considered during this evaluation as follows:

1. The LCS concentration should be at 20 times the laboratory's Minimum Detectable Activity.
2. The MDC for the LCS should be less than the project specified Required Detection Limit.
3. The primary acceptance criterion for LCS percent recovery is 75-125 percent.
4. The secondary criterion for LCS is based on Z-statistics (Z_{LCS}) as follows:

$$Z_{LCS} = \frac{x - d}{\sqrt{u_c^2(x) + u_c^2(d)}}$$

where

x = Measured result from the spiked sample
d = Spike concentration added
$u_c(x)$ = Combined Standard Uncertainty (spike sample)
$u_c(d)$ = Combined Standard Uncertainty (spike).

The calculated Z_{LCS} statistic(s) should be between -1.96 and +1.96. Calculated Z_{LCS} within the performance range are considered acceptable. Calculated ZLCS outside the performance range require further evaluation.

8.3.3 Laboratory Duplicate/Replicates

The purpose of the laboratory duplicate/laboratory replicate (LDUP/LREP) is to monitor the precision of the analytical method, provided the sample is fully homogenized prior to preparation and analysis. For sample and LDUP/LREP result pairs, a Duplicate Error Ratio (DER), which is functionally equivalent to the normalized absolute difference, will be calculated by using the following equation:

$$DER = \frac{\left|(x_1 - x_2)\right|}{\sqrt{ku_c^2(x_1) + ku_c^2(x_2)}}$$

where

x_1 = First sample value (regular sample).
x_2 = Second sample value (duplicate sample).
$u_c(x_1)$ = Combined Standard Uncertainty (regular sample).
$u_c(x_2)$ = Combined Standard Uncertainty (duplicate sample).
k = Coverage Factor representing the 95 percent Uncertainty Level.

The calculated DER results will be compared to an acceptable performance range of from -1.96 to +1.96. Calculated DER results within the performance range are considered acceptable. Calculated DER results outside the performance range are investigated for possible discrepancies in analytical precision.

8.3.4 Matrix Spike

The purpose of the MS is to measure the effect of interferences from the sample matrix that will hinder accurate quantification by the instrument. One primary and one secondary acceptance criterion will be considered during this evaluation as follows:

1. The primary acceptance criterion for MS percent recovery is 75-125 percent.

2. The secondary criterion for MS is based on calculation of Multi-Agency Radiological Laboratory Analytical Protocols Z statistics (Z_{MS}) as follows:

$$Z_{MS} = \frac{x - x_o - d}{\sqrt{u_c^2(x) + u_c^2(x_o) + u_c^2(d)}}$$

where

x = Measured concentration from the spiked sample.
x_o = Measured concentration from the unspiked sample.
d = Spike concentration added.
$u_c(x)$ = Combined Standard Uncertainty (spiked sample).
$u_c(x_o)$ = Combined Standard Uncertainty (unspiked sample).
$u_c(d)$ = Combined Standard Uncertainty (spike).

The calculated Z_{MS} statistic(s) should be between -1.96 and +1.96. Calculated Z_{MS} outside the performance range require further evaluation.

8.3.5 Method Blank

The purpose of the MB is to monitor the presence of external sources of contamination for parameters of interest in the sample preparation and analysis process. The MB is a laboratory-generated sample of the same matrix as the analytical samples but in absence of the parameters of interest.

Primary Acceptance Criteria for MB are <MDC (95 percent Control Limit) or <1.96 $u_c^2(x)$. If either primary acceptance criterion is met, the MB is considered acceptable. When both primary criteria fail, a secondary MB acceptance evaluation will be performed by calculation of a Z-blank (Z_{BLANK}) statistic with Warning and Control Limits of +/-2sigma and +/-3sigma, respectively. The formula for calculation of the Z_{BLANK} is as follows:

$$Z_{BLANK} = \frac{x}{u_c^2(x)}$$

where

x = Reported MB result.
$u_c(x_1)$ = Combined Standard Uncertainty.

8.3.6 Tracer Yield

A tracer is defined as a radioactive isotope introduced into the sample preparation/analysis process that will behave chemically similar to the analyzed isotopes of interest. Tracers provide a means of evaluating chemical separation. The activity of the tracer detected at the end of analysis compared to that of the spiked amount is used to calculate the percent recovery. The acceptance range for tracer percent recovery is 20-110 percent.

8.3.7 Field Duplicate

The purpose of the FDUP/field replicate (FREP) is to monitor the precision of the entire sampling and analysis process, provided the sample is fully homogenized prior to preparation and analysis. The criteria selected for initial evaluation is the relative percent difference with an acceptance criteria of ≤ 50 percent and a formula presented as follows:

$$\%RPD = \left|\frac{(x_1 - x_2)}{0.5(x_1 + x_2)}\right| * 100$$

where

x_1 = First sample value (regular sample)
x_2 = Second sample value (field duplicate sample)

For FSS samples, samples that fail to meet primary acceptance criteria, the DER ratio will be calculated with an acceptance criterion of ≤1.96 by using the following equation:

$$DER = \frac{\left|(x_1 - x_2)\right|}{\sqrt{ku_c^2(x_1) + ku_c^2(x_2)}}$$

where

x_1	=	First sample value (regular sample).
x_2	=	Second sample value (field duplicate sample).
$u_c(x_1)$	=	Combined Standard Uncertainty (regular sample).
$u_c(x_2)$	=	Combined Standard Uncertainty (field duplicate sample).
k	=	Coverage Factor representing the 95 percent Uncertainty Level.

The purpose of the DER calculation in this case is to assess whether a discrepancy identified by the relative percent difference is primarily attributable to normal analysis uncertainties. Result uncertainty is not a consideration in the relative percent difference calculation. The calculated DER results will be compared to an acceptable performance criterion of ≤ 1.96. Calculated DER results within the performance range are considered acceptable. Calculated DER results outside the performance range are investigated for possible discrepancies in analytical precision.

9.0 Laboratory Analysis

Confirmatory FSS samples and QIS will be collected by Cabrera in support of the remediation efforts at Site WR111. Samples will be submitted to designated offsite laboratory, TestAmerica, and analyzed for Isotopic Thorium (^{230}Th and ^{232}Th) by EML HASL 300 Modified and ^{226}Ra by EPA 903.1 Modified. In accordance with MARSSIM, analytical techniques will provide a minimum detection level of 25 percent of the individual radionuclide DCGL for all primary contaminants, with a preferred target minimum detection level of 10 percent of the individual radionuclide DCGL. Table D-5 presents the target detection limits for each ROC.

In addition, following completion of remedial action, air filters from air monitoring stations will be sent to TestAmerica to analyze for gross alpha and gross beta.

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10.0 Final Site Survey Report

An FSS report will be prepared following the completion of the remedial action to show that the remedial action performed at the site meet the release criteria established for the site. The report will, at a minimum, contain the following information:

- A site map showing the GWS results, locations of elevated radiation levels, and sampling locations from each SU
- Tables of radionuclide concentrations in each sample from the reference area and each SU including but not limited to the results in pCi/g, measurement errors, detection limits, and sample depth.
- Summary statistics for analytical data and surface scan data from reference area and each SU
- A graphical display of individual sample concentrations using histograms for each SU and reference area for visual identification of trends
- Results of the WRS test.

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11.0 References

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TABLE D-1
Site-Specific Derived Concentration Guideline Levels
Appendix D: Final Status Survey Plan
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench, Hill Air Force Base, Utah

ROC	Receptor Specific Derived Concentration Guideline Levels (picoCuries per gram)		Site-Specific Derived Concentration Guideline Level (picoCurie per gram)
	Resident Farmer	**Airman**	
^{226}Radium	1.6	7.5	**1.6**
^{230}Thorium	4.3	135.2	**4.3**
^{232}Thorium	1.9	5.5	**1.9**

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TABLE D-2
Decision Errors
Appendix D: Final Status Survey Plan
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench, Hill Air Force Base, Utah

Error Type	Decision Error	Confidence Level
Type I Decision Error (α)	0.05	95 percent
Type II Decision Error (β)	0.05	95 percent

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TABLE D-3
Gamma Walkover Survey Sensitivity Assumptions
Appendix D: Final Status Survey Plan
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench, Hill Air Force Base, Utah

Detector Model No.	ROC[a]	Survey Speed (meters per second)	Background Count Rate (counts per minute)	Observation Interval (observations/ second)	Minimum Detectable Count Rate[b] (counts per minute)	Minimal Detectable Concentration (picoCuries per gram)
Ludlum 44-20	^{226}Ra	0.5	36,000	1	2,028	1.7
Ludlum 44-20	^{232}Th	0.5	36,000	1	2,028	1.3

NOTES:
a. ROC = radionuclide of concern
b. Assumes a surveyor efficiency of 50 percent. See Attachment A, Section A.5 and Attachment B, Section B.5 for derivations of these values.

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TABLE D-4
Survey Units
Appendix D: Final Status Survey Plan
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench, Hill Air Force Base, Utah

Survey Unit No.	Class	Matrix	Area (square meters)	No. of Samples
1	1	Soil	1,168	18
2	1	Soil	1,103	18
3	2	Soil	3,397	18

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TABLE D-5
Target Detection Limits
Appendix D: Final Status Survey Plan
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench, Hill Air Force Base, Utah

Radionuclide of Concern	**Maximum Detection Limit[a] (picoCurie per gram)**	**Target Detection Limits[b] (picoCurie per gram)**
^{226}Radium	0.8	**0.2**
^{230}Thorium	2.1	**0.4**
^{232}Thorium	0.9	**0.2**

NOTES:
a. Maximum detection limit = 50% of the DCGL
b. Target detection limit = 10% of the DCGL

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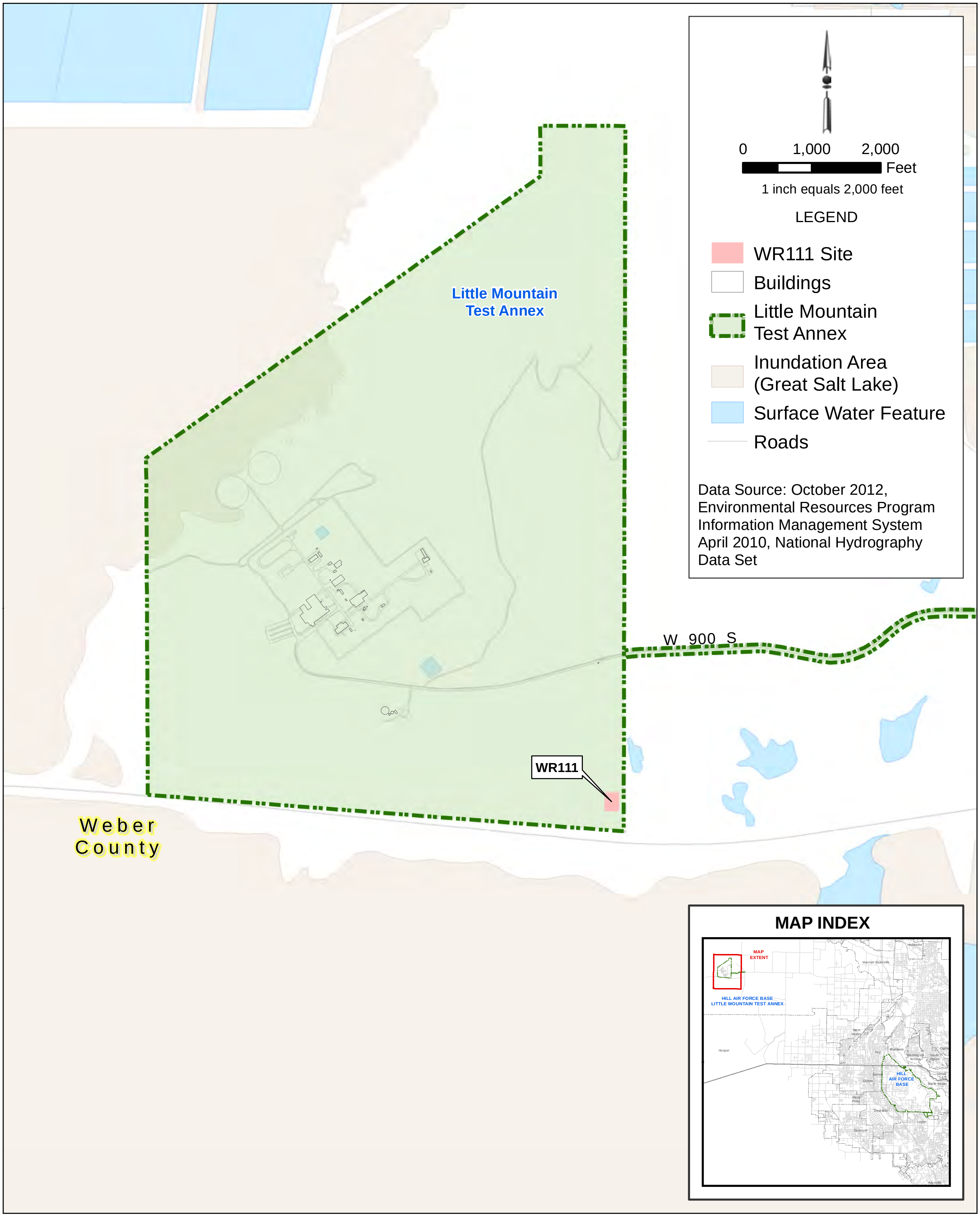

75th AIR BASE WING

FIGURE D-1
SITE LOCATION
WR111 DECOMMISSIONING PLAN
HILL AIR FORCE BASE, UTAH

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K:\arcgis\Cabrera GIS Projects\Hill AFB\MXDs\Figure D-2 - Site Layout.mxd 2/17/2014 K. Wheatley

0 50 100 200
Feet

1 inch = 200 feet

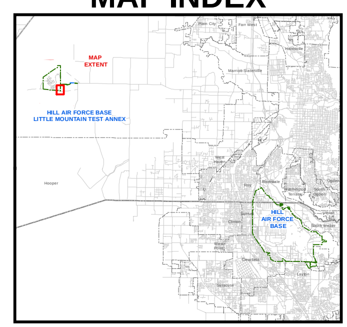
Legend

Approximate Property Boundary

WR111 Magnesium Thorium Disposal Trench

Aerial: 2012, The Utah Automated Geographic Reference Center
Data Source: October 2012, Environmental Resources Program Information Management System

MAP INDEX



75th AIR BASE WING

FIGURE D-2
SITE LAYOUT
WR111 DECOMMISSIONING PLAN
HILL AIR FORCE BASE, UTAH

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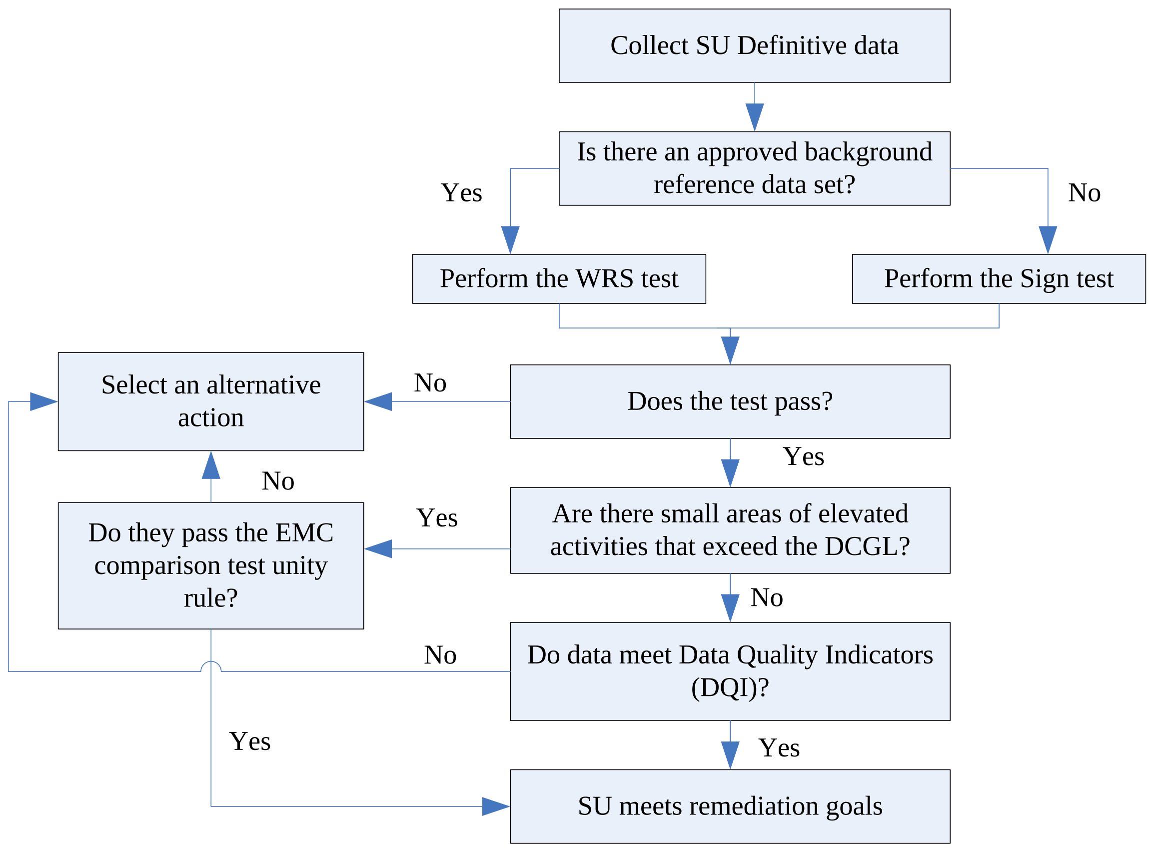
FIGURE D-3
Final Status Survey Decision Tree
Appendix D: Final Status Survey Plan
WR111 Little Mountain Test Annex Magnesium-Thorium Disposal Trench, Hill Air Force Base, Utah



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I:\GIS Projects\Hill AFB\MXDs\Figure D-4 - SUs and Sample Loc_050515.mxd 5/5/2015 K. Wheatley

FIGURE D-4
REFERENCE AREA AND SURVEY UNIT DELINEATIONS
WR111 DECOMMISSIONING PLAN
HILL AIR FORCE BASE, UTAH

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Attachment A
Ludlum 44-20 Sodium Iodide Detector MDC_{SCAN}
and
Instrument Sensitivity Results for Thorium-232
Calculated Using Microshield®

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Scan Minimum Detectable Concentration Calculation and Methodology

The methodology used to determine the sodium iodide (NaI) scintillation detector scan minimum detectable concentration (MDC) for thorium-232 (^{232}Th) is based on Nuclear Regulatory Commission (NRC) Guidance (NUREG) –1507, titled *MDCs with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions*, December 1997. Factors included in this analysis are the surveyor scan efficiency, index of sensitivity, the natural background of the surveyed area, scan rate, detector to source geometry, areal extent of the hot spot, and energy and yield of gamma emissions.

The computer code Microshield was used to model the presence of a normalized 1 picoCurie per gram (pCi/g) total thorium with its 50-year decay progeny in soil with the further assumption that the activity is uniformly distributed to a depth of 15 centimeters (cm) and spread over a disk shaped area with a diameter of 28 cm. The uncontaminated soil cover thickness has zero thickness (contamination on the surface) and there is a 0.051 cm aluminum shield simulating the cover of the NaI detector to complete the model source term. This model is consistent with the NUREG-1507 methodology and provides for a count rate to exposure rate ratio (cpm/µR/hr) to be calculated.

The following sections provide tabulated data based upon the NUREG-1507 methodology as applied toward the Ludlum 44-20 NaI scintillation detector used in this survey, zero thickness soil cover, and a 28 cm diameter soil uniformly contaminated to a 15 cm thickness. The dose point is centered over the contaminated disk of soil. Additional details and discussion describing the NUREG analysis methodology are described in that publication.

A.1 Fluence Rate to Exposure Rate (No Units)

The fluence rate to exposure rate (FRER) may be approximated by:

$$\text{FRER} \sim (1\ \mu\text{R/hr})/(E_\gamma)(\mu_{en}/\rho)_{air}$$

where

E_γ = Energy of the gamma photon of concern, keV
$(\mu_{en}/\rho)_{air}$ = The mass energy absorption coefficient for air, square centimeters per gram (cm^2/g)

and in tabular form in Table 1.

A.2 Probability of Interaction (P) through Detector End for a Given Energy

The probability, P, of a gamma ray interaction in the NaI scintillation crystal entering through the end of the crystal is given by:

$$\text{Probability (P)} = 1\text{-}e^{-(\mu/\rho)_{NaI}(X)(\rho_{NaI})}$$

where

$(\mu/\rho)_{NaI}$	=	The mass attenuation coefficient for NaI.
X	=	The thickness through the bottom edge (end facing the soil) of the Ludlum 44-20.3 × 3-inch NaI crystal, 7.6 cm.
ρ	=	The density of the NaI crystal, 3.67 g/cm^3.

and in tabular form in Table 2.

A.3 Relative Detector Response

The Relative Detector Response (RDR) by energy is determined by multiplying the relative fluence rate to exposure rate (FRER) by P of an interaction and is given by:

$$\text{RDR} = \text{FRER (Table 1)} \times \text{P (Table 2)}$$

and in tabular form in Table 3.

A.4 Determination of Counts per Minute per µR/hr as a Function of Energy

The equivalent FRER, P, and finally RDR may be calculated for a NaI Scintillation detector at the cesium-137 energy of 662 keV. Manufacturers of this equipment typically provide an instrument response in terms of cpm and µR/hr at the cesium-137 energy. This point allows one to determine the cpm per µR/hr and ultimately activity concentration and minimum detection sensitivity level in terms of pCi/g.

Based on measured counts in a known field, it is estimated that a typical Ludlum 44-20 NaI response is 2,700 cpm/µR/hr and, using the same methodology as shown in Tables 1, 2, and 3, the FRER, P, and RDR are calculated. The mass energy absorption coefficient for air and the mass attenuation coefficient for NaI are interpolated from tables in the Radiological Health Handbook, Revised Edition January 1970, Pages 139 and 140.

FRER	Energy$_\gamma$, keV	$(\mu_{en}/\rho)_{air}$, cm^2/g
0.0514	662	0.0294

and

Energy$_\gamma$, keV	$(\mu/\rho)_{NaI}$, cm^2/g	P
662	0.0780	0.89

and Cesium-137 RDR (662 keV) = 0.0455.

The detector response (cpm) to another energy is based upon the ratio of the RDR at an energy to the known Cs-137 energy RDR:

$$\text{cpm}/\mu\text{R/hr}, E_i = (\text{cpm}_{\text{Cs-137}}) \times (\text{RDR}_{\text{Ei}}) / (\text{RDR}_{\text{Cs-137}})$$
$$= (2{,}700) \times (\text{RDR}_{\text{Ei}}) / (\text{RDR}_{\text{Cs-137}})$$

and in tabular form in Table 4.

The measured reference area average count rate was 36,000 cpm using a Ludlum 44-20 NaI scintillation detector. Based on the measured reference area background cpm and an expected background exposure rate of 10 μR/hr, a count rate to exposure rate ratio of 1,800 - 900 cpm/μR/hr is calculated.

Finally, the count rate to exposure rate ratio for each of the thorium isotopes and progeny gamma emissions and their contribution to the total exposure rate may be computed using the output of the Microshield runs and the count rate to exposure rate ratios from Table 5.

A.5 Scan Minimum Detectable Concentration Value

The scan MDC is calculated using the NUREG-1507 methodology where the average number of background counts in a one second interval, b_i = cpm/60.

For the Ludlum Ludlum 44-20 NaI scintillation detector and the measured reference area background count rate of 36,000 cpm, the calculated background counts in the interval is:

$$b_i = (36{,}000 \text{ cpm}) / 60 = 600 \text{ counts}$$

The minimum detectable count rate, MDCR is:

$$\text{MDCR} = (d') \times (b_i)^{0.5} \times (60 \text{ second/1 minute})$$

Where d', equal to 1.38 from Table 6.1 of NUREG-1507, represents the rate of detections at a 95 percent true positive proportion with a false positive proportion of 60 percent, $b_{i,}$ equals 600 counts, is based on the reference area background counts in the interval, and 60 seconds/1 minute is a conversion factor:

$$\text{MDCR} = (1.38) \times \sqrt{600} \times (60 \text{ second/1 minute}) = 2028 \text{ cpm}$$

The MDCR for the surveyor is given as:

$$\text{MDCR}_{\text{surveyor}} = \text{MDCR}/(p)^{0.5}$$

where

p = Surveyor Efficiency, equal to 0.75 to 0.5 as given by NUREG-1507 (0.5 is chosen as a conservative choice):

$$\text{MDCR}_{\text{surveyor}} = 2028/0.707 = 2{,}868 \text{ cpm}$$

The Minimum Detectable Exposure Rate for the surveyor is obtained from the $\text{MDCR}_{\text{surveyor}}$ divided by the Table 5 weighted count rate to exposure rate value of 2361 cpm/μR/hr for thorium and its progeny is:

$$(2{,}868 \text{ cpm}) / (2{,}361 \text{ cpm}/\mu\text{R/hr}) = 1.215\ \mu\text{R/hr}$$

The scan MDC is then equal to the ratio of the Minimum Detectable Exposure Rate in the field to the exposure rate determined for the normalized 1 pCi/g concentration of total thorium:

$$\text{Scan MDC} = (\text{Normalized Th}_{\text{Total Conc}}) \times (\text{Exposure Rate}_{\text{Surveyor}})/(\text{Exposure Rate}_{\text{normalized Th conc}})$$
$$\text{Scan MDC} = (1\ \text{pCi/g}) \times (1.215\ \mu\text{R/hr})/(9.523\text{E-1}\ \mu\text{R/hr}) = 1.3\ \text{pCi/g}$$

A.6 Conclusion

The Ludlum 44-20 NaI Scintillation scan MDC, for ^{232}Th in 50-year equilibrium with progeny, being uniformly distributed in surface soil with dimensions of 28 cm diameter and 15 cm thick, is estimated to be 1.3 pCi/g.

TABLE 1

$Energy_{\gamma}$, keV	$(\mu_{en}/\rho)_{air}$, cm^2/g	FRER
40	0.064	0.3906
60	0.0292	0.5708
80	0.0236	0.5297
100	0.0231	0.4329
150	0.0251	0.2656
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214
3,000	0.0205	0.0163

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TABLE 2

Energy$_\gamma$, keV	$(\mu/\rho)_{NaI}$, cm^2/g	P
40	18.3	1.00
60	6.23	1.00
80	2.86	1.00
100	1.58	1.00
150	0.566	1.00
200	0.302	1.00
300	0.153	0.99
400	0.11	0.95
500	0.0904	0.92
600	0.079	0.89
800	0.0657	0.84
1,000	0.0576	0.80
1,500	0.0464	0.73
2,000	0.0412	0.68
3,000	0.0367	0.64

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TABLE 3

Energy, keV	FRER	P	RDR
40	0.3906	1.00	0.3906
60	0.5708	1.00	0.5708
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
150	0.2656	1.00	0.2656
200	0.1866	1.00	0.1865
300	0.1157	0.99	0.1141
400	0.0845	0.95	0.0805
500	0.0673	0.92	0.0619
600	0.0563	0.89	0.0501
800	0.0433	0.84	0.0363
1,000	0.0357	0.80	0.0286
1,500	0.0214	0.73	0.0155
2,000	0.0214	0.68	0.0146
3,000	0.0163	0.64	0.0104

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TABLE 4

Energy$_\gamma$, keV	RDR_{Ei}	Ludlum 44-20 3 × 3-inch Sodium Iodide Detector, Ei, cpm per μR/hr
40	0.3906	23161
60	0.5708	33842
80	0.5297	31404
100	0.4329	25667
150	0.2656	15748
200	0.1865	11059
300	0.1141	6766
400	0.0805	4775
500	0.0619	3672
600	0.0501	2970
662	0.0455	2700
800	0.0363	2154
1,000	0.0286	1693
1,500	0.0155	920
2,000	0.0146	865
3,000	0.0104	618

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TABLE 5

keV	MicroShield Exposure Rate, μR/hr (with buildup 1 picoCurie per gram ^{232}Thorium)	cpm/μR/hr	cpm/μR/hr (weighted)	Percent of Sodium Iodide Detector Response
40	3.940E-05	23161	1	0.0
60	6.276E-05	33842	2	0.1
80	7.070E-03	31404	233	9.9
100	1.804E-03	25667	49	2.1
150	2.121E-03	15748	35	1.5
200	4.115E-02	11059	478	20.2
300	3.238E-02	6766	230	9.7
400	4.014E-03	4775	20	0.9
500	2.958E-02	3672	114	4.8
600	8.056E-02	2970	251	10.6
800	1.051E-01	2154	238	10.1
1000	2.343E-01	1693	416	17.6
1500	7.503E-02	920	72	3.1
2000	2.120E-03	865	2	0.1
3000	3.370E-01	618	219	9.3
Total	9.523E-01		2361	100

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Attachment B
Ludlum 44-20 Sodium Iodide Detector MDC_{SCAN}
and
Instrument Sensitivity Results for Radium-226
Calculated Using Microshield®

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Scan Minimum Detectable Concentration Calculation and Methodology

The methodology used to determine the sodium iodide (NaI) scintillation detector scan minimum detectable concentration (MDC) for radium-226 (^{226}Ra) is based on Nuclear Regulatory Commission (NRC) Guidance (NUREG) –1507, titled *MDCs with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions*, December 1997. Factors included in this analysis are the surveyor scan efficiency, index of sensitivity, the natural background of the surveyed area, scan rate, detector to source geometry, areal extent of the hot spot, and energy and yield of gamma emissions.

The computer code Microshield was used to model the presence of a normalized 1 picoCurie per gram (pCi/g) ^{226}Ra with its 50-year decay progeny in soil with the further assumption that the activity is uniformly distributed to a depth of 15 centimeters (cm) and spread over a disk shaped area with a diameter of 28 cm. The uncontaminated soil cover thickness has zero thickness (contamination on the surface) and there is a 0.051 cm aluminum shield simulating the cover of the NaI detector to complete the model source term. This model is consistent with the NUREG-1507 methodology and provides for a count rate to exposure rate ratio (cpm/µR/hr) to be calculated.

The following sections provide tabulated data based upon the NUREG-1507 methodology as applied toward the Ludlum 44-20 NaI scintillation detector used in this survey, zero thickness soil cover, and a 28 cm diameter soil uniformly contaminated to a 15 cm thickness. The dose point is centered over the contaminated disk of soil. Additional details and discussion describing the NUREG analysis methodology are described in that publication.

B.1 Fluence Rate to Exposure Rate (No Units)

The fluence rate to exposure rate (FRER) may be approximated by:

$$\mathrm{FRER} \sim (1\ \mu\mathrm{R/hr})/(E_\gamma)(\mu_{en}/\rho)_{air}$$

where

E_γ = Energy of the gamma photon of concern, keV
$(\mu_{en}/\rho)_{air}$ = The mass energy absorption coefficient for air, square centimeters per gram (cm^2/g)

and in tabular form in Table 6.

B.2 Probability of Interaction (P) through Detector End for a Given Energy

The probability, P, of a gamma ray interaction in the NaI scintillation crystal entering through the end of the crystal is given by:

$$\text{Probability (P)} = 1\text{-}e^{-(\mu/\rho)_{NaI}(X)(\rho_{NaI})}$$

where

$(\mu/\rho)_{NaI}$	=	The mass attenuation coefficient for NaI.
X	=	The thickness through the bottom edge (end facing the soil) of the Ludlum 44-20.3 × 3-inch NaI crystal, 7.6 cm.
ρ	=	The density of the NaI crystal, 3.67 g/cm^3.

and in tabular form in Table 7.

B.3 Relative Detector Response

The Relative Detector Response (RDR) by energy is determined by multiplying the relative fluence rate to exposure rate (FRER) by P of an interaction and is given by:

$$RDR = FRER\ (\text{Table 6}) \times P\ (\text{Table 7})$$

and in tabular form in Table 8.

B.4 Determination of Counts per Minute per μR/hr as a Function of Energy

The equivalent FRER, P, and finally RDR may be calculated for a NaI Scintillation detector at the cesium-137 energy of 662 keV. Manufacturers of this equipment typically provide an instrument response in terms of cpm and μR/hr at the cesium-137 energy. This point allows one to determine the cpm per μR/hr and ultimately activity concentration and minimum detection sensitivity level in terms of pCi/g.

Based on measured counts in a known field, it is estimated that a typical Ludlum 44-20 NaI response is 2,700 cpm/μR/hr and, using the same methodology as shown in Tables 6, 7, and 8, the FRER, P, and RDR are calculated. The mass energy absorption coefficient for air and the mass attenuation coefficient for NaI are interpolated from tables in the Radiological Health Handbook, Revised Edition January 1970, Pages 139 and 140.

FRER	Energy$_\gamma$, keV	$(\mu_{en}/\rho)_{air}$, cm^2/g
0.0514	662	0.0294

and

Energy$_\gamma$, keV	$(\mu/\rho)_{NaI}$, cm^2/g	P
662	0.0780	0.89

and Cesium-137 RDR (662 keV) = 0.0455.

The detector response (cpm) to another energy is based upon the ratio of the RDR at an energy to the known Cs-137 energy RDR:

$$\text{cpm}/\mu\text{R/hr}, E_i = (\text{cpm}_{Cs\text{-}137}) \times (\text{RDR}_{Ei}) / (\text{RDR}_{Cs\text{-}137})$$
$$= (2{,}700) \times (\text{RDR}_{Ei}) / (\text{RDR}_{Cs\text{-}137})$$

and in tabular form in Table 9.

The measured reference area average count rate was 36,000 cpm using a Ludlum 44-20 NaI scintillation detector. Based on the measured reference area background cpm and an expected background exposure rate of 10 μR/hr, a count rate to exposure rate ratio of 1,800 - 900 cpm/μR/hr is calculated.

Finally, the count rate to exposure rate ratio for ^{226}Ra and progeny gamma emissions and their contribution to the total exposure rate may be computed using the output of the Microshield runs and the count rate to exposure rate ratios from Table 10.

B.5 Scan Minimum Detectable Concentration Value

The scan MDC is calculated using the NUREG-1507 methodology where the average number of background counts in a one second interval, b_i = cpm/60.

For the Ludlum Ludlum 44-20 NaI scintillation detector and the measured reference area background count rate of 36,000 cpm, the calculated background counts in the interval is:

$$b_i = (36{,}000 \text{ cpm}) / 60 = 600 \text{ counts}$$

The minimum detectable count rate, MDCR is:

$$\text{MDCR} = (d') \times (b_i)^{0.5} \times (60 \text{ second/1 minute})$$

Where d', equal to 1.38 from Table 6.1 of NUREG-1507, represents the rate of detections at a 95 percent true positive proportion with a false positive proportion of 60 percent, $b_{i,}$ equals 600 counts, is based on the reference area background counts in the interval, and 60 seconds/1 minute is a conversion factor:

$$\text{MDCR} = (1.38) \times \sqrt{600} \times (60 \text{ second/1 minute}) = 2028 \text{ cpm}$$

The MDCR for the surveyor is given as:

$$\text{MDCR}_{surveyor} = \text{MDCR}/(p)^{0.5}$$

where

p = Surveyor Efficiency, equal to 0.75 to 0.5 as given by NUREG-1507 (0.5 is chosen as a conservative choice):

$$\text{MDCR}_{surveyor} = 2028/0.707 = 2{,}868 \text{ cpm}$$

The Minimum Detectable Exposure Rate for the surveyor is obtained from the $\text{MDCR}_{surveyor}$ divided by the Table 10 weighted count rate to exposure rate value of 2428 cpm/μR/hr for ^{226}Ra and its progeny is:

$$(2{,}868 \text{ cpm}) / (2{,}428 \text{ cpm}/\mu\text{R/hr}) = 1.1813\ \mu\text{R/hr}$$

The scan MDC is then equal to the ratio of the Minimum Detectable Exposure Rate in the field to the exposure rate determined for the normalized 1 pCi/g concentration of total radium:

$$\text{Scan MDC} = (\text{Normalized Th}_{\text{Total Conc}}) \times (\text{Exposure Rate}_{\text{Surveyor}})/(\text{Exposure Rate}_{\text{normalized Th conc}})$$

$$\text{Scan MDC} = (1\ \text{pCi/g}) \times (1.1813\ \mu\text{R/hr})/(6.921\text{E-}1\ \mu\text{R/hr}) = 1.7\ \text{pCi/g}$$

B.6 Conclusion

The Ludlum 44-20 NaI Scintillation scan MDC, for ^{226}Ra in 50-year equilibrium with progeny, being uniformly distributed in surface soil with dimensions of 28 cm diameter and 15 cm thick, is estimated to be 1.7 pCi/g.

TABLE 1

Energy$_\gamma$, keV	$(\mu_{en}/\rho)_{air}$, cm^2/g	FRER
15	1.29	0.0517
20	0.516	0.0969
30	0.147	0.2268
40	0.064	0.3906
50	0.0384	0.5208
80	0.0236	0.5297
100	0.0231	0.4329
200	0.0268	0.1866
300	0.0288	0.1157
400	0.0296	0.0845
500	0.0297	0.0673
600	0.0296	0.0563
800	0.0289	0.0433
1,000	0.0280	0.0357
1,500	0.0255	0.0261
2,000	0.0234	0.0214

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TABLE 2

Energy$_{\gamma}$, keV	$(\mu/\rho)_{NaI}$, cm^2/g	P
15	47.4	1.00
20	22.3	1.00
30	7.45	1.00
40	19.3	1.00
50	10.7	1.00
80	3.12	1.00
100	1.72	1.00
200	0.334	1.00
300	0.167	0.99
400	0.117	0.96
500	0.0955	0.93
600	0.0826	0.90
800	0.0676	0.85
1,000	0.0586	0.80
1,500	0.0469	0.73
2,000	0.0413	0.68

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TABLE 3

Energy, keV	FRER	P	RDR
15	0.0517	1.00	0.0517
20	0.0969	1.00	0.0969
30	0.2268	1.00	0.2268
40	0.3906	1.00	0.3906
50	0.5208	1.00	0.5208
80	0.5297	1.00	0.5297
100	0.4329	1.00	0.4329
200	0.1866	1.00	0.1866
300	0.1157	0.99	0.1146
400	0.0845	0.96	0.0812
500	0.0673	0.93	0.0626
600	0.0563	0.90	0.0507
800	0.0433	0.85	0.0367
1,000	0.0357	0.80	0.0287
1,500	0.0261	0.73	0.0191
2,000	0.0214	0.68	0.0146

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TABLE 4

Energy$_{\gamma}$, keV	RDR_{Ei}	Ludlum 44-20 3 × 3-inch Sodium Iodide Detector, Ei, cpm per μR/hr
15	0.0517	3064
20	0.0969	5745
30	0.2268	13445
40	0.3906	23161
50	0.5208	30881
80	0.5297	31404
100	0.4329	25667
200	0.1866	11061
300	0.1146	6797
400	0.0812	4816
500	0.0626	3714
600	0.0507	3005
662	0.0455	2700
800	0.0367	2175
1,000	0.0287	1704
1,500	0.0191	1131
2,000	0.0146	867

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TABLE 5

keV	MicroShield Exposure Rate, μR/hr (with buildup 1 picoCurie per gram ^{226}Radium)	cpm/μR/hr	cpm/μR/hr (weighted)	Percent of Sodium Iodide Detector Response
15	0.000E+00	3064	0	0.0%
20	0.000E+00	5745	0	0.0%
30	0.000E+00	13445	0	0.0%
40	0.000E+00	23161	0	0.0%
50	7.508E-05	30881	3	0.1%
80	3.941E-03	31404	179	7.4%
100	3.566E-05	25667	1	0.1%
200	8.348E-03	11061	133	5.5%
300	2.616E-02	6797	257	10.6%
400	6.621E-02	4816	461	19.0%
500	3.887E-03	3714	21	0.9%
600	1.247E-01	3005	541	22.3%
800	3.177E-02	2175	100	4.1%
1000	1.283E-01	1704	316	13.0%
1500	1.084E-01	1131	177	7.3%
2000	1.903E-01	867	238	9.8%
Total	6.921E-01		2428	100%

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