FINAL

SITE-SPECIFIC ENVIRONMENTAL RADIATION MONITORING PLAN DONNELLY TRAINING AREA, FORT WAINWRIGHT, ALASKA ANNEX 1

FOR MATERIALS LICENSE SUC-1593, DOCKET NO. 040-09083

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ACRONYMS AND ABBREVIATIONS

ASR	Archives Search Report
bgs	Below Ground Surface
BRAC	Base Realignment and Closure Act
CD	Compact Disk
cfm	Cubic Feet per Minute
CFR	Code of Federal Regulations
CG	Commanding General
CoC	Chain-of-Custody
DGPS	Differential Global Positioning System
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DU	Depleted Uranium
ELAP	Environmental Laboratory Accreditation Program
ERM	Environmental Radiation Monitoring
ERMP	Environmental Radiation Monitoring Plan
GPS	Global Positioning System
HASL	Health and Safety Laboratory
ICP-MS	Inductively Coupled Plasma-Mass Spectroscopy
IMCOM	Installation Management Command
kg	Kilogram
m^2	Square Meters
mrem/y	Millirem per Year
mSv/y	MilliSievert per Year
NRC	U.S. Nuclear Regulatory Commission
ORAP	Operational Range Assessment Program
PAERMP	Programmatic Approach for Preparation of Site-Specific Environmental Radiation Monitoring Plans
QA	Quality Assurance
QC	Quality Control
RCA	Radiation Control Area
RESRAD	Residual Radiation
RSO	Radiation Safety Officer
SDZ	Surface Danger Zone
SML	Source Material License
SOP	Standard Operating Procedure
TA	Training Area
TEDE	Total Effective Dose Equivalent
U-234	Uranium-234
U-235	Uranium-235
U-238	Uranium-238
UFP-QAPP	Uniform Federal Policy for Quality Assurance Project Plan
UXO	Unexploded Ordnance

1.0 INTRODUCTION

This Site-Specific Environmental Radiation Monitoring Plan (ERMP) has been developed to fulfill the U.S. Army's compliance with license conditions #18 and #19 of the U.S. Nuclear Regulatory Commission (NRC) source material license (SML) SUC-1593 for the possession of depleted uranium (DU) spotting rounds and fragments as a result of previous use at sites located at U.S. Army installations. This Site-Specific ERMP is an annex to the Programmatic Approach for Preparation of Site-Specific ERMPs (PAERMP) (ML16004A369) (U.S. Army 2015) and describes the additional details related to Donnelly Training Area (TA) in Fort Wainwright, Alaska, in addition to those presented in the PAERMP.

1.1 PURPOSE

NRC issued SML SUC-1593 to the Commanding General (CG) of the U.S. Army Installation Management Command (IMCOM) authorizing the U.S. Army to possess DU related to historical training with the 1960s-era Davy Crockett weapons system at several installations nationwide. In order to comply with the conditions of the license, this Site-Specific ERMP has been developed to identify potential routes for DU transport and describe the monitoring approach to detect any off-installation migration of DU remaining from the use of the Davy Crockett weapons system at Donnelly TA. The installation will retain the final version of this Site-Specific ERMP. In accordance with license condition #19, the U.S. Army is required to implement fully this Site-Specific ERMP within 6 months of NRC approval. This Site-Specific ERMP and its implementation is then subject to NRC inspection. Table 1-1 summarizes the locations, media, and frequency of sampling described further in this Site-Specific ERMP.

Table 1-1. Recommended ERM Sample Location

Sample Location	Sample Media	Sample Frequency
Co-located surface water and sediment samples downstream (**SWS-01**) from the Georgia Range RCA, as shown in Figure 1-2 based on the rationale presented in Section 2.1	Surface water and sediment based on the programmatic rationale presented in the PAERMP and site-specific details presented in Section 2	Quarterly unless prevented by weather (e.g., frozen stream)

1.2 INSTALLATION BACKGROUND

Donnelly TA is a 631,324-acre installation located in interior Alaska, directly south of Delta Junction and 108 miles southeast of Fairbanks (Figure 1-1). The entire installation is operational and includes 124 ranges.

In 1942, an Army Air Corps Base (Station 17) was established at Donnelly TA during World War II, which was deactivated in 1945, reactivated in 1947, and transferred to the Department of the Army. In 1955, the installation was expanded and renamed Fort Greely in honor of Major Adolphus Greely. In 1995, Fort Greely was realigned under the Base Realignment and Closure Act (BRAC). During this time, the operational range area associated with Fort Greely was realigned, renamed Donnelly TA, and is now under the control of U.S. Army Alaska at Fort Wainwright.

The remaining portion of Fort Greely (6,805 acres), adjacent to Donnelly TA, is operated by the U.S. Army Space and Missile Defense Command in support of the Ground Based Midcourse Defense Joint Program Office. In addition to standard personnel training, Fort Greely was and continues to be used by the U.S. Air Force and U.S. Army for cold weather testing and training (EA 2009).

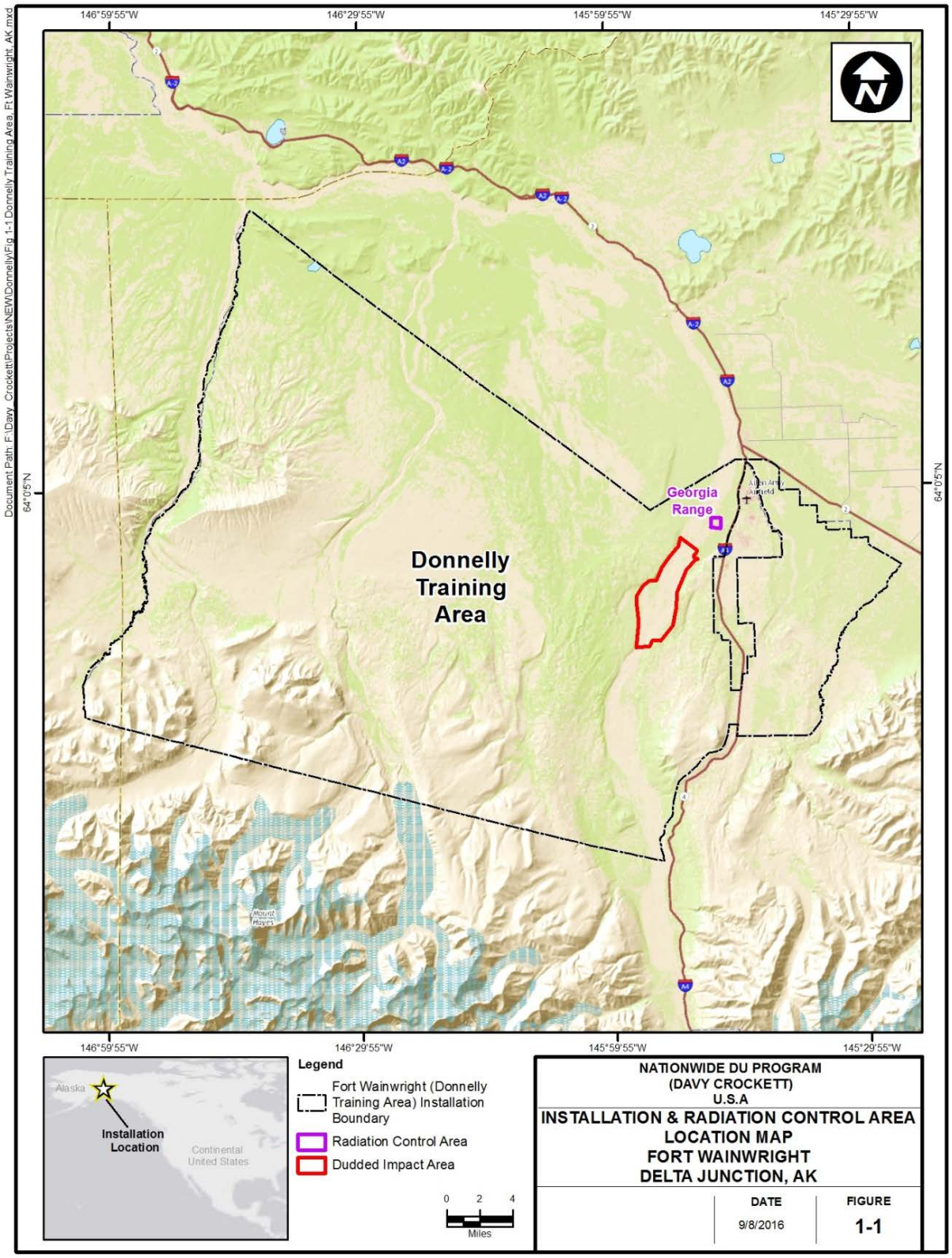

Figure 1-1. Installation and Radiation Control Area Location Map

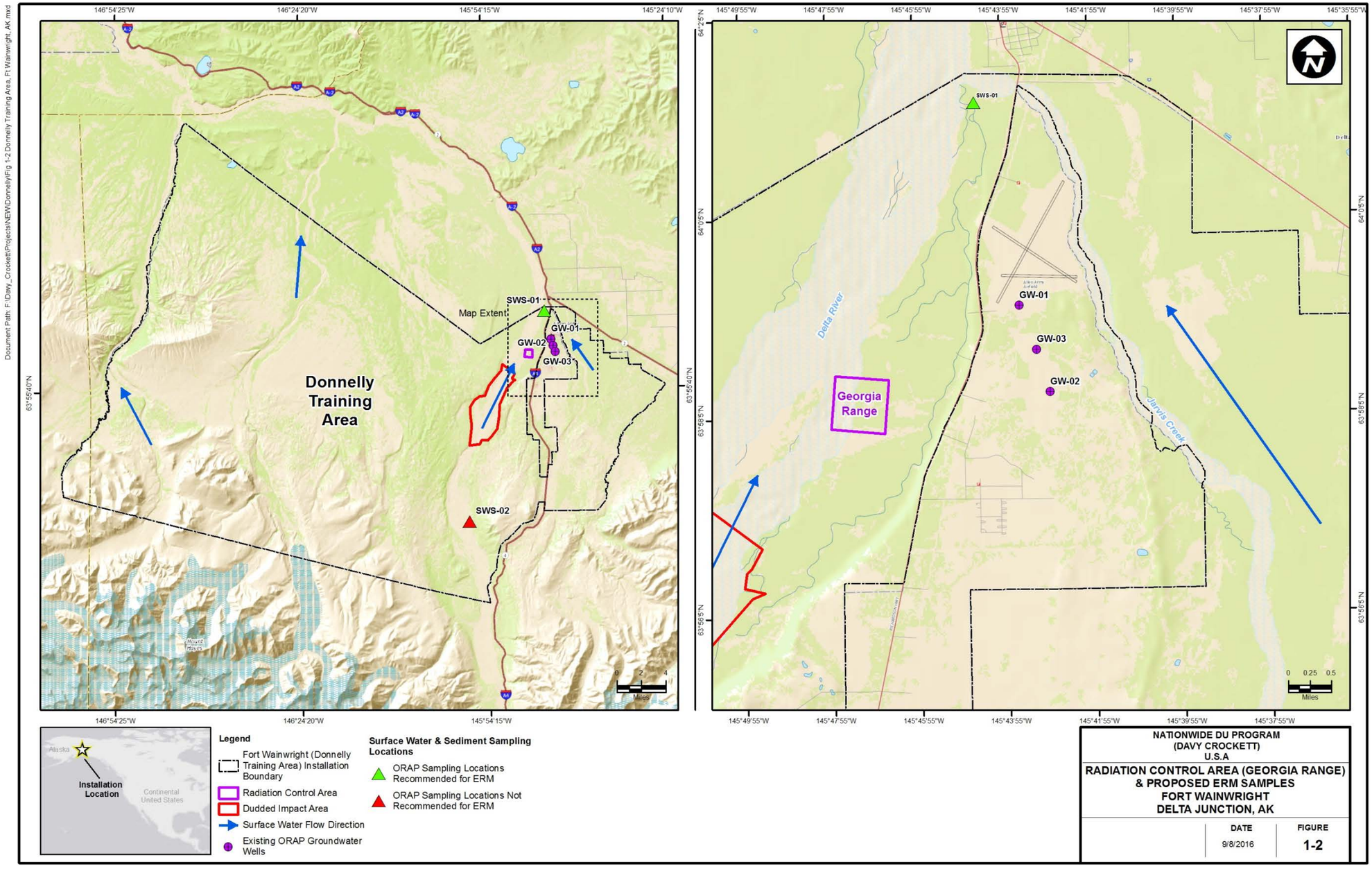

Figure 1-2. Radiation Control Area (Georgia Range) and Proposed ERM Samples

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An Archives Search Report (ASR) (USACE 2008) confirmed the presence of one range where the Davy Crockett weapons system was used at Donnelly TA. The historical Davy Crockett surface danger zone (SDZ) consists of 984 acres and was known as the Georgia Range (Figure 1-2). The nearest normally occupied areas to the Georgia Range or radiation control area (RCA) is the firehouse, which is located approximately 1.5 miles east to northeast of the RCA.

1.3 HISTORICAL INFORMATION

The M101 spotting round contains DU that was a component of the 1960s-era Davy Crockett weapons system. Used for targeting accuracy, the M101 spotting rounds emitted white smoke upon impact. The rounds remained intact or mostly intact on or near the surface following impact and did not explode. Remnants of the tail assemblies may remain at each installation where the U.S. Army trained with the Davy Crockett weapons system from 1960 to 1968. These installations include Fort Benning, Fort Bragg, Fort Campbell, Fort Carson, Fort Gordon, Fort Hood, Fort Hunter Liggett, Fort Jackson, Fort Knox, Fort Polk, Fort Riley, Fort Sill, Fort Wainwright (includes Donnelly TA), Joint Base Lewis-McChord (Fort Lewis and Yakima TA), Joint Base McGuire-Dix-Lakehurst (Frankford Arsenal Range), Schofield Barracks Military Reservation, and Pohakuloa TA.

The U.S. Army does not know if any cleanup or retrieval of these rounds or remnants has occurred at the Georgia Range; therefore, it is assumed that most, if not all, of the 20 kilograms (kg) of DU (SUC-1593) from the rounds fired remains in the RCA.

1.4 PHYSICAL ENVIRONMENT

Donnelly TA is situated in the Tanana-Kuskokwim Lowland and the northern foothills of the Alaska Range. The installation is bisected by the Delta River and the Richardson Highway, which generally follows the east bank of the Delta River. The topography of the installation is dominated by wide braided river channels of the Delta River, areas of elevated alluvial terraces, and glacial deposits east and west of the Delta River.

The installation is located in the Tanana River Basin, which drains approximately 44,000 square miles. The Tanana River flows northeast and receives discharge from the installation's main drainages. The installation can be divided into five sub-basins that drain northward, including the Little Delta River, Delta Creek, 100 Mile Creek, Delta River, and Jarvis Creek.

The area of the RCA in Donnelly TA is bisected and drained to the north into the Tanana River by the primary channels of the Delta River (Figure 1-2). The Delta River is a braided stream that originates in the Tangle Lakes on the south side of the Alaska Range. Surface water discharge rates measured on the Delta River, 1.8 miles south of Big Delta, indicate flows are highest in July (approximately 10,000 cubic feet per minute [cfm]) and lowest in October (approximately 24 cfm) (USACE 1996).

Groundwater in the vicinity of Donnelly TA is found in the generally highly permeable unconsolidated alluvial and glacial-fluvial sediments. The alluvial aquifer underlying the installation receives recharge from the Delta River and Jarvis Creek. The hydraulic gradient ranges from 0.001 to 0.004. Regionally, groundwater flows in a northeasterly direction from the Alaska Range toward the Tanana and Clearwater Rivers and Clearwater Lake. The water table becomes deeper, farther south, as it approaches the Alaska Range. Near Fort Greely, the water table is approximately 150 to 200 feet below ground surface (bgs) (EA 2009).

The Delta River is a losing surface water feature located in an area surrounding the RCA, which acts to recharge the groundwater system. Groundwater recharge is highly dependent upon the river conditions, which vary seasonally in accordance with freeze-thaw cycles. Water levels in installation wells, located near the Delta River, fluctuate in direct response to changes in seasonal recharge to the alluvial aquifer from river and stream channel losses, and precipitation. The rise in river level has been correlated with a staggered rise in groundwater level, indicating that the river and aquifer are hydraulically connected. Groundwater level fluctuation has been approximately 20 feet per year in the installation cantonment area. Typically, groundwater levels are their lowest in late May to early June (when recharge begins) and at their peak in September to October (when recharge ceases), in connection with the river ice break-up (snow melt) and the refreezing of the river, respectively.

1.5 EVALUATION OF POTENTIAL SOURCE-RECEPTOR INTERACTIONS

The transport of DU can be potentially completed along the identified pathways to human and/or ecological receptors. Specific details regarding the potential receptors for the Georgia Range at Donnelly TA are as follows:

- ***Surface Water Use***—No known use of surface water exists for consumption of drinking water downstream from Donnelly TA.
- ***Recreational Use***—There are no designated recreational use areas within 15 miles downstream from the installation. Fishing is limited downstream from the installation on the Delta River, Delta Creek, and Little Delta River due to the braided stream channels and silt-laden waters. Although human receptors are identified in the U.S. Army Operational Range Assessment Program (ORAP) Phase I assessment as being exposed via the food chain from off-range recreational fishing, evidence suggests that the limited uptake and bioaccumulation of metals, explosives, and perchlorate in fin fish do not pose a risk to humans when consumed at the recreational level.
- ***Sensitive Environments***—Sensitive environments on and around Donnelly TA include wetlands and watercourses designated as important for anadromous fish species.
- ***Habitat***—Approximately 68 percent of Donnelly TA is classified as wetland or open water. The most common wetland types include alpine tussock meadow and alpine wet low scrub, lowland wet low scrub and lowland tussock scrub bog, lowland wet forests, and riverine and lacustrine wetland complexes. The Tanana River is considered an important waterway for the spawning, rearing, and migration of anadromous fish species, which is within 15 miles downstream.
- ***Ecological Receptors***—There are currently no federally listed or state-listed threatened or endangered species identified on or around Donnelly TA. The Tanana River system is recognized as a critical habitat for anadromous Chinook and Chum salmon. Anadromous salmon spend periods of their lives in both saltwater and freshwater and utilize the river system for transit, rearing, and spawning.
- ***Groundwater Use***—Groundwater within 4 miles downgradient from the installation is used for public and private drinking water supply. There are numerous community and private wells surrounding Donnelly TA that rely on drinking water from the shallow unconsolidated alluvial aquifer. In addition, several potable drinking water wells, located downgradient from the installation, are utilized by Fort Greely.

Potential human receptors include those within Fort Greely and near Delta Junction relying on potential public and private wells within 4 miles downgradient from the RCA for potable water. Ecological receptors include sensitive environments (e.g., wetlands and anadromous fish habitat).

2.0 ERMP SAMPLE DESIGN

The PAERMP documented the conditions (i.e., "if-then" statements) for the sampling of each environmental medium to be used during the development of the Site-Specific ERMPs, and only environmental media recommended for sampling in the PAERMP are presented in the sections below. Per the PAERMP, no sampling will occur within the RCA or in the unexploded ordnance (UXO) areas (also referred to as Dudded Impact Areas). In addition, background/reference sampling is not required because the determination of DU presence will be based on an examination of the isotopic uranium ratios. The sampling approach and rationale for each medium for the Georgia Range at Donnelly TA are discussed in the following sections.

2.1 SURFACE WATER AND SEDIMENT

The surface water and sediment sampling approach will involve the quarterly collection of one collocated sample from a location downstream from the RCA near the property boundary of the Donnelly TA (Figure 1-2) where surface water flows throughout the year. If surface water is not flowing when a quarterly sampling event is planned (e.g., frozen stream, dry stream) or when sampling is too dangerous (e.g., rapid flow during flooding), no surface water samples will be collected during that event. Sediment samples will be collected on a quarterly basis unless sediment is inaccessible when a quarterly sampling event is planned (e.g., frozen stream, flooding).

The surface water and sediment sampling location at Donnelly TA was selected based on the surface water hydrology and potential for DU contribution and is located as follows:

- ***SWS-01***—The selected sampling point is located on the Delta River, downstream from the RCA at the installation's northern boundary and upstream of the confluence between the Delta River and Jarvis Creek. SWS-01 allows for relatively easy access and is located on the east river bank. It is located at the foot of an access road just south of Jarvis Creek.

Surface water and sediment samples will be analyzed for total/isotopic uranium using U.S. Department of Energy (DOE) Health and Safety Laboratory (HASL) method 300 (alpha spectrometry). Further details on analytical procedures and quality assurance/quality control (QA/QC) information are presented in Annex 19. When analytical sampling results from locations outside the RCA indicate that the uranium-238/uranium-234 (U-238/U-234) activity ratio exceeds 3.0, the U.S. Army will notify NRC within 30 days and collect additional surface water and sediment samples within 30 days of the notification to NRC, unless prohibited by the absence of the sampling media. The analytical samples displaying an activity ratio exceeding 3.0 will be reanalyzed using inductively coupled plasma-mass spectroscopy (ICP-MS) for their U-234, uranium-235 (U-235), and U-238 content to calculate the U-235 weight percentage specified in 10 Code of Federal Regulations (CFR) § 110.2 (Definitions) and then to determine if the sample results are indicative of totally natural uranium (at or about 0.711 weight percent U-235) or DU mixed with natural uranium (obviously less than 0.711 weight percent U-235).

Donnelly TA lies in a region with a subarctic climate that will likely prevent sampling on the PAERMP's specified quarterly interval. Due to Donnelly TA's unique weather conditions, including the existence of snow and ice accumulations greater than the national average (and subsequent flow in streams associated with spring thaw), samples will be collected every 3 months, if possible, depending on weather (e.g., time periods when streams are not frozen).

The recommended downstream sampling location, SWS-01, for the environmental radiation monitoring (ERM) and the upstream reference location, SWS-02, were sampled during the ORAP Phase II assessment in 2012 and analyzed for uranium in both surface water and sediment (U.S. Army 2014).

The range of U-238/U-234 activity ratios from the May, June, and September sampling events is presented in Table 2-1.

Table 2-1. U-238/U-234 Activity Ratios for Surface Water and Sediment Samples

Sample Location	Number of Samples	Observed Ratios*
Surface Water		
Downstream (SWS-01)	4	0.70-1.63
Reference (SWS-02)	4	0.53-0.98
Sediment		
Downstream (SWS-01)	3	0.93-1.26
Reference (SWS-02)	3	0.82-0.91

* The U-238 to U-234 activity ratio and the weight percent U-235 are used to determine whether a given sample is indicative of natural, depleted, or enriched uranium. U-238/U-234 activity ratios of 3.0 or less are representative of natural uranium, whereas higher ratios are potentially indicative of DU (NRC 2016).

2.2 GROUNDWATER

Groundwater samples collected during the ORAP Phase II assessment in June 2012 were analyzed for uranium (U.S. Army 2014). The results of the June 2012 sampling event are presented in Table 2-2. The existing groundwater monitoring wells are shown in Figure 1-2.

Table 2-2. U-238/U-234 Activity Ratios for Groundwater Samples

Sample Location	Number of Samples	Observed Ratios*
GW-01	2 (includes duplicate)	0.70-1.04
GW-02	1	1.36

* The U-238 to U-234 activity ratio and the weight percent U-235 are used to determine whether a given sample is indicative of natural, depleted, or enriched uranium. U-238/U-234 activity ratios of 3.0 or less are representative of natural uranium, whereas higher ratios are potentially indicative of DU.

Presently, no groundwater monitoring wells are located at or near the RCA. In addition, groundwater in the shallowest aquifer flows toward the river and the RCA is located on the river. Since surface water is known to recharge groundwater, any DU potentially present in surface water that could impact groundwater will likely be detected through surface water and sediment sampling. For these reasons and the additional rationale included in the PAERMP (U.S. Army 2015), groundwater sampling is not planned for Donnelly TA.

2.3 SOIL

If an area of soil greater than 25 square meters (m^2) eroded from an RCA is discovered during routine operations and maintenance activities, the U.S. Army will sample that deposit semiannually with one sample taken per 25 m^2 unless the soil erosion is located in a UXO area. The collection of ERM samples in UXO areas generally will not occur. Exceptions will occur only with documented consultation among the License Radiation Safety Officer (RSO), installation safety personnel, and range control personnel, who will advise the Installation Commander (i.e., they will prepare a formal risk assessment in accordance with U.S. Army [2014]). The Installation Commander will then decide whether to allow the collection. Otherwise, Donnelly TA does not meet any other criteria that would require soil sampling in accordance with the PAERMP (U.S. Army 2015).

Prior to mobilization, field sampling personnel will contact Range Control, the Installation RSO, or designee to determine if erosional areas within the RCA have been identified and, if so, sampled in accordance with requirements in Section 3.0 and Annex 19.

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3.0 ERMP METHODOLOGY

The sampling and laboratory analysis procedures to be utilized during the ERM are described below. These procedures provide additional details and required elements to support the Site-Specific ERMP and must be utilized in conjunction with the standard operating procedures (SOPs) during execution of ERM activities. This Site-Specific ERMP is to be used in conjunction with Annex 19, which addresses programmatic requirements associated with ERM sampling, such as chain-of-custody (CoC), packaging for shipment, shipping, collecting field QC samples (e.g., field duplicate samples), and documenting potential variances from sampling procedures. Annex 19 has been prepared in accordance with guidance from the Uniform Federal Policy for Quality Assurance Project Plan (UFP-QAPP) Optimized Worksheets (IDQTF 2012). All entry to Donnelly TA will be coordinated with the Fort Wainwright Installation Safety Office and Range Control prior to mobilizing for fieldwork.

Only a laboratory that the U.S. Department of Defense (DoD) Environmental Laboratory Accreditation Program (ELAP) has accredited for uranium analysis using both alpha spectrometry and ICP-MS methods will perform radiochemical analyses for the purposes of NRC license compliance. The U-238 to U-234 activity ratio and the weight percent U-235 are used to determine whether a given sample is indicative of natural uranium or DU. The laboratory will use alpha spectrometry to analyze samples for U-234 and U-238 activities in order to comply with license condition #17 in NRC SML SUC-1593. All samples with U-238/U-234 activity ratios exceeding 3.0 will be reanalyzed using ICP-MS for their U-234, U-235, and U-238 content to identify samples with DU content (NRC 2016). The ICP-MS results for U-234, U-235, and U-238 are summed to calculate a total mass of uranium present, which will be used to calculate the weight percentage of U-235 and then to determine if the sample results are indicative of totally natural uranium (at or about 0.711 weight percent U-235) or DU mixed with natural uranium (obviously less than 0.711 weight percent U-235). Additional details about the sampling and analysis to support this Site-Specific ERMP are included in Annex 19.

3.1 SURFACE WATER SAMPLING

A surface water sample will be collected from SWS-01 and submitted for laboratory analysis. The grab surface water sample will be collected using disposable equipment (e.g., tubing) or collected directly into sample containers. Details of the surface water sampling and the associated field procedures are provided in Annex 19.

Sampling activities, including documentation of the site conditions and the sample details, will be included within the field logbook. Following the sampling, each location will be surveyed with a differential global positioning system (DGPS) unit to identify the location with sub-meter accuracy and documented in the field logbook. Digital photographs will be taken during the sampling.

Once the sample is collected, the sample and all QA/QC samples will be shipped to the selected laboratory for analysis. Sample handling (i.e., labeling, packaging, and shipping) and CoC procedures will follow those detailed in Annex 19.

3.2 SEDIMENT SAMPLING

The collection of the sediment sample will coincide with the surface water sampling activities and consist of the compositing of at least 10 subsamples collected from various areas of the stream bed. Sediment samples will be collected in the shallow surface water locations from multiple braided channels using a clean, disposable plastic scoop. Sampling locations within the stream beds should be selected

where the surface water flow is low and/or deposition is most likely, such as bends in the creek as it changes direction. The sediment sampling procedure is as follows:

1. The individual performing the sampling will don clean gloves and prepare a disposable tray or sealable plastic bag and a plastic scoop.
2. Use a disposable scoop to remove the loose upper sediment uniformly from at least 10 subsample locations, starting downstream from the area to be sampled and moving upstream. Do not exceed 3 centimeters in depth into the sediment. Collect a sufficient quantity of sediment for QA/QC.
3. Place sediment into a disposable tray or sealable plastic bag (e.g., Ziploc®).
4. Remove rocks, large pebbles, large twigs, leaves, or other debris.
5. Remove excess water from the sediment. This may require allowing the sample to settle.
6. Thoroughly mix (homogenize) the sediment within the disposable tray or bag.
7. Fill the appropriate sample containers.
8. Mark the sample location with a stake and log its coordinates using a global positioning system (GPS) unit.
9. Collect digital photographs and document data in the field logbook.

Additional details on the sediment sampling and the field procedures are provided in Annex 19. Once samples are collected, the samples and all QA/QC samples will be shipped to the selected laboratory for analysis. Sample handling (i.e., labeling, packaging, and shipping) and CoC procedures will follow those detailed in Annex 19.

4.0 RESRAD CALCULATIONS

This section documents the dose assessment results for a hypothetical residential farmer receptor located on each RCA, as applicable, and for the same receptor scenario located at the nearest normally occupied area, respectively. The dose assessments were completed to comply with license condition #19 of SML SUC-1593.

The dose assessments were conducted using the Residual Radiation (RESRAD) 7.2 (Yu et al. 2016a) and RESRAD-OFFSITE 3.2 (Yu et al. 2016b) default residential farmer scenario pathways and parameters with the following exceptions:

- Nuclide-specific soil concentrations for U-238, U-235, and U-234 were calculated for each RCA by multiplying the entire mass of DU listed on the license for the installation (i.e., 20 kg) by the nuclide-specific mass abundance, the nuclide specific activity, and appropriate conversion factors to obtain a total activity in picocuries (Table 4-1). That total activity was then assumed to be distributed homogenously in the top 6 inches (15 cm) of soil located within the area of the RCA.

Table 4-1. Specific Activity and Mass Abundance Values

Nuclide	Specific Activity Ci/g	Mass Abundance[b] %
U-234	6.22×10^{-3}	3.56×10^{-4}
U-235	2.16×10^{-6}	0.0938
U-238	3.36×10^{-7}	99.9058
Depleted uranium[a]	3.6×10^{-7}	100

[a] 10 CFR 20, Appendix B, Footnote 3.
[b] Mass abundance calculations provided in Attachment 1.

- Non-default site-specific parameters applicable to both RESRAD and RESRAD-OFFSITE are listed in Table 4-2.
- Non-default site-specific parameters applicable only to RESRAD-OFFSITE are listed in Table 4-3.

4.1 RESRAD INPUTS

Table 4-2. Non-Default RESRAD/RESRAD-OFFSITE Input Parameters for Donnelly TA RCA

Parameter		Default Value	Donnelly TA Georgia Range	Justification or Source
Internal Dose Library		DCFPAK 3.02	FGR 11 & 12	Conservative dose coefficients for site contaminants
Contaminated Zone				
Soil concentrations (pCi/g)	U-234	N/A	1.97×10^{-3}	Site-specific calculation based on the DU mass listed in the NRC Materials License = DU mass × nuclide specific mass abundance[a] × nuclide specific activity[a] / (CZ area × CZ depth × CZ density)
	U-235	N/A	1.8×10^{-4}	
	U-238	N/A	0.03	
Area of contaminated zone (m^2)		10,000	1,000,000	One square kilometer
Depth of contaminated zone (m)		2	0.15	SML SUC-1593, Item 11, Attachment 5
Fraction of contamination that is submerged		0	0	Depth to groundwater is generally 178 to 260 ft bgs
Length parallel to aquifer flow (m)		100	1,000	Length of RCA is approximately 1,000 m
Contaminated zone total porosity		0.4	0.39	RESRAD Manual Table E-8 (DOE 2001) for Coarse Sand (Soil is loamy sand from web soil survey)
Contaminated zone hydraulic conductivity (m/y)		10	5,550	RESRAD Manual Table E.2 (DOE 2001) for Sand
Contaminated zone b parameter		5.3	4.05	RESRAD Manual Table E.2 (DOE 2001) for Sand
Average annual wind speed (m/s)		2.0	8.1	www.usa.com for Fort Wainwright, AK
Precipitation rate (annual rainfall) (m/y)		1.0	0.35	www.usa.com for Fort Wainwright, AK
Saturated Zone				
Saturated zone total porosity		0.4	0.39	RESRAD Manual Table E-8 (DOE 2001) for Coarse Sand
Saturated zone effective porosity		0.2	0.3	RESRAD Manual Table E-8 (DOE 2001) for Coarse Sand
Saturated zone hydraulic conductivity (m/y)		100	5,550	RESRAD Manual Table E.2 (DOE 2001) for Sand
Saturated zone b parameter		5.3	4.05	RESRAD Manual Table E.2 (DOE 2001) for Sand
Unsaturated Zone				
Unsaturated zone 1, thickness (m)		4.0	54	Depth to groundwater is generally 178 to 260 ft bgs
Unsaturated zone 1, total porosity		0.4	0.39	RESRAD Manual Table E-8 (DOE 2001) for Coarse Sand
Unsaturated zone 1, effective porosity		0.2	0.3	RESRAD Manual Table E-8 (DOE 2001) for Coarse Sand
Unsaturated zone 1, soil-specific b parameter		5.3	4.05	RESRAD Manual Table E.2 (DOE 2001) for Sand
Unsaturated zone 1, hydraulic conductivity (m/y)		10	5,550	RESRAD Manual Table E.2 (DOE 2001) for Sand

[a] See Table 4-1.

Table 4-3. Non-Default RESRAD-OFFSITE Input Parameters for Donnelly TA RCA

RCA Layout Parameter	Donnelly TA Georgia Range			
Distance to nearest normally occupied area (m)	3,200			
Bearing of X axis (degrees)	180 (east)			
X dimension of primary contamination (m)	1,000			
Y dimension of primary contamination (m)	1,000			
Location	X Coordinate		Y Coordinate	
	Smaller	Larger	Smaller	Larger
Fruit, grain, non-leafy vegetables plot	500	531.25	4300	4332
Leafy vegetables plot	500	531.25	4334	4366
Pasture, silage growing area	500	600	4516	4616
Grain fields	500	600	4366	4466
Dwelling site	500	531.25	4200	4232
Surface-water body	500	800	4616	4916
Atmospheric Transport Parameter				
Meteorological STAR file*	WA_SPOKANE.str			
Groundwater Transport Parameter				
Distance to well (parallel to aquifer flow)	3,200			
Distance to surface water body (SWB) (parallel to aquifer flow)	3,616			
Distance to well (perpendicular to aquifer flow)	0			
Distance to right edge of SWB (perpendicular to aquifer flow)	-150			
Distance to left edge of SWB (perpendicular to aquifer flow)	150			
Anticlockwise angle from x axis to direction of aquifer flow	0			

* RESRAD Offsite has no meteorological STAR files for Alaska or Hawaii. The selected STAR file is based on nearest available location. The inhalation pathway dose is insignificant to external and groundwater dose pathways.

4.2 RESULTS

Table 4-4 presents the dose assessment results. Figure 4-1 presents graphs of the dose assessment results over the evaluation period. The calculated site-specific all pathway dose for each RCA evaluated at Donnelly TA does not exceed 1.0×10^{-2} milliSievert per year(mSv/y) (1.0 millirem per year [mrem/y]) total effective dose equivalent (TEDE) and meets license condition #19 of SML SUC-1593.

Table 4-4. RESRAD-Calculated Maximum Annual Doses for Resident Farmer Scenario

RCA	Onsite[a] (RESRAD)	Offsite[b] (RESRAD-OFFSITE)
	Maximum Annual Dose (mrem/y)	
Donnelly Training Area Georgia Range	3.5×10^{-3}	1.6×10^{-3}

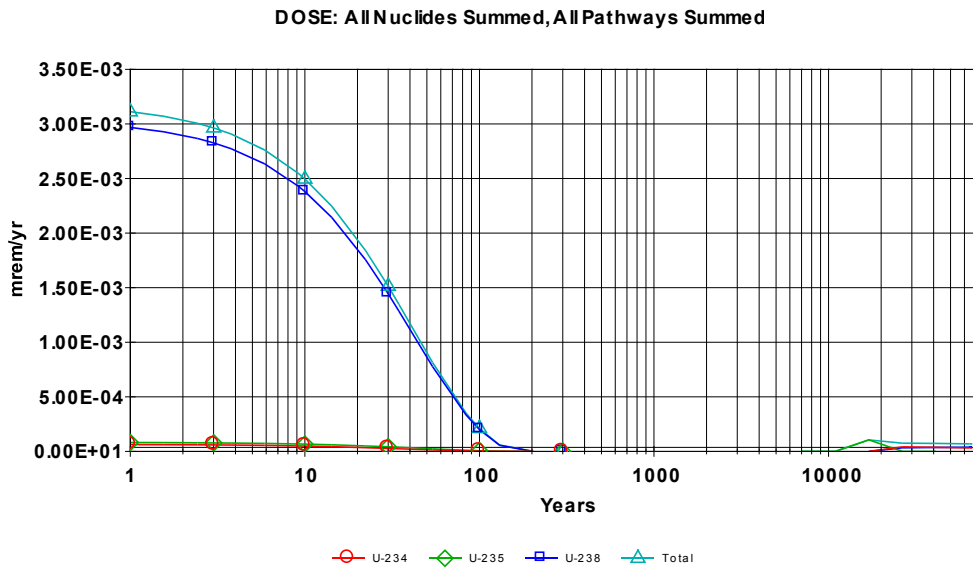
[a] The onsite residential farmer receptor resides on the RCA.
[b] The offsite residential farmer receptor resides off of the RCA, but within the installation, at the nearest normally occupied area.

RESRAD and RESRAD-OFFSITE output reports for each RCA are provided on the compact disk (CD).

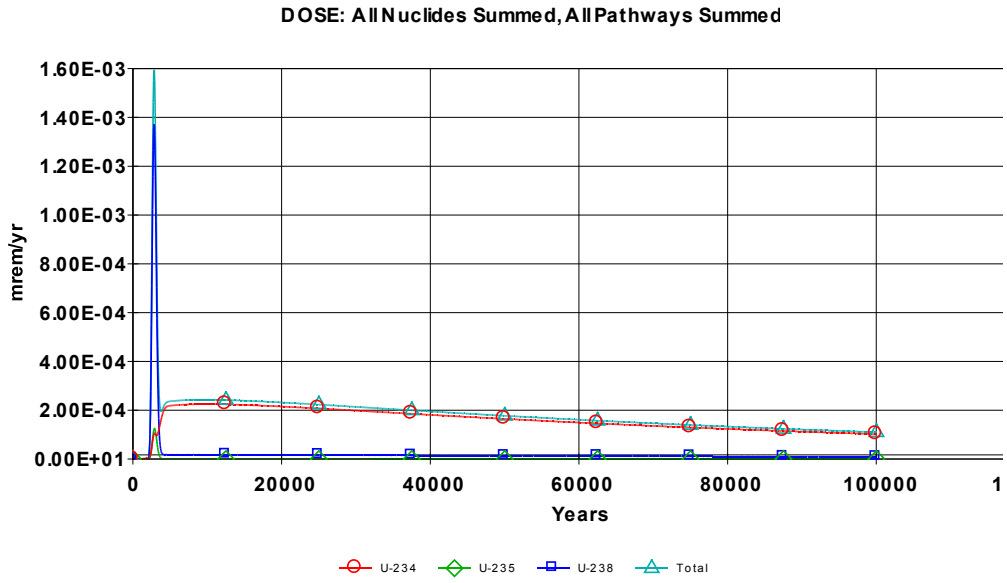
Figure 4-1. Residential Farmer Receptor Dose Graphs

Donnelly Training Area Georgia Range

RCA Onsite (RESRAD)



RCA Offsite (RESRAD-OFFSITE)



Attachment 1

Analysis of NRC's Default Value for Depleted Uranium Specific Activity

Analysis of NRC's Default Value for Depleted Uranium Specific Activity

Each of the values of the relative mass abundances for the naturally occurring uranium isotopes in the legacy Davy Crockett depleted uranium on Army ranges helps determine the source terms for RESRAD calculations, the performance of which is a license condition. This note shows how I estimated them using the NRC default value for the specific activity of depleted uranium.

The third footnote to the tables in Appendix B of Title 10, Code of Federal Regulations (CFR), Part 20, "Standards for Protection Against Radiation," says, "The specific activity for ... mixtures of U-238, U-235, and U-234, if not known, shall be: SA = 3.6E-7 curies/gram U for U-depleted." However, 10 CFR 20 does not describe how the NRC arrived at that value and I have not been able to learn this from NRC sources.

In general, the following equation provides the specific activity for a mixture of the three naturally occurring isotopes of uranium[1]:

$$S = \sum_i S_i \, a_i$$

S is the specific activity of the mixture of naturally occurring uranium isotopes, S_i is the specific activity for uranium isotope i, a_i is the relative molar mass abundance for uranium isotope i in the depleted uranium, and i denotes the uranium isotopes uranium-234 (^{234}U), ^{235}U and ^{238}U.

Rather than looking up each S_i in a table, I calculated them from fundamental values to maximize accuracy. By definition, the specific activity for a particular isotope S_i is the activity A_i per mass m_i for the isotope i. Also, by definition:

$$A_i = \lambda_i N_i$$

λ_i is the decay constant and N_i is the number of atoms of uranium isotope i in the sample with mass m_i. Thus,

$$S_i = \frac{\lambda_i N_i}{m_i}$$

λ_i is related to the half-life $t_{½i}$ as follows:

$$\lambda_i = \frac{\ln 2}{t_{½i}}$$

If N_i is set to Avogadro's number (N = 6.02 × 10^{23}),[2] then, by definition, m_i is the mass of a mole of isotope i, given by M_i, which is the atomic weight of isotope i with assigned units of grams. So,

$$S_i = \frac{N \ln 2}{t_{½i} M_i}$$

[1] Although contaminants, including ^{236}U, are possible, even likely, at levels less than parts per million, I am not including contaminants in these calculations nor in the RESRAD calculations because of their negligible impact on the results.

[2] In performing the calculations, I used all available significant digits in a spreadsheet. This note generally displays only two or three significant digits in the equations. Minor discrepancies in calculated results are due to round-off.

Values of the relative molar mass abundances, the half-lives, and the atomic weights for the naturally occurring uranium isotopes are available on a chart of the nuclides.[3] The following table contains data used in calculations below:

Table — Isotopic Properties

Isotope	Natural Relative Molar Mass Abundance	Half-life (s)	Molar Mass (g)	Specific Activity[4]	
				(Bq g^{-1})	(Ci g^{-1})
^{234}U	0.000054	7.75×10^{12}	234.04	2.30×10^{8}	6.22×10^{-3}
^{235}U	0.007204	2.22×10^{16}	235.04	7.99×10^{4}	2.16×10^{-6}
^{238}U	0.992742	1.41×10^{17}	238.05	1.24×10^{4}	3.36×10^{-7}

By definition:

$$1 = a_{\text{U-234}} + a_{\text{U-235}} + a_{\text{U-238}}$$

A second equation involves the ratio of $a_{\text{U-234}}$ to $a_{\text{U-235}}$ in depleted uranium. If $a_{0,\text{U-234}}$ is the natural relative mass abundance for ^{234}U and $a_{0,\text{U-235}}$ similarly for ^{235}U, then

$$a_{\text{U-234}} = a_{0,\text{U-234}} D_{\text{U-234}}$$
$$a_{\text{U-235}} = a_{0,\text{U-235}} D_{\text{U-235}}$$

$D_{\text{U-234}}$ is the depletion of ^{234}U in depleted uranium and $D_{\text{U-235}}$ similarly for ^{235}U, with

$$0 \text{ (complete depletion)} \leq D_i \leq 1 \text{ (no depletion)}$$

Kolafa[5] estimated the depletion of ^{234}U relative to the depletion of ^{235}U as follows:

$$D_{\text{U-234}} = (1 - 4\varepsilon)^n$$
$$D_{\text{U-235}} = (1 - 3\varepsilon)^n$$

ε is the single stage enrichment efficiency per the difference of the uranium isotope atomic mass number from the atomic mass number of ^{238}U and is much less than one. n is the number of enrichment stages.

For large n:

$$D_{\text{U-234}} \to e^{-4n\varepsilon}$$
$$D_{\text{U-235}} \to e^{-3n\varepsilon}$$

Eliminate the product $n\varepsilon$ by taking the logarithm of both equations:

$$\ln D_{\text{U-234}} = -4n\varepsilon$$
$$\ln D_{\text{U-235}} = -3n\varepsilon$$

[3] For example, see http://atom.kaeri.re.kr/nuchart/.
[4] 1 curie (Ci) = 3.7×10^{10} becquerels (Bq)
[5] http://www.ratical.org/radiation//vzajic/u234.html

So,

$$n\varepsilon = -\frac{1}{3}\ln D_{\text{U-235}}$$

Substituting for $n\varepsilon$

$$\ln D_{\text{U-234}} = \frac{4}{3}\ln D_{\text{U-235}}$$

Finally, exponentiating both sides of the equation,

$$D_{\text{U-234}} = D_{\text{U-235}}^{(4/3)}$$

So,

$$a_{\text{U-234}} = a_{0,\text{U-234}} D_{\text{U-235}}^{(4/3)}$$

Thus,

$$\begin{aligned} a_{\text{U-234}} &= (5.4 \times 10^{-5}) D_{\text{U-235}}^{(4/3)} \\ a_{\text{U-235}} &= (7.204 \times 10^{-3}) D_{\text{U-235}} \\ a_{\text{U-238}} &= 1 - (5.4 \times 10^{-5}) D_{\text{U-235}}^{(4/3)} - (7.204 \times 10^{-3}) D_{\text{U-235}} \end{aligned}$$

The NRC provides in 10 CFR 20:

$$S = 3.6 \times 10^{-7}\ \text{Ci g}^{-1}$$

Returning to the first equation above, then

$$\begin{aligned} &(6.22 \times 10^{-3}\ \text{Ci g}^{-1})(5.4 \times 10^{-5}) D_{\text{U-235}}^{(4/3)} + (2.16 \times 10^{-6}\text{Ci g}^{-1})(7.204 \times 10^{-3}) D_{\text{U-235}} \\ &\quad + (3.36 \times 10^{-7}\text{Ci g}^{-1}) \left[1 - (5.4 \times 10^{-5}) D_{\text{U-235}}^{(4/3)} - (7.204 \times 10^{-3}) D_{\text{U-235}}\right] \\ &\quad = 3.6 \times 10^{-7}\text{Ci g}^{-1} \end{aligned}$$

Dividing by 10^{-7} Ci g^{-1} and collecting terms,

$$3.36 D_{\text{U-235}}^{(4/3)} + 0.131 D_{\text{U-235}} - 0.239 = 0$$

Solving, $D_{\text{U-235}} = 0.13$, and[6]

$$\boxed{\begin{aligned} a_{\text{U-234}} &= 0.00000356 \\ a_{\text{U-235}} &= 0.00093806 \\ a_{\text{U-238}} &= 0.99905838 \end{aligned}}$$

[6] The values for ^{234}U and ^{235}U actually contain only one or two significant digits. I show more digits because I will use them in RESRAD calculations. Properly, the results should read $a_{\text{U-234}} = 0.000004$, $a_{\text{U-235}} = 0.0009$, and $a_{\text{U-238}} = 0.9991$. For comparison, typical isotopic abundances in depleted uranium according to the Department of Energy are $a_{\text{U-234}} = 0.000007$, $a_{\text{U-235}} = 0.0020$, and $a_{\text{U-238}} = 0.9980$ (DOE-STD-1136-2009), which corresponds to a specific activity of $S = 3.8 \times 10^{-7}$ Ci g^{-1}. I note that the derived DOE value for $D_{\text{U-234}}$ is 0.13, which is inconsistent with Kolafa's estimate calculated from the derived DOE value for $D_{\text{U-235}}$: $D_{\text{U-235}}^{(4/3)} = (0.28)^{(4/3)} = 0.18$.

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