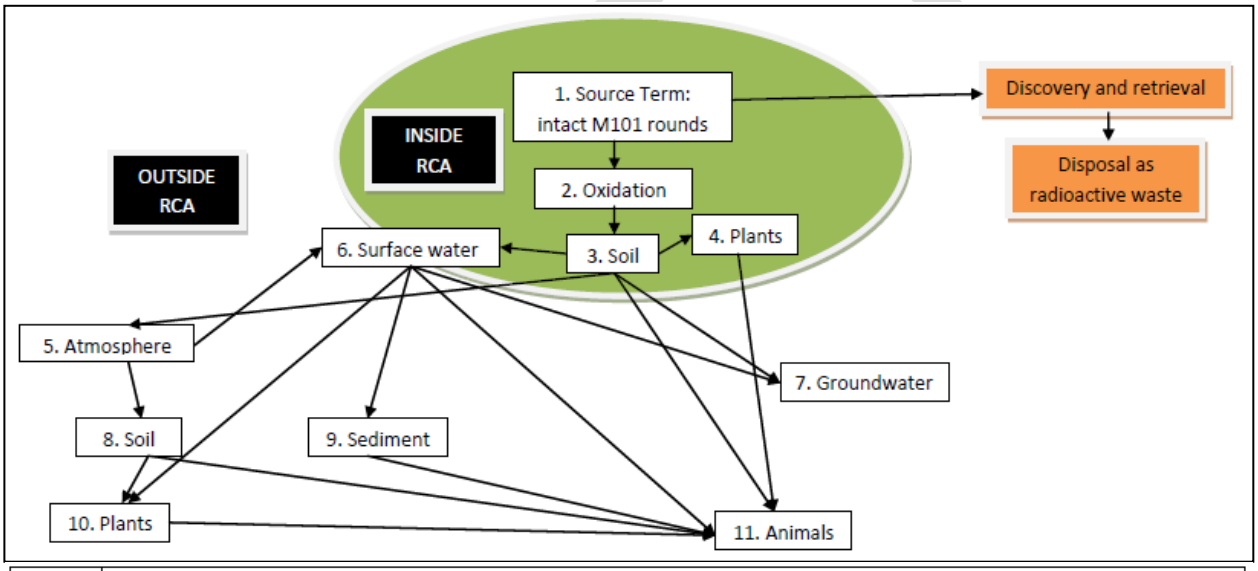
Programmatic Approach for Preparation of Site-Specific Environmental Radiation Monitoring Plans

1. Introduction

The purpose of a site-specific environmental radiation monitoring plan (ERMP) is to provide guidance about an environmental sampling program to detect M101 depleted uranium (DU) leaving the radiation controlled area (RCA). Specifically, the plan will describe, for a specific RCA, which samples will be taken, where these samples will be taken, how often these samples will be taken, and how these samples will be analyzed for depleted uranium.

Figure 1 shows generic environmental pathways (depicted by arrows) that DU could follow from inside the RCA (inside the shaded oval) to outside the RCA (outside the shaded oval). Rectangles inside the shaded oval depict media in which DU resides



Pathway	Comment
1→2	Rate of oxidation (corrosion) depends on environmental conditions in RCA
2→3	Oxidized uranium becomes part of soil matrix in immediate vicinity of M101 round in RCA
3→4	Plants in RCA uptake oxidized uranium
3→5	Soil windblown from RCA
3→6	Water flowing through RCA erodes soil and carries it outside RCA, or precipitation dissolves oxidized uranium and carries it to surface water flowing away from RCA
3→7	Precipitation dissolves oxidized uranium and seeps into groundwater
3→11 8→11	Animals ingest soil containing oxidized uranium
4→11 10→11	Animals ingest DU-affected plants (or animals ingest other animals that ingested DU-affected plants) and proceed outside the RCA
5→6	Windblown soil deposits on surface water outside RCA
5→8	Windblown soil deposits on soil outside RCA
6→7	Surface water with dissolved oxidized uranium seeps into groundwater
6→9	Surface water carrying oxidized uranium (in suspended soil or in solution) transfers it to sediment
6→10	Plants outside RCA and adjacent to stream uptake dissolved oxidized uranium
6→11	Animals drink surface water containing dissolved oxidized uranium
8→10	Plants outside RCA uptake soil containing oxidized uranium
9→11	Animals ingest sediment that contains oxidized uranium

Figure 1 Environmental Pathways for M101 depleted uranium leaving a radiation controlled area

inside the RCA. Rectangles outside the shaded oval depict potential sample media outside the RCA.

2. Principles

The Nuclear Regulatory Commission (NRC) has told the Army that the purpose of an ERMP is to provide sampling procedures to detect whether DU is leaving the RCA. Specifically, the NRC has said, "Environmental monitoring is used to determine if material is being released from a facility, in this case the range, which could potentially impact public health and safety or the environment. In developing ERMPs, it should not be assumed that DU is not being released from a facility. Rather, it is the implementation of the ERMP that will demonstrate whether the DU is being released from the facility. If the ERMP demonstrates that DU is not being released [*sic*][1] from a range or its environs only then could consideration be given to reduce or even eliminate the particular monitoring program." (Michalak 2010)

Although natural uranium is ubiquitous, DU, which is depleted in uranium isotopes uranium-234 (^{234}U) and uranium-235 (^{235}U) relative to natural uranium, does not occur in nature. Hence, background reference areas and background sampling is unnecessary.

Each ERMP will include a statement of license condition 24 (USNRC 2013), which says, "When analytical sampling results from locations outside of the Radiation Control Area indicate that the U-238/U-234 activity ratio exceeds 3, the licensee shall notify NRC within 30 days and collect additional environmental samples within 30 days of the notification of NRC, unless prohibited by the absence of the sampling media."

Each garrison named in the license will produce a site-specific ERMP following the guidance in this document. The ERMP will describe why each potential sample media is or is not being sampled, how many samples will be taken of each media, how often the samples will be taken,[2] where these samples will be taken, and why those locations were chosen.

The ERMP will include criteria for reduction or cessation of sampling (for example, no detection of DU in three consecutive years). However, the criteria must consider the likelihood that DU may migrate to that location in the future.

The ERMP will include the name and contact information for each radiochemistry laboratory used for analysis and a protocol for sampling each type of media.[3]

[1] Results of implementing an ERMP cannot demonstrate "that DU is not being released." The best they can show is that DU was not detected in the samples above certain levels.
[2] Samples at each location will be taken at least annually but should be taken more often (semiannually or quarterly) if seasonal variations are prevalent.
[3] The radiochemistry laboratory to which the samples will be sent can provide definitive information about how it wants the sample taken, packaged, and shipped.

The License Radiation Safety Officer and Army Environmental Command personnel will assist and guide the production of these ERMPs. The License RSO, in consultation with AEC personnel, will approve each site-specific ERMP before it becomes effective.

Each garrison named in the license will implement its site-specific ERMP upon License RSO approval. The NRC will inspect ERMPs and results of implementing ERMPs during its site inspections.

Garrisons are not in isolation regarding their ERMPs and sampling programs. The License RSO will identify "best practices" and provide them to all the M101-affected garrisons. Garrisons can obtain additional guidance from the Army Environmental Command, which has pledged to support license activities.

If results of sampling certain media over time for an RCA indicate that M101 DU is not migrating outside the RCA into that media, the License RSO may ask the NRC to relieve the Army from continued sampling of that media or to allow reduced sampling frequency of that media.

The garrison will bear all costs for preparation and implementation of the ERMP and for collection, shipping, and radiochemical analyses of the environmental samples.

This document cannot address every environmental circumstance at every installation. Local information and data should be incorporated in site-specific ERMPs. In particular, the Army Operational Range Assessment Program (ORAP 2013) has produced environmental data for many ranges.[4] The garrison should refer to relevant ORAP reports for its M101-affected ranges.

3. Inside the RCA

See Figure 1. Given the purpose of an ERMP, sampling will not usually be performed inside the RCA, with an exception below for plants [Potential sample media 4 Plants in RCA].

[1 Intact M101 rounds] The original source of DU contamination is intact M101 spotting rounds fired into an impact area, which is now an RCA. Upon impact, these rounds remained intact or mostly intact on or near the surface of the RCA. It is not known for any RCA, except for the RCA at Schofield Barracks, whether a cleanup or retrieval of these rounds ever occurred, so the assumption is that most, if not all, rounds fired into an RCA remain there in one form or another. The DU in these solid pieces generally is not available for transport within or outside of the RCA.

The Radiation Safety Plan, section 3.3, says, "…deliberate searches for and removal of DU are not authorized within an RCA except for explosive ordnance disposal (EOD) unexploded ordnance (UXO) blow-in-place activities …. However, unintended discovery of M101 DU debris in an RCA and its location will be reported immediately to the

[4] The License RSO has asked and ORAP has agreed to continue to produce environmental uranium data for its reports even when ORAP's protocols indicate that uranium should not be a contaminant of concern.

Garrison RSO. The Garrison RSO, in consultation with the EOD personnel and the License RSO, will determine whether it is more reasonable to pick up the DU and hold it for appropriate disposal … than it is to leave it in place."

Any M101 DU removed from the RCA in accordance with this guidance will be held for proper disposition as radioactive waste.

[Pathway 1 M101 rounds → 2 oxidation] The rate of corrosion (oxidation) of the DU in the DU-molybdenum alloy in the M101 rounds left in the environment is not known. This rate will depend on several factors such as annual precipitation, covered or not covered by soil, and soil acidity or alkalinity. A contractor working at Schofield Barracks in 2012 found both contaminated soil and solid DU fragments (Cabrera Services Inc. 2013).

An Army contractor working on the Jefferson Proving Ground decommissioning project for DU penetrators consisting of DU-tungsten-carbide alloy reported (SAIC 2013):

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> Corrosion of DU penetrators and subsequent dissolution of the corrosion products is the primary mechanism for introducing DU into the soil and for subsequent transport to the media (e.g., surface runoff to surface water and sediment). The rates of corrosion and dissolution were determined based on laboratory testing and field observations for conditions similar to those experienced by the DU penetrators at the DU Impact Area. Based on this information, the most likely time to complete corrosion and dissolution of a JPG penetrator was calculated to be approximately 107 years.

UNQUOTE

Although M101 spotting rounds and DU penetrators have different geometries and contain different DU alloys, it should be safe to assume from the above observations that not all of the M101 rounds have corroded completely since the Army fired them in the 1960s.

[2 Oxidation] Corrosion products initially will be on the surfaces of M101 rounds. Sampling of corrosion products in the RCA is unnecessary.

[Pathway 2 Oxidation → 3 Soil] Corrosion products are attached loosely to M101 round surfaces and gradually will leave those surfaces. Therefore, corrosion products will be present on and near the soil surface in an RCA.

[3 Soil] The contractor at JPG observed (SAIC 2013), "… each penetrator or portion thereof served as a point source rather than forming a homogeneous mixture of DU in site soils." Analysis (see appendix) of data obtained at Schofield Barracks during a characterization survey (Cabrera Services Inc. 2008) showed that DU contamination

Figure 2 Typical form of DU at Schofield Barracks (Cabrera Services 2008)

was concentrated in specific locations in the surveyed area and that the rest of the surveyed area was at background concentrations of natural uranium.

An Army contractor reported (Cabrera Services 2008), “The mobility and persistence of DU in the environment is influenced by the amount, form, and oxidation state of the metal, as well as by the composition and physicochemical properties of the affected media. In the metal form, DU tends to persist in the soil, and undergo few chemical changes other than oxidation due to weathering and exposure. [Figure 2] illustrates the appearance of Davy Crockett round fragments found at [Schofield Barracks]. Note the oxidized state (bright yellow) of the fragments. … The nature of the underlying soils, coupled with the relatively dry climate favors the retention and reduced solubility of metals, thereby reducing their mobility.”

Of course, the different conditions at other sites will result in different DU migration rates.

Durante and Pugliese wrote (Durante and Pugliese 2003), “… studies of radiological contamination in the soil from impacted DU rounds [in Bosnia in 1994 and 1995] suggest that dispersion and deposition are localized within 10 m from the hit target.”

The Director of the NRC's Office of Nuclear Material Safety and Safeguards provided a "Director's Decision" to a petitioner and wrote, regarding environmental sampling in Vieques, Puerto Rico (Kane 2001):

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> From May 29 to June 12, 2000, the U.S. Navy performed radiological surveys of the [Live Impact Area (LIA)]. … The surveys conducted by the U.S. Navy, and independently observed by the NRC, concluded that there were no elevated exposure rates or count rates indicative of radioactive contamination on areas of the LIA exclusive of the North Convoy Site, where the DU was fired during the February 19, 1999, incident. While observing the U.S. Navy survey activities between May 31 and June 12, 2000, the NRC staff also performed numerous surveys and collected soil samples. Soil samples were collected from the areas where DU penetrators had already been excavated. In addition, soil samples were collected downhill of areas known to have been impacted by the DU penetrators. … [A] purpose was … to determine whether the surrounding environment and members of the public had been exposed to DU.
>
> … The NRC Inspection Reports dated July 13, 2000, and September 28, 2000, document the performance and results of the environmental samples taken in June 2000. Copies of these reports are available in ADAMS (ML003767608 and ML003755565). The NRC samples demonstrated that there was no spread of DU contamination to areas outside of the LIA and that contamination from the DU inside the LIA was limited to the soil immediately surrounding the DU penetrators. With the exception of the soil samples taken from holes where the Navy had recovered DU penetrators, neither the direct measurement nor the environmental sample results identified the presence of radioactive materials exceeding those associated with naturally occurring radioactive materials routinely found in the environment.

UNQUOTE

A review of United Nations Environment Programme (UNEP) reports [(UNEP 2001) (UNEP 2002) (UNEP 2003)] (Papastefanou 2002) summarized those reports, "There was no detectable widespread contamination of the ground surface by depleted uranium. This was in such low levels that it cannot be detected or differentiated from the natural uranium existing in soil globally. Detectable ground surface contamination by depleted uranium is limited to areas around and below penetrators and the associated points of concentrated contamination."

Uyttenhove et al. reported on independent measurements in Kosovo (Uyttenhove, Lemmens and Zizi 2002) and wrote, "Based on our [minimum detectable activity (MDA)]-considerations (and the experimental confirmation with calibration samples), we can state with good confidence that there is no DU present at our 50 sampling points in Kosovo, with MDA values as low as 15 Bq [corresponding approximately to a milligram DU in a typical sample (100–150 g)]. Some samples, taken near places where DU-

ammunitions were used, have been re-examined very carefully with extra long measuring times (27.8 h), always with negative results."

The Air Force did not find DU outside range boundaries at Eglin Air Force Base, as an NRC staffer (Spitzberg 2005) wrote, "The licensee sampled the environs of the site as part of the site characterization process. Radioactive material in excess of the NRC-approved DCGLs was not identified offsite during recent site characterization studies suggesting that the DU material, a heavy metal, was not migrating outside of the site boundary."

The US Army Environmental Policy Institute wrote (USAEPI 1995), "Investigations of DU migration at U.S. test sites have not identified significant migration in the environment."

An Army contractor that has performed environmental monitoring for DU at Jefferson Proving Ground for many years has never detected DU in soil or sediment samples outside the DU impact area. Reports dating back to 2005 are available on the NRC ADAMS website.[5]

The US Department of the Army Soldier and Biological Chemical Command (USASSBC) took sediment samples at Jefferson Proving Ground and reported (USASSBC 2002), "Sediment samples were collected at the same locations where surface water samples were obtained during the scoping survey. The total uranium concentration in sediment samples ranged from 0.88 to 1.09 pCi/g within the DU Impact Area. Along the firing line trajectories, the total uranium concentration in sediment was measured at 2 and 3 pCi/g along two different streams south of the DU Impact Area. The U-238 to U-234 activity ratio in the sediment samples collected during the scoping survey indicates that the uranium is naturally occurring."

Also for Jefferson Proving Ground in 1995, an Army contractor (Scientific Ecology Group 1995) reported that all results of samples taken in the impact area showed U238-U234 ratios less than three.

The implication of the above is that M101 DU does not migrate readily in soil in many, if not almost all, cases.

Generic calculations (Cherry 2012) have shown that if in a typical RCA (a one-kilometer square) 1000 M101 DU rounds have completely corroded with the corrosion products completely dispersed in the top 15 centimeters of soil, the resulting uranium activity concentration in RCA soil would be about 0.3 picocurie of DU per gram of soil (pCi/g).[6] This value is scalable for different sizes of RCAs and different number of rounds.

Sampling of soil in the RCA is unnecessary. DU is expected to be in RCA soil.

[5] http://www.nrc.gov/reading-rm/adams.html

[6] According to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) the normal concentration of uranium in soil is 300 micrograms per kilogram to 11.7 milligrams/kilogram (0.1 pCi/g to 3.9 pCi/g) (UNSCEAR 1993).

[Pathway 3 Soil → 4 Plants in RCA] The following is an extract from Table 6.4 in Till and Grogan (Whicker and Rood 2008):

Table 1 Typical plant/soil concentration ratios for selected elements and crops, adapted from the International Atomic Energy Agency (IAEA 1994)

		Concentration Ratio (dry mass basis)	
Element	**Crop**	**Expected**	**Range (95%)**
Uranium	Cereal grains	0.001	
	Fruits, tubers	0.01	0.0008 to 0.14
	Grass	0.02	0.002 to 0.2

Some plants, such as lichens, are known to concentrate uranium in their tissues more than most plants do. For example, The USASSBC took vegetation samples at Jefferson Proving Ground and reported (USASSBC 2002), "Twenty vegetation samples were collected during the scoping survey using the same methods for soil sampling. Fourteen samples were obtained from within the DU Impact Area, and six samples were obtained along the firing line trajectories. The total uranium concentration in vegetation samples was less than 0.7 pCi/g in all samples. Two lichen samples from the south-central portion of the DU Impact Area had U-238 to U-234 activity ratios of 2.3 and 2.6, which indicate DU contamination."

The UNEP also detected DU in lichen in the three areas it surveyed [(UNEP 2001) (UNEP 2002) (UNEP 2003)]. According to UNEP, "This indicates that at least some of the penetrators at these sites hit hard targets and surfaces, partly aerosolized into dust, and dispersed into the air" (UNEP 2003). The M101 DU spotting rounds hit no such hard targets and surfaces, therefore no aerosolizing occurred.

The above indicates that plant uranium concentrations are expected to be no more than about two percent of soil uranium concentrations, except for plants such as lichens. However, plant uranium concentrations could be as high as about 20 percent of soil uranium concentrations.

[Potential sample media 4 Plants in RCA] Sampling of plants in the RCA is generally unnecessary. However, at least at one location (Fort Hood), the Army has allowed beef cattle to graze in the RCA. The ERMP for Fort Hood should include periodic sampling of the grasses that the cattle consume.

[Pathway 3 Soil → 6 Surface water in RCA] The most common forms of uranium oxide are U_3O_8 and UO_2. Both oxide forms are solids that have low solubility in water and are relatively stable over a wide range of environmental conditions (Argonne National Laboratory n.d.). Triuranium octaoxide (U_3O_8) is the most stable form of uranium and is the form most commonly found in nature. Uranium dioxide (UO_2) is the form in which uranium is most commonly used as a nuclear reactor fuel. At ambient temperatures, UO_2 will gradually convert to U_3O_8.

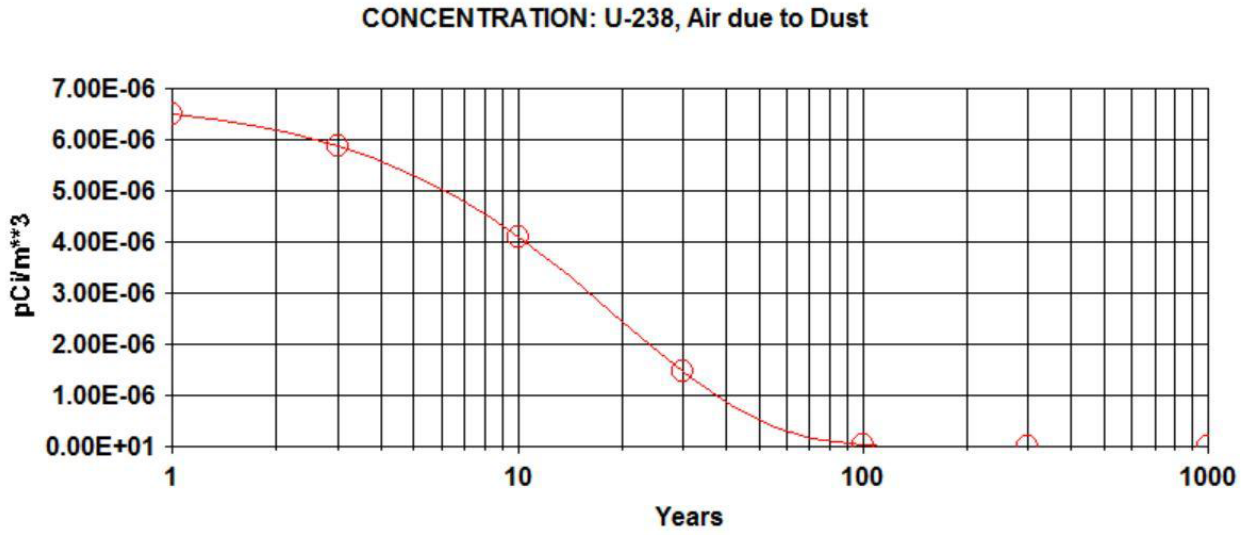

Figure 3 From RESRAD, ^{238}U concentration in air due to dust vs. time for 1000 M101 spotting rounds in a circular impact area of 10^6 m^2, resident farmer scenario (Cherry 2012)

[6 Surface water in RCA] Sampling of static surface water, such as water in a pond, entirely in the RCA is unnecessary.

4. Outside the RCA

[Pathway 3 Soil → 5 Atmosphere] Table 8.1 of National Council on Radiation Protection and Measurements Report (NCRP) No. 169 (NCRP 2010) provides a typical ambient ^{238}U concentration in air of 5×10^{-6} pCi/m^3.

Figure 3 (Cherry 2012) shows that, if DU from 1000 M101spotting rounds was evenly dispersed in surface soil over 10^6 m^2, RESRAD predicts a maximum ^{238}U air concentration of about 6.5×10^{-6} pCi/m^3, which is comparable to the ambient ^{238}U air concentration. However, rounds found on RCAs so far seem to be mostly intact with corrosion products in or on the soil in the immediate area adjacent to round. This implies that the expected ^{238}U soil concentration and, hence, the expected ^{238}U air concentration due to dust will be much less than the typical ^{238}U ambient air concentration.

The NRC did not require the Air Force to perform air sampling during DU remediation at a range at Eglin Air Force Base (Spitzberg 2005): "… perimeter sampling was only required at the discretion of the on-site radiation safety officer. The permittee planned to establish environmental controls to prevent erosion, to manage storm water runoff, and to minimize dust emissions. The permittee subsequently discontinued some of these environmental controls because reclamation activities had a minimal impact on the environment."

The NRC has never required the Army to perform air sampling at Jefferson Proving Ground since test operations ceased there in 1995. The NRC source materials license number SUB-1435[7] allows JPG to possess up to 80,000 kg of DU at a single site, which

[7] ADAMS ML073030415

is more than 14 times greater than the estimated total of all M101 DU at 14 Army installations.

The Army provided a contractor-prepared report to the NRC (Shia 2005),[8] which said "The assessments at [Jefferson Proving Ground], [Los Alamos National Laboratory], and [Aberdeen Proving Ground], among other sites indicate that risks associated with potential transport of DU in the air from controlled burns are negligible. The benefit/cost ratio of an air sampling program is extremely low (i.e., the benefits are small and the costs of the program high). Therefore, an air monitoring program is not recommended given the low probability of DU release and transport and the negligible effects on receptors."

The Enewetak Cleanup Project (1977-1980) was a joint DOD-Department of Energy (DOE) project to remove debris and radioactive contamination (mostly uranium and plutonium, not fission products) from the islands and lagoon of the atoll. Since both are actinides, uranium and plutonium behave similarly in the environment. The DOD operated air samplers whenever contaminated soil movements were underway. The report of the project (Defense Nuclear Agency 1981)concluded, "Throughout the cleanup project, over 760,000 cubic meters of air were sampled on the controlled islands plus more than 211,000 cubic meters at Lojwa. Nearly 5,200 air samplers [sic] filters were analyzed by the lab. No significant airborne radioactivity of any type (including beta) was detected. It is clear from these results – as it was from resuspension experiments performed during early [Radiation Safety Advisory and Inspection Team] visits to the atoll – that the Enewetak contamination situation was not conducive to creation of a resuspension hazard."

The Environmental Protection Agency (USEPA 2006) says, "The amount of uranium in the air is usually very small and effectively insignificant for remedial operations. … The high density of DU in most particulate forms limits the air transport of DU to relatively small particles. … It is reported that most of the DU dust will be deposited within a distance of 100 meters from the source."

[Potential sample media 5 Atmosphere] Air sampling is generally unnecessary. Remedial actions, discussed above and which did not produce significant air concentrations, are not underway at any RCA.

However, the above discussion does not address detonations of high explosives (HE) in the RCA. The NRC expects the Army to produce acceptable air sampling data before it will permit routine HE fire into an RCA. Therefore, before any HE fire will occur into an RCA, the Army will produce an air sampling plan acceptable to the NRC. After performance of the air sampling during HE fire, the Army will submit a report of the results to the NRC for NRC approval. This process will continue until the NRC permits HE fire without air sampling.

[8] ADAMS ML070090201

[Pathway 3 Soil → 6 Surface water flowing from the RCA] The most common forms of uranium oxide are U_3O_8 and UO_2. Both oxide forms are solids that have low solubility in water and are relatively stable over a wide range of environmental conditions (Argonne National Laboratory n.d.). Triuranium octaoxide (U_3O_8) is the most stable form of uranium and is the form most commonly found in nature. Uranium dioxide (UO_2) is the form in which uranium is most commonly used as a nuclear reactor fuel. At ambient temperatures, UO_2 will gradually convert to U_3O_8.

[Pathway 5 Atmosphere → 6 Surface water] As discussed above, "The amount of uranium in the air is usually very small and effectively insignificant [even] for remedial operations" (USEPA 2006). Therefore, transfer from the atmosphere to surface water outside the RCA is also "effectively insignificant."

[Pathway 6 Surface water in RCA → 6 Surface water outside the RCA] The DU concentration in surface water outside the RCA that has flowed from the RCA should be about the same as that the concentration in the flowing water at the RCA boundary.

[Potential sample media 6 Surface water] Sampling of surface water that has flowed from the RCA may be considered but the low solubility of uranium in water and the low concentration of DU in soil in the RCA make it improbable that DU will be detected. A slow flow rate makes detection more likely.

[Pathway 3 Soil → 7 Groundwater] The DU concentration in groundwater depends on several factors, including distance of the groundwater from the soil surface, leachability of the DU through the soil, acidity/alkalinity of the soil and leaching water, amount of precipitation, and so on. Most of the influencing factors for this pathway have not been measured for any RCA.

[Pathway 6 Surface water → 7 Groundwater] the low solubility of uranium in water and the low concentration of DU in soil in the RCA make it improbable that surface water contributions to DU in groundwater are significant.

[Potential sample media 7 Groundwater] The sampling of groundwater should be considered. However, only existing wells that could be influenced by DU in the RCA should be used for sampling. No new wells should be created because the cost-benefit ratio is highly unfavorable.

All measurements of groundwater for uranium with the purpose of meeting Safe Drinking Water Act requirements will be made available for NRC review upon request.

[Pathway 5 Atmosphere → 8 Soil] Since the atmosphere is unlikely to carry more than barely detectable amounts of DU from inside to outside the RCA, this pathway will contribute negligible amounts to soil outside the RCA.

[Potential sample media 8 Soil] Soil sampling is generally unnecessary. However, if a local condition indicates that massive erosion of soil from the RCA to areas outside the

RCA has occurred, consideration should be given to sampling the soil deposited due to that erosion.

[Pathway 6 Surface water → 9 Sediment] Water flowing out of the RCA could carry DU-contaminated sediment. Sediment sampling at Jefferson Proving Ground has occasional detected small amounts of DU in sediment inside the RCA, but never outside the RCA.

[Potential sample media 9 Sediment] Sediment sampling is generally unnecessary. However, a one-time sample of sediment deposits outside the RCA should be considered.

[Pathway 6 Surface water → 10 Plants] The DU concentration in surface water will be low if it is even detectable. However, some plants, such as lichens discussed above, can concentrate DU above ambient levels.

[Pathway 8 Soil →10 Plants] The DU concentration in soil outside the RCA will be low if it is even detectable. However, some plants, such as lichens discussed above, can concentrate DU levels.

[Potential sample media 10 Plants] Plant sampling is generally unnecessary. However, a one-time sample of certain plants, such as lichens if they are present, outside the RCA should be considered.

[Pathway 3 Soil → 11 Animals] The DU concentration in soil outside the RCA will be low if it is even detectable. However, some animals could concentrate DU in their bodies above ambient levels.

The following is an extract from Table 6.8 in Till and Grogan (Whicker and Rood 2008) that demonstrates this possibility:

Table 2 Expected values for transfer coefficients (day/kg^{-1}) in various animal food products (IAEA 1994)[b]

Element	Beef	Pork	Poultry
Uranium	3×10^{-4}	6×10^{-2}	1

[a] The transfer coefficient TC is defined as TC = $C_{prod}(eq)/R$, where $C_{prod}(eq)$ is the measured equilibrium (activity per unit mass) in the product of interest at equilibrium and R is the radionuclide ingestion rate (activity per unit time), in this case the rate of entry into the mouth.

[b] See original source for other data and ranges of values

[Pathway 4 Plants in RCA → 11 Animals] The same discussion for [Pathway 3 Soil → 11 Animals] applies to this pathway.

[Pathway 6 Surface water → 11 Animals] The same discussion for [Pathway 3 Soil → 11 Animals] applies to this pathway.

[Pathway 8 Soil → 11 Animals] The same discussion for [Pathway 3 Soil → 11 Animals] applies to this pathway.

[Pathway 9 Sediment → 11 Animals] The same discussion for [Pathway 3 Soil → 11 Animals] applies to this pathway.

[Potential sample media 11 Animals] The USASSBC took biological samples at Jefferson Proving Ground and reported (USASSBC 2002), "A total of eight biological samples were collected from deer, freshwater clams, fish, and a soft-shelled turtle. All of the biological samples from Big Creek were collected from the area adjacent to the DU Impact Area. The total uranium concentrations ranged from 0.091 pCi/g in deer liver to a maximum of 0.774 pCi/g in a freshwater clam. … The U-238 to U-234 activity ratio ranged from 0.4 to 1.2 and does not indicate the presence of DU contamination."

An Army contractor working at Jefferson Proving Ground wrote (SAIC 2013), "To evaluate the total effective dose equivalent (TEDE) associated with consumption of deer meat, a total of 132 tissue samples from 30 deer were collected and analyzed during the winter of 2005/2006. DU was not detected in any tissue sample during laboratory analysis."

Animal sampling is generally unnecessary

5. Radiochemistry

The ERMP will require all radiochemical analyses to be performed by an accredited[9] laboratory.

All samples will be analyzed for ^{234}U and ^{238}U activities and concentrations using alpha spectroscopy.

A $^{238}U/^{234}U$ concentration or activity ratio less than 3 is representative of natural uranium; whereas, higher ratios are potentially indicative of DU. All samples with a $^{238}U/^{234}U$ concentration or activity ratio greater than 3 will be reanalyzed using inductively coupled plasma-mass spectroscopy (ICP-MS) for their ^{235}U and ^{238}U content in an effort to definitively identify samples with DU content.

6. Other requirements

The ERMP will address all other requirements normally associated with environmental sampling, such as chain-of-custody, health and safety, packaging for shipment, shipping, and so on.

[9] Examples are the Department of Defense Environmental Laboratory Accreditation Program (DOD ELAP) and the Department of Energy Laboratory Accreditation Program (DOELAP).

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Appendix

The following table was produced in 2010 from laboratory data with the purpose of demonstrating whether the background reference area for a characterization survey in the RCA in the Battle Area Complex at Schofield Barracks (Cabrera Services Inc. 2008) was chosen appropriately. The assumption was made that the results of analyzing 416 unbiased samples from the RCA were indicative of background radionuclide concentrations and did not contain depleted uranium contamination. The resulting ^{234}Th (surrogate for ^{238}U) concentration in soil in the RCA was less than that in the chosen background reference area (calculated from 12 samples) and, therefore, supported the assumption. This also indicates that DU has not migrated far from the M101 points of impact in the fifty years since it was deposited.

Table — Calculation of background soil concentrations from laboratory results for the Davy Crockett impact area and for the background reference area at Schofield Barracks

Matrix	Activity Concentration (pCi/g)[a b]																	
	^{40}K		^{232}Th Progeny								^{238}U Progeny						^{235}U	
			^{208}Tl		^{212}Bi		^{212}Pb		^{228}Ac		^{214}Bi		^{214}Pb		^{234}Th[c]			
	BRA	DCIA	BRA	DCIA	BRA	DCIA	BRA	DCIA	BRA	DCIA	BRA	DCIA	BRA	DCIA	BRA	DCIA	BRA	DCIA
Surface soil	3.16 ± 0.15	5.2 ± 0.2	0.278 ± 0.013	0.293 ± 0.016	0.60 ± 0.07	0.62 ± 0.07	0.96 ± 0.02	0.85 ± 0.04	1.02 ± 0.05	0.94 ± 0.05	0.87 ± 0.03	0.79 ± 0.04	0.95 ± 0.03	0.79 ± 0.04	1.47 ± 0.11	1.09 ± 0.12	0.01 ± 0.04	0.04 ± 0.03
Subsurface soil	3.31 ± 0.18	4.3 ± 0.2	0.350 ± 0.017	0.303 ± 0.016	0.78 ± 0.09	0.66 ± 0.06	1.07 ± 0.03	0.91 ± 0.04	1.18 ± 0.06	0.99 ± 0.05	0.88 ± 0.04	0.60 ± 0.06	0.95 ± 0.03	0.66 ± 0.03	1.77 ± 0.13	1.19 ± 0.13	0.05 ± 0.04	0.06 ± 0.03
Combined	3.22 ± 0.11	4.70 ± 0.16	0.307 ± 0.010	0.298 ± 0.012	0.67 ± 0.05	0.65 ± 0.05	1.00 ± 0.02	0.88 ± 0.03	1.09 ± 0.04	0.96 ± 0.04	0.87 ± 0.02	0.67 ± 0.03	0.95 ± 0.02	0.72 ± 0.02	1.60 ± 0.08	1.14 ± 0.09	0.02 ± 0.03	0.05 ± 0.02

[a] pCi/g = picocurie/g; BRA = background reference area; DCIA = Davy Crockett impact area. The background reference area is more than seven miles from the Schofield Barracks Davy Crockett impact area.

[b] Activity concentrations are weighted means of laboratory results for unbiased samples from the DCIA and from the background reference area. Uncertainties are two standard deviations.

[c] ^{234}Th is a surrogate for ^{238}U.

Conclusion: The uranium concentration in the background reference area does not well represent the background uranium concentration in the DCIA. It is assumed that it is unlikely that DU is contained in any of the unbiased DCIA samples and so the uranium in these samples is naturally occurring.