Attachment 4

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

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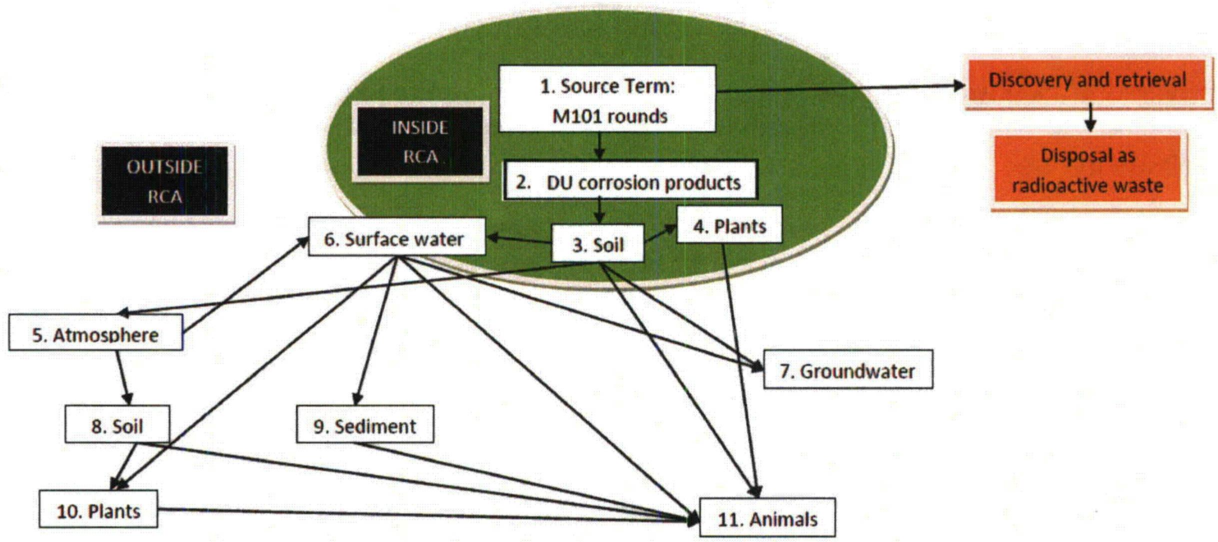
1. Introduction

The purpose of this document is to provide guidance to garrison personnel on the design of site-specific environmental radiation monitoring plans (ERMPs). The Nuclear Regulatory Commission (NRC) requires the Army to develop and implement these plans at every garrison named on NRC license number SUC-1593, which the NRC issued to CG IMCOM.

The purpose of a site-specific ERMP is to describe the environmental radiation sampling program to detect M101 spotting round depleted uranium (DU) leaving the radiation control area (RCA). The plan explains, for a specific RCA, which environmental pathways require evaluation, which samples will be taken for those



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

evaluations, where these samples will be taken, how often these samples will be taken, and how these samples will be analyzed for DU.

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

2. Risk Assessment

According to the "standardized Army risk matrix" (US Army 2014a), entry into an area know to contain unexploded ordnance (UXO) involves "high risk."[1] "High risk" means "... high potential for serious injury to personnel ... if hazards occur during the mission. This implies that, if a hazardous event occurs, serious consequences will occur. The decision to continue must be weighted carefully against the potential gain to be achieved by continuing this [course of action]" (US Army 2014a).

Entry into a UXO area requires support from explosive ordnance disposal (EOD) personnel.[2] While EOD support mitigates the risk of entry into a UXO area, it does not eliminate the risk.

The "potential gain to be achieved" by collection of environmental radiation samples in a UXO area is knowledge of the concentration of DU in samples of soil, water, air, or biota in the UXO area. However, according to results of RESRAD calculations,[3] it is almost certain that laboratory results from analyses of these samples will indicate DU concentrations (if any DU is detected at all) and implied average annual doses that are far below NRC standards. That is, the potential gain is minimal.

Therefore, collection of environmental radiation samples in UXO areas generally will not occur. Exceptions will occur only with documented consultation among the License Radiation Safety Officer, garrison safety personnel, and range control personnel, who will advise the garrison commander (that is, they will prepare a formal risk assessment (US Army 2014a)). The garrison commander will then decide whether to allow the collection.

[1] From Table 3-3, Standardized Army risk matrix, in DA PAM 385-63 (US Army 2014a): [*Severity* (expected consequence) = Catastrophic (Death, unacceptable loss ...) vs. *Probability* (expected frequency) = Seldom (infrequent occurrences)] → *H* = "high risk."
[2] "Access into temporary and/or dedicated impact areas will be strictly controlled. Those portions of temporary and dedicated impact areas authorized for training or other authorized purposes will be surface cleared of UXO before access is permitted." (US Army 2014b)
[3] See "Bounding Calculations Using RESRAD 7.0 and RESRAD-OFFSITE 3.1," which is included with this license amendment application.

3. Principles

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,[4]
- where these samples will be taken, and
- why those locations were chosen.

Each garrison will provide a site-specific ERMP for each RCA to the License Radiation Safety Officer (RSO) within six months of the date of the NRC's approval of this document.[5] The License RSO will review those ERMPs and ask for changes or corrections, as necessary. The Garrison and License RSO will work together to produce final ERMPs within the next six months. The Garrison will retain these final ERMPs and begin immediate implementation of them. The ERMPs and their implementations are then subject to NRC inspection.

The NRC issued the Davy Crockett M101 spotting round legacy DU license to Commanding General, US Army Installation Management Command (IMCOM). Therefore, the garrison will bear all costs for preparation and implementation of the ERMP and for collection, shipping, and radiochemical analyses of environmental samples. As necessary, the garrison should request funding for these costs through the usual channels in the usual way from HQ IMCOM.

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.[6]

The ERMP will include criteria for adjusting sampling. The adjustments could be to increase or reduce number of sampling locations or to increase or reduce the sampling frequencies. Decisions to make adjustments will consider, for example, previous results of sampling, changing environmental conditions, and increased understanding of environmental hazards.

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 for DU is unnecessary.

Each ERMP will include the statement (USNRC 2013), "When analytical sampling results from locations outside of the Radiation Control Area indicate that the U-238/U-

[4] Samples at each location will be taken at least annually but should be taken more often (semiannually or quarterly) if seasonal variations are prevalent.
[5] The approval will be in the form of an amendment to NRC License Number SUC-1593.
[6] The radiochemistry laboratory to which samples will be sent should provide definitive information about how it wants the samples taken, packaged, and shipped.

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."

The ERMP will show the distance and direction to the nearest normally occupied areas (for example, residential areas, commercial areas, and business areas) for each RCA at that installation. The ERMP will provide a description/narrative of the physical environment of each RCA on that installation.

The License Radiation Safety Officer and Army Environmental Command (AEC) 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. Assume that 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 spotting round-affected garrisons. Garrisons can obtain additional guidance from AEC, which has pledged to support license activities.

If results of sampling certain media over time for an RCA indicate that M101 spotting round 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.

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.[7] The garrison should refer to relevant ORAP reports for its M101 spotting round-affected ranges.

4. Inside the RCA

Each RCA is within a larger impact area that is part of an Army training area or range facility. Generally, RCAs are open, grassy areas, but young trees and large undergrowth could be present. Their minimum distances from normally occupied areas outside the training area or range facility depends on the type of munitions used in the large impact areas, but typically are a few kilometers.[8]

Given the purpose of an ERMP, sampling will not usually be performed inside the RCA.

[7] 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.
[8] For specific information on range safe distances, see DA PAM 385-63 (US Army 2014b).

a. M101 spotting rounds

The original source of DU contamination is 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 part of the RCA at Schofield Barracks (Cabrera 2013), whether a cleanup or retrieval of these rounds ever occurred, so the assumption is that most, if not all, the DU in rounds fired into an RCA remain in the RCA in some form.

Any M101 spotting round DU removed from the RCA in accordance with the guidance in the Radiation Safety Plan will be held for proper disposition as radioactive waste.

No conditions require collection or sampling of DU metal alloy in the RCA.

b. Pathway: M101 spotting rounds → DU corrosion products

The rate of corrosion of the DU in the DU-molybdenum alloy in the M101 spotting rounds left in the environment is not known. A contractor working at Schofield Barracks in 2012 found both contaminated soil and solid DU fragments (Cabrera 2013).

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

QUOTE

> 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 geometries and DU alloys that are different from the DU penetrators at JPG, the above observations imply that most M101 spotting rounds have not corroded completely since the Army fired them in the 1960s.

c. DU corrosion products

Corrosion products initially will be on the surfaces of M101 spotting rounds that are then subject to spalling. Sampling of corrosion products in the RCA is unnecessary.

No conditions require collection or sampling of DU corrosion products in the RCA.

d. Pathway: DU corrosion product → Soil

Corrosion products attach loosely to M101 spotting round surfaces. They gradually will leave those surfaces (spalling). Therefore, corrosion products will be present on and near the soil surface in an RCA.

e. 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 ... of data obtained at Schofield Barracks during a characterization survey [(Cabrera 2008a)] showed that DU contamination 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 2008b), "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."

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 wrote, regarding environmental sampling in Vieques, Puerto Rico (Kane 2001):

QUOTE

> 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

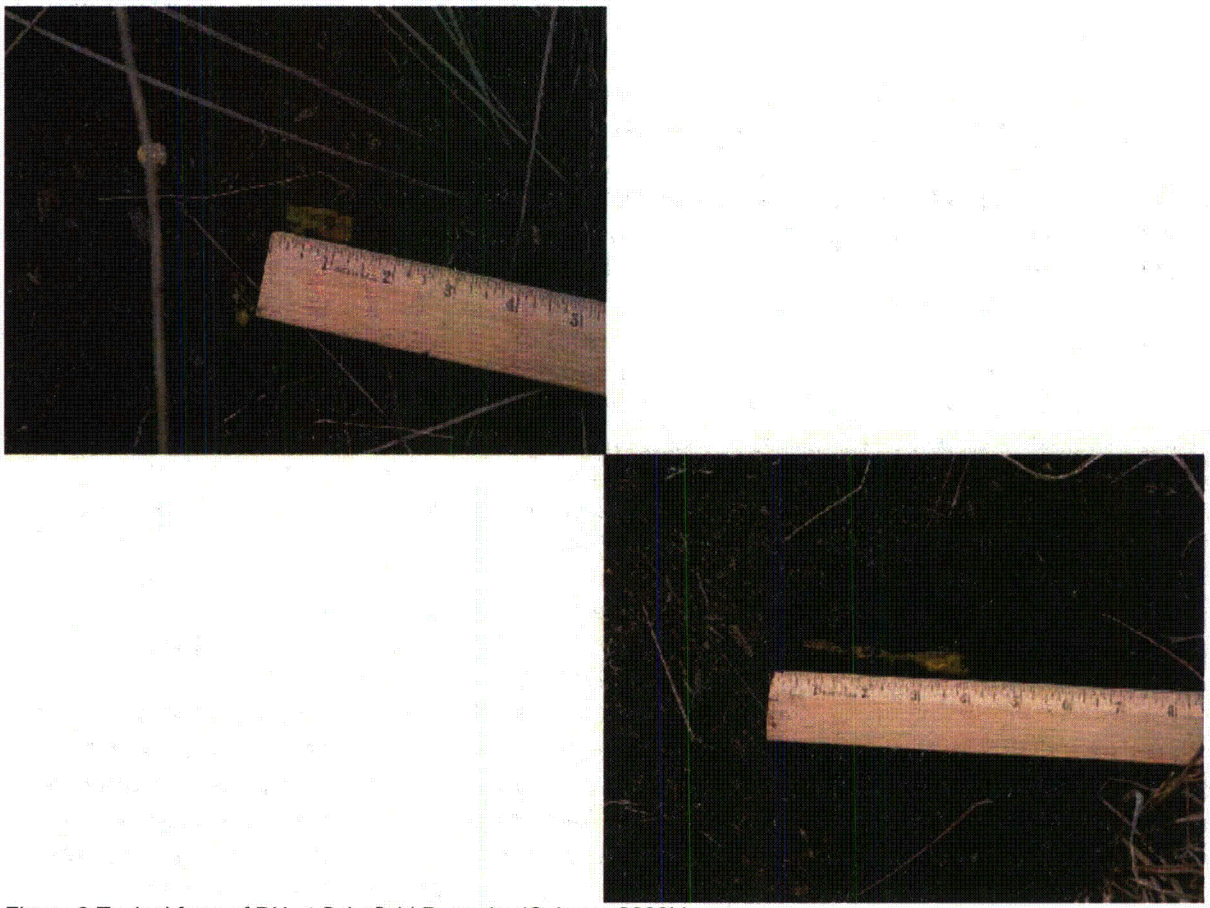


Figure 2 Typical form of DU at Schofield Barracks (Cabrera 2008b)

> 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 of 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 [derived concentration guideline limits] was not identified offsite during ... 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 JPG 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.[9]

The US Department of the Army Soldier and Biological Chemical Command (USASSBC) took sediment samples at JPG 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 JPG in 1995, an Army contractor (Scientific Ecology Group 1995) reported that all results of samples taken in the impact area showed $^{238}U/^{234}U$ ratios less than three.

In 2010, the current License RSO performed an analysis of results in a contractor's characterization survey report for the RCA in the Battle Area Complex at Schofield Barracks (Cabrera 2008a). The results of his analysis (see the Appendix) showed that

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

unbiased soil samples taken in the RCA contained only natural uranium. The contractor's report showed that biased samples contained both natural uranium and DU. A conclusion is that DU remains close to its point of original deposition in the RCA and is not likely to move outside the RCA in appreciable amounts.

An implication of the above is that M101 spotting round DU does not migrate readily in soil in many, if not almost all, cases. Once it becomes part of the soil matrix, it remains in the same soil matrix for many years.

Generic calculations (Cherry 2012) have shown that if in a typical RCA (a one-kilometer square) 1000 M101 spotting 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).[10] This value is scalable for different RCA areas and different numbers of rounds.[11]

Table 1 is a derivation from Table 3.4 in National Council on Radiation Protection and Measurements (NCRP) Report No. 160 (NCRP 2009):

Table 1 Summary of soil concentration data for uranium

Natural Uranium in Soil	Mean	Median	Standard Deviation	5^{th} Percentile	95^{th} Percentile
Parts per million by weight	1.84	1.81	0.7	0.63	3.1
Activity concentration (pCi U/g soil)[a]	1.25	1.23	0.5	0.43	2.1

[a] Specific activity of natural uranium = 6.77×10^{-7} Ci U/g U

The table shows that typical the typical natural uranium concentration in soil (about 1.2 pCi/g) is about four times more than the typical DU activity concentration in RCA soil (about 0.3 pCi/g after complete corrosion and distribution in surface soil).

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

No conditions require deliberate collection or sampling of soil within the RCA.

f. Pathway: Soil → Plants in RCA

The following is an extract from Table 6.4 in Till and Grogan (Whicker and Rood 2008):

[10] 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).
[11] The NRC's derived default screening level for decommissioning is 14 pCi DU/g soil (NRC 2006). For the derivation of this value, see "Arguments against Air Sampling during HE Fire into RCAs" included with this license amendment application.

Table 2 Typical plant/soil concentration ratios for selected elements and crops, adapted from the International Atomic Energy Agency (IAEA 1994)

Element	Crop	Concentration Ratio (dry mass basis)	
		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, concentrate uranium in their tissues more than most plants do. For example, The USASSBC took vegetation samples at JPG 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 spotting rounds hit no such hard targets and surfaces, therefore no aerosolization occurred.

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

g. Plants in RCA

Sampling of plants in the RCA is generally unnecessary.

The Army allows livestock (beef cattle) to graze in an RCA at Fort Hood. RESRAD bounding calculations[3] show that the maximum annual total dose to a resident farmer on the RCA at Fort Hood is about 0.14 millirem. The consumption of meat contributes less than 2 percent of that dose, or less than 0.003 millirem.

The calculations assumed that all meat that the resident farmer consumes derives from livestock grazing only in the RCA. In the case of Fort Hood, the livestock graze over a much larger area that includes the RCA, and consumers of that meat also consume meat from numerous other sources. The conclusion is that sampling plants in the RCA will provide little or no useful information.

No conditions require deliberate collection or sampling of plants within the RCA.

h. Pathway: Soil → Surface water in 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.

i. Surface water in RCA

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

No conditions require deliberate collection or sampling of surface water within the RCA.

5. Outside the RCA

a. Pathway: Soil → Atmosphere

RESRAD bounding calculations[3] show that the maximum possible ^{238}U air concentration for any site is about 1.3×10^{-4} pCi/m^3. However, the Army has found many M101 spotting rounds on RCAs that seem to be mostly intact with corrosion products in or on the soil in the immediate area adjacent to the round. This means that not all the DU in an RCA is available for suspension into the atmosphere. The expected ^{238}U air concentration due to dust will be much less than the maximum possible value.

For comparison, the NRC effluent standard for ^{238}U in air is 6×10^{-14} µCi/mL = 0.06 pCi/m^3 (NRC 2012), which is more than 450 times greater than the highest possible ^{238}U concentration in air due to DU in the soil.

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[12] allows JPG to possess up to 80,000 kg of DU at a single site,

[12] ADAMS ML073030415

which is 14 times greater than the estimated total of all M101 spotting round DU at 16 Army installations.

The Army provided a contractor-prepared report to the NRC (Shia 2005),[13] 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[14] 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."

b. Atmosphere

Air sampling is generally unnecessary. Remedial actions, discussed above and which did not produce significant air concentrations, are not underway at any RCA. In addition, the NRC allowed high explosive testing throughout the JPG impact area, to include the DU impact area, without a requirement for air sampling.

The document, "Arguments against Air Sampling during HE Fire into RCAs," included with this license amendment application, presents four different arguments to

[13] ADAMS ML070090201

[14] "Movements" of Pu-contaminated soil included digging and scraping soil, pushing soil into windrows, loading soil into trucks, dumping soil from trucks into boats, transporting soil to the "storage" island, unloading soil from boats into trucks, dumping the soil at a plant for mixing with concrete, and dumping the mixture into a crater for disposal.

demonstrate that air sampling during HE detonations in a DU impact area is unnecessary and likely to be ineffectual.

No conditions require air sampling.

c. Pathway: Soil → 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.). The most stable form of uranium is U_3O_8, which is the form most commonly found in nature. At ambient temperatures, UO_2 will gradually convert to U_3O_8.

d. Pathway: Atmosphere → 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."

e. Pathway: Surface water in RCA → 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.

f. Surface water

The low solubility of uranium in water and the low concentration of DU in soil in the RCA compared to the concentration of natural uranium in soil make it improbable that DU is detectable in surface water. A slow flow rate makes detection more likely.

The Army and its contractors sampled surface water extensively at JPG over the last twenty years (SAIC 2013). The amount of DU at JPG is about 73,000 kg, whereas the largest amount of M101 spotting round DU at any one installation is 1843 kg at Fort Benning. Detection of DU in surface water at JPG occurred, albeit rarely and always well within NRC effluent limits and USAEPA drinking water standards.

If surface water routinely flows from the RCA, then sampling of this surface water will occur. If flow occurs throughout the year, then sampling will occur every three months. If flow is intermittent, then sampling will occur during that flow, but no less than three months apart.

g. Pathway: Soil → Groundwater

The DU concentration in groundwater depends on several factors, including distance of the groundwater from the soil surface, acidity/alkalinity of the soil and leaching water, soil porosity, amount of precipitation, and so on. The Army has not measured most of the influencing factors for this pathway for any RCA.

h. Pathway: Surface water → Groundwater

The low solubility of uranium oxide 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.

i. Groundwater

Only existing wells potentially influenced by DU in the RCA will be sampled. The Army will create no new wells solely for the purpose of DU sampling because the cost-benefit ratio is highly unfavorable.

The Army will make available for NRC review upon request the results of all Army measurements of uranium concentration in groundwater that were taken with the purpose of meeting Safe Drinking Water Act requirements.

If existing wells potentially influenced by DU in the RCA are available, then whenever anyone samples these wells for any purpose, he or she will also require analyses for isotopes of uranium and report the results to the Garrison Radiation Safety Officer. Otherwise, no conditions require groundwater sampling.

j. Pathway: Atmosphere → 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 virtually immeasurable amounts of DU to soil outside the RCA.

k. Soil

Soil sampling is generally unnecessary because DU contamination tends to remain in place in the RCA (see paragraph 4e). However, if a local condition indicates that massive erosion of soil from the RCA to areas outside the RCA has occurred, sampling the soil deposited due to that erosion will occur (following risk assessment if UXO is present).

If an area of soil greater than 25 m^2 eroded from an RCA is clearly discernible, then that deposit will be sampled semiannually with one sample taken per 25 m^2. No other conditions require soil sampling.

l. Pathway: Surface water → Sediment

Water flowing out of the RCA could carry DU-contaminated sediment. Sediment sampling at JPG has occasionally detected small amounts of DU in sediment inside the RCA, but never outside the RCA.

m. Sediment

If surface water sampling occurs, sediment sampling will also occur at the same time and near the same place. No other conditions require sediment sampling.

n. Pathway: Surface water → 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.

o. Pathway: Soil →Plants

The DU concentration in soil outside the RCA will be much lower than it is in the RCA, if it is even detectable. However, some plants, such as lichens discussed above, can concentrate DU levels.

p. Plants

No condition requires plant sampling.

q. Pathway: Soil → Animals

The DU concentration in soil outside the RCA will be much lower than that in the RCA, 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 3 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

r. Pathway: Plants in RCA → Animals

Plants that herbivorous and omnivorous animals normally consume do not concentrate uranium above ambient levels, and neither do the herbivorous, carnivorous, and omnivorous animals themselves.

s. Pathway: Surface water → Animals

Depleted uranium concentrations in any water that animals consume are orders of magnitude less than the uranium concentrations that NRC effluent standards and EPA drinking water regulations limit. As shown in paragraph 5q, animals generally do not concentrate uranium above ambient levels.

t. Pathway: Soil → Animals

Depleted uranium concentrations in any RCA soil that animals consume are, on the average, less than the default derived concentration guideline limits.[11] The DU concentration in soil outside the RCA is less than that for soil in the RCA. As shown in paragraph 5q, animals generally do not concentrate uranium above ambient levels.

u. Pathway: Sediment → Animals

Depleted uranium concentrations in any RCA sediments that animals consume are, on the average, less than the default derived concentration guideline limits.[11] The average DU concentration in sediments outside the RCA is less than that for sediments in the RCA. As shown in paragraph 5q, animals generally do not concentrate uranium above ambient levels.

v. 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."

No conditions require animal sampling.

6. Radiochemistry

Only accredited[15] laboratories will perform radiochemical analyses for the purposes of NRC license compliance. The laboratories will use alpha spectroscopy to analyze samples for ^{234}U and ^{238}U activities and concentrations.

The NRC's criterion is that a ^{238}U/^{234}U concentration or activity ratio less than 3 is assumed representative of natural uranium, whereas higher ratios are potentially indicative of the presence 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 identify samples with DU content.

7. 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.

8. Bibliography

Argonne National Laboratory. *Chemical Forms of Uranium.* http://web.ead.anl.gov/uranium/guide/ucompound/forms/ (accessed February 11, 2015).

Cabrera. *Characterization Report, Schofield Barracks Davy Crockett Impact Area, Oahu, Hawaii.* Las Vegas, Nevada: Cabrera Services Inc., 2008a.

Cabrera. *Final Status Survey of the Initial 100 Acres of Radiological Control Area at Schofield Barracks.* North Highlands, California: Cabrera Services Inc., 2013.

Cabrera. *Schofield Barracks Impact Range Baseline Human Health Risk Assessment for Residual Depleted Uranium.* Las Vegas, Nevada: Cabrera Services, 2008b.

Cherry, Robert N. "Army Response to US Nuclear Regulatory Commission (NRC) Proposed License Conditions for Davy Crockett M101 Spotting Round Depleted Uranium (DU)." ADAMS ML110830582, 2012.

Defense Nuclear Agency. *The Radiological Cleanup of Enewetak Atoll.* Washington, DC: Defense Nuclear Agency, 1981.

Durante, Marco, and Mariagabriella Pugliese. "Depleted uranium residual radiological risk assessment for Kosovo sites." *Journal of Environmental Radioactivity* 64 (2003): 237-245.

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

IAEA. *Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments.* Technical Report Series 364, Vienna, Austria: International Atomic Energy Agency, 1994.

Kane, William F. January 9, 2001. http://pbadupws.nrc.gov/docs/ML0100/ML010050342.pdf (accessed February 11, 2015).

Michalak, Paul. "U.S. Nuclear Regulatory Commission Staff Review of the U.S. Army's Applicaiton for a Rdioactive Materials License for Depleted Uranium from the Davy Crockett Munitions Sstem." Rockville, Maryland: US Nuclear Regulatory Commission, November 20, 2010.

NCRP. *NCRP Report No. 160, Ionizing Radiation Exposure of the Population of the United States.* Bethesda, Maryland: National Council on Radiation Protection and Measurements, 2009.

NCRP. *NRCP Report No. 169: Design of Effective Radiological Effluent Monitoring and Environmental Surveillance Programs.* Bethesda, Maryland: National Council on Radiation Protection and Measurements, 2010.

NRC. "10 CFR Part 20 Standards for Protection Against Radiation." August 23, 2012. http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/full-text.html (accessed August 31, 2012).

NRC. *NUREG-1757, Volume 2, Revision 1: Consolidated Decommissioning Guidance: Characterization, Survey, and Determination of Radoiological Criteria.* Washington, DC: Nuclear Regulatory Commission, 2006.

ORAP. *U.S. Army Operational Range Assessment Program (ORAP) Reports.* August 23, 2013. http://denix.osd.mil/sri/Policy/orap.cfm (accessed February 11, 2015).

Papastefanou, C. "Depleted uranium in military conflicts and the impact on the environment." *Health Physics* 83, no. 2 (August 2002).

SAIC. *Army's Decommissioning Plan for NRC Materials License SUB-1435.* Louisville, Kentucky: US Army Corps of Engineers Louisville District, 2013.

Scientific Ecology Group. *Jefferson Proving Ground Depleted Uranium Impact Area NRC License No. SUB-1435 Scoping Survey Report Volume 1, Survey Report.* Oak Ridge, Tennessee: Scientific Ecology Group, 1995.

Shia, Corinne. *Airborne Transport of Depletcd Uranium (DU) and Site Characterization Needs.* Email to Paul D. Cloud, Reston, Virginia, Virginia: Science Applications International Corporation, 2005.

Spitzberg, D. Blair. *Safey Evaluation Report for Eglin Air Force Base.* Arlington, Texas: US Nuclear Regulatory Commission, 2005.

UNEP. *Depleted Uranium in Bosnia and Herzegovina: Post-Conflict Environmental Assessment.* Nairobi, Kenya: United Nations Environment Programme, 2003.

UNEP. *Depleted Uranium in Kosovo: Post-Conflict Environmental Assessment.* Nairobi, Kenya: United Nations Environment Programme, 2001.

UNEP. *Depleted Uranium in Serbia and Montenegro: Post-Conflict Environmental Assessment in the Federal Republic of Yugoslavia.* Nairobi, Kenya: United Nations Environment Programme, 2002.

UNSCEAR. *Sources and effects of ionizing radiation : UNSCEAR 1993 Report to the General Assembly, with Scientific Annexes.* New York, New York: United Nations, 1993.

US Army. "DA Pamphlet 385-30." *Risk Management.* Washington, DC: Department of the Army, December 2, 2014a.

—. "DA Pamphlet 385-63." *Range Safety.* Washington, DC: Department of the Army, April 16, 2014b.

USAEPI. *Health and Environmental Consequences of Depleted Uranium Use in the U.S. Army.* Atlanta, Georgia: US Army Environmental Policy Institute, 1995.

USASSBC. *Environmental Report: Jefferson Proving Ground, Madison, Indiana.* Aberdeen Proving Ground: U.S. Department of the Army Soldier and Biological Chemical Command, 2002.

USEPA. *Depleted Uranium: Technical Brief (EPA 402-R-06-011).* Washington, DC: US Environmental Protection Agency, 2006.

USNRC. "US Nuclear Regulatory Commission License Number SUC-1593." Rockville, Maryland: US Nuclear Regulatory Commission, October 13, 2013.

Uyttenhove, J, M Lemmens, and M Zizi. "Depleted Uranium in Kosovo: Results of a Survey by Gamma Spectrometry on Soil Samples." *Health Physics* 83, no. 4 (October 2002): 543-548.

Whicker, F. Ward, and Arthur S. Rood. "Terrestrial Food Chain Pathways: Concepts and Models." In *Radiological Risk Assessment and Environmental Analysis*, edited by John E. Till and Helen A. Grogan. New York, New York: Oxford University Press, 2008.

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 2008a) 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 spotting round 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.

Attachment 5

Bounding Calculations Using RESRAD 7.0 and RESRAD-OFFSITE 3.1

Bounding Calculations Using RESRAD 7.0 and RESRAD-OFFSITE 3.1 [1]

1. Summary

These calculations were performed to demonstrate that no plausible conditions for the M101 spotting round depleted uranium (DU) on Army ranges could produce annual doses and activity concentrations in water and air that exceed Nuclear Regulatory Commission standards and Environmental Protection Agency drinking water standards. The following table summarizes the results of the calculations.

Situation	Maximum Value			
	Average Annual Dose (mrem)	Water Concentration: Effluent (pCi/L ^{238}U)	Water Concentration: Drinking water (μg/L total U)	Air Concentration (pCi/m^3 ^{238}U)
Regulatory standard (NRC; EPA for drinking water)	100	3000	30	0.06
Typical: 1000 rounds, 1 km^2, default parameters (Section 2)	0.029	0.13	0.43	0.0000065
Maximum reasonable: 9700 rounds, 1 km^2, default parameters (Section 3)	0.28	1.3	3.7	0.0000065
Maximum bounded: 9700 rounds, 1 km^2, several changed defaults (Section 5)	0.33	0.63	1.8	0.00013
Maximum, not reasonable: 9700 rounds, 0.1 km^2, several changed defaults (Section 6)	3.2	6.3	18	0.0011
Maximum reasonable 1 km offsite: 9700 rounds, 1 km^2, default parameters (Section 7)	0.035	0.23	0.66	0.000000088

2. Baseline Resident Farmer Scenario, 1000 M101 Rounds, RESRAD Default Parameters

To establish a conservative baseline, the "resident farmer" scenario[2] is used, even though residential farming is not a foreseeable use of an operational range in the near

[1] RESRAD is a computer model code designed to estimate radiation doses and risks from RESidual RADioactive materials. Sponsored by the Office of Health, Safety and Security and the Office of Environmental Management, with support from the US Nuclear Regulatory Commission, Argonne National Laboratory (ANL) developed this family of codes. The Department of Energy (DOE) through ANL currently maintains code and version control (DOE 2015).

[2] According to *NUREG-1757, Consolidated Decommissioning Guidance, Vol. 2, Rev. 1* (NRC 2006), the resident farmer scenario accounts for exposure involving residual radioactivity that is initially in the surficial soil. A farmer moves onto the site, grows some of his or her diet, and uses water tapped from the aquifer under the site. Pathways include external exposure from soil, inhalation to (re)suspended soil, ingestion of soil, ingestion of drinking water from aquifer, ingestion of plant products grown in

future, to estimate annual doses and soil, water, and air depleted uranium (DU) activity concentrations. The RESRAD calculations for this baseline calculation used the following parameters:

- The true impact area is a square, 1000 meters (m) × 1000 m = 10^6 m^2 = 1 km^2. However, in the calculations the area is assumed circular (radius ≈ 564 m) by default for simplicity. RESRAD allows other shapes, such as a square, but approximates those shapes with a set of circles when it performs its calculations. This greatly increases computation time.
- One thousand M101 spotting rounds[3] were fired into the impact area.[4] Initially, M101 DU contamination in the impact area is uniform[5] and confined to the top 15 centimeters of soil,[6] resulting in activity concentrations in soil due to the 1000 rounds of 0.256 picocurie per gram (pCi/g) ^{238}U, 0.00236 pCi/g ^{235}U, and 0.0337 pCi/g ^{234}U.[7]
- All other parameters were RESRAD defaults.

Table 1 is an extract from Table 2.3 in the RESRAD manual (Yu, et al. 2001) that shows the key parameters that RESRAD uses in the resident farmer scenario.

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contaminated soil and using aquifer to supply irrigation needs, ingestion of animal products grown onsite (using feed and water derived from potentially contaminated sources) and ingestion of fish from a pond filled with water from the aquifer. A resident farmer scenario ... is considered to be a credible bounding scenario for the purpose of [the RESRAD] manual (Yu, et al. 2001).

[3] The geometric mean of the number of rounds shipped to each installation and presumably fired is about 1500. Some installations had more than one impact area, so 1000 was chosen as a representative number for the rounds fired into a single impact area. The results of the calculations for a one-kilometer square are proportional to the number of rounds fired into that square.

[4] Each M101 round contains (3180 ± 25) grains = (0.2061 ± .0015) kg of molybdenum-DU alloy (USACE St Louis 2011). The molybdenum-DU alloy is 92 percent DU, so each M101 round contains about 0.190 kg of DU.

[5] RESRAD does not allow for non-uniform distribution of radioactive material in the contaminated zone. Experience in Hawaii and at Fort Hood (PIKA International 2007) shows that M101 spotting rounds remain mostly intact for many years and so their DU is not available for transport and uptake, and even after about 50 years since the Army fired the rounds, M101 DU has remained in a small area around the resting place of each round. Thus, assuming the rounds have completely corroded is a conservative assumption. As time goes on, the DU will become more uniformly distributed in soil than it currently is, and so the distribution will approach the assumed distribution. RESRAD does not allow for gradual corrosion adding to the source term available to contribute to dose. A conservative assumption is that all the M101 DU is immediately available and is evenly distributed throughout the RCA. Section 6 addresses the consideration that the DU might be concentrated in a smaller area.

[6] The M101 spotting round was not a high-velocity penetrating round. It has been found only on or near the ground surface. According to *MARSSIM* (NRC, DOE, EPA, DOD 2000), "Surface soil is the top layer of soil on a site that is available for direct exposure, growing plants, resuspension of particles for inhalation, and mixing from human disturbances. Surface soil may also be defined as the thickness of soil that can be measured using direct measurement or scanning techniques. Typically, this layer is represented as the top 15 cm (6 in.) of soil (40 CFR 192)."

[7] Included in the calculation of the soil activity concentrations for the baseline resident farmer scenario are the RESRAD default value of 1.5 g/cm^3 for soil density and the relative mass abundances of 99.80 percent, 0.20 percent, and 0.0007 percent in DU and specific activities of 0.33 pCi/g, 6200 pCi/g, and 2.2 pCi/g for ^{238}U, ^{234}U, and ^{235}U, respectively (DOE 2009).

Table 1 Key parameters used in the resident farmer scenario

Parameter	Value
Exposure duration	1 year
Inhalation rate [a]	8400 m^3/y
Fraction of time indoors [b]	0.50
Fraction of time outdoors [c]	0.25
Contaminated fractions of food [d]	
Plant food	0.5
Milk	1.0
Meat	1.0
Aquatic food	0.5
Soil ingestion [e]	36.5 g/y
Drinking water intake [f]	510 L/y

[a] RESRAD assumes an average inhalation of 8400 m^3/y for the resident farmer. The average inhalation rate of 15.2 m^3/d is given in the EPA *Exposure Factor Handbook* (USEPA 1997).

[b] RESRAD assumes the resident farmer spends 50 percent of the time inside on the contaminated site. The EPA *Exposure Factor Handbook* (USEPA 1997) assumes that the resident spends an average of 16.4 h/d inside.

[c] RESRAD assumes that the resident farmer spends 25 percent of the time outside on the contaminated site. The EPA *Exposure Factor Handbook* (USEPA 1997) assumes that the resident spends an average of 2 h/d outside.

[d] RESRAD corrects the contaminated fractions for plant, meat, and milk food on the basis of the contaminated area. The values in the table are for a very large contaminated area (> 20,000 m^2 for the meat and milk pathway and > 1000 m^2 for the plant food pathway).

[e] RESRAD uses 36.5 g/y as the soil ingestion rate. The actual soil ingestion rate is corrected by the occupancy factor, which is the sum of the time spent on site (time fraction inside + time fraction outside). The average value suggested in the EPA *Exposure Factor Handbook* (USEPA 1997) is 50 mg/d.

[f] RESRAD considers water ingestion only for the rural resident, and the ingestion rate is 510 L/yr. The EPA *Exposure Factor Handbook* (USEPA 1997) recommends an average drinking water intake of 1.4 L/d.

Figure 1 through Figure 4 [8] are selected RESRAD graphical outputs for the baseline resident farmer scenario. The RESRAD report for the baseline resident farmer scenario is in Attachment 1.[9]

[8] Figures follow the bibliography.

[9] For the purpose of the RESRAD calculations, the timeline begins with DU uniformly distributed in the top15 cm of soil. As discussed in above footnotes, the true situation is more complicated and one that RESRAD cannot fully address. However, the purpose of *performing* the RESRAD calculations is to estimate maximum annual doses and maximum concentrations of DU in soil, air, and water, regardless of when those maxima occur.

Part I, page 13 of the RESRAD report for the baseline resident farmer scenario shows that the maximum annual dose of 0.029 millirem (mrem) occurs in the first year. Figure 1 shows that the annual dose declines continuously for more than 100 years to less than 0.001 mrem and then rises to approximately 0.017 mrem at approximately 450 years. All estimated annual doses are less than 1/10,000 of 311 mrem, which is the average annual background dose per individual in the US population for ubiquitous background (NCRP 2009).

Figure 2 shows that ^{238}U soil concentration (and hence, the M101 DU soil concentration) decreases significantly over the first hundred years due to erosion and leaching. This explains the accompanying decrease in annual dose over the same period.

Figure 3 shows that ^{238}U does not show up in well water for about 300 years. Then its ^{238}U activity concentration gradually increases for about 150 years, eventually reaching about 0.13 pCi/L, holding steady after that. The corresponding DU concentration is 0.15 pCi/L or about 0.4 μg DU/L. The drinking water standard for uranium is 30 μg U/L.[10] RESRAD assumes that groundwater is the source for well water and a surface pond (Yu, et al. 2001), so the DU activity concentration in well water and the pond reflect the DU concentration in groundwater.

Figure 4 shows that the maximum ^{238}U activity concentration in air due to dust is about 6.5×10^{-6} pCi/m^3 and occurs during the first year. Its decrease to zero over the first one hundred years parallels the decrease in DU activity concentration in surface soil. For comparison, the NRC's effluent standard for ^{238}U is 6×10^{-14} μCi/mL = 0.06 pCi/m^3,[11] which is more than 9000 times greater than the calculated RESRAD value.

3. Bounding Value for Source Term, 9700 M101 Rounds, RESRAD Default Parameters

The greatest number of M101 rounds shipped to any installation was 9700 to Fort Benning. Fort Benning is where Infantry Soldiers received their qualification training on the Davy Crockett weapon systems. It is unlikely that Soldiers fired all 9700 rounds on a single range because eight M101 impact areas are at Fort Benning.

Fort Bragg, Fort Hood, and Fort Knox received 4212, 4038, and 3956 M101 rounds, respectively. Fort Bragg, and Fort Hood each has one M101 impact area, and Fort Knox has five (with two sets of two or three overlapping impact areas). Therefore, the most conservative realistic concentration of M101 rounds occurs at Fort Bragg.

However, the source term bounding calculation will assume 9700 rounds in a single M101 impact area. The results of RESRAD calculations using this bounding value for number of rounds are 9.7 times the results of the baseline calculations in the previous section, as expected.

[10] 40 CFR § 141.66(e)
[11] 10 CFR 20, appendix B, table 2

Again assuming the M101 DU contamination in the impact area is uniform and confined to the top 15 centimeters of soil, the resulting activity concentrations in soil due to the 9700 rounds are 2.48 pCi/g ^{238}U, 0.0228 pCi/g ^{235}U, and 0.327 pCi/g ^{234}U.

The RESRAD report for the 9700 M101 rounds bounding scenario is in Attachment 2. Figure 5 through Figure 8 for the 9700 M101 rounds bounding scenario are the same as the corresponding Figure 1 through Figure 4 for the resident farmer scenario (1000 M101 rounds), except that the resulting values vs. time are 9.7 times larger.

Part I, page 13 of the RESRAD report and Figure 5 for the 9700 M101 rounds bounding scenario show that the maximum annual dose of 0.28 mrem occurs in the first year.

Figure 6 shows that ^{238}U soil concentration (and hence, the M101 DU soil concentration) decreases significantly over the first hundred years due to erosion and leaching. This explains the accompanying decrease in annual dose over the same period.

Similar to the baseline resident farmer scenario, ^{238}U does not show up in well water for about 300 years (Figure 7). Then its ^{238}U activity concentration gradually increases for about 150 years, eventually reaching about 1.3 pCi/L. The corresponding DU concentration is 1.5 pCi/L or about 4 µg DU/L. The drinking water standard for uranium is 30 µg U/L.[10] RESRAD assumes that groundwater is the source for well water and a surface pond (Yu, et al. 2001), so the DU activity concentration in well water and the pond reflect the DU concentration in groundwater.

Similar to the baseline resident farmer scenario, the maximum ^{238}U activity concentration in air due to dust is about 6.5×10^{-5} pCi/m^3 and occurs during the first year (Figure 8). Its decrease to zero over the first one hundred years parallels the decrease in DU activity concentration in surface soil. For comparison, the NRC's effluent standard for ^{238}U is 6×10^{-14} µCi/mL = 0.06 pCi/m^3,[11] which is more than 900 times greater than the calculated RESRAD value.

4. Other Bounding Values with 9700 M101 Rounds Resident Farmer Scenario

The following RESRAD results are for the 9700 M101 Rounds Resident Farmer Scenario with only one default parameter changed.

a. Water table 7.5 cm below ground surface instead of default 4 m

To set up this scenario, in the "contaminated zone parameters" dialog box, "Does the initial contamination penetrate the water table?" check "yes," and set the "contaminated fraction below the water table" to 0.5 (that is, 50 percent). This means the water table is only 7.5 cm below the ground surface.[12] The default depth of the water table is 4 m.

The RESRAD report for this bounding scenario is in Attachment 3.

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[12] The contaminated zone is the top 15 cm of soil. None of the impact areas is normally submerged in water. Setting the top of the water table halfway in the top 15 cm allows for direct contact of the water table with half of the contamination while keeping the water below the surface.

Part I, page 12 of the RESRAD report and Figure 9 for the 9700 M101 rounds bounding scenario for a high water table show that the maximum annual dose of 0.32 mrem occurs in the first year.

Figure 10 shows that ^{238}U soil concentration (and hence, the M101 DU soil concentration) decreases significantly over the first hundred years due to erosion and leaching. This accounts for most of the decrease in annual dose over that same period.

Part IV, page 2 of the RESRAD concentration report shows that the activity concentration of ^{238}U in well water in the first year is 0.37 pCi/L. Figure 11 then shows it gradually increases for about 100 years, eventually reaching about 1.3 pCi/L. The corresponding DU concentration in well water is 1.5 pCi/L or about 4 μg DU/L. It then gradually drops to zero beginning at about 500 years.

Similar to the baseline resident farmer scenario with 9700 rounds, the maximum ^{238}U activity concentration in air due to dust is about 6.5×10^{-5} pCi/m^3 and occurs during the first year (Figure 12). Its decrease to zero over the first one hundred years parallels the decrease in DU activity concentration in surface soil.

b. Contaminated zone erosion rate is 0.01 m/y instead of default 0.001 m/y

To set up this scenario, in the "cover and contaminated zone hydrological data" dialog box, change the "contaminated zone erosion rate" from the default 0.001 m/y to 0.01 m/y.[13]

The RESRAD report for this bounding scenario is in Attachment 4.[14]

Part 1, page 12 of the RESRAD report and Figure 13 for the 9700 M101 rounds bounding scenario for a high erosion rate that the maximum annual dose of 0.28 mrem occurs in the first year.

Figure 14 shows that ^{238}U soil concentration (and hence, the M101 DU soil concentration) decreases significantly over the first hundred years due to erosion and leaching. This accounts for most of the decrease in annual dose over that same period.

Part IV, page 3 of the RESRAD report shows that the activity concentration of ^{238}U in well water at the first year is 0.006 pCi/L. Figure 15 then shows it gradually increases, reaching about 0.4 pCi/L in about 15 years. The corresponding DU concentration in well water is about 0.5 pCi/L or about 1.1 μg DU/L. It then gradually drops to zero beginning at about 500 years.

[13] If this scenario produced a large change in the maximum annual dose and activity concentration results, an additional calculation with ten times less erosion rate than the default could be performed. However, a large change did not occur.

[14] When the water table parameter was changed (Section 4a), RESRAD 7.0 automatically changed another parameter, the water table drop rate, from its default value of 1 mm/y to zero. This was not noticed until all additional RESRAD 7.0 calculations described in sections 4b through 5 were completed and discussed herein. Since this oversight did not affect the maximum values of annual dose and of soil, water, and air concentrations and because of time constraints, these calculations were not redone.

Similar to the baseline resident farmer scenario with 9700 rounds, the maximum ^{238}U activity concentration in air due to dust is about 6.5 $\times 10^{-5}$ pCi/m^3 and occurs during the first year (Figure 16). It decreases to zero in about twenty years.

c. Contaminated zone total porosity is 0.6 instead of default 0.4

The highest value for total porosity in Table E.8 of the RESRAD manual (Yu, et al. 2001) is 0.57 for clay or for weathered granite, so a porosity of 0.6 is chosen as a bounding value.[15]

The RESRAD report for this bounding scenario is in Attachment 5.

Part 1, page 12 of the RESRAD report and Figure 17 for the 9700 M101 rounds bounding scenario for high total porosity show that the maximum annual dose of 0.28 mrem occurs in the first year.

Figure 18 shows that ^{238}U soil concentration (and hence, the M101 DU soil concentration) decreases significantly over the first hundred years due to erosion and leaching. This accounts for much of the decrease in annual dose over that same period.

Part IV, page 3 of the RESRAD report shows that the activity concentration of ^{238}U in well water at the first year is 0.006 pCi/L. Figure 19 then shows it gradually increases, reaching about 1.25 pCi/L in about 100 years. The corresponding DU concentration in well water is about 1.4 pCi/L or about 3.6 μg DU/L. It then gradually drops to zero beginning at about 600 years.

Similar to the baseline resident farmer scenario with 9700 rounds, the maximum ^{238}U activity concentration in air due to dust is about 6.5 $\times 10^{-5}$ pCi/m^3 and occurs during the first year (Figure 20). It decreases to zero in about 100 years.

d. Contaminated zone hydraulic conductivity is 6000 m/y instead of default 10 m/y

The highest value for contaminated zone hydraulic conductivity in Table E.2 of the RESRAD manual (Yu, et al. 2001) is 5550 m/y for sand, so a hydraulic conductivity of 6000 m/y is chosen as a bounding value.[16]

The RESRAD report for this bounding scenario is in Attachment 6.

Part 1, page 12 of the RESRAD report and Figure 21 for the 9700 M101 rounds bounding scenario for high hydraulic conductivity show that the maximum annual dose of 0.28 mrem occurs in the first year.

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[15] If this scenario produced a large change in the maximum annual dose and activity concentration results, an additional calculation with porosity than the default could be performed. However, a large change did not occur.

[16] If this scenario produced a large change in the maximum annual dose and activity concentration results, an additional calculation with a hydraulic conductivity than the default could be performed. However, a large change did not occur.

Figure 22 shows that ^{238}U soil concentration (and hence, the M101 DU soil concentration) decreases significantly over the first hundred years due to erosion and leaching. This accounts for much of the decrease in annual dose over that same period.

Part IV, page 3 of the RESRAD report shows that the activity concentration of ^{238}U in well water at the first year is 0.006 pCi/L. Figure 23 then shows it gradually increases, reaching about 1.25 pCi/L in about 100 years. The corresponding DU concentration in well water is about 1.4 pCi/L or about 3.6 μg DU/L. It then gradually drops to zero beginning at about 600 years.

Similar to the baseline resident farmer scenario with 9700 rounds, the maximum ^{238}U activity concentration in air due to dust is about 6.5×10^{-5} pCi/m^3 and occurs during the first year (Figure 24). It decreases to zero in about 100 years.

e. Average annual wind speed is 1 m/h instead of default 2 m/h

The smallest value for average annual wind speed in Table B.2 of the RESRAD manual (Yu, et al. 2001) is 1 m/y, so that is chosen as a bounding value.

The RESRAD report for this bounding scenario is in Attachment 7.

Part 1, page 12 of the RESRAD report and Figure 25 for the 9700 M101 rounds bounding scenario for low average wind speed show that the maximum annual dose of 0.29 mrem occurs in the first year.

Figure 26 shows that ^{238}U soil concentration (and hence, the M101 DU soil concentration) decreases significantly over the first hundred years due to erosion and leaching. This accounts for much of the decrease in annual dose over that same period.

Part IV, page 3 of the RESRAD report shows that the activity concentration of ^{238}U in well water at the first year is 0.006 pCi/L. Figure 27 then shows it gradually increases, reaching about 1.25 pCi/L in about 100 years. The corresponding DU concentration in well water is about 1.4 pCi/L or about 3.6 μg DU/L. It then gradually drops to zero beginning at about 600 years.

Similar to the baseline resident farmer scenario with 9700 rounds, the maximum ^{238}U activity concentration in air due to dust is about 6.5×10^{-5} pCi/m^3 and occurs during the first year (Figure 28). It decreases to zero in about 100 years.

f. Average annual wind speed is 10 m/h instead of default 2 m/h

The largest value for average annual wind speed in Table B.2 of the RESRAD manual (Yu, et al. 2001) is 10 m/y, so that is chosen as a bounding value.

The RESRAD report for this bounding scenario is in Attachment 8.

Part 1, page 12 of the RESRAD report and Figure 29 for the 9700 M101 rounds bounding scenario for low average wind speed show that the maximum annual dose of 0.28 mrem occurs in the first year.

Figure 30 shows that ^{238}U soil concentration (and hence, the M101 DU soil concentration) decreases significantly over the first hundred years due to erosion and leaching. This accounts for much of the decrease in annual dose over that same period.

Part IV, page 3 of the RESRAD report shows that the activity concentration of ^{238}U in well water at the first year is 0.006 pCi/L. Figure 27 then shows it gradually increases, reaching about 1.25 pCi/L in about 100 years. The corresponding DU concentration in well water is about 1.4 pCi/L or about 3.6 μg DU/L. It then gradually drops to zero beginning at about 600 years.

Similar to the baseline resident farmer scenario with 9700 rounds, the maximum ^{238}U activity concentration in air due to dust is about 6.5×10^{-5} pCi/m^3 and occurs during the first year (Figure 28). It decreases to zero in about 100 years.

g. Average annual precipitation is 2 m instead of default 1 m

Hawaii has the highest average total annual precipitation of about 64 inches or 1.6 m (NOAA 2015). Two meters is used as a bounding value in RESRAD.

The RESRAD report for this bounding scenario is in Attachment 9.

Part 1, page 12 of the RESRAD report and Figure 33 for the 9700 M101 rounds bounding scenario for low average wind speed show that the maximum annual dose of 0.28 mrem occurs in the first year.

Figure 34 shows that ^{238}U soil concentration (and hence, the M101 DU soil concentration) decreases significantly over the first hundred years due to erosion and leaching. This accounts for much of the decrease in annual dose over that same period.

Part IV, page 3 of the RESRAD report shows that the activity concentration of ^{238}U in well water at the first year is 0.11 pCi/L. Figure 35 then shows it gradually increases, reaching about 1.4 pCi/L in about 100 years. The corresponding DU concentration in well water is about 1.5 pCi/L or about 3.9 μg DU/L. It then gradually drops to zero beginning at about 600 years.

Similar to the baseline resident farmer scenario with 9700 rounds, the maximum ^{238}U activity concentration in air due to dust is about 6.6×10^{-5} pCi/m^3 and occurs during the first year (Figure 36). It decreases to zero in about 100 years.

5. All above bounding values

Clearly, adjusting environmental parameters from their default values in RESRAD has little or no effect on the maximum annual dose. Using all the above bounding environmental parameters (with low average annual wind speed instead of high average annual wind speed) simultaneously produces similar results.

The RESRAD report for this bounding scenario is in Attachment 10.

Part 1, page 12 of the RESRAD report and Figure 37 for the 9700 M101 rounds bounding scenario with several bounding environmental parameters show that the maximum annual dose of about 0.33 mrem occurs in the first year.

Figure 38 shows that ^{238}U soil concentration (and hence, the M101 DU soil concentration) decreases significantly over the first hundred years due to erosion and leaching. This accounts for much of the decrease in annual dose over that same period.

Part IV, page 2 of the RESRAD report shows that the activity concentration of ^{238}U in well water at the first year is 0.37 pCi/L. Figure 39 then shows it gradually increases, reaching about 0.63 pCi/L in about 10 years. The corresponding DU concentration in well water is about 0.72 pCi/L or about 1.8 μg DU/L. It then gradually drops to zero beginning after about 300 years.

The *maximum* ^{238}U *activity concentration in air due to dust is about* 1.3×10^{-4} *pCi/m*^{3} *and* occurs during the first year (Figure 40). It decreases to zero in less than 30 years.

6. All above bounding values in 0.1 km^2

Instead of assuming that the DU from 9700 completely corroded M101 spotting rounds is evenly distributed in an area of 1 km^2, assume the area to be 0.1 km^2. This bounding value assumption is made because trainers may have avoided firing near the boundaries of the range. Using only 10 percent of the available area in the RESRAD calculations is a highly conservative assumption, but it will provide an additional bounding condition.

With this assumption of the same amount of DU in an area 10 times smaller than used above (that is, 0.1 km^2 or a circle of radius 178 m), the concentrations of the uranium isotopes will be ten times larger than those used above (that is, 24.8 pCi/g ^{238}U, 0.228 pCi/g ^{235}U, and 3.27 pCi/g ^{234}U).

The RESRAD report for this bounding scenario is in Attachment 11.

Part 1, page 12 of the RESRAD report and Figure 41 for the 9700 M101 rounds bounding scenario with several bounding environmental parameters show that the *maximum annual dose of about 3.2 mrem occurs in the first year.*

Figure 42 shows that ^{238}U soil concentration (and hence, the M101 DU soil concentration) decreases significantly over the first hundred years due to erosion and leaching. This accounts for much of the decrease in annual dose over that same period.

Part IV, page 2 of the RESRAD report shows that the activity concentration of ^{238}U in well water at the first year is 5.2 pCi/L. Figure 43 then shows it gradually increases, reaching about 6.3 pCi/L in about 10 years. The corresponding DU concentration in well water is about 7.2 pCi/L or about 18 μg DU/L. It then gradually drops to zero beginning after about 300 years.

The maximum ^{238}U activity concentration in air due to dust is about 1.1 $\times 10^{-3}$ pCi/m^3 and occurs during the first year (Figure 44). It decreases to zero in less than 30 years.

7. RESRAD-OFFSITE, 9700 M101 Rounds, Default Parameters, Resident Farmer about 1 km from DU Impact Area

Instead assuming the resident farmer lives on the former DU impact area, assume the resident farmer lives about one kilometer from the DU impact area. One kilometer is a typical minimum distance from current Army training ranges to normally occupied areas. RESRAD-OFFSITE performs these calculations, which also suffice to demonstrate compliance with the NRC requirement to measure or calculate the maximum annual dose to a member of the public (10 CFR 20, § 20.1101) to assure that NRC standards are not exceeded.

The RESRAD-OFFSITE report for this bounding scenario is in Attachment 12.

Part 1, page 39 of the RESRAD-OFFSITE report and Figure 45 for the 9700 M101 rounds offsite resident farmer scenario show that the maximum annual dose of about 0.035 mrem occurs in the first year.

Figure 46 shows that ^{238}U soil concentration rises to about 5.7 $\times$ 10^{-8} pCi/g in the first 20 years. It then decreases to zero over the next 100 years or so.

Figure 47 shows that the maximum activity concentration of ^{238}U in surface water near the offsite dwelling is about 0.23 pCi/L. The corresponding DU concentration in well water is about 0.26 pCi/L or about 0.7 μg DU/L.

Figure 48 shows that the maximum ^{238}U activity concentration in air above the offsite dwelling due to dust is about 8.8 $\times 10^{-8}$ pCi/m^3.

8. Bibliography

Argonne National Laboratory. *Chemical Forms of Uranium.* http://web.ead.anl.gov/uranium/guide/ucompound/forms/ (accessed February 11, 2015).

Cabrera Services Inc. *Characterization Report, Schofield Barracks Davy Crockett Impact Area, Oahu, Hawaii.* Las Vegas, Nevada: Cabrera Services Inc., 2008.

Cabrera Services Inc. *Final Status Survey of the Initial 100 Acres of Radiological Control Area at Schofield Barracks.* North Highlands, California: Cabrera Services Inc., 2013.

Cabrera Services. *Schofield Barracks Impact Range Baseline Human Health Risk Assessment for Residual Depleted Uranium.* Las Vegas, Nevada: Cabrera Services, 2008.

Cherry, Robert N. "Army Response to US Nuclear Regulatory Commission (NRC) Proposed License Conditions for Davy Crockett M101 Spotting Round Depleted Uranium (DU)." ADAMS ML110830582, 2012.

Defense Nuclear Agency. *The Radiological Cleanup of Enewetak Atoll.* Washington, DC: Defense Nuclear Agency, 1981.

DOE. *DOE-STD-1136-2009 Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities.* Washington DC: Department of Energy, 2009.

—. *RESRAD Home Page.* Department of Energy. 2015. https://web.evs.anl.gov/resrad/home2/index.cfm (accessed March 27, 2015).

Durante, Marco, and Mariagabriella Pugliese. "Depleted uranium residual radiological risk assessment for Kosovo sites." *Journal of Environmental Radioactivity* 64 (2003): 237-245.

IAEA. *Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments.* Technical Report Series 364, Vienna, Austria: International Atomic Energy Agency, 1994.

Kane, William F. January 9, 2001. http://pbadupws.nrc.gov/docs/ML0100/ML010050342.pdf (accessed February 11, 2015).

Michalak, Paul. "U.S. Nuclear Regulatory Commission Staff Review of the U.S. Army's Applicaiton for a Rdioactive Materials License for Depleted Uranium from the Davy Crockett Munitions Sstem." Rockville, Maryland: US Nuclear Regulatory Commission, November 20, 2010.

NCRP. *NCRP Report No. 160, Ionizing Radiation Exposure of the Population of the United States.* Bethesda, Maryland: National Council on Radiation Protection and Measurements, 2009.

NCRP. *NRCP Report No. 169: Design of Effective Radiological Effluent Monitoring and Environmental Surveillance Programs.* Bethesda, Maryland: National Council on Radiation Protection and Measurements, 2010.

NOAA. *National Climatic Data Center.* 2015. http://www.ncdc.noaa.gov/ (accessed April 17, 2015).

NRC. "10 CFR Part 20 Standards for Protection Against Radiation." August 23, 2012. http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/full-text.html (accessed August 31, 2012).

NRC. *NUREG-1757, Volume 2, Revision 1: Consolidated Decommissioning Guidance: Characgterization, Survey, and Determination of Radoiological Criteria.* Washington, DC: Nuclear Regulatory Commission, 2006.

NRC, DOE, EPA, DOD. *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (NUREG-1575), Revision 1.* Washington, DC: NRC, 2000.

ORAP. *U.S. Army Operational Range Assessment Program (ORAP) Reports.* August 23, 2013. http://denix.osd.mil/sri/Policy/orap.cfm (accessed February 11, 2015).

Papastefanou, C. "Depleted uranium in military conflicts and the impact on the environment." *Health Physics* 83, no. 2 (August 2002).

PIKA International. *Survey Report for U.S. Army Ft. Hood Firing Range, Project # USA 2007-042, Phase I.* Stafford, Texas: PIKA International, 2007.

SAIC. *Army's Decommissioning Plan for NRC Materials License SUB-1435.* Louisville, Kentucky: US Army Corps of Engineers Louisville District, 2013.

Scientific Ecology Group. *Jefferson Proving Ground Depleted Uranium Impact Area NRC License No. SUB-1435 Scoping Survey Report Volume 1, Survey Report.* Oak Ridge, Tennessee: Scientific Ecology Group, 1995.

Shia, Corinne. *Airborne Transport of Depletcd Uranium (DU) and Site Characterization Needs.* Email to Paul D. Cloud, Reston, Virginia, Virginia: Science Applications International Corporation, 2005.

Spitzberg, D. Blair. *Safey Evaluation Report for Eglin Air Force Base.* Arlington, Texas: US Nuclear Regulatory Commission, 2005.

UNEP. *Depleted Uranium in Bosnia and Herzegovina: Post-Conflict Environmental Assessment.* Nairobi, Kenya: United Nations Environment Programme, 2003.

UNEP. *Depleted Uranium in Kosovo: Post-Conflict Environmental Assessment.* Nairobi, Kenya: United Nations Environment Programme, 2001.

UNEP. *Depleted Uranium in Serbia and Montenegro: Post-Conflict Environmental Assessment in the Federal Republic of Yugoslavia.* Nairobi, Kenya: United Nations Environment Programme, 2002.

UNSCEAR. *Sources and effects of ionizing radiation: UNSCEAR 1993 Report to the General Assembly, with Scientific Annexes.* New York, New York: United Nations, 1993.

USACE St Louis. *Project Archive Search Report: Use of Cartridge, 20mm Spotting M101.* St Louis, Missouri: US Army Corps of Engineers, St Louis District, 2011.

USAEPI. *Health and Environmental Consequences of Depleted Uranium Use in the U.S. Army.* Atlanta, Georgia: US Army Environmental Policy Institute, 1995.

USASSBC. *Environmental Report: Jefferson Proving Ground, Madison, Indiana.* Aberdeen Proving Ground: U.S. Department of the Army Soldier and Biological Chemical Command, 2002.

USEPA. *Depleted Uranium: Technical Brief (EPA 402-R-06-011).* Washington, DC: US Environmental Protection Agency, 2006.

USEPA. *Exposure Factor Handbook (EPA/600/P-95/002Fa).* Washington, DC: US Environmental Protection Agency, 1997.

USNRC. "US Nuclear Regulatory Commission License Number SUC-1593." Rockville, Maryland: US Nuclear Regulatory Commission, October 13, 2013.

Uyttenhove, J, M Lemmens, and M Zizi. "Depleted Uranium in Kosovo: Results of a Survey by Gamma Spectrometry on Soil Samples." *Health Physics* 83, no. 4 (October 2002): 543-548.

Whicker, F. Ward, and Arthur S. Rood. "Terrestrial Food Chain Pathways: Concepts and Models." In *Radiological Risk Assessment and Environmental Analysis*, edited by John E. Till and Helen A. Grogan. New York, New York: Oxford University Press, 2008.

Yu, C., et al. *User's Manual for RESRAD Version 6.* Argonne, Illinois: Department of Energy Argonne National Laboratory, 2001.

Figures

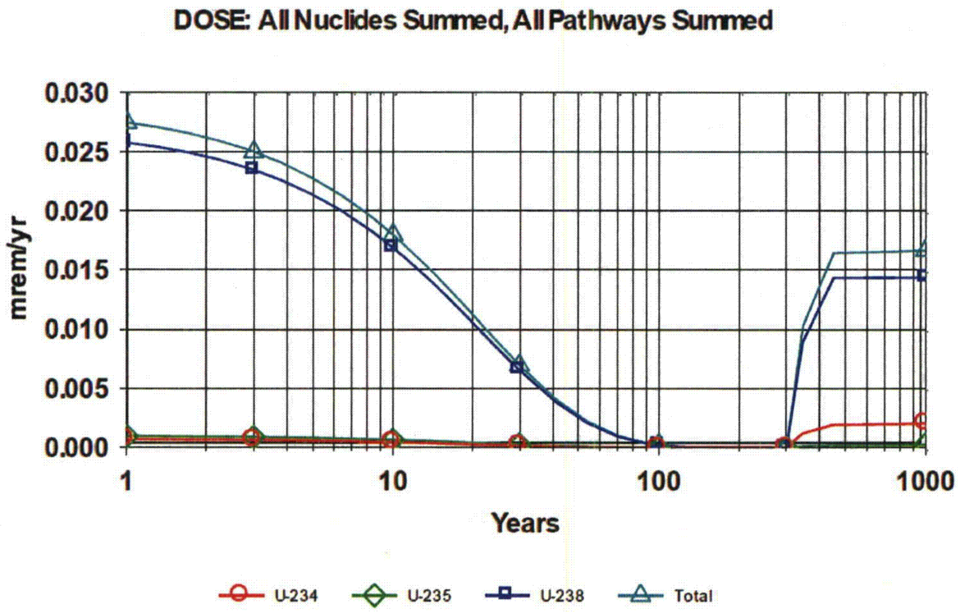

Figure 1 Annual dose vs. time for DU from 1000 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area, using RESRAD 7.0 defaults for resident farmer scenario

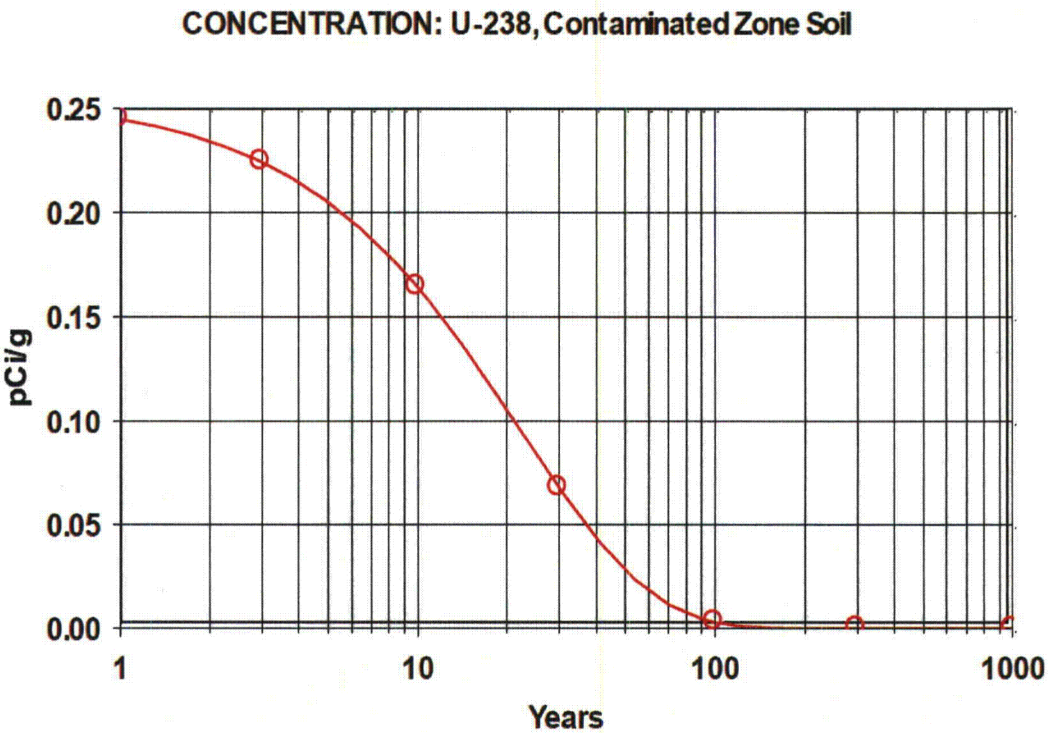

Figure 2 Uranium-238 activity concentration in impact area soil vs. time for DU from 1000 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area, using RESRAD 7.0 defaults for resident farmer scenario

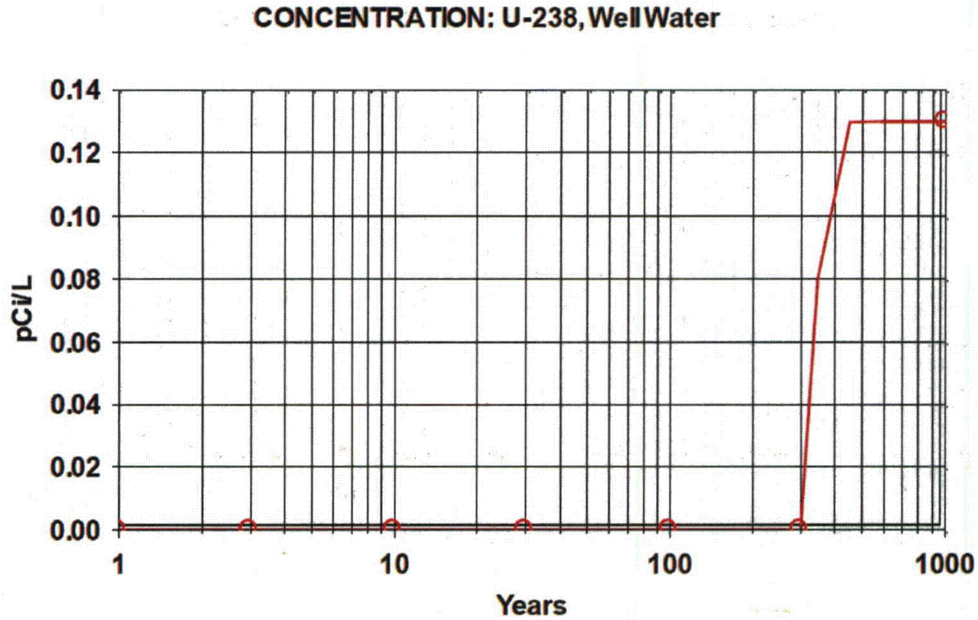

Figure 3 Uranium-238 activity concentration in well water vs. time for DU from 1000 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area, using RESRAD 7.0 defaults for resident farmer scenario

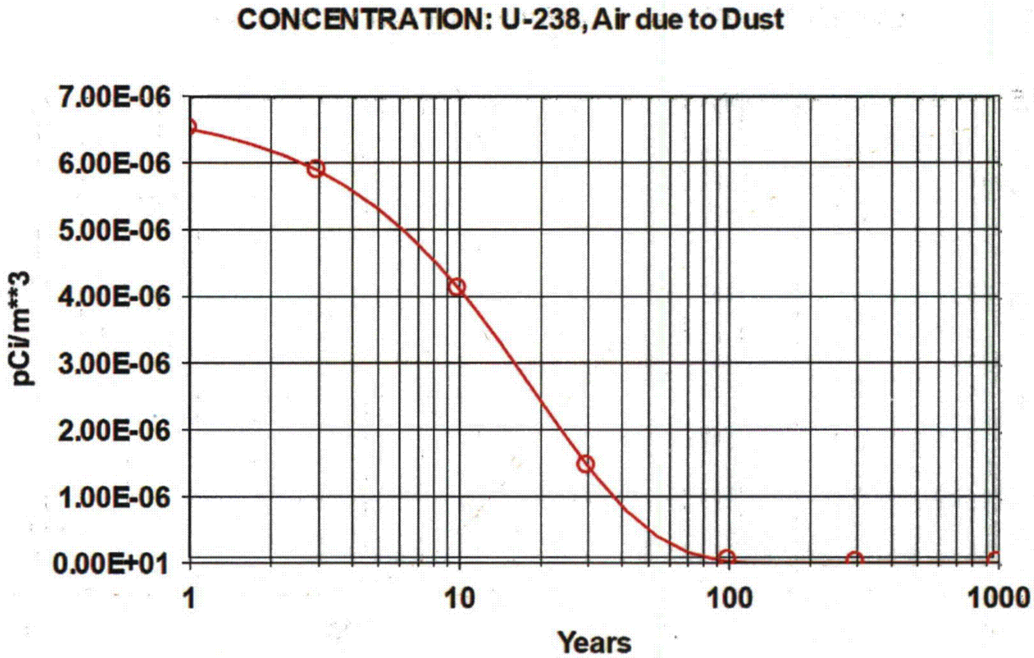

Figure 4 Uranium-238 activity concentration in air over impact area vs. time for DU from 1000 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area, using RESRAD 7.0 defaults for resident farmer scenario

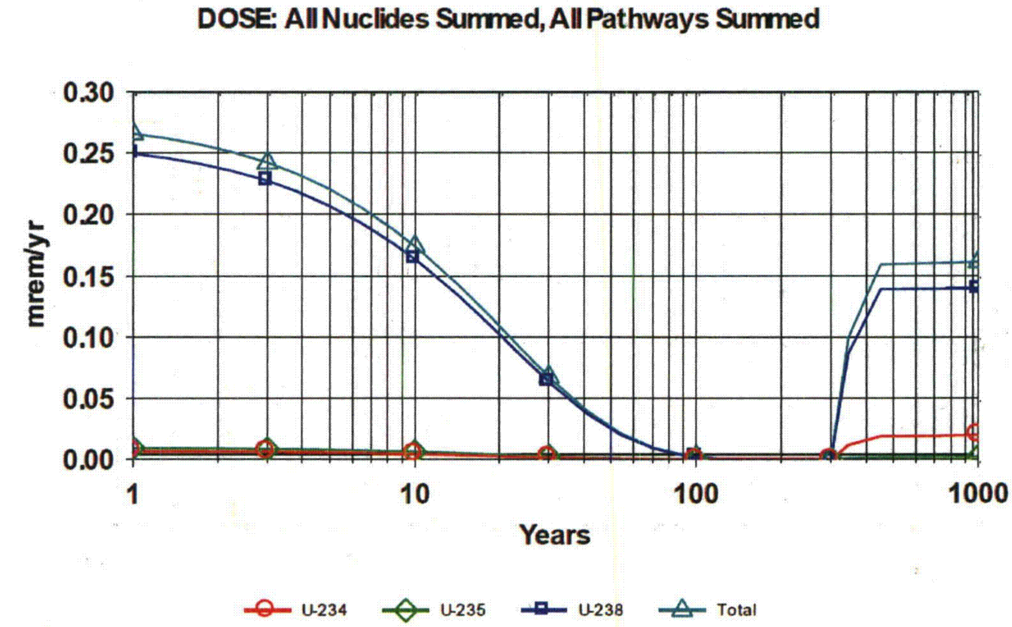

Figure 5 Annual dose vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area, using RESRAD 7.0 defaults for resident farmer scenario

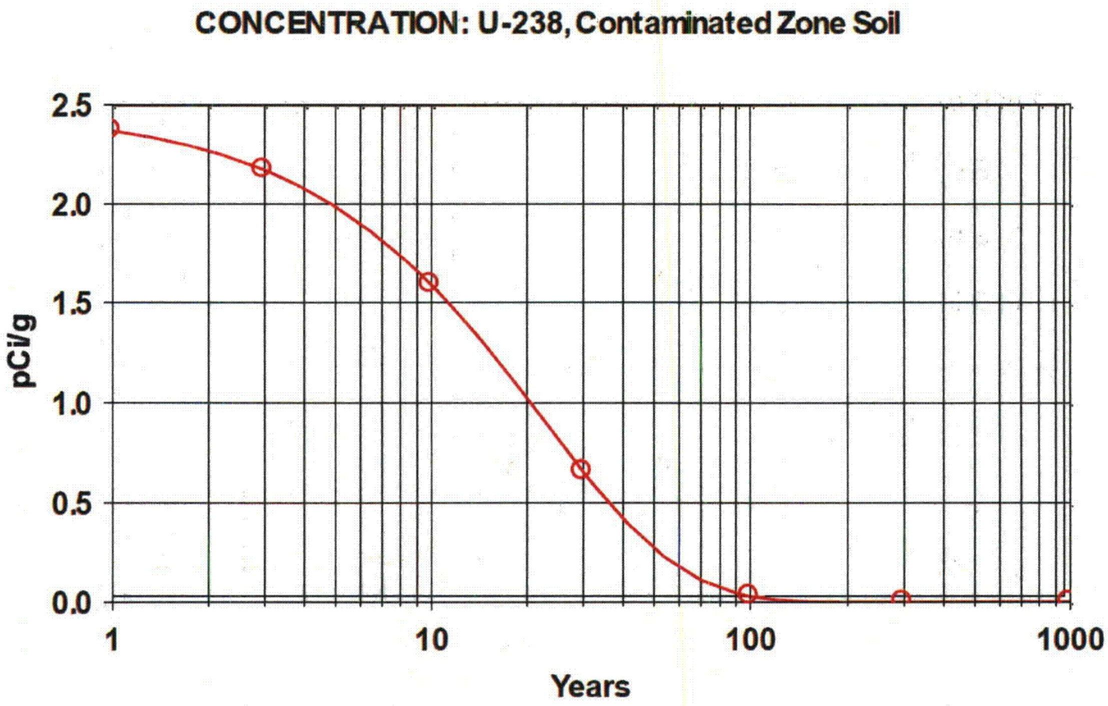

Figure 6 Uranium-238 activity concentration in impact area soil vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area, using RESRAD 7.0 defaults for resident farmer scenario

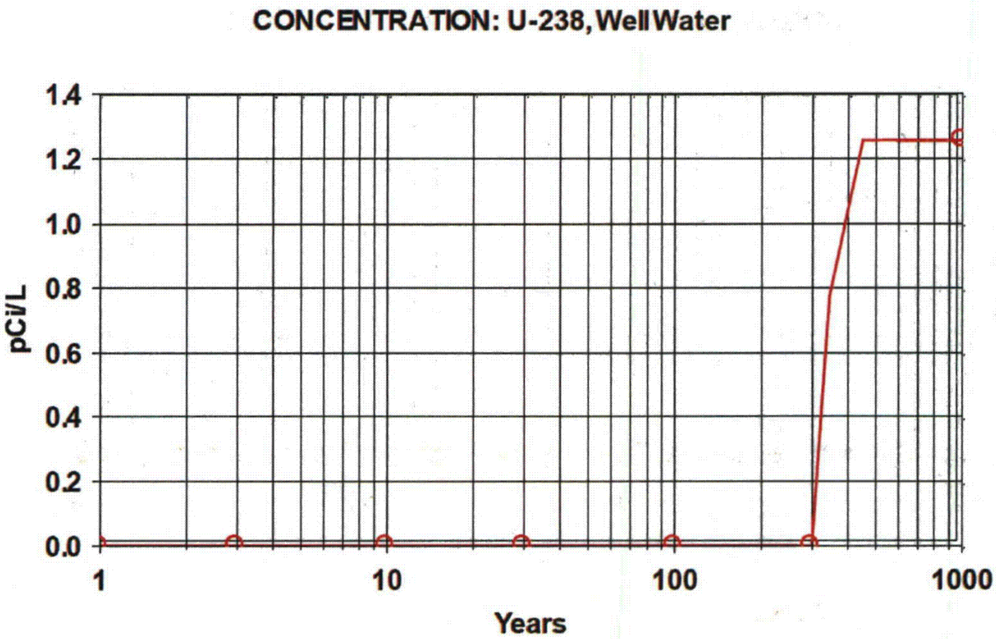

Figure 7 Uranium-238 activity concentration in well water vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area, using RESRAD 7.0 defaults for resident farmer scenario

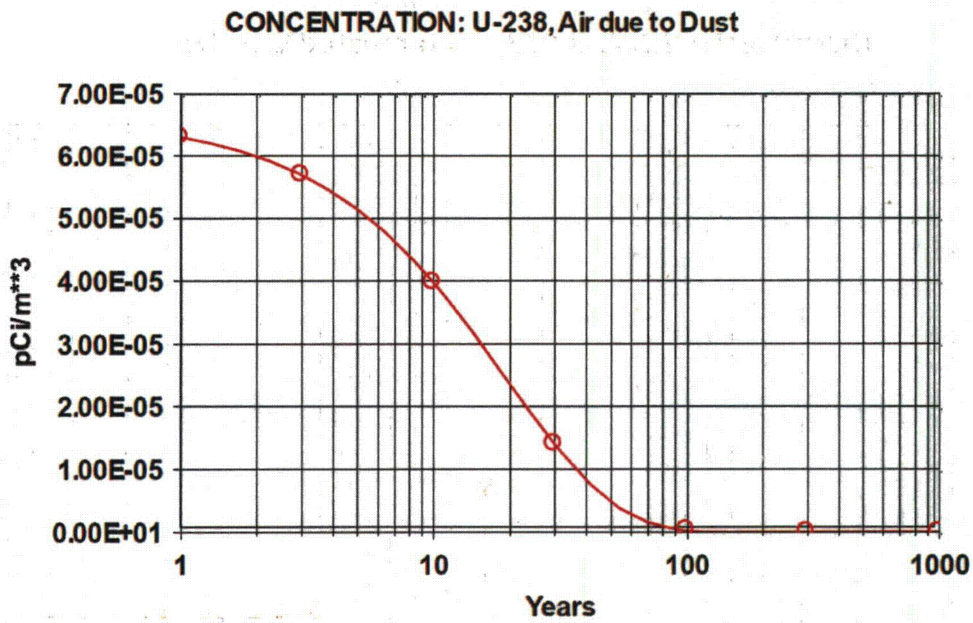

Figure 8 Uranium-238 activity concentration in air over impact area vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area, using RESRAD 7.0 defaults for resident farmer scenario

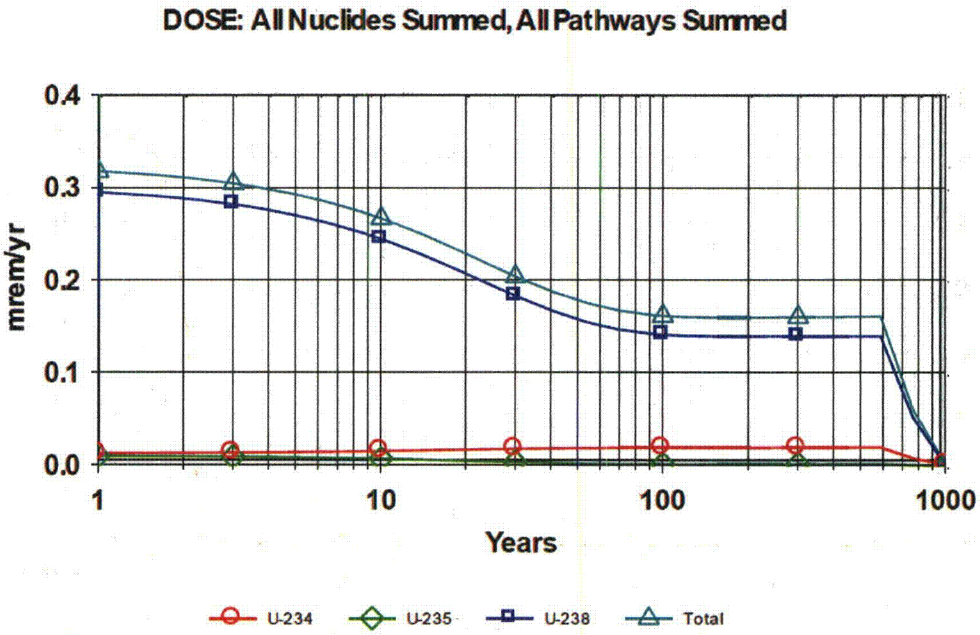

Figure 9 Annual dose vs. time from bounding value for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and water table 7.5 cm below ground surface, otherwise using RESRAD 7.0 defaults for resident farmer scenario

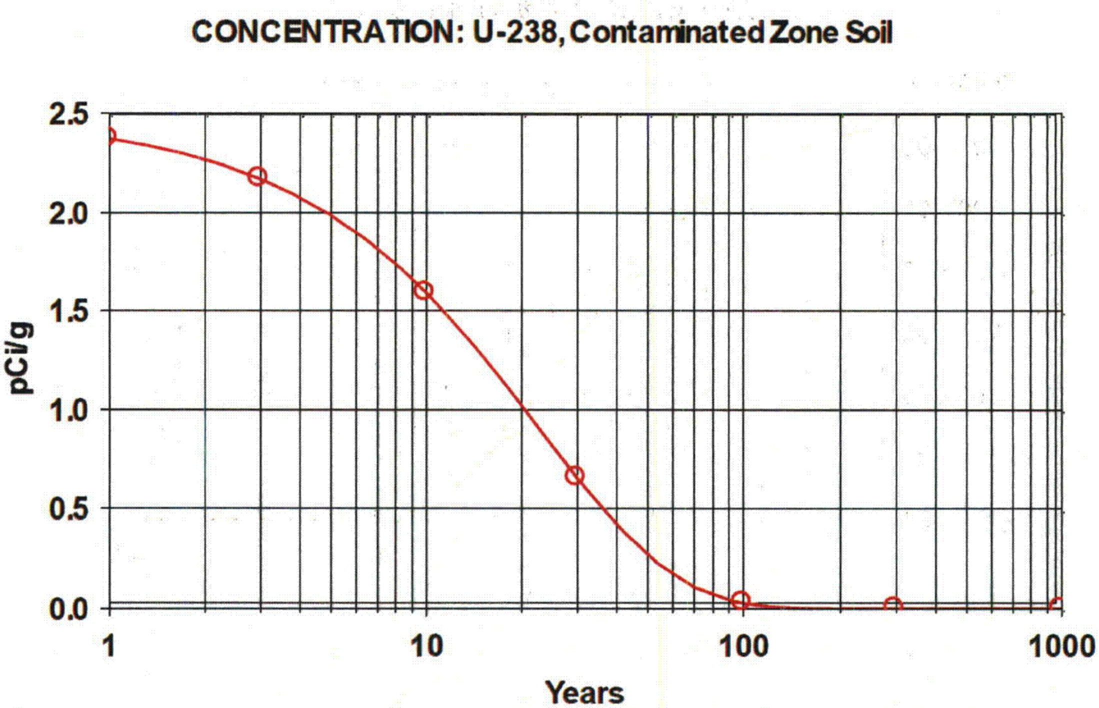

Figure 10 Uranium-238 activity concentration in impact area soil vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and water table 7.5 cm below ground surface, otherwise using RESRAD 7.0 defaults for resident farmer scenario

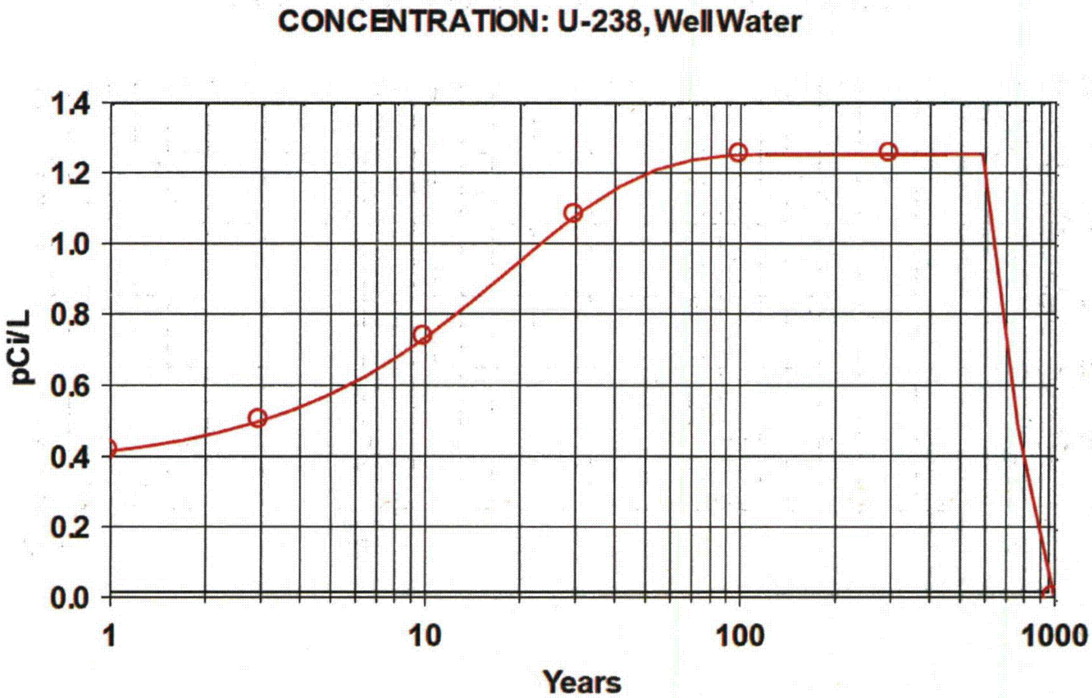

Figure 11 Uranium-238 activity concentration in well water vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and water table 7.5 cm below ground surface, otherwise using RESRAD 7.0 defaults for resident farmer scenario

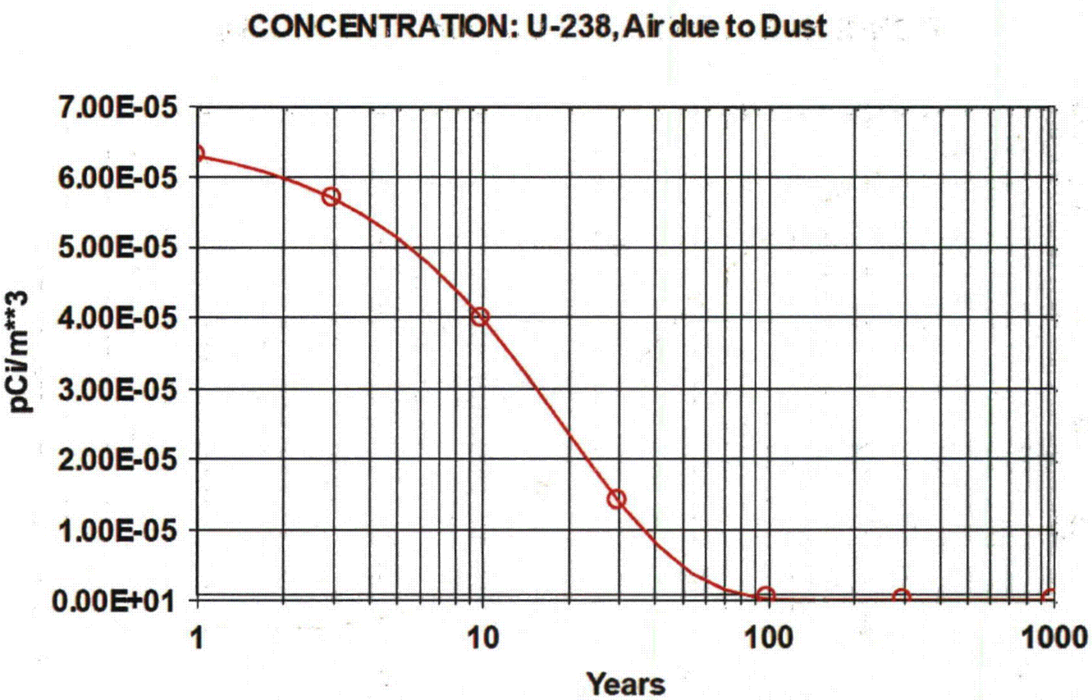

Figure 12 Uranium-238 activity concentration in air over impact area vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and water table 7.5 cm below ground surface, otherwise using RESRAD 7.0 defaults for resident farmer scenario

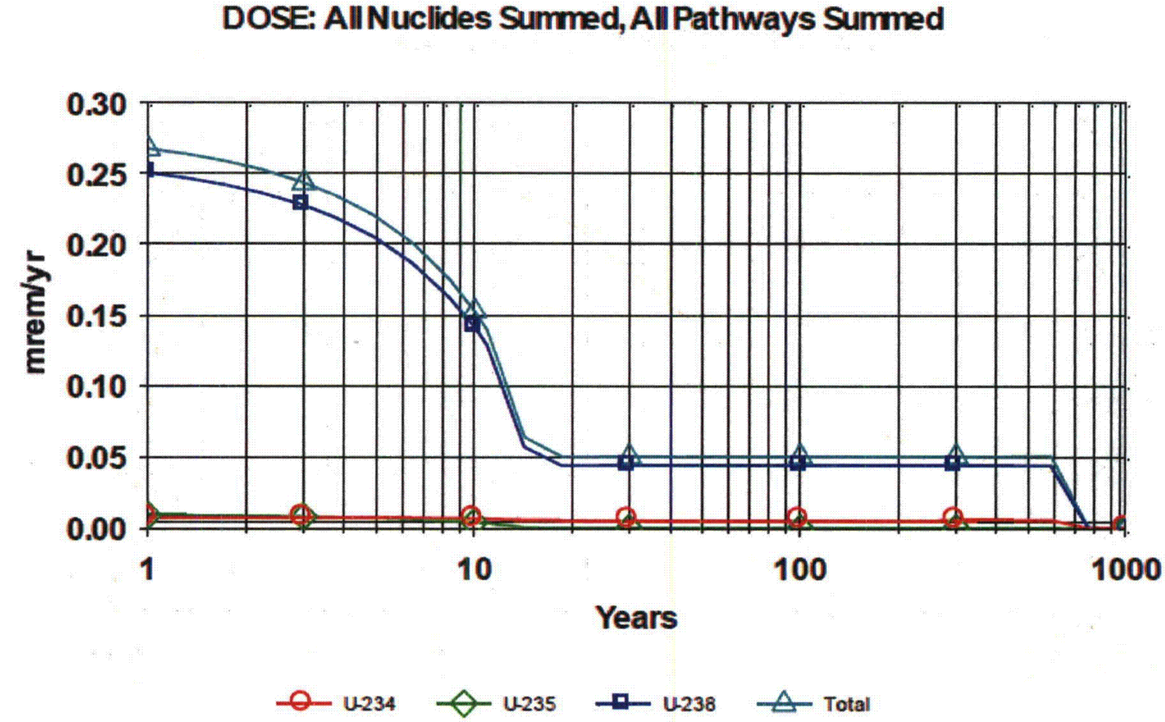

Figure 13 Annual dose vs. time from bounding value for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and contamination zone erosion rate of 0.01 m/y, otherwise using RESRAD 7.0 defaults for resident farmer scenario

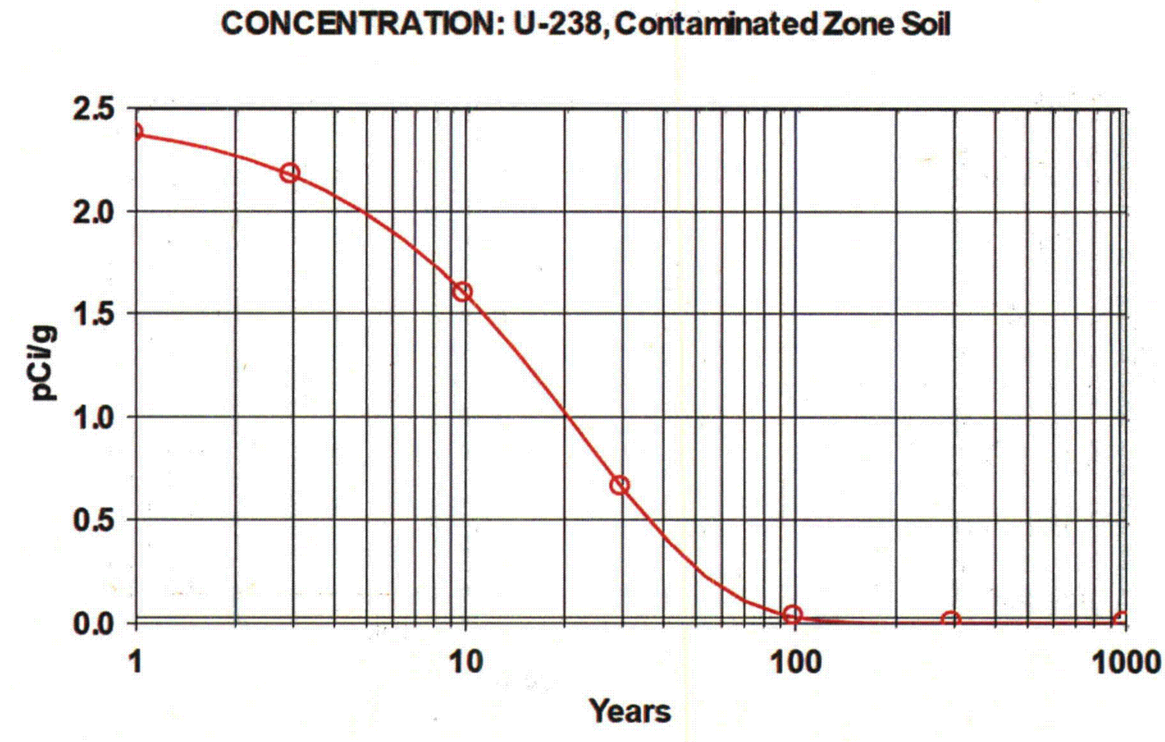

Figure 14 Uranium-238 activity concentration in impact area soil vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and contamination zone erosion rate of 0.01 m/y, otherwise using RESRAD 7.0 defaults for resident farmer scenario

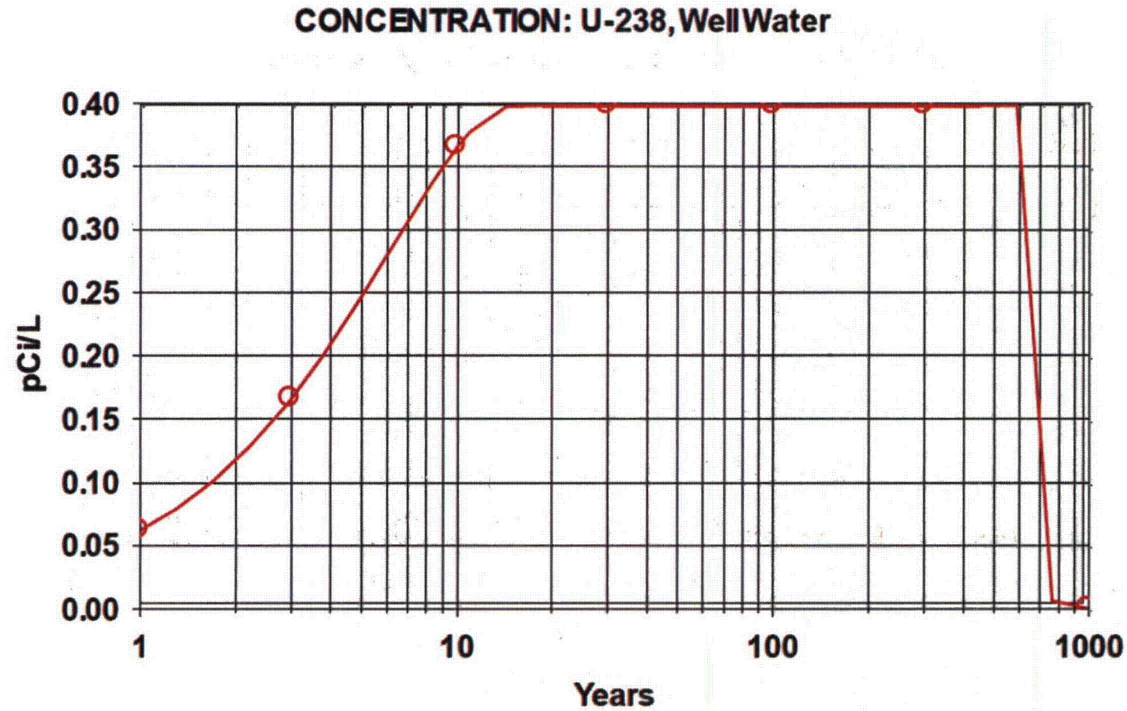

Figure 15 Uranium-238 activity concentration in well water vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and contamination zone erosion rate of 0.01 m/y, otherwise using RESRAD 7.0 defaults for resident farmer scenario

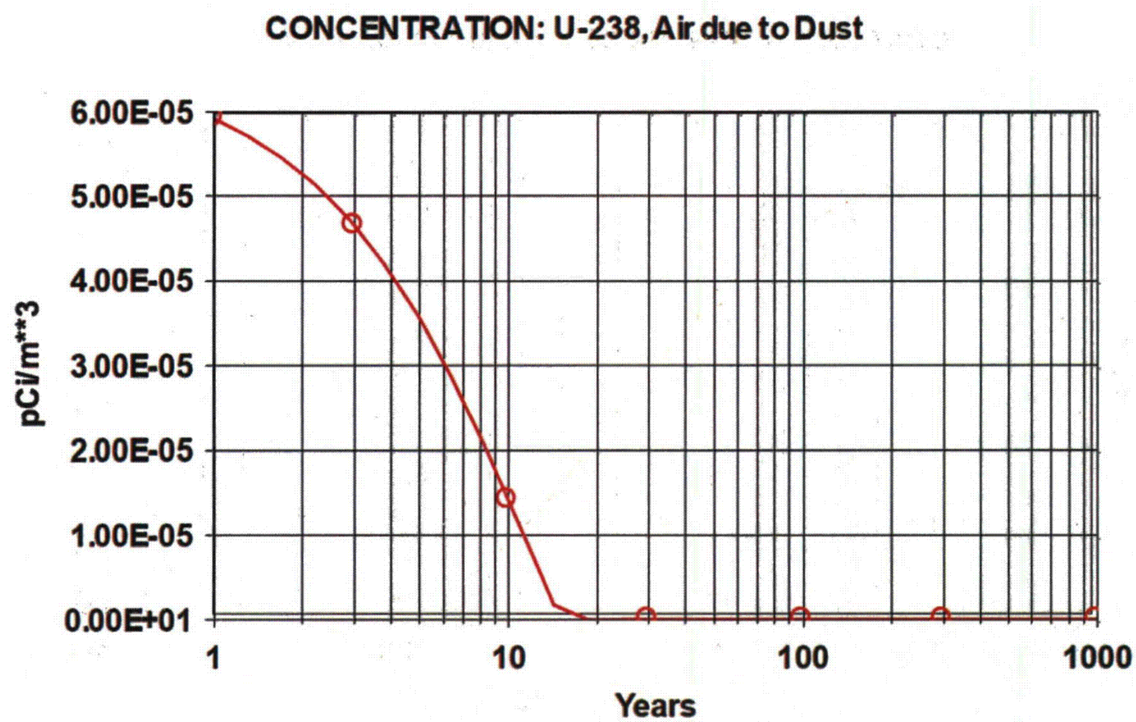

Figure 16 Uranium-238 activity concentration in air over impact area vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and contamination zone erosion rate of 0.01 m/y, otherwise using RESRAD 7.0 defaults for resident farmer scenario

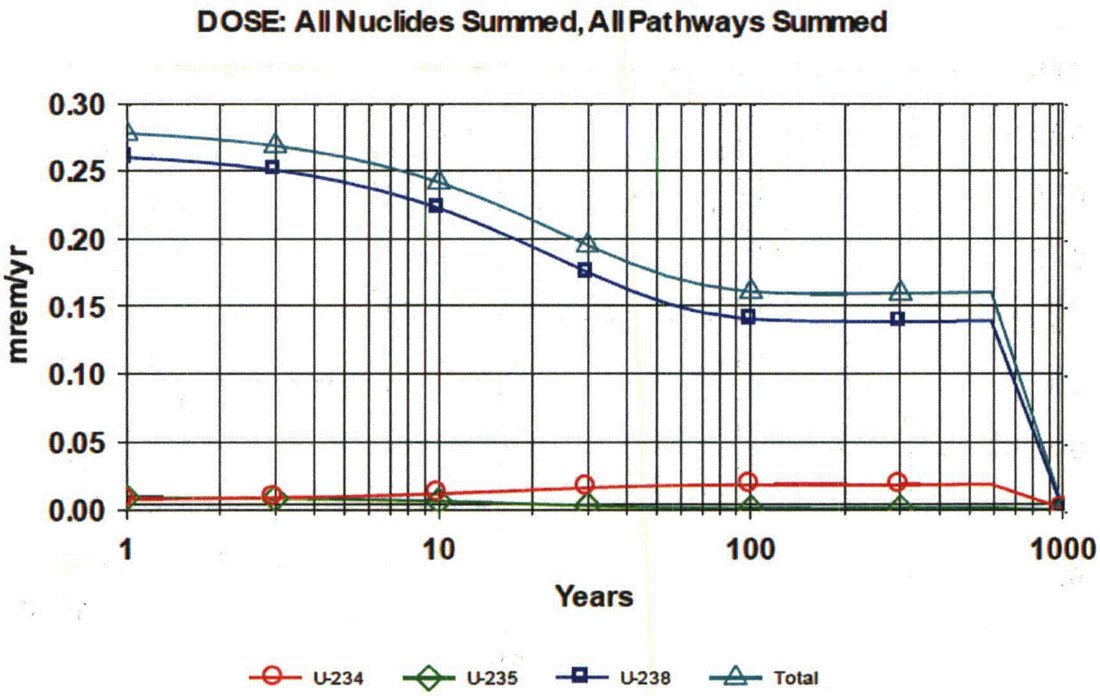

Figure 17 Annual dose vs. time from bounding value for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and contamination zone total porosity of 0.6, otherwise using RESRAD 7.0 defaults for resident farmer scenario

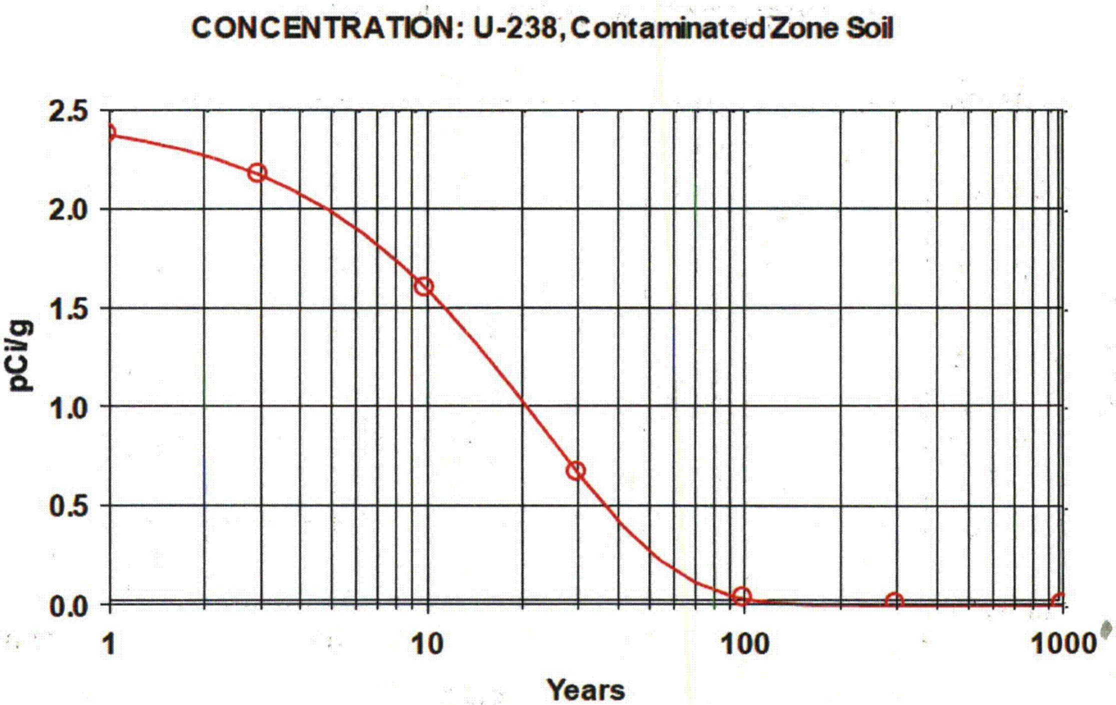

Figure 18 Uranium-238 activity concentration in impact area soil vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and contamination zone total porosity of 0.6, otherwise using RESRAD 7.0 defaults for resident farmer scenario

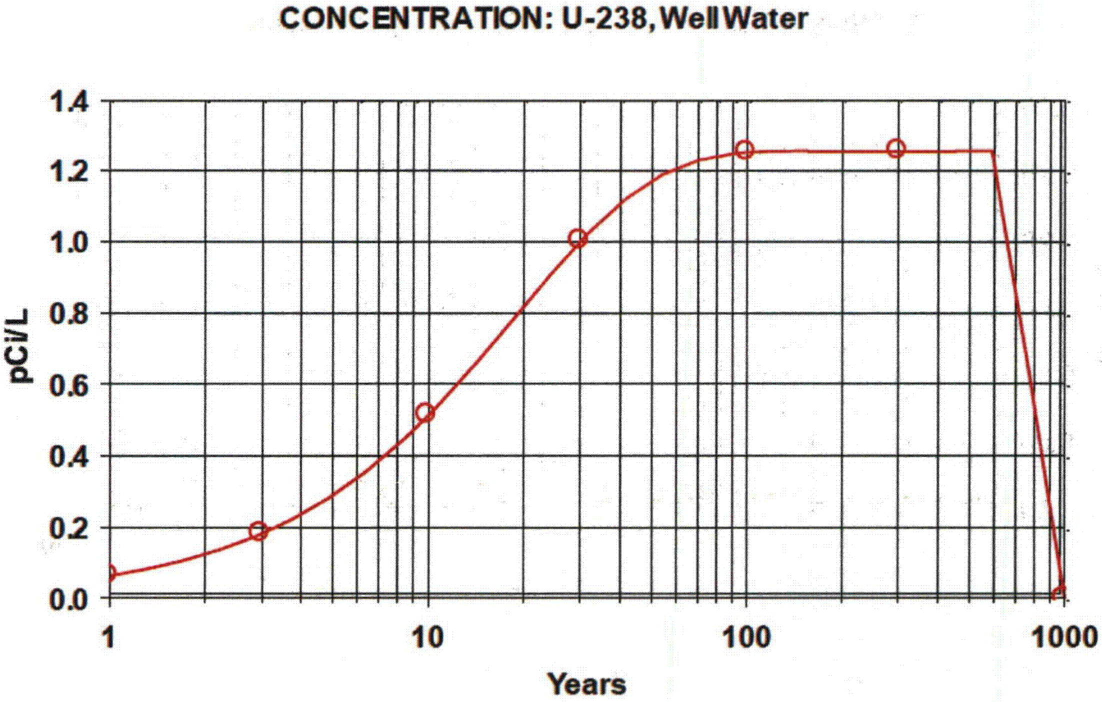

Figure 19 Uranium-238 activity concentration in well water vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and contamination zone total porosity of 0.6, otherwise using RESRAD 7.0 defaults for resident farmer scenario

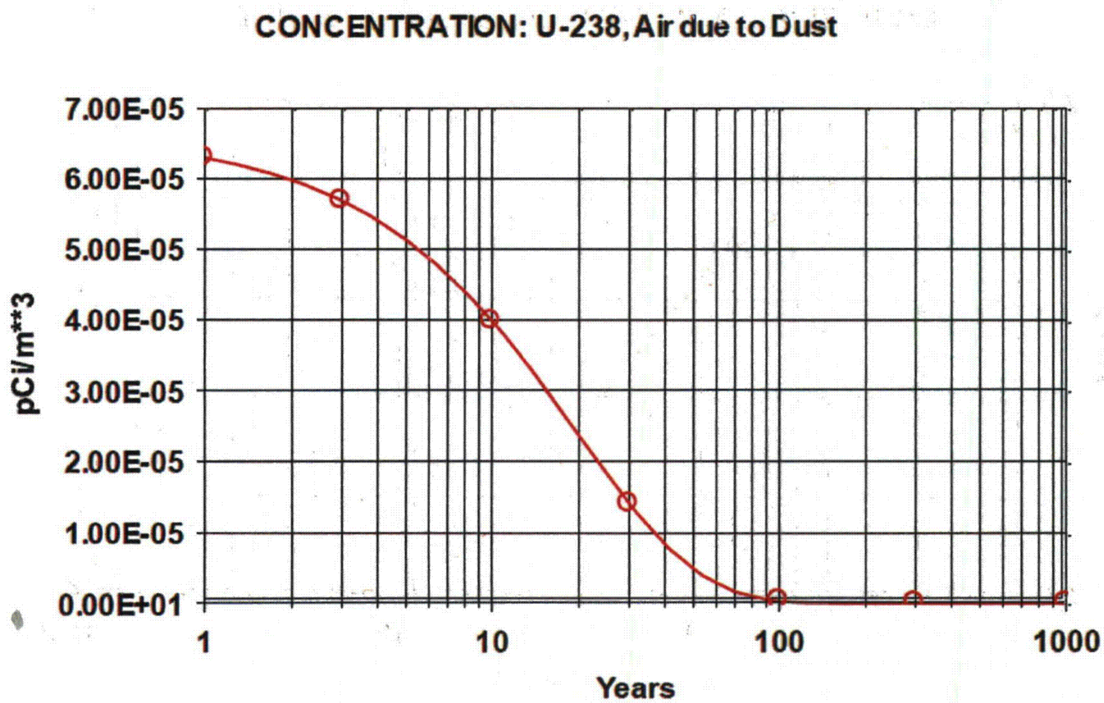

Figure 20 Uranium-238 activity concentration in air over impact area vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and contamination zone total porosity of 0.6, otherwise using RESRAD 7.0 defaults for resident farmer scenario

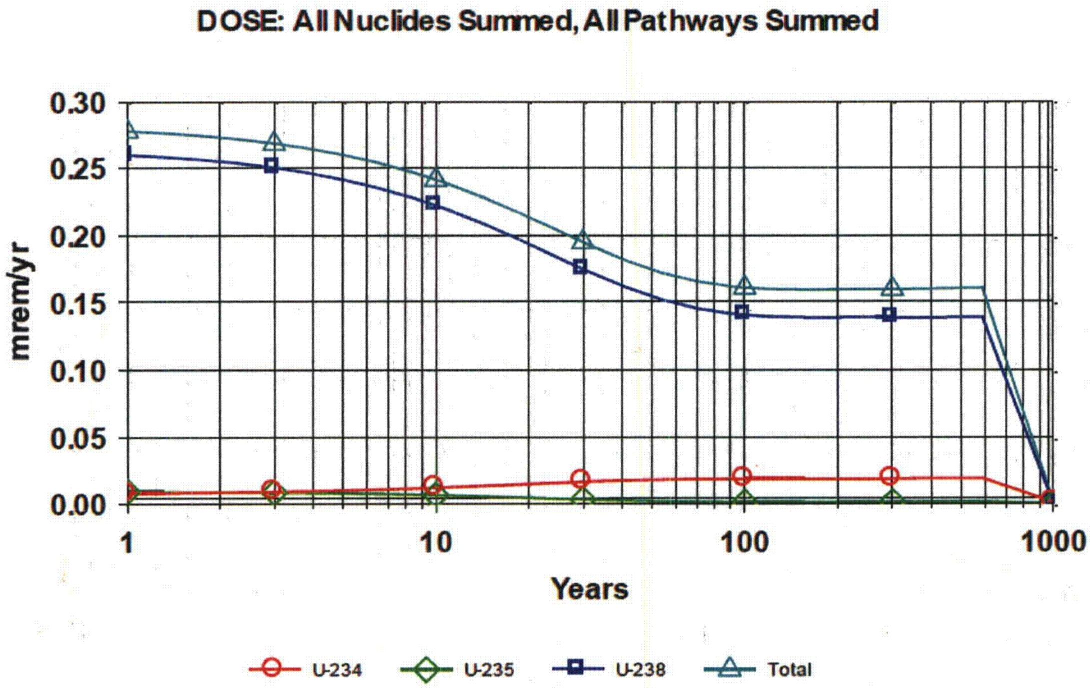

Figure 21 Annual dose vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and contamination zone hydraulic conductivity of 6000 m/y, otherwise using RESRAD 7.0 defaults for resident farmer scenario

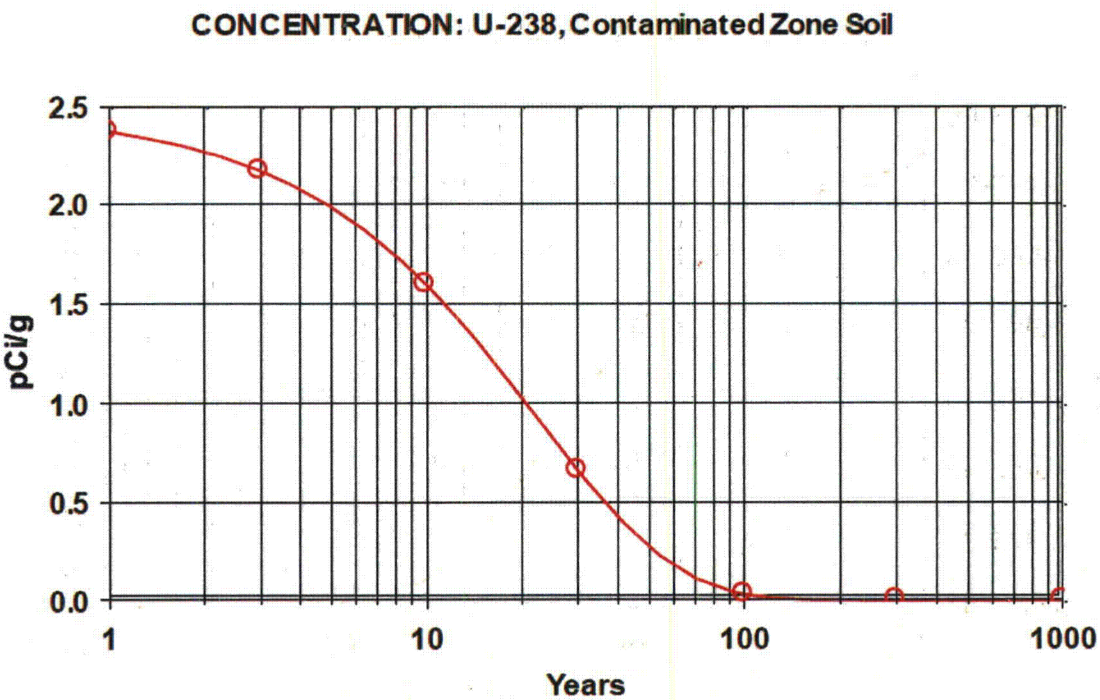

Figure 22 Uranium-238 activity concentration in impact area soil vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and contamination zone hydraulic conductivity of 6000 m/y, otherwise using RESRAD 7.0 defaults for resident farmer scenario

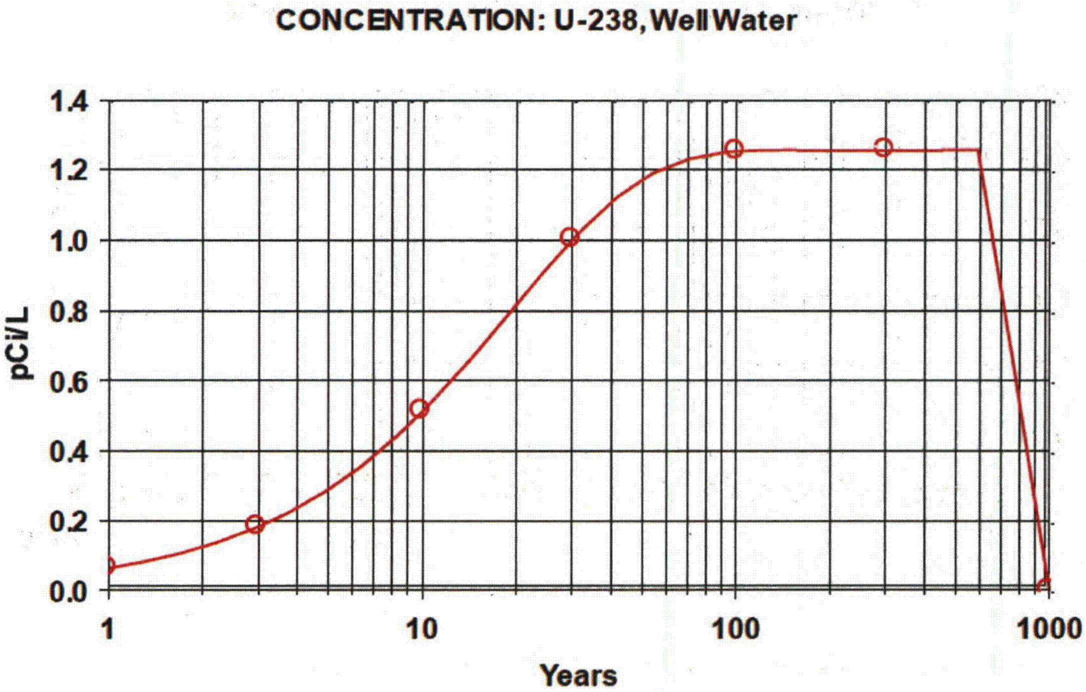

Figure 23 Uranium-238 activity concentration in well water vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and contamination zone hydraulic conductivity of 6000 m/y, otherwise using RESRAD 7.0 defaults for resident farmer scenario

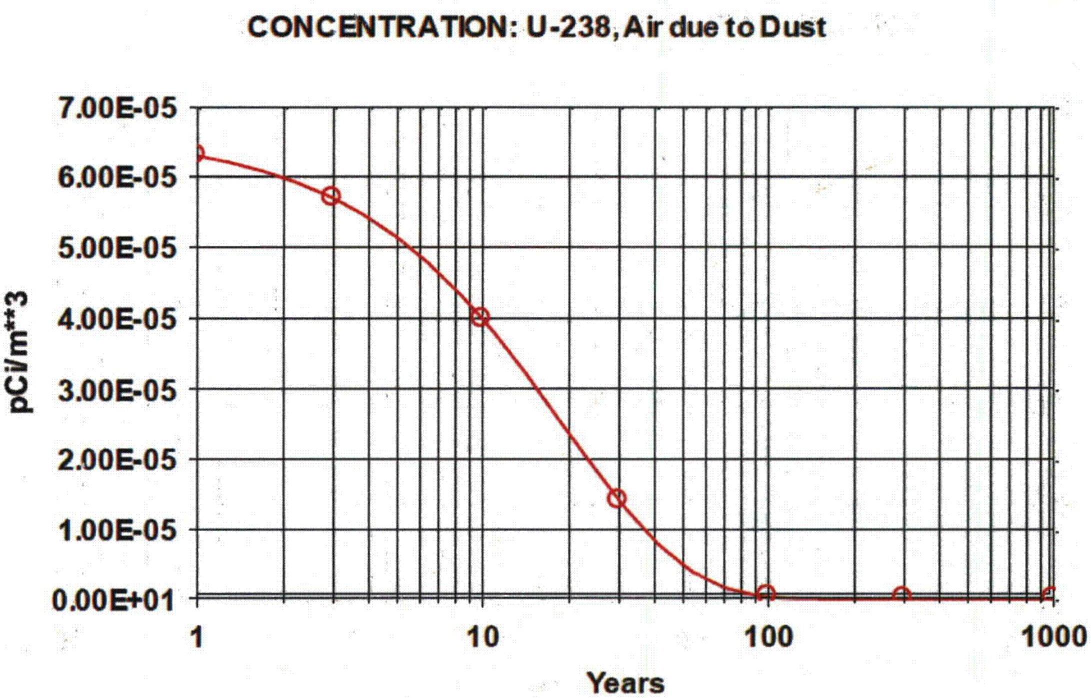

Figure 24 Uranium-238 activity concentration in air over impact area vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and contamination zone hydraulic conductivity of 6000 m/y, otherwise using RESRAD 7.0 defaults for resident farmer scenario

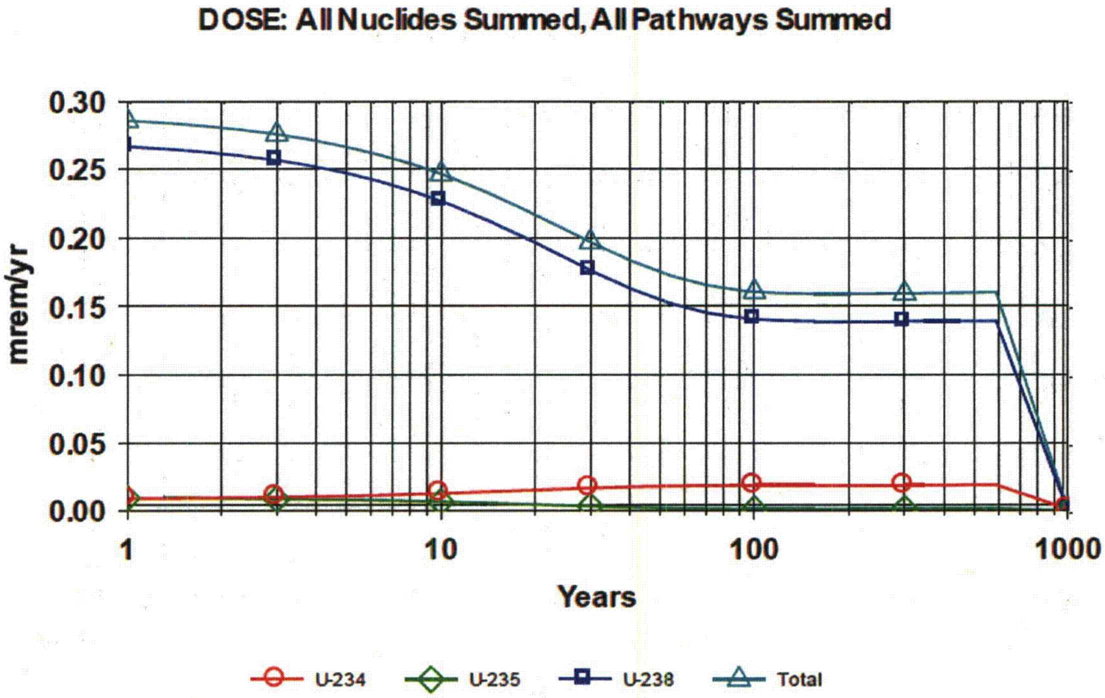

Figure 25 Annual dose vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and average annual wind speed of 1 m/h otherwise using RESRAD 7.0 defaults for resident farmer scenario

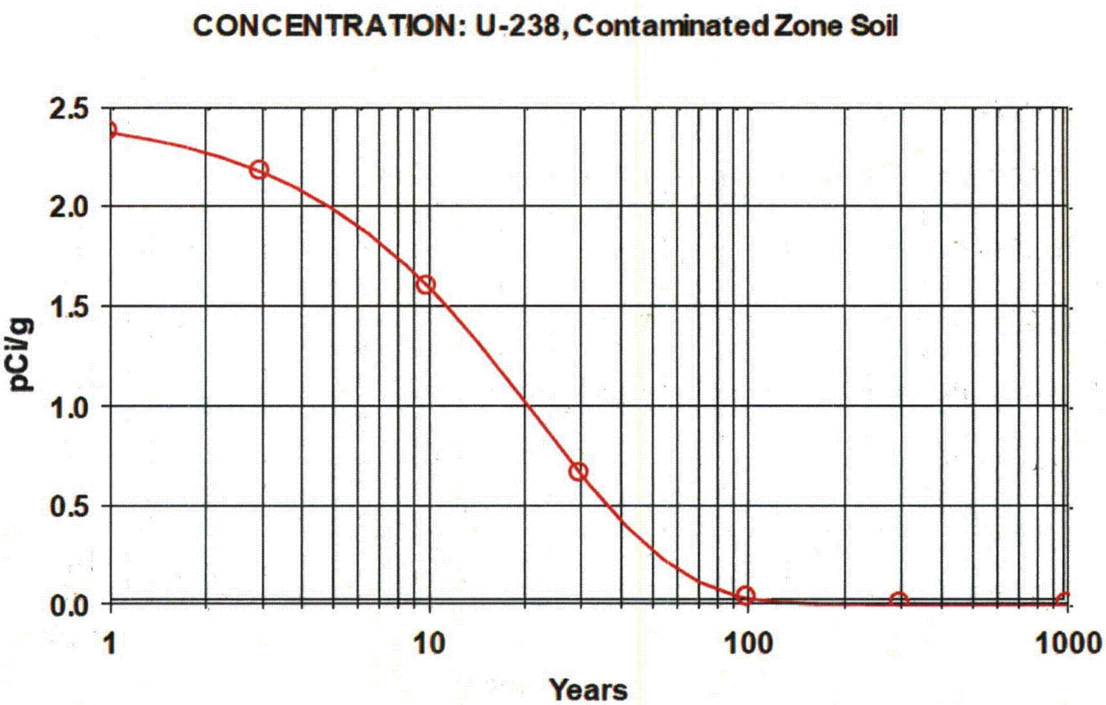

Figure 26 Uranium-238 activity concentration in impact area soil vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and average annual wind speed of 1 m/h, otherwise using RESRAD 7.0 defaults for resident farmer scenario

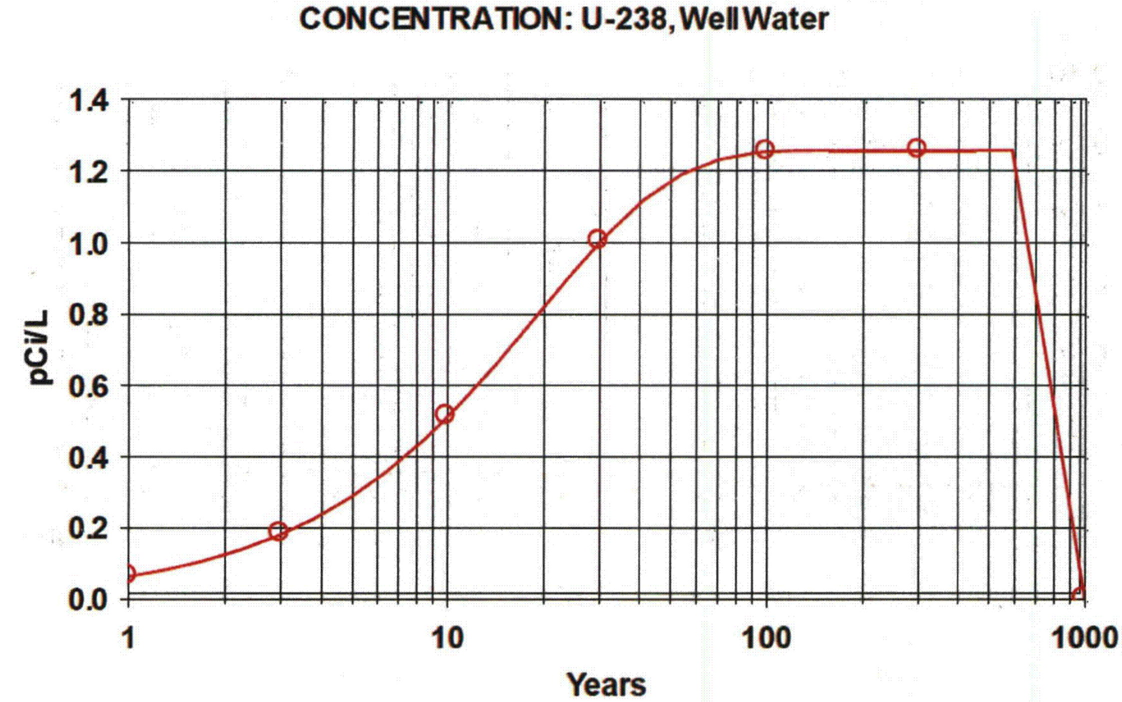

Figure 27 Uranium-238 activity concentration in well water vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and annual wind speed of 1 m/h, otherwise using RESRAD 7.0 defaults for resident farmer scenario

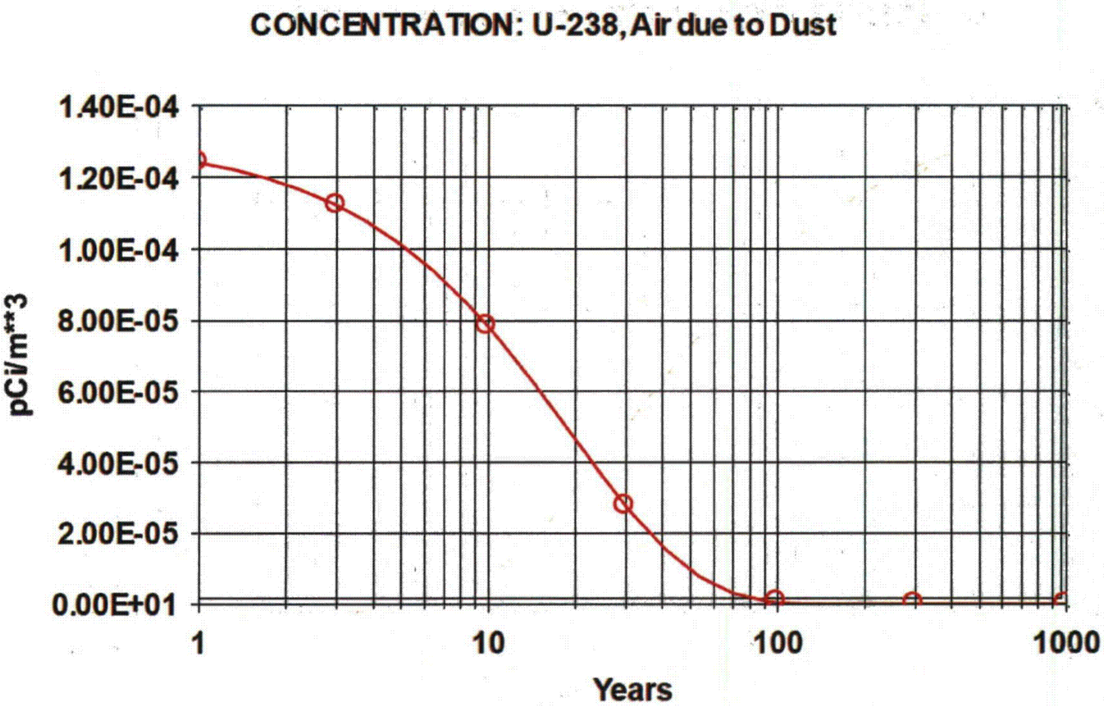

Figure 28 Uranium-238 activity concentration in air over impact area vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and annual wind speed of 1 m/h, otherwise using RESRAD 7.0 defaults for resident farmer scenario

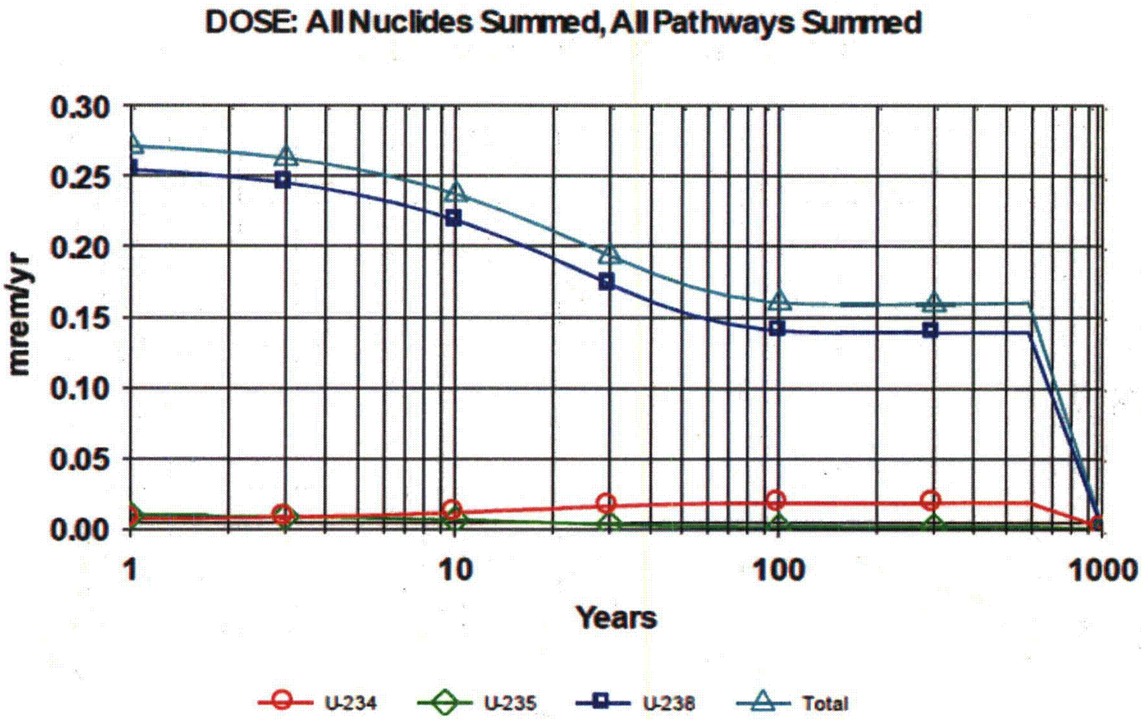

Figure 29 Annual dose vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and average annual wind speed of 10 m/h otherwise using RESRAD 7.0 defaults for resident farmer scenario

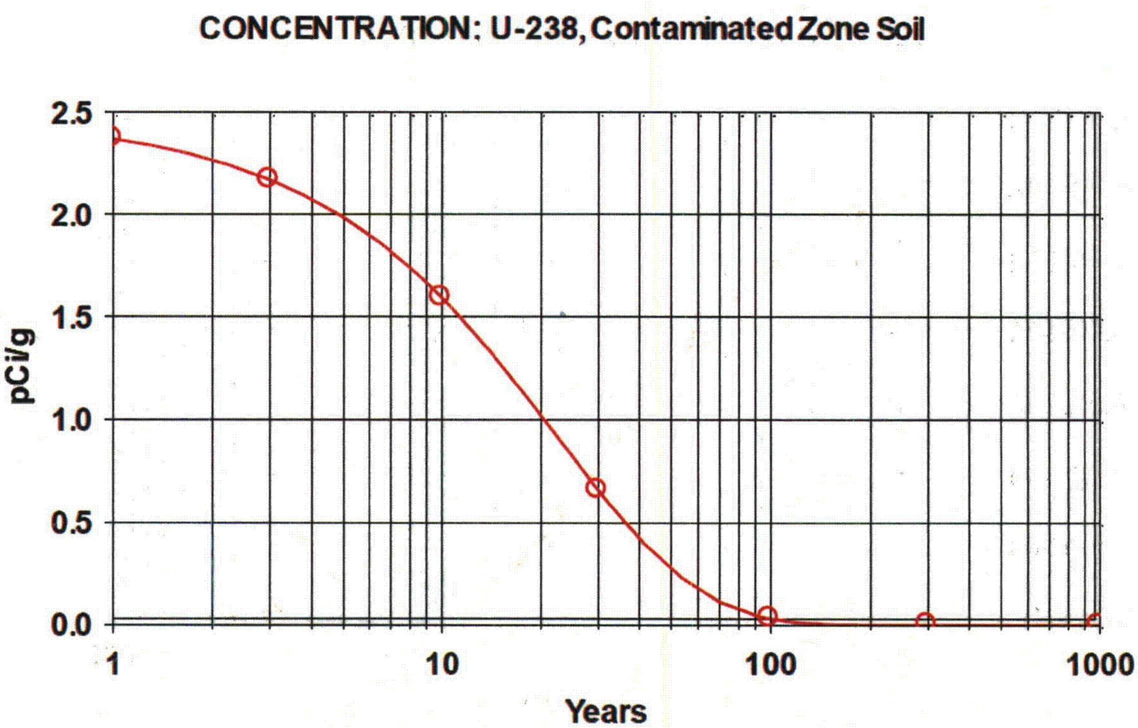

Figure 30 Uranium-238 activity concentration in impact area soil vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and average annual wind speed of 10 m/h, otherwise using RESRAD 7.0 defaults for resident farmer scenario

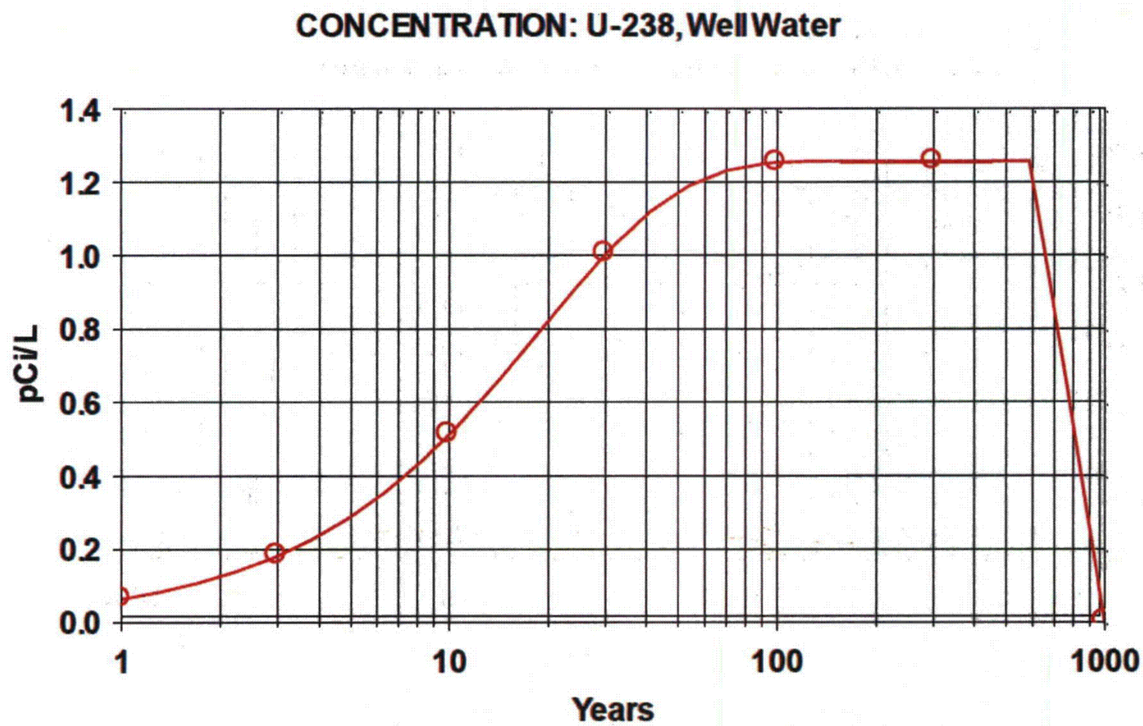

Figure 31 Uranium-238 activity concentration in well water vs. time for bounding value for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and annual wind speed of 10 m/h, otherwise using RESRAD 7.0 defaults for resident farmer scenario

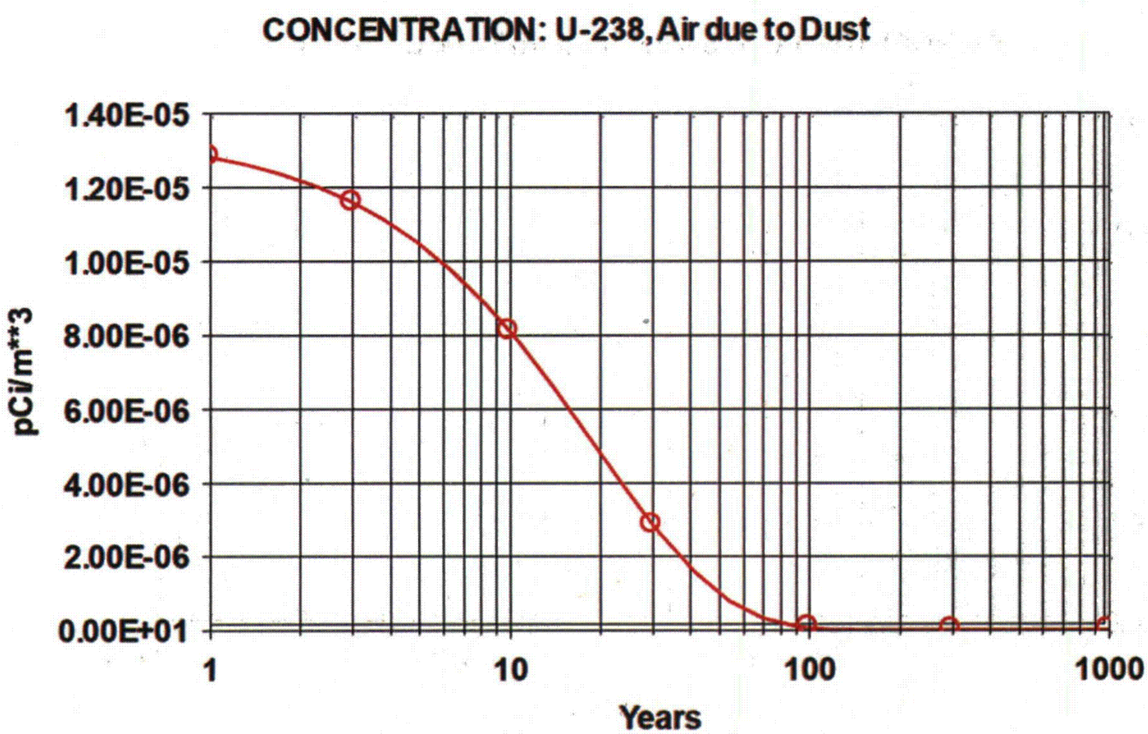

Figure 32 Uranium-238 activity concentration in air over impact area vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and annual wind speed of 10 m/h, otherwise using RESRAD 7.0 defaults for resident farmer scenario

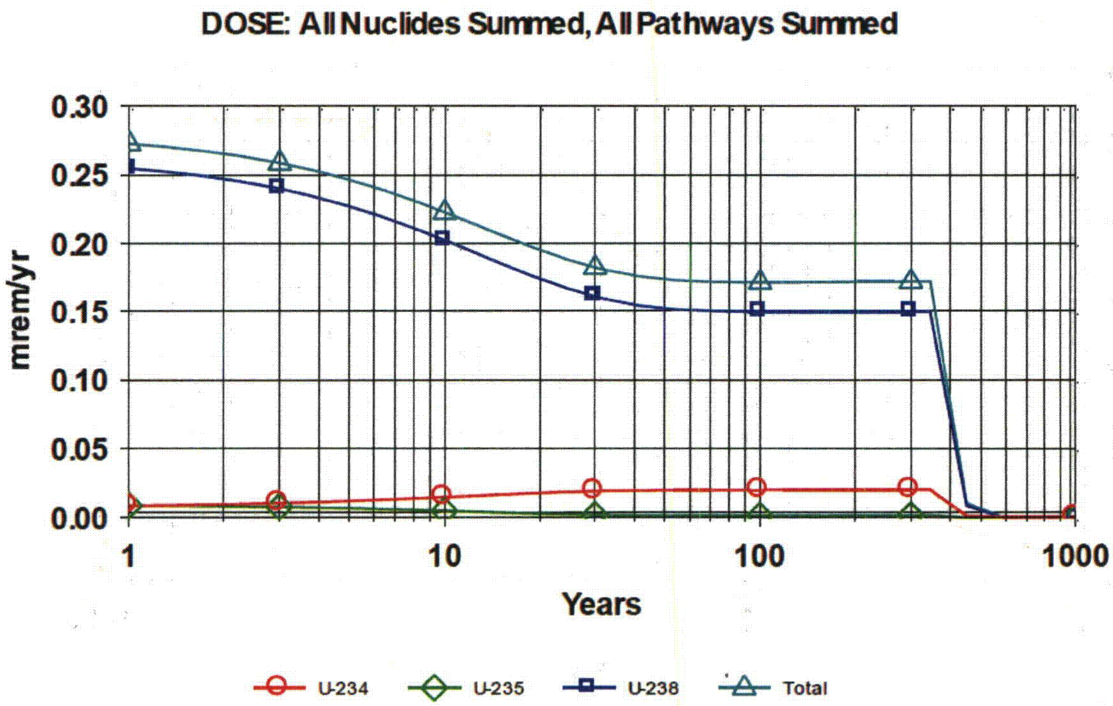

Figure 33 Annual dose vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and average annual precipitation of 2 m otherwise using RESRAD 7.0 defaults for resident farmer scenario

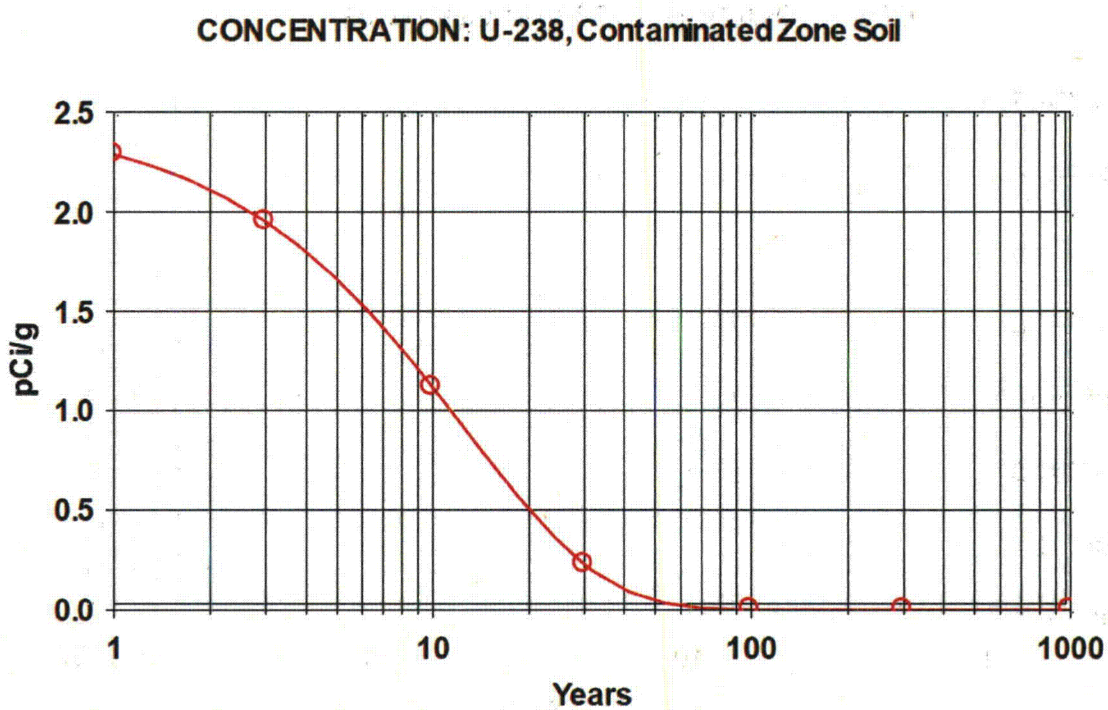

Figure 34 Uranium-238 activity concentration in impact area soil vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and average annual precipitation of 2 m, otherwise using RESRAD 7.0 defaults for resident farmer scenario

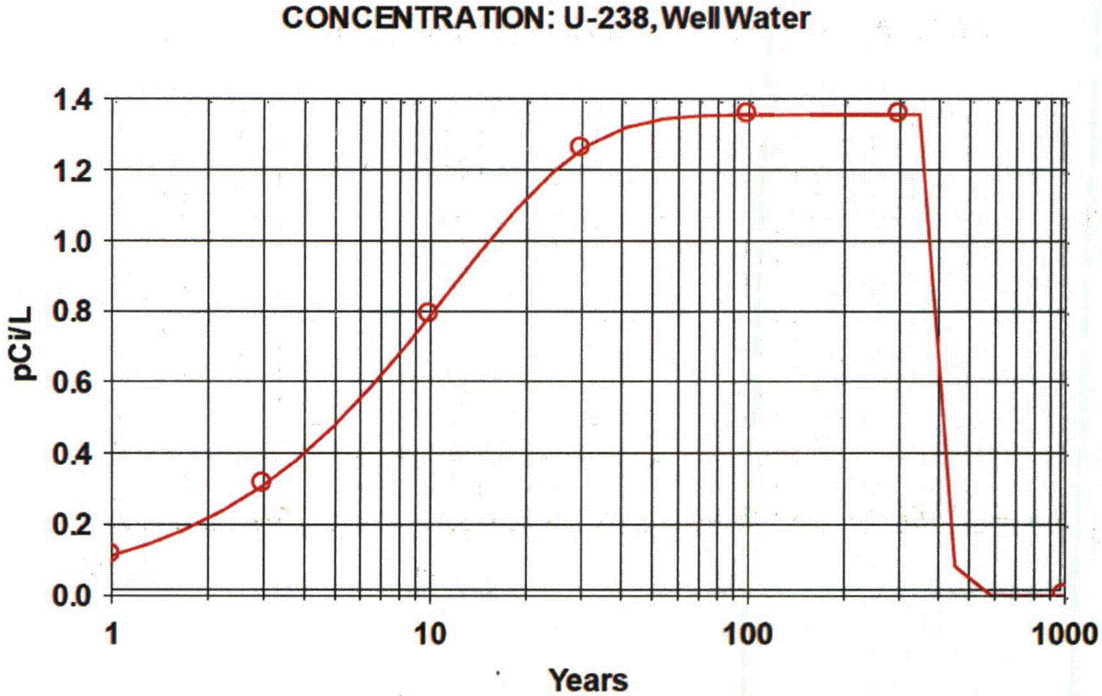

Figure 35 Uranium-238 activity concentration in well water vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and annual precipitation of 2 m, otherwise using RESRAD 7.0 defaults for resident farmer scenario

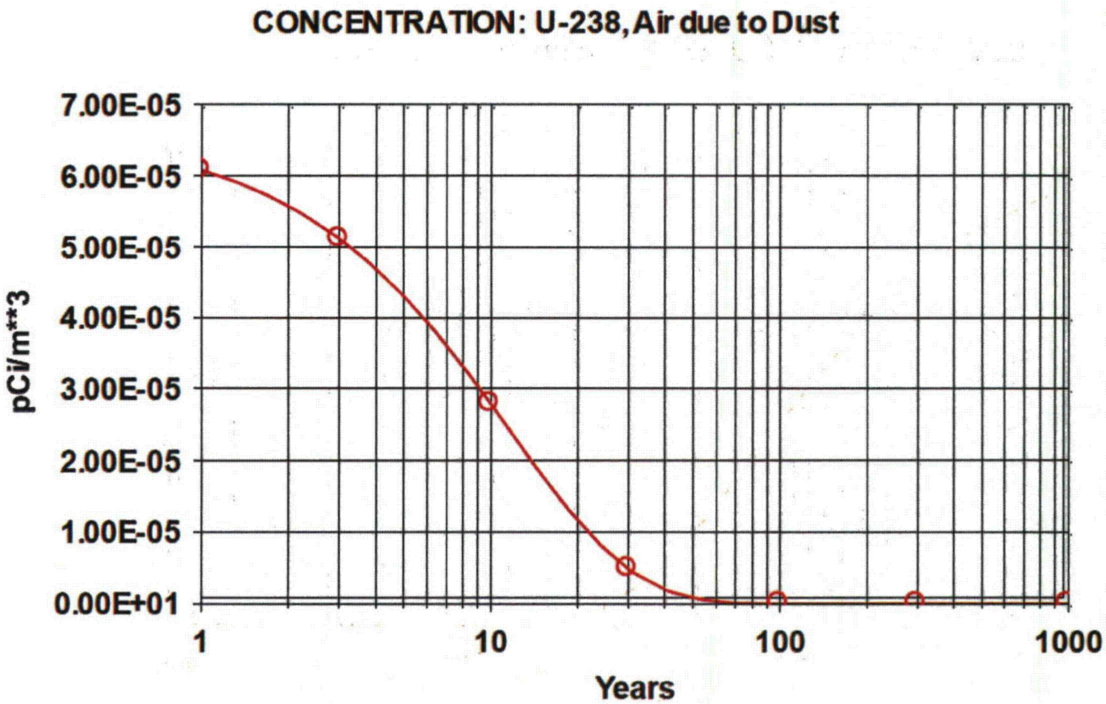

Figure 36 Uranium-238 activity concentration in air over impact area vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area and annual precipitation of 2 m, otherwise using RESRAD 7.0 defaults for resident farmer scenario

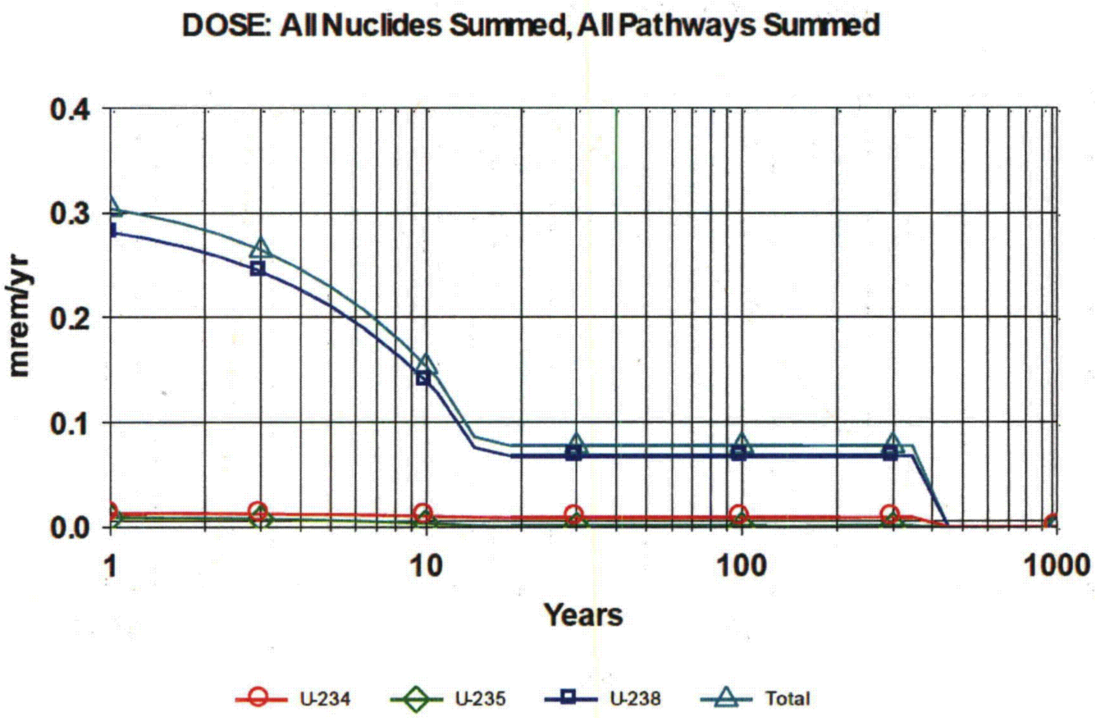

Figure 37 Annual dose vs. time from 9700 M101 DU rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area with several bounding environmental parameters using RESRAD 7.0 for the resident farmer scenario

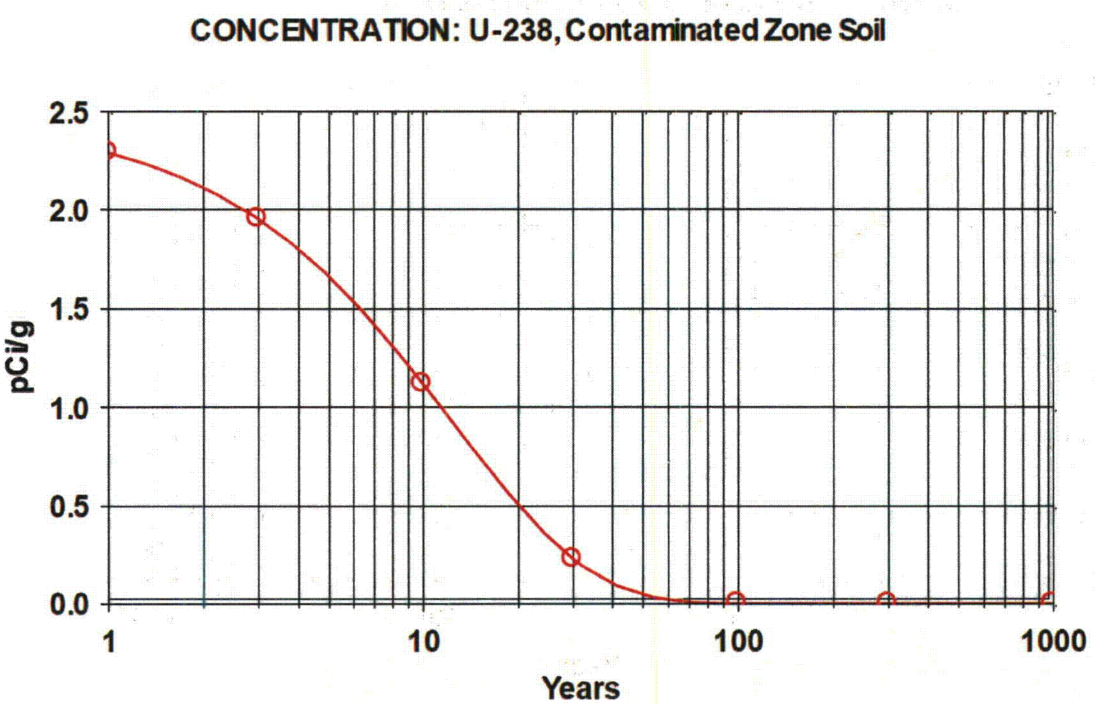

Figure 38 Uranium-238 activity concentration in impact area soil vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area with several bounding environmental parameters using RESRAD 7.0 for the resident farmer scenario

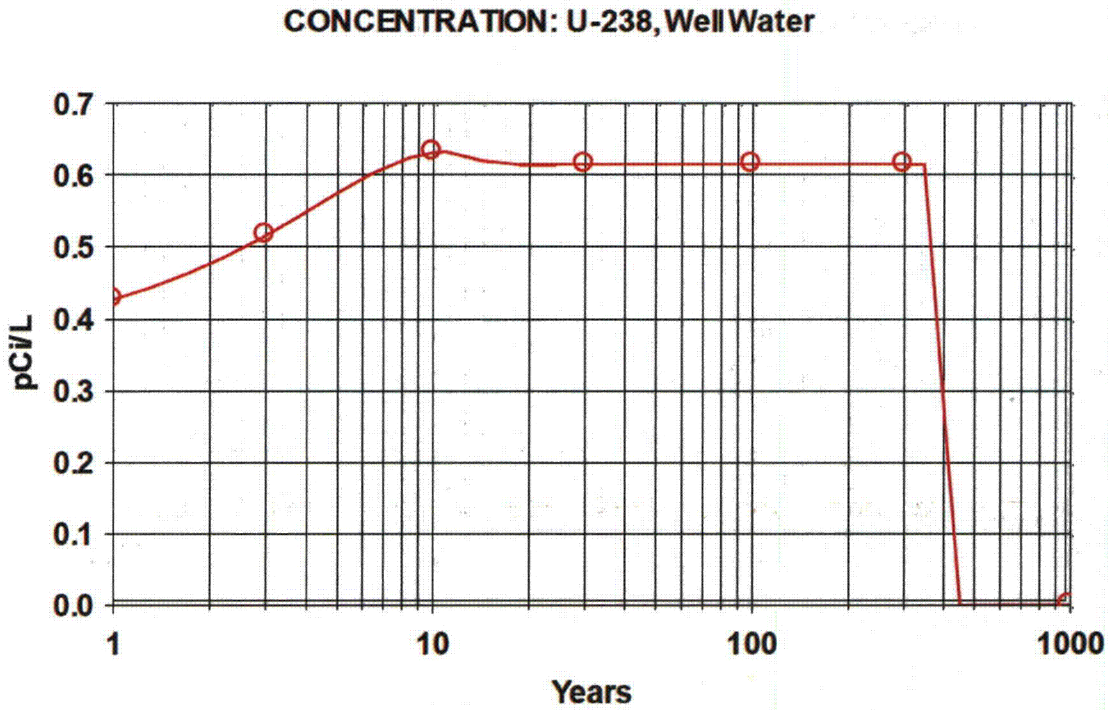

Figure 39 Uranium-238 activity concentration in well water vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area with several bounding environmental parameters using RESRAD 7.0 for the resident farmer scenario

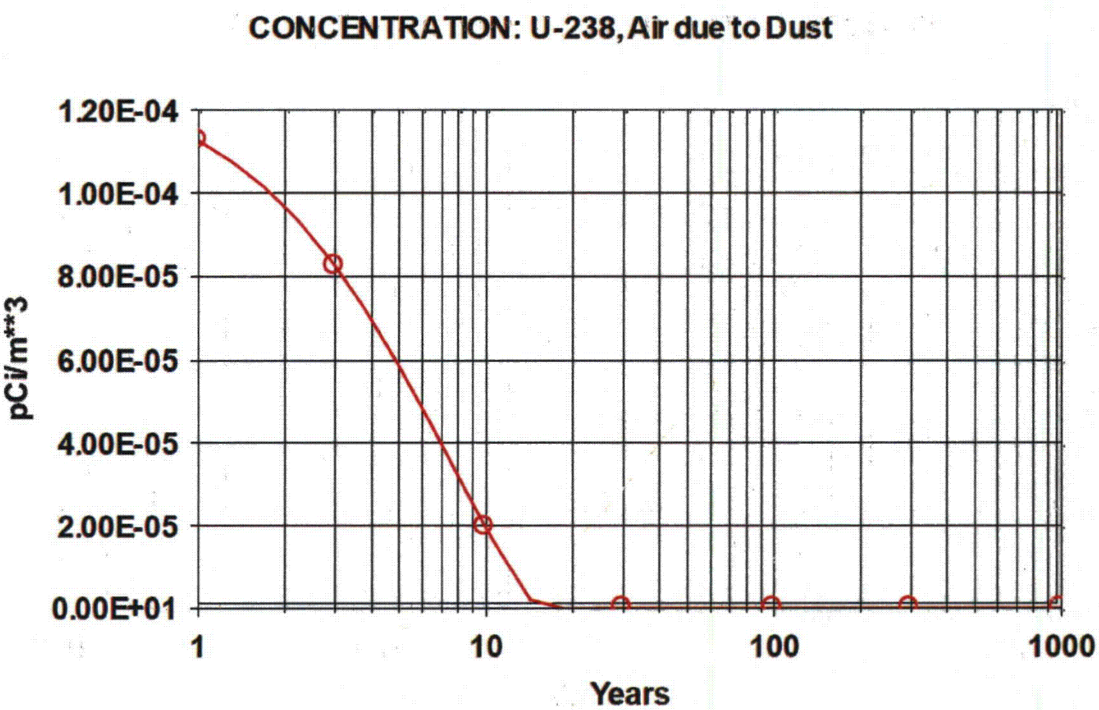

Figure 40 Uranium-238 activity concentration in air over impact area vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a one square kilometer impact area with several bounding environmental parameters using RESRAD 7.0 for the resident farmer scenario

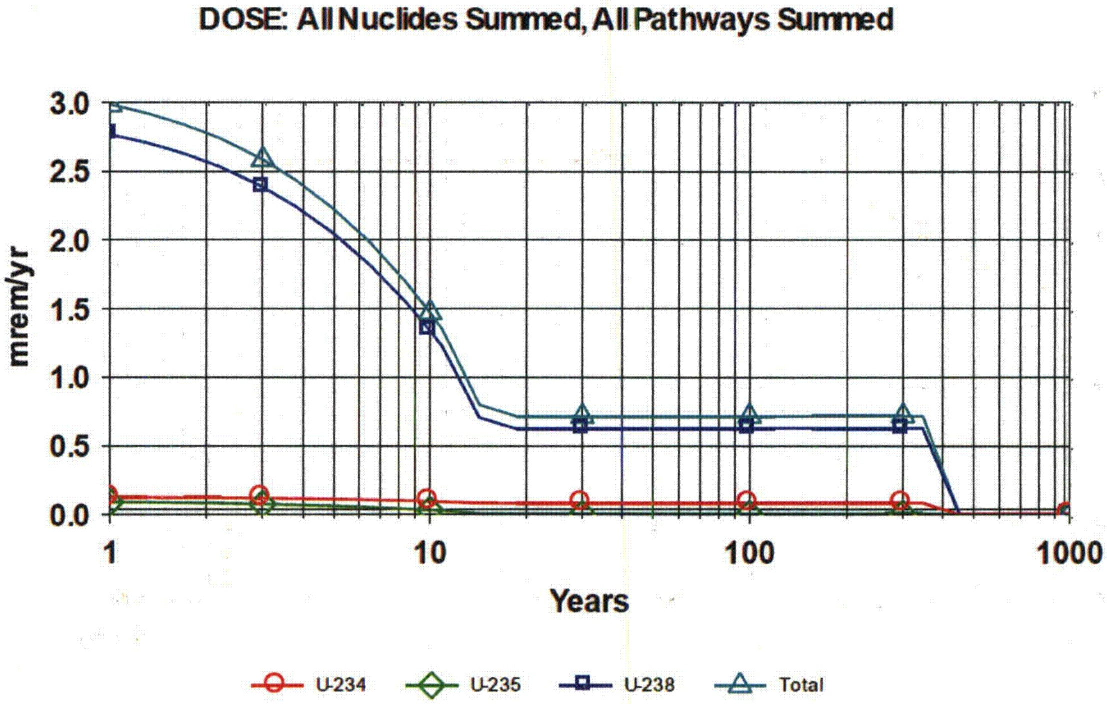

Figure 41 Annual dose vs. time for DU from 9700 M101 DU rounds evenly dispersed in top 15 cm of soil in a 0.1 square kilometer impact area with several bounding environmental parameters using RESRAD 7.0 for the resident farmer scenario

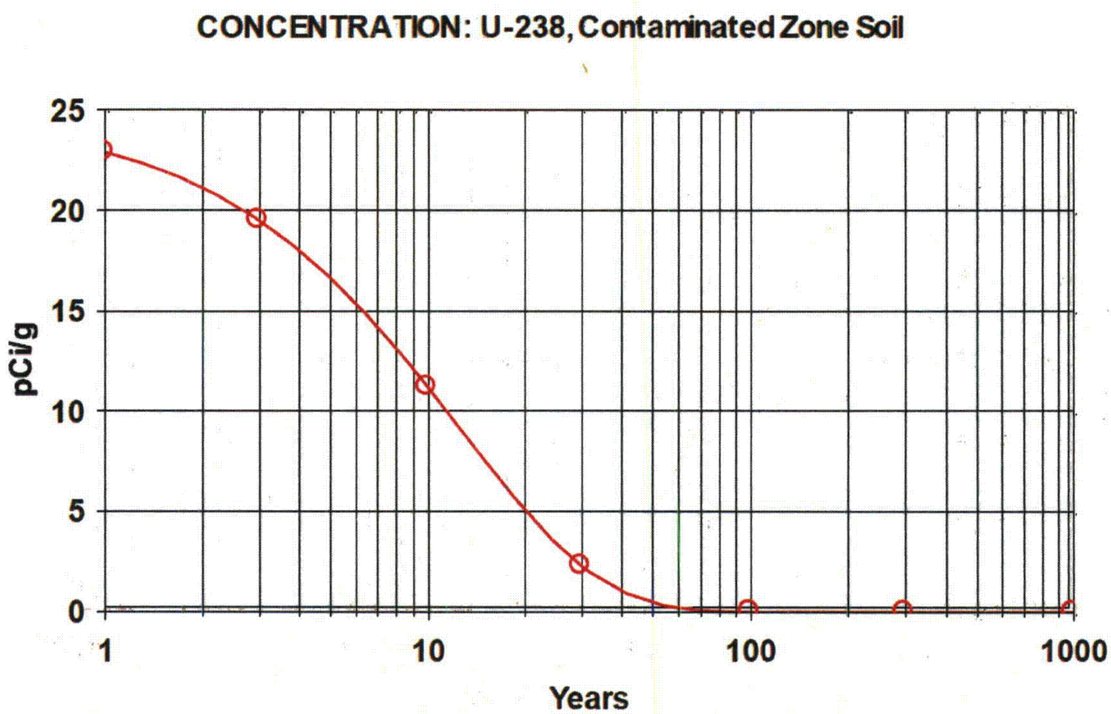

Figure 42 Uranium-238 activity concentration in impact area soil vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a 0.1 square kilometer impact area with several bounding environmental parameters using RESRAD 7.0 for the resident farmer scenario

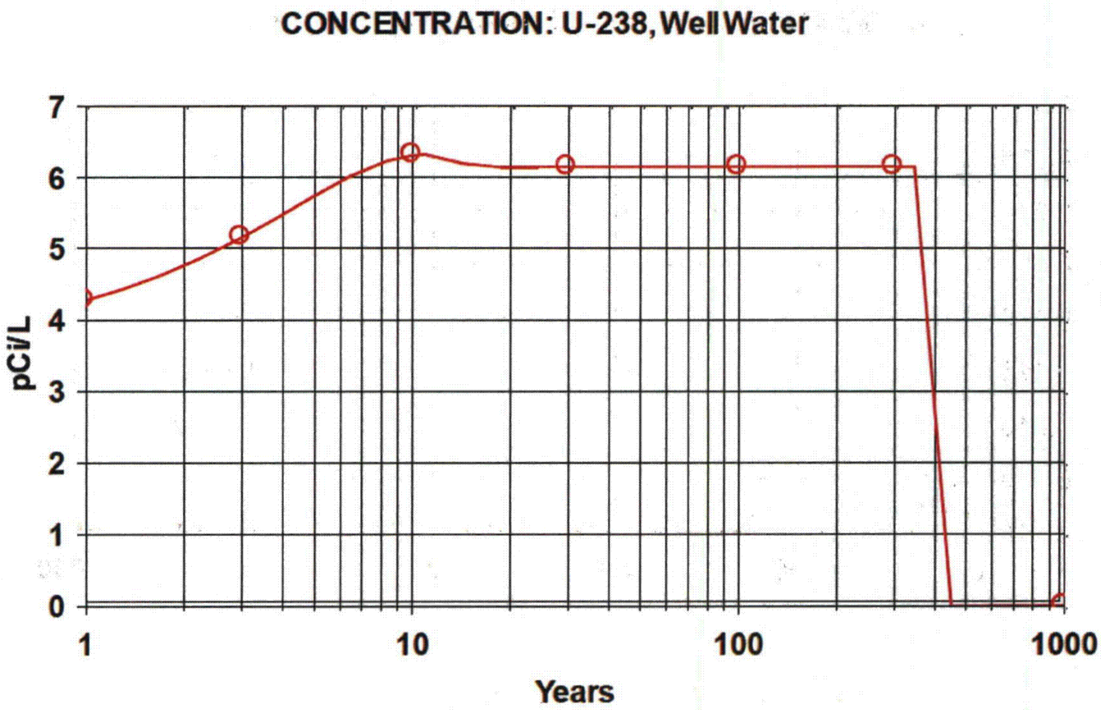

Figure 43 Uranium-238 activity concentration in well water vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a 0.1 square kilometer impact area with several bounding environmental parameters using RESRAD 7.0 for the resident farmer scenario

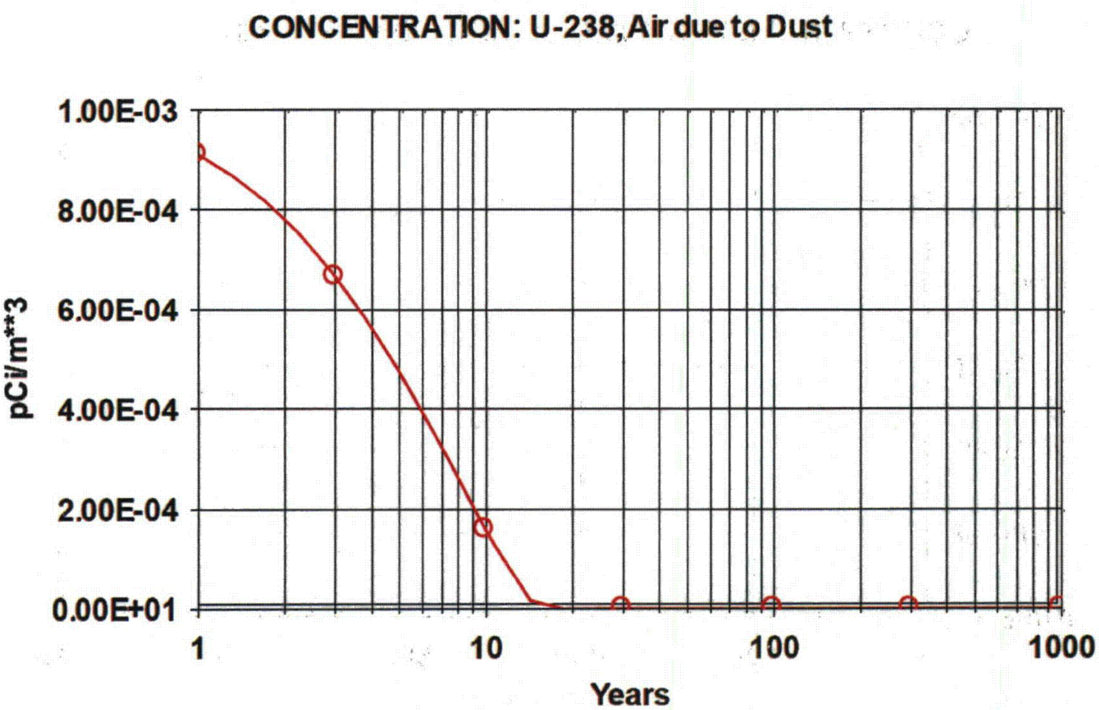

Figure 44 Uranium-238 activity concentration in air over impact area vs. time for DU from 9700 M101 rounds evenly dispersed in top 15 cm of soil in a 0.1 square kilometer impact area with several bounding environmental parameters using RESRAD 7.0 for the resident farmer scenario

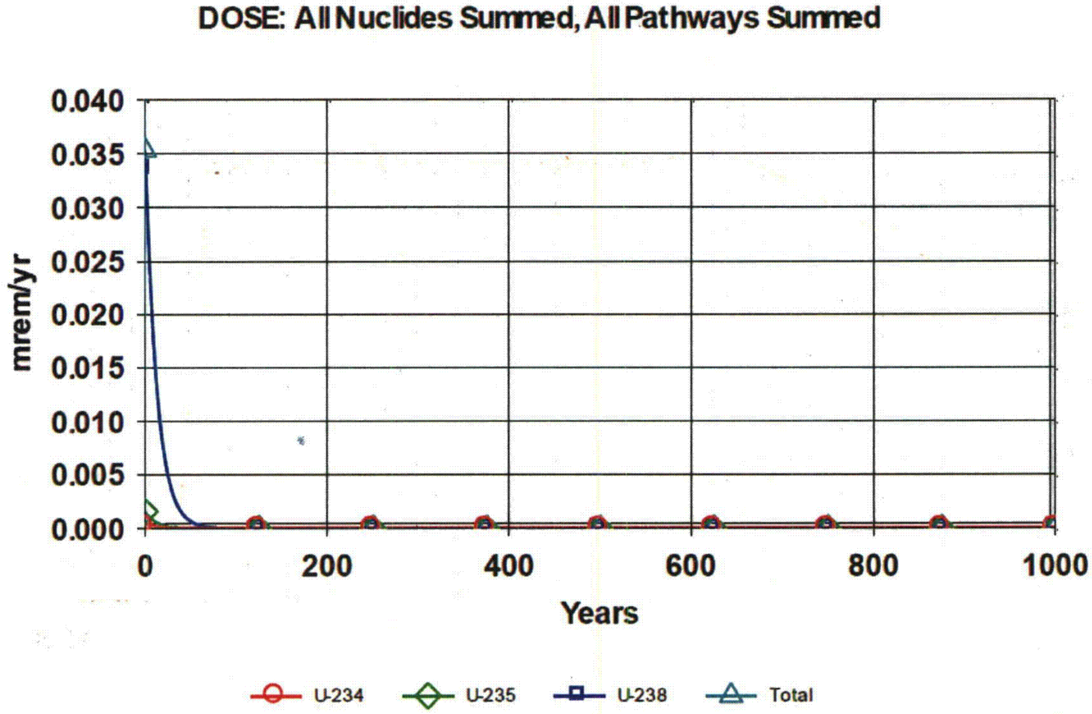

Figure 45 Annual dose vs. time from 9700 M101 DU rounds evenly dispersed in top 15 cm of soil in a 1 square kilometer impact area with default parameters using RESRAD-OFFSITE 3.1 for the scenario of resident farmer 1 km away from the contaminated site

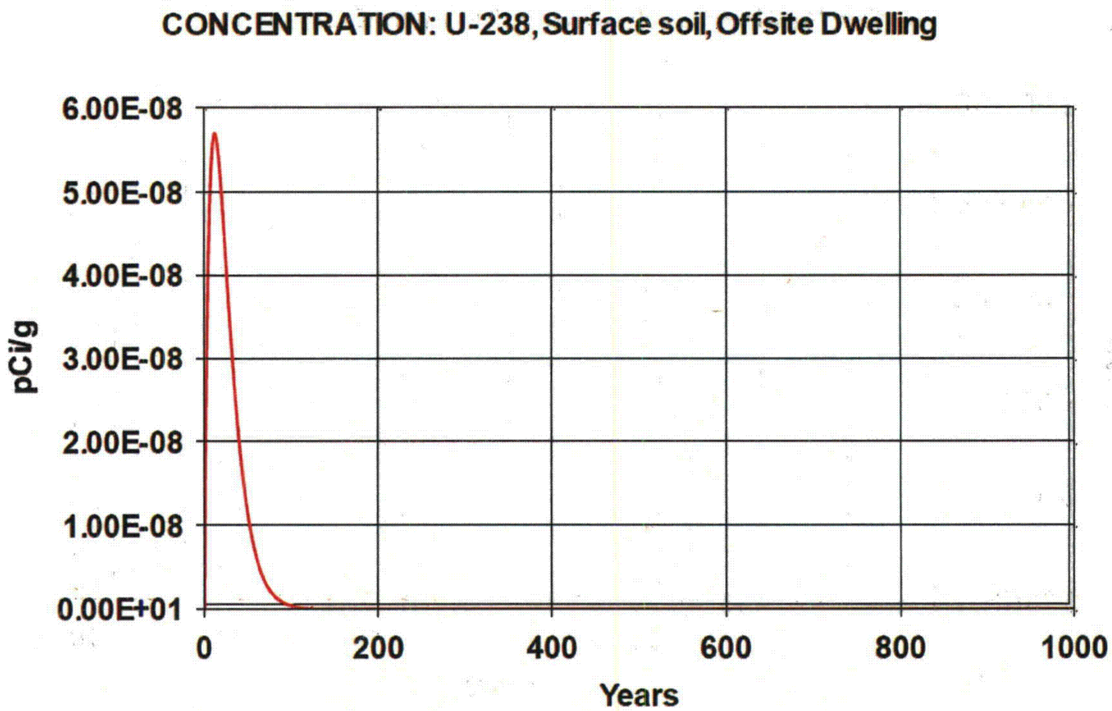

Figure 46 Uranium-238 activity concentration in offsite dwelling surface soil from 9700 M101 DU rounds evenly dispersed in top 15 cm of soil in a 1 square kilometer impact area with default parameters using RESRAD-OFFSITE 3.1 for the scenario of resident farmer 1 km away from the contaminated site

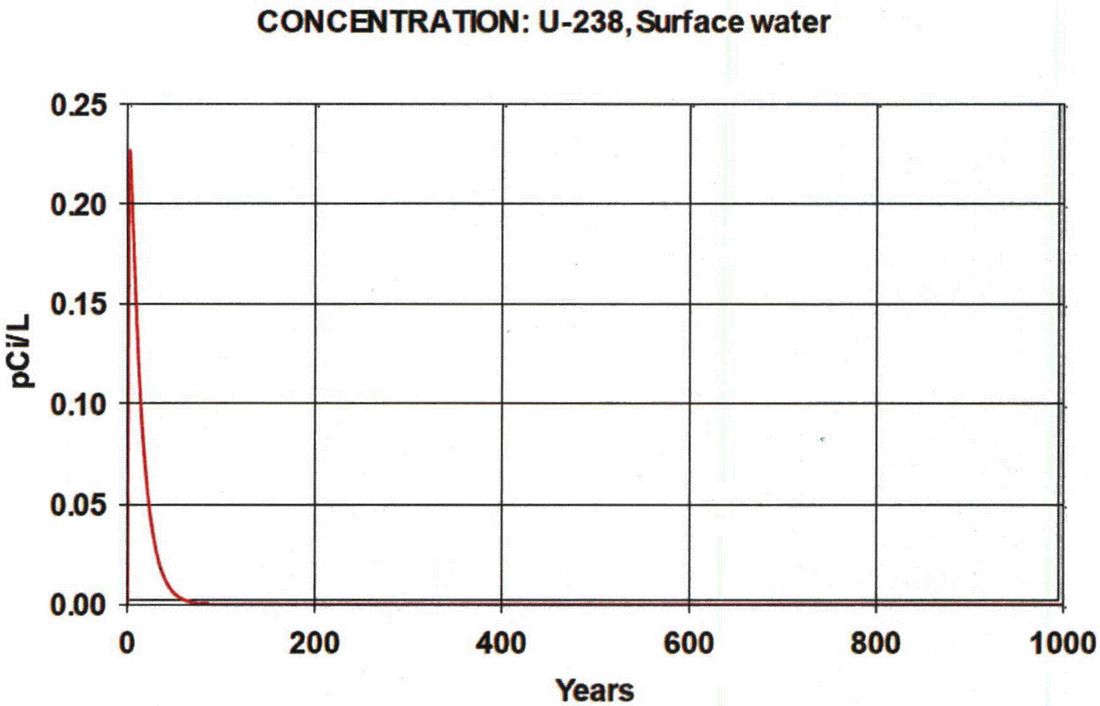

Figure 47 Uranium-238 activity concentration in offsite surface water from 9700 M101 DU rounds evenly dispersed in top 15 cm of soil in a 1 square kilometer impact area with default parameters using RESRAD-OFFSITE 3.1 for the scenario of resident farmer 1 km away from the contaminated site

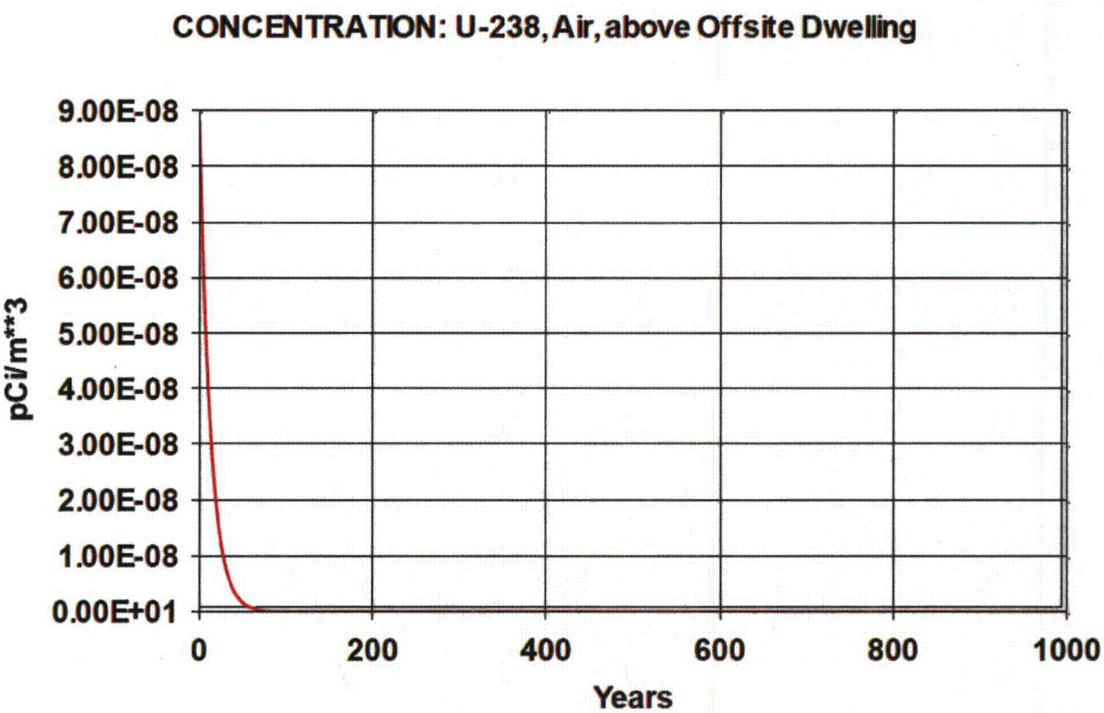

Figure 48 Uranium-238 activity concentration in air above offsite dwelling for 9700 M101 DU rounds evenly dispersed in top 15 cm of soil in a 1 square kilometer impact area with default parameters using RESRAD-OFFSITE 3.1 for the scenario of resident farmer 1 km away from the contaminated site

Attachments[17]

1. RESRAD report for the baseline 1000 M101 rounds in 1 km^2 scenario
2. RESRAD report for the 9700 M101 rounds in 1 km^2 resident farmer bounding scenario
3. RESRAD report for the 9700 M101 rounds in 1 km^2 resident farmer bounding scenario (Water table 7.5 cm below ground surface)
4. RESRAD report for the 9700 M101 rounds in 1 km^2 resident farmer bounding scenario (contaminated zone erosion rate = 0.01 m/y = 1 cm/y)
5. RESRAD report for the 9700 M101 rounds in 1 km^2 resident farmer bounding scenario (contaminated zone total porosity = 0.6)
6. RESRAD report for the 9700 M101 rounds in 1 km^2 resident farmer bounding scenario (contaminated zone hydraulic conductivity = 6000 m/y)
7. RESRAD report for the 9700 M101 rounds in 1 km^2 resident farmer bounding scenario (average annual wind speed = 1 m/s)
8. RESRAD report for the 9700 M101 rounds in 1 km^2 resident farmer bounding scenario (average annual wind speed = 10 m/s)
9. RESRAD report for the 9700 M101 rounds resident farmer bounding scenario (average annual total precipitation = 2 m)
10. RESRAD report for the 9700 M101 rounds in 1 km^2 resident farmer bounding scenario (set of bounding environmental parameters)
11. RESRAD report for the 9700 M101 rounds in 0.1 km^2 resident farmer bounding scenario (set of bounding environmental parameters)
12. RESRAD-OFFSITE report for 9700 M101 rounds in 1 km^2 farmer residing one kilometer from contaminated site, default parameters[18]

[17] RESRAD provides five parts for its report following each calculation run: Part I, Mixture Sums and Single Radionuclide Guidelines; Part II, Source Terms, Factors, and Parameters for Individual Pathways; Part III, Intake Quantities and Health Risk Factors; Part IV, Concentration of Radionuclides; and Part V, Dose from Radionuclide at Point of Action. The total number of pages in these five parts is more than 673 pages, so the eleven full reports consist of more than 7400 pages. Anyone using RESRAD can produce these reports, so they are provided in electronic form only, rather than including paper copies with the submission.

[18] RESRAD-OFFSITE provides three parts for its report following each calculation run: Part I, Mixture Sums and Single Radionuclide Guidelines; Part II, Health Risk Factors; and Part III, Dose from Radionuclide at Point of Action. Anyone using RESRAD-OFFSITE can produce this report, so it is provided in electronic form only, rather than including a paper copy with the submission.

Attachment 6

Physical Security Plan

Physical Security Plan for US Army Installation Management Command Ranges Affected by Depleted Uranium in M101 Davy Crockett Spotting Rounds

27 May 2015

Contents

Abbreviations and Acronyms

^{234}U	uranium-234
^{235}U	uranium-235
^{238}U	uranium-238
ASR	Archive Search Report
CFR	Code of Federal Regulations
DOD	Department of Defense
DU	depleted uranium
EOD	explosive ordnance disposal
IMCOM	US Army Installation Management Command
km	kilometer
m	meter
NRC	US Nuclear Regulatory Commission
PSP	Physical Security Plan
RCA	Radiation Controlled Area
RSO	Radiation Safety Officer
RSP	Radiation Safety Plan
UXO	unexploded ordnance

1 Introduction

This Physical Security Plan (PSP) is applicable at US Army Installation Management Command (IMCOM) ranges that may have been affected by Davy Crockett M101 spotting rounds. The M101 spotting round contains depleted uranium (DU). The affected areas are controlled for radiation safety purposes and are radiation controlled areas (RCAs).

The License Radiation Safety Officer (RSO) will review this PSP annually and update it as necessary. If any updates to this PSP represent a significant change in approach to physical security, then the License RSO will inform the US Nuclear Regulatory Commission of the update.

1.1 Background

Depleted uranium is a byproduct of uranium enrichment, part of the process of manufacturing fuel for nuclear power plants. When uranium is *enriched* in the fissile[1] uranium-235 (^{235}U) isotope, the leftover uranium is *depleted* in ^{235}U.[2] DU is useful in certain commercial and military applications because of its high density, which is about twice the density of lead. It is slightly radioactive, but it poses some chemical toxicity danger to the kidneys if ingested in sufficient quantities, for example, by inhaling DU-laden dust or drinking DU-contaminated water.

The M101 spotting round was a 20-millimeter low-speed projectile, weighing approximately one pound that the Army used as part of the M28 Davy Crockett weapon system from 1960 to 1968. The M28 Davy Crockett weapon system was classified to some extent in the 1960s, and records of its use were guarded.

In 2005, the Army discovered tail assemblies from the M101 spotting round during range clearance before construction of a Battle Area Complex at the Schofield Barracks target impact area in Hawaii. The Army then began investigating various sites where the M101 spotting round may have been used. Characterization studies have determined that NRC-licensable quantities of DU in the form of M101 fragments exist at several IMCOM sites.[3]

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[1] A *fissile* nuclide is a nuclide that is capable of undergoing fission after capturing low-energy thermal (slow) neutrons. This definition excludes natural uranium and DU that have not been irradiated or have only been irradiated in thermal reactors.

[2] Uranium-234 (^{234}U) is enriched or depleted as well in enriched uranium and DU, respectively, but it is not fissile.

[3] These sites are Schofield Barracks/Pohakuloa Training Area HI, Fort Knox KY, Joint Base Lewis-McChord/Yakima Training Center WA, Fort Riley KS, Fort Polk LA, Fort Benning GA, Fort Campbell KY, Fort Bragg NC, Fort Carson CO, Fort Gordon GA, Fort Hood TX, Fort Hunter Liggett CA, Fort Jackson SC, Fort Sill OK, Fort Greely AK, and Joint Base McGuire-Dix-Lakehurst NJ.

1.2 Purpose

The purpose of this PSP is to address physical security issues involving M101 spotting round DU in RCAs on IMCOM Ranges. The goals are to protect the health and safety of Army personnel and of members of the public; maintain security of licensed material (DU); and meet all applicable Federal, Department of Defense, and Army regulations.

1.3 Scope

This PSP defines the roles and responsibilities of supporting physical security staff, and explains the physical security controls for M101 spotting round DU on IMCOM Ranges.

1.4 Applicability

The requirements of this plan are applicable to all personnel, including members of the public, who may seek access to an RCA.

Requirements of this plan are in addition to, not in lieu of, any and all other physical security requirements, especially those related to unexploded ordnance in or around RCAs.

1.5 The Unexpected and the Unanticipated

While all physical security contingencies are intended to be addressed by this plan, something unexpected or unanticipated may arise. If this occurs, the Garrison RSO will promptly establish appropriate procedures and then inform the License RSO. These procedures will be documented by including them in this plan or as an addendum to it.

2 Physical Security Organization and Responsibilities for M101 Spotting Round DU

2.1 US Army Installation Management Command (IMCOM) Commander

Regarding M101 spotting round DU on IMCOM ranges, the IMCOM Commander is responsible for:

- Physical security and control of M101 spotting round DU
- Completeness and accuracy of the physical security records and all information provided to the NRC
- Knowledge about the contents of the license and application
- Compliance with current NRC regulations and the licensee's operating and emergency procedures
- Commitment to provide adequate resources (including space, equipment, personnel, time, and, if needed, contractors) to the physical security program to maintain security of DU
- Selection and assignment of a qualified individual to serve as the License RSO with responsibility for the overall physical security program
- Prohibition against discrimination of employees engaged in protected activities

2.2 Garrison Commander

Regarding M101 spotting round DU on IMCOM ranges, each Garrison Commander is responsible to the IMCOM Commander for assuring compliance with requirements of NRC regulations and license conditions (including this PSP) on his or her installation.

The Garrison Commander will select and assign a qualified individual to serve as the Garrison RSO with responsibility to the License RSO for Garrison compliance with NRC regulations and license conditions regarding M101 spotting round DU on installation ranges, including physical security of that DU.

2.3 License Radiation Safety Officer

The License RSO is responsible to the IMCOM Commander for the development, implementation, and overall administration of this PSP. He is also responsible to both the IMCOM Commander and the NRC for assuring and monitoring compliance with NRC regulations and license conditions for M101 spotting round DU on IMCOM Ranges.

The License RSO has authority to:

- Directly contact personnel of IMCOM Headquarters, IMCOM Regions, IMCOM garrisons, and the Army Environmental Command (AEC) in the performance of the License RSO duties[4]
- Task personnel of IMCOM Headquarters, IMCOM Regions, IMCOM garrisons, and the Army Environmental Command (AEC) within their capabilities and resources in order to maintain compliance with NRC regulations and license conditions[4]

Regarding physical security of DU, the License RSO will:

- Coordinate with appropriate personnel as necessary to assure compliance with the requirements of this PSP
- Ensure security of radioactive material
- Act as liaison with NRC and other regulatory authorities
- Provide necessary information on all aspects of physical security to personnel at all levels of responsibility, pursuant to Title 10, Code of Federal Regulations (CFR), Parts 19 and 20, and any other applicable regulations
- Conduct training programs and otherwise instruct personnel in the proper procedures
- Oversee the storage of radioactive waste
- Maintain an inventory of all radioisotopes possessed under the license
- Maintain other records not specifically designated above, for example, records of receipts, transfers, and surveys as required by 10 CFR 20, Subpart L, "Records"
- Hold periodic meetings with, and provide reports to, licensee management
- Perform periodic audits of the physical security program to ensure that the licensee is complying with all applicable NRC regulations and the terms and conditions of the license
- Ensure that the results of audits, identification of deficiencies, and recommendations for change are documented (and maintained for at least 3 years) and provided to management for review; ensure that prompt action is taken to correct deficiencies
- Ensure that the audit results and corrective actions are communicated to all affected personnel
- Maintain understanding of and up-to-date copies of NRC regulations, the license, revised licensee procedures, and ensure that the license is amended whenever there are changes in licensed activities, responsible individuals, or information or commitments provided to NRC during the licensing process.

[4] HQ IMCOM Operations Order 11-302, Delegation of Authority to Nuclear Regulatory Commission (NRC) License Radiation Safety Officer (RSO) (U), 132138Z Apr 11

2.4 US Army Garrison RSO

The Garrison RSO represents both the Garrison Commander and the License RSO in the day-to-day physical security operations and oversight during routine range activities. The Garrison RSO will maintain records of physical security activities in the RCAs ready for review at any time by the License RSO and by NRC inspectors.

The Garrison RSO, as necessary, will:

- On behalf of the Garrison Commander and License RSO, assure implementation of and compliance with this PSP and applicable NRC regulations and license conditions
- Discuss deviations from routine range activities that affect physical security with appropriate garrison personnel and the License RSO
- Routinely report on physical security activities at Garrison Radiation Safety Committee meetings (with appropriate documentation in the minutes of these meetings)
- Perform audits as necessary to verify compliance with provisions of this PSP and of NRC regulations and license conditions
- Advise personnel as they carry out their physical security responsibilities
- Ensure appropriate physical security training is provided to appropriate personnel and maintain documentation of this training

2.5 Personnel in the RCA

Personnel entering the RCA will receive physical security and DU awareness training (essentially on provisions of this PSP applicable to them) from the Garrison RSO at a level commensurate with their activities in the RCA as the Garrison RSO determines and documents.

Each person who enters the RCA is responsible for strict adherence to physical security rules and regulations.

2.6 Visitors

All visitors to the RCA are required to comply with the requirements of this PSP.

The Garrison RSO or his or her designee will brief authorized visitors requiring entry to the RCA on the presence of DU in the RCA. Visitors will be escorted at all times in the RCA.

Unauthorized visitors, and visitors not meeting the specified qualifications, will not be permitted within the RCA.

3 Radiation Controlled Areas

The St. Louis District of the US Army Corps of Engineers performed the Archive Search Report (ASR) Project from 2006 to 2011.[5] The result was a report with annexes for specific installations that described Army efforts to identify Army ranges where the Army fired M101 Davy Crockett spotting rounds. The typical Davy Crockett range impact area is a one-kilometer (km) square, area = 1 km^2 = 1,000,000 m^2 $\approx$ 247 acres.

The Army and the NRC consider RCAs to be M101 spotting round impact areas (and any M101 DU-affected areas) identified in ASR annexes. Figures attached to the Radiation Safety Plans (RSP) show the locations of the M101 spotting round impact areas on Garrisons as the ASR Project has determined.

The Garrison RSO and License RSO will be notified when M101 spotting round debris (or any other previously unknown radioactive material) is found on IMCOM Ranges. The sizes and locations of the RCAs will be adjusted and the requirements of this PSP will be extended accordingly.

[5] USACE St Louis. *Project Archive Search Report: Use of Cartridge, 20mm Spotting M101*. St Louis, Missouri: US Army Corps of Engineers, St Louis District, 2011.

4 Posting Requirements

The Garrison RSO shall post "CAUTION - RADIOACTIVE MATERIAL" signs at a sufficient number of locations around the Radiation Control Area to ensure that individuals entering the Radiation Control Area are aware of the presence of DU. The signs may be placed at the perimeter of the range impact areas if posting them at the Radiation Control Area boundary is unsafe due to the presence of unexploded ordnance (UXO). The signs may contain additional information, as appropriate, to make individuals aware of potential radiation exposures and to minimize the exposures.

The ranges are operational and essential for Army training and readiness. Access to the ranges and, hence, the RCAs, is otherwise controlled for reasons of security, operations, and/or UXO.

Deliberate searches for and removal of DU from an RCA is not authorized. However, unintended discovery of M101 spotting round DU debris and its location will be reported immediately to the Garrison RSO. The Garrison RSO, in consultation with explosive ordnance disposal (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.

Containers of DU held for disposal as radioactive waste will be appropriately labeled with "CAUTION - RADIOACTIVE MATERIAL" labels.

5 Access Control

This section provides specific guidance for access to RCAs. For convenience and reference purposes, it also provides relevant excerpts (with minor edits to suit context) from US Army regulations[6] and official policy for control of access to Army installations and ranges.

5.1 General

All unescorted persons entering a US Army installation must have a valid purpose to enter, have their identity proofed and vetted, and be issued, or in possession of an authorized and valid access credential.

Federal Personal Identity Verification and valid Department of Defense (DOD)-issued cardholders require identity proofing and vetting to determine fitness and eligibility for access. Persons possessing a DOD-issued Common Access Card are vetted to DOD personnel security standards and shall be considered identity proofed.

Non-Federal Government and non-DOD issued card holders who are provided unescorted access require identity proofing and vetting to determine fitness and eligibility for access.

Garrison representatives shall query the national crime information center database as the Government authoritative data source to vet the claimed identity and to determine fitness, using biographical information including, but not limited to, the person's name, date of birth, and social security number.

5.2 US Army Installations

5.2.1 Training Areas and Range Facilities

The Army prohibits unauthorized persons from entering the installation training complexes.[7] The Army controls access to training area facilities to provide maximum training and safety. The Army authorizes access to training area facilities only for conducting official business.

5.2.2 Impact Areas

The Army prohibits unauthorized persons are prohibited from entering impact areas and other areas known or suspected to contain UXO by use of positive controls to include fencing and/or posting of UXO hazard warning signs. Passing any hazard warnings without Range Operation's permission is forbidden. Range Operations must approve entry into an impact area.

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[6] Army Regulation 190-13, *The Army Physical Security Program*, 2011

[7] Department of the Army Pamphlet 385-63, *Range Safety*, 2014

5.3 RCAs

All RCAs are within impact areas in Army training areas and range facilities. Hence, the controls discussed in Section 5.2 apply to all RCAs as well.

Personnel access to an RCA is not authorized except with the knowledge and approval of the Garrison RSO. This is because the Garrison RSO must make appropriate arrangements to assure compliance with NRC regulations and license conditions as promulgate in this PSP. The Garrison RSO will assure that all appropriate range operators, trainers, and security are aware of this requirement. This requirement is in addition to and not in lieu of any other approvals for access that may be required.

Whenever personnel access to an RCA is required, the Garrison RSO will establish a minimum number of access control points on the RCA's perimeter for entry and exit (except in an emergency), known as "hot-lines."

Personnel otherwise qualified to enter the RCA will escort official visitors.

The Garrison RSO will refer to the License RSO for additional guidance as necessary.

6 Markings on Containers and Equipment

Title 10 CFR Part 20, § 20.1904 requires that all containers that contain more than 100 microcuries of ^{238}U or of natural uranium[8] be properly labeled with a "CAUTION—RADIOACTIVE MATERIALS" sign or label. The label will also provide information, such as the radionuclides present (DU), an estimate of the quantity of radioactivity, the date for which the activity is estimated, radiation levels, and kinds of materials, to permit individuals handling or using the containers, or working in the vicinity of the containers, to take precautions to avoid or minimize exposures.

The specific activity of DU is about 0.4 microcurie per gram, so 100 microcuries of DU has a mass of about 40 grams or 3 ounces. A single, intact M101 spotting round contains about 190 grams of DU.

The only containers of M101 spotting round DU on the installations should be containers of DU held for disposal as radioactive waste.

[8] The activity in DU is mostly due to ^{238}U. The activity in natural uranium is mostly due to ^{234}U and ^{238}U in equilibrium with each other. Table C in Appendix C to 10 CFR Part 20 does not list DU explicitly, but the inference is taken that the labeling requirement for an activity of more than 100 microcuries should also apply for DU.

7 Radioactive Waste

The Garrison RSO will, in coordination with EOD personnel, double-bag in plastic bags all M101 spotting round DU that is picked up and removed from the RCA. Anyone handling DU will use tools or gloved hands to handle it. The bags then will be stored in sturdy containers with appropriate markings.

The Garrison RSO will secure these containers in a locked storage facility with access limited to personnel appropriately trained in radiation safety and security.

The Garrison RSO, in coordination with the License RSO, will contact Chief, Army Low-Level Radioactive Waste Disposal Division, US Army Joint Munitions Command, ATTN: AMSJM–SF, Rock Island Arsenal, Rock Island, IL 61299–6500, who will arrange for appropriate disposal of the DU.

8 Program Audits

Each Radiation Safety Program audit will include an assessment of the effectiveness of this PSP.

The License RSO or his or her designee will review the physical security program content and implementation and document the results of this review at least annually to ensure the following:

- Compliance with NRC and the terms and conditions of the license
- Records of audits and other reviews of program content are maintained for 3 years

9 Training

Before RCA entry, all personnel (except one-time visitors; see section 2.6) will receive and acknowledge training on essential elements of this PSP. The Garrison RSO or his or her designee will conduct this training as part of radiation safety training.

The essential elements of DU physical security training for non-physical security personnel are:

- Access to RCAs is authorized only in accordance with the RSP and this PSP
- Notify the Garrison RSO if DU is found in a location where it was not previously known
- Do not pick up or remove DU from a range except as authorized by and under the supervision of the Garrison RSO, who will coordinate with the License RSO

Attachment 7

Proposed Changes to Conditions of NRC License #SUC-1593

The current license amendment application contains information that requires changes to current license conditions. The following are proposed changes to current license conditions.

Old LC	Proposed New Wording	Comment
10	The authorized places of use shall be United States Department of Army Installations at Schofield Barracks/Pohakuloa Training Area, HI; Fort Benning, GA; Fort Gordon, GA; Fort Campbell, KY; Fort Carson, CO; Fort Hood, TX; Fort Knox, KY; Joint Base Lewis-McChord/Yakima Training Center, WA; Fort Bragg, NC; Fort Polk, LA; Fort Sill, OK; Fort Jackson, SC; Fort Hunter Liggett, CA; Fort Riley, KS; Fort Greely, AK; and Joint Base McGuire-Dix-Lakehurst, NJ	Includes all known places of use
11	[see comment]	NRC will provide appropriate text
12	[delete and renumber subsequent LCs]	All known Army installations with M101 DU present and under NRC will be included following NRC approval of license amendment application.
13	If the licensee identifies information indicating that Davy Crockett-related depleted uranium may be present at a US Army installation not identified in License Condition 10, the licensee will notify the NRC in writing within 15 days of the identification of this information. The licensee will evaluate the information and provide the NRC with a schedule for evaluating the presence of depleted uranium at the installation within 90 days of the identification of the information.	Removes reference to old LC 12.
14	If it is determined that Davy Crockett-related depleted uranium is present at an US Army installation not listed in License Condition 10, the licensee shall submit a request to include the installation on this license. The request will includea site-specific Decommissioning Funding Plan and the name of the Garrison Radiation Safety Officer. Any additional procedures necessary to ensure compliance with License Conditions 9A - 9D that are not included in the licensee's applications dated November 6,	Removes reference to old LC 12. Deletes reference to RSP and PSP because license RSP and PSP will apply for any new site. Deletes reference to site-specific ERMP, because programmatic approach (PA) to ERMPs will dictate design of site-specific ERMP. Added reference to current license amendment application.

Old LC	Proposed New Wording	Comment
	2008 and June 1, 2015 will also be included in the request.	
15	[delete and renumber subsequent LCs]	The Army has met this condition.
16	[no change]	
17	[delete and renumber subsequent LCs]	The Army has provided information to allow HE fire into RCAs without license restrictions or conditions.
18	[delete and renumber subsequent LCs]	The RSP includes this requirement.
19	The licensee shall not perform any decommissioning or ground disturbing activities to collect or remove depleted uranium fragments or contaminated soil that is identified during routine range activities at the authorized places of use in license condition 10 without prior authorization from NRC.	Updates places of use
20	NRC or Agreement State licensed contractors may undertake decommissioning or ground disturbing activities to collect or remove depleted uranium fragments or contaminated soil that is identified during routine range activities at the authorized places of use in license condition 10 consistent with the conditions and commitments of their license(s).	Updates places of use
21	When the licensee engages an NRC or Agreement State licensed contractor to undertake decommissioning or ground disturbing activities to collect or remove depleted uranium fragments or contaminated soil that is identified during routine range activities at the authorized places of use in license condition 10, the licensee will notify NRC in accordance with the requirements of 10 CFR 40.42. The licensee shall provide NRC with the contractor's site-specific decommissioning plans and all other documents associated with radiation safety and environmental monitoring associated with the proposed decommissioning or ground disturbing activities in accordance with the requirements of 10 CFR 40.42 prior to the commencement of the activity. If issues are identified by NRC that could impact radiological health and safety, they will be resolved prior to the commencement of the activity.	Updates places of use
22	[delete and renumber subsequent LCs]	The Army has provided information to allow HE fire into RCAs without license restrictions or conditions.

Old LC	Proposed New Wording	Comment
23	[delete and renumber subsequent LCs]	The PA to ERMP and site-specific ERMPs will address plant sampling both inside and outside RCAs.
24	[delete and renumber subsequent LCs]	The PA to ERMP contains this statement.
25	[no change]	

Attachment 8

Arguments against Air Sampling During HE Fire into RCAs

Argument 1

"Back of the envelope" simple-minded calculation assumes steady-state DU concentration in air:

NRC requires effluent monitoring if air concentration exceeds 10 percent of the value in Table 2, Appendix B, 10 CFR 20. The effluent concentration for ^{238}U is 6×10^{-14} μCi/mL = 0.06 pCi/m^3.

Assume, for the purpose of the calculation, that:

- Ten percent of the maximum effluent concentration for ^{238}U or 0.006 pCi ^{238}U/m^3 is constantly in the atmosphere exiting the RCA for 50 y = 1.57788×10^9 s ("steady state").
- The average annual wind speed is the RESRAD default of 2 m/s
- The wind blows in a single direction
- The cross-section of the air that is exiting the RCA with suspended DU in it is 5 m high by 1000 m wide or 5000 m^2.

Given:

- The DU mass/M101 round is 190 g.
- The specific activity of ^{238}U is 3.3×10^{-7} Ci/g.
- The relative activity abundance of ^{238}U in DU is 0.875.
- The specific activity of DU is 3.77×10^{-7} Ci/g = 3.77×10^5 pCi/g.

So:

$$5000\ \text{m}^2 \times 2\ \text{m/s} \times (1.57788 \times 10^9\ \text{s}) \times (0.006\ \text{pCi}\ ^{238}\text{U/m}^3) \times [1/(0.875\ \text{pCi}\ ^{238}\text{U/pCi DU})] \times [1/(3.77 \times 10^5\ \text{pCi DU/g DU})] \times [1/(190\ \text{g DU/M101 round})] = 1511\ \text{M101 rounds}$$

That is, the dust equivalent of more than 1500 M101 rounds per RCA would have to be suspended in air and blown away from the RCA in a single direction over the 50 years since the Army fired them before the NRC would require routine air sampling in accordance with 10 CFR 20. Many RCAs do not contain this number of rounds. On those that do, it is highly unlikely that this has happened. The Army simply could not sustain the firepower required to make it happen.

The equivalent of more than 15,000 M101 rounds per RCA would have to be suspended in air and blown away from the RCA in a single direction over the 50 years before the Army could exceed effluent standards. The Army fired the most M101 rounds at Fort Benning (9700) on eight firing ranges, so it is impossible for the Army to exceed effluent standards for any RCA even if the Army could sustain the HE fire required to cause the suspension, so air sampling should not be necessary at any RCA during HE fire.

In actuality:

- Rounds can remain largely intact after 50 y in the environment, depending on climate.
- Corrosion products remain on and in the soil in proximity to where each round landed.
- The wind does not blow in a single direction.
- Any suspension into the atmosphere is short-lived because of DU's density (that is, only DU suspended in air close to the RCA boundary is likely to leave the RCA; DU suspended in air more than about 25 m from a boundary will fall to the ground within the RCA).

If the actual conditions are taken into account, the possibility of approaching ten percent of the effluent standard is even more highly improbable.

Argument 2

Table B.2 in NUREG-1757 (Nuclear Regulatory Commission 2006) provides screening "values that represent surficial surface soil concentrations of individual radionuclides that would be deemed in compliance with the 25 mrem/y (0.25 mSv/y) unrestricted release dose limit in 10 CFR 20.1402. NUREG-1757 says, "The licensee may adopt these screening DCGLs without additional dose modeling, if the site is suitable for screening analysis."

For radionuclides in a mixture, the "sum of fractions" rule applies; see Part 20, Appendix B, Note 4." The screening values for ^{234}U, ^{235}U, and ^{238}U are 13 pCi/g, 8.0 pCi/g, and 14 pCi/g, respectively. Using the relative activity abundances of the three uranium isotopes in DU, the screening value for DU is $(0.115 \times 13$ pCi/g$) + (0.011 \times 8$ pCi/g$) + (0.874 \times 14$ pCi/g$) \approx 14$ pCi DU/g.

For the DU in 1,000 M101 rounds evenly distributed in the surface soil (top 15 cm) of a typical 1-km^2 RCA, we have calculated that the DU concentration is about 0.3 pCi/g (Cherry 2012). The maximum possible number of rounds in an RCA occurs at Fort Benning if we assume that the Army fired all 9700 rounds into a single RCA, which is unlikely because Fort Benning has eight RCAs on its ranges. The maximum possible DU concentration (at Fort Benning) is then 3.0 pCi/g, which is still well below the DU screening level of 14 pCi/g.

Thus, every RCA already meets the unrestricted dose limit, assuming the M101 rounds are completely corroded,[1] which implies that each RCA could be released for unrestricted use (while following ALARA measures and NRC protocols/approval), which then implies that air sampling, which is a restriction, should not be necessary during HE fire for any RCA.

The Army notes that until 2011, when the NRC placed the restrictions on HE fire into M101 impact areas, the Army had no such restrictions on its HE fire. This lack of restrictions had no discernible effect on human health or the environment and was with the tacit approval of the Atomic Energy Commission and later the Nuclear Regulatory Commission.

Argument 3

An Army contractor's report (Morrow 2008)[2] says:

QUOTE

> In order to evaluate the potential air quality impact of M101 rounds at [Pohakuloa Training Area (PTA)], we conducted a computer modeling analysis using onsite wind data along with a number of conservative assumptions regarding atmospheric stability conditions and the fate of M101 spotting rounds lying on the surface within the impact zone at PTA. The EPA's Industrial Source Complex - Short Term (ISCST) model[3] was employed in a screening mode with the following input:
>
> - wind direction and wind speed data from four (4) monitoring stations at PTA
> - neutral stability (Class 4) assumed during the period 8:00 a.m. - 10:00 p.m. daily
> - stable atmosphere (Class 6) during the period 11:00 p.m. - 7:00 a.m. daily when wind speed was less than 4 meters per second
> - 100 intact M-101 rounds [per day] were struck by a high explosive round and 100% aerosolized
> - three (3) scenarios were modeled: detonation at 8:00 a.m., 2:00 p.m. or 12:00 midnight (to reflect different meteorological conditions)
> - the detonation was assumed to occur every day of the year at the specified hour

[1] If the rounds are not completely corroded, then even less DU is available to contribute to average annual dose.
[2] We attach a copy of this report with the license amendment application for convenience.
[3] EPA developed the ISCST model to provide estimates of air concentrations and deposition rates of the stack emissions of contaminants from industrial sources located in varied terrain (e.g., from simple to complex terrain) (USEPA 1986).

- *annual average uranium (U) concentrations were computed at 966 receptor locations spaced at 100 meter intervals on the PTA boundary*

UNQUOTE

The highest result Morrow obtained from this "worst-case" analysis (36,500 M101 rounds completely aerosolized in a year) was an annual average DU mass concentration in air of 0.25 $\mu g/m^3$, which, Morrow points out, is "below the World Health Organization's recommended public exposure level of 1.0 microgram per cubic meter ... of air for soluble forms of DU."[4]

However, Morrow's result requires additional study. Using the specific activity of DU, 3.77×10^{-7} Ci/g = 3.77×10^{-7} µCi/µg, the annual average DU activity concentration in air for the above highly conservative scenario is approximately 9.4×10^{-8} µCi/m^3 = 9.4×10^{-14} µCi/mL. The ^{238}U *activity content is* $0.875 \times 9.4 \times 10^{-14}$ µCi/mL $\approx 9.3 \times 10^{-14}$ µCi/mL For comparison, the NRC effluent standard for ^{238}U in air is 6×10^{-14} µCi/mL, so Morrow's highly conservative scenario produces an average DU activity concentration in air that marginally exceeds the NRC effluent standard for DU in air.

Morrow then adopts a more realistic but still highly conservative scenario. Because no more than 714 M101 spotting rounds were available for aerosolization by HE munitions on the two Hawaii ranges, he changed his scenario from 100 M101 spotting rounds per day aerosolized over a year to two M101 spotting rounds per day (or 730 rounds in a year) aerosolized over a year. This reduces the maximum DU activity concentration in air by a factor of 50 to 1.9×10^{-15} µCi/mL, which is less than 1/30th of the NRC effluent limit for DU in air.

A realistic but still conservative scenario, such as one HE munitions direct hit per week on an M101 spotting round, would reduce the hypothetical maximum DU activity concentration in air to much less than one percent of the NRC effluent limit for DU in air.

Clearly, the hypothetical aerosolization of M101 DU by HE munitions on Army ranges would produce DU air concentrations that "are authorized by law and will not endanger life or property or the common defense and security."

Argument 4

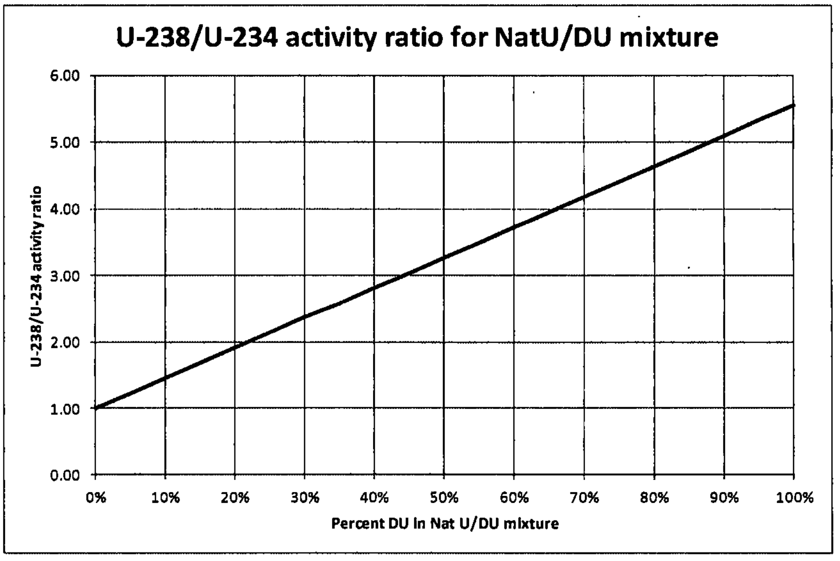
This argument has to do with the detectability of uranium in air samples and the sensitivity of $^{238}U/^{234}U$ activity ratios for determining the presence of DU in air samples.

[4] The forms of DU on Army ranges are uranium alloy (before corrosion) and uranium oxide (after corrosion), both of which are essentially insoluble.

To date the Army has been unable to detect DU in the atmosphere using air sampling in Hawaii during routine contractor survey and construction operations, during planned range burns, and during limited HE fire in a training exercise.[5] Indeed, the radiochemistry laboratories were not able to detect even natural uranium above minimum detection limits for most air samples. Attempts to detect DU using a composite of air samples also failed to detect DU in air samples.

With this in mind, consider only those air samples for which the total uranium in the samples is above detection limits. This total uranium will certainly include natural uranium. The sample may or may not include DU. The NRC states in license condition 24, "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." That is, as it often does, the NRC considers that a $^{238}U/^{234}U$ activity ratio of 3 or greater is a positive indication that the sample contains DU.

The $^{238}U/^{234}U$ isotopic composition of the uranium in the sample is determined by either gamma spectroscopy or alpha spectroscopy. This is possible because the activities of these two isotopes are roughly comparable in samples of natural uranium, where the ratio is 1.0, and of depleted uranium, where the ratio is about 5.5.



As the above figure shows, a fifty-fifty mixture of natural uranium and DU has a $^{238}U/^{234}U$ activity ratio of about 3.25 or approximately, 3. The NRC criterion apparently presumes that at a ratio of 3, it is more likely than not that a sample contains DU. The

[5] For the HE fire during training, the NRC did not approve the Army's proposed air sampling plan and did not accept the Army's report for the air sampling.

presumption must be stated this way because, although the criterion has no uncertainty, the measured activity ratio has an uncertainty that depends on the uncertainties of the laboratory results.

The measured uranium isotope activities are usually barely above the minimum detectable activities and so have large relative uncertainties. Hence, the ratios will also have large relative uncertainties, so large that they may be useless to determine the presence of DU even when uranium is detectable in the sample.

Finally, the distribution of M101 DU in the impact area is not uniform. Experience has shown that the DU remains either in un-corroded portions of the M101 round or in M101 corrosion products in the immediate vicinity of the resting place of each round. Hence, when an HE round explodes in the DU impact area, it likely will not suspend any DU unless it explodes on or near the resting place of an M101 round. The required nearness depends on the HE content of the impacting round, while the likelihood of being near enough depends on the number of M101 rounds in the RCA. Thus, the results of a calculation would depend on various debatable assumptions and probabilities.

Instead, consider what Argument 2 above says: If the DU is uniformly distributed in the top 15 cm of soil in a 1-km^2 M101 impact area, the maximum possible DU concentration, 3.0 pCi/g, occurs at Fort Benning. However, this estimate is improbable because Fort Benning has eight ranges. The most probable maximum DU activity concentration, 1.3 pCi/g, occurs at Fort Bragg, which has only one range and 4212 M101 rounds. The concentration for a typical 1000 rounds is about 0.31 pCi/g.

The average natural uranium concentration in United States soil is about 1.25 pCi/g. An HE detonation in an M101 impact area would suspend natural uranium as well as DU. The likelihood of the detected mixture containing more than 50 percent DU (to meet the criterion of 3 for the $^{238}U/^{234}U$ activity ratio) is low on most ranges and near fifty-fifty on the most highly contaminated ranges (Fort Bragg and Fort Hood). Detecting DU through air sampling under these circumstances so far has been fruitless, is likely to remain so, and is fraught with uncertainties. As the other arguments show, even if DU is detected, the likelihood that the DU air concentration, after averaging over a year for comparison with NRC effluent standards, is miniscule,

Bibliography

Cherry, Robert N. "Army Response to US Nuclear Regulatory Commission (NRC) Proposed License Conditions for Davy Crockett M101 Spotting Round Depleted Uranium (DU)." ADAMS ML110830582, 2012.

Morrow, J. W. *Potential Air Quality Impacts of Aerosolizing M101 Spotter Rounds at Pohakuloa Training Area.* Honolulu, Hawai: J. W. Morrow, 2008.

Nuclear Regulatory Commission. *NUREG-1757, Consolidated Decommissioning Guidance, volume 1, revision 2.* Washington: Nuclear Regulatory Commission, 2006.

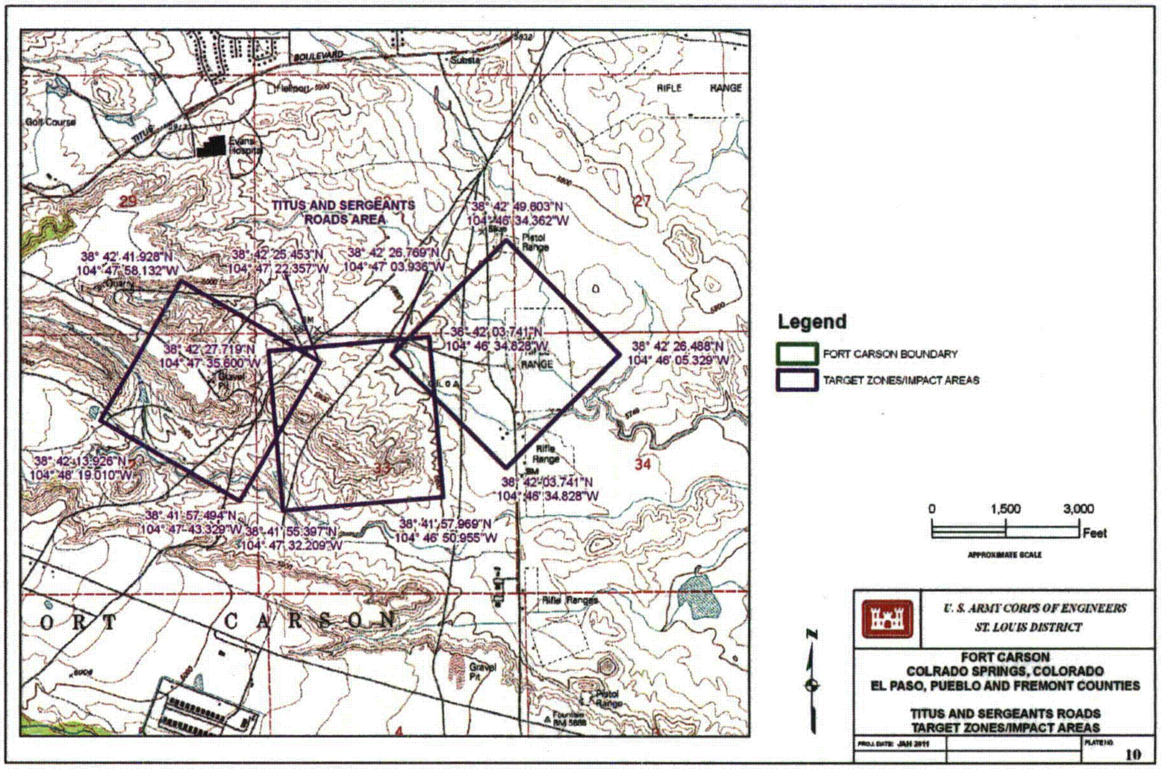
USEPA. *Industrial Source Complex (ISC) Dispersion Model User's Guide, second edition.* Research Triangle Park, North Carolina: US Environmental Protection Agency, 1986.

Attachment 9

Fort Carson Titus and Sergeants Roads Target Zones/Impact Areas

Fort Carson Titus and Sergeants Roads Target Zones/Impact Areas

Section 3.2 of the Radiation Safety Plan says, “Only the NRC can authorize area reduction of an RCA once the RCA is established in the license.” The M101 impact area shown in the following figure, “Fort Carson Titus and Sergeants Roads Target Zones/Impact Areas,” is not established yet in the license. The Army asks the NRC not to include (that is, not to “establish”) this area on the license as an RCA.



Although the Archive Search Report (ASR) for Fort Carson (USACE St Louis 2008) shows standard 1-km^2 impact areas for the Titus and Sergeant Roads Target Zones/Impact Area, the Army used true impact area, which was much smaller, only for demonstration fire.

Following are extracts from the ASR (USACE St Louis 2008):

QUOTE

> Three “Davy Crockett” ranges were identified at Fort Carson. ... A second range (area) was used for demonstration and was located near the corner of Titus and Sergeant Roads. This area is currently occupied by the hospital parking areas and Special Forces Buildings. No Davy Crockett or munitions debris was found in this area during the project inspection. ...

. . .

[A] demonstration of the [Fifth Infantry] Division's nuclear capabilities was held at the monthly retirement review the week of 22 January 1965. The demonstration was held just south of the housing area. The infantry's Davy Crockett was fired by the 2nd Battalion, 10th Infantry in the vicinity of coordinates EN 183850, approximately 1,000 meters south of the company grade quarters in Area II C on Sergeants Road.

An artillery shoot was staged on 6 June 1966 in connection with the visit of Reserve Officers from NATO nations. Interested spectators were welcome. The demonstration opened with a Davy Crockett being fired by Headquarters Company 1st Battalion, 10th Infantry. This demonstration was held just south of Titus Road behind officer family quarters.

. . .

Based on collected information and on the range inspection conducted by the Davy Crockett team, three Fort Carson ranges/training areas were confirmed to have been used for training and demonstrations with the Davy Crockett weapons. One area is located contiguous to the cantonment.

. . .

<u>Titus and Sergeants Roads Area</u>

This area was used for demonstrations and was located just south of Titus Road along Sergeants Road .... Because the direction of fire is unknown, three possible [surface danger area diagrams] are shown on [the above figure]. One demonstration that occurred at this range is chronicled in the Fort Carson "Mountaineer", dated February 5, 1965. The caption reads "The Davy Crockett received its first public airing at Fort Carson on Friday as part of the nuclear weapons demonstration. The projectile was fired at a white square on the side of a hill 1,500 meters in front of the spectators."

. . .

... at ranges where the firing point is known [but] the direction of fire is not known, multiple SDADs and directions of fire are shown [as on the above figure] emanating from the same firing point, producing multiple Target Zones/Impact Areas. This multiple impact areas condition is referred to a "windshield effect". By applying a windshield effect condition, the impact area of a Davy Crockett range is expanded appropriately, thereby maximizing the certainty of conclusions made regarding the expected location of Cartridge, 20mm Spotting M101 debris/residue.

...

... Although the location of the firing point of the former range at the Titus Road and Sergeants Road Area is known, the direction of fire into the impact area was not confirmed. Accordingly, the windshield effect (multiple impact areas) is used to identify the appropriate set of target zones/impact areas for this range ...

...

Titus and Sergeants Roads Area

During the morning of 14 March 2008, Mr. Valdez, Ms. Zoeller, and Mr. Hutchinson inspected the firing points and impact areas of this range complex. The area of the former firing points is currently occupied by the hospital parking areas and by Special Forces Buildings. Both the firing points and the probable impact areas ... were inspected. No Davy Crockett munitions debris or any other munitions debris was found.

UNQUOTE

A contractor performed a scoping survey of the area in March 2008 (Cabrera 2009) and reported the following.

QUOTE

The cantonment area was extensively surveyed visually, instrument assisted and specifically with a dose rate meter. Visual surveys were conducted along the hillsides in potential downrange areas with crews focusing on finding dummy warheads, launch pistons and spotter round bodies. No [Davy Crockett] debris was observed. The FIDLER probe was used during visual surveys for identifying radioactive material, (DU), associate [*sic*] with the DC spotter round. Soil samples and dose rates were collected in and around major construction areas (both planned and in progress).

...

No evidence of DC debris, specifically DU, was observed in any manner within the cantonment area. If the DC was used in this area, the DU was likely either removed or has since been covered by existing construction or fill. Given the low usage of the area as a DC demonstration range, the risks presented in the area are extremely low. No further action is recommended in this area.

UNQUOTE

We believe that probably two but not more than three M101 spotting rounds were fired in this area for demonstration purposes. The total DU mass, if the M101 spotting rounds remain in the area, is probably 0.38 kg but no more than 0.57 kg.[1] The total DU activity is probably about 140 μCi but no more than 210 μCi.[2] The NRC requires posting of an area with "CAUTION, RADIOACTIVE MATERIAL" signs if the area contains more than 1000 μCi of DU.[3] Consequently, this area does not require posting no matter what size it is.

Therefore, the Army requests that the NRC not establish this area as an RCA for the purposes of source material license number SUC-1593.

The Army notes that the possession of this DU meets the requirements for a general license under the provisions of 10 CFR 40, § 40.22(a)(1). Although the Army does not know the exact location of this DU, the Army can meet the conditions for a general license in 10 CFR 40, §§ 40.22(b) through (e).

Bibliography

Cabrera. *Fort Carson Davy Crockett Phase I, Depleted Uranium Investigation, Fort Carson, Colorado.* Baltimore, Maryland: Cabrera Services, 2009.

USACE St Louis. *Installation Specific Archive Search Report on the Use of Cartridge, 20MM Spotting M101 Davy Crockett Light Weapon M28 at Fort Carson, Colorado.* St Louis, Missouri: US Army Corps of Engineers, St Louis District, 2008.

[1] Each M101 spotting round contains 0.190 kg of DU.
[2] The specific activity of DU is 3.7×10^{-7} Ci/g.
[3] 10 CFR 20, § 20.1902(e)