U.S Army Installation Management Command

Environmental Radiation Monitoring Plan
For Depleted Uranium
From the M101 Spotting Round
For
Schofield Barracks

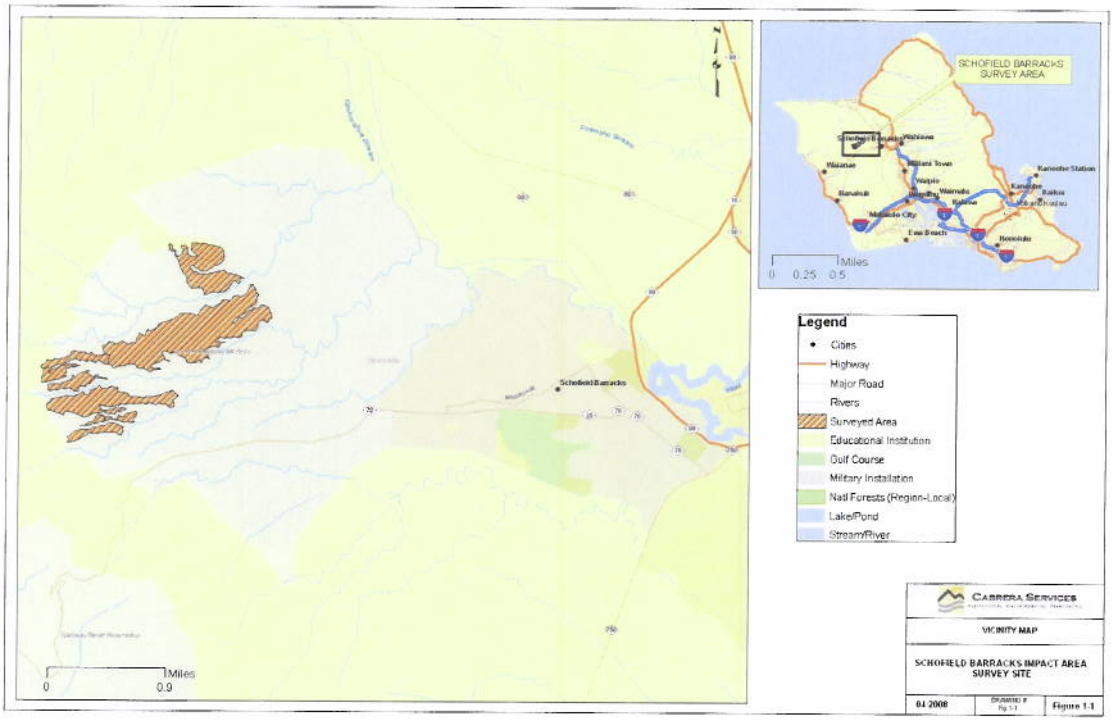
Enclosure 3

1.0 SITE DESCRIPTION

Schofield Barracks Military Reservation (SBMR)

Physiography

Most of the SBMR is in the Schofield Plateau geomorphic province, which is a broad interior highland that lies between the Waianae Range and the Koolau Range. The western side of the SBMR lies within the Waianae Range geomorphic province (USAG-HI, 2004). The SBMR is bounded on the east by Kaukonahua Stream, Wahiawa Reservoir, the town of Wahiawa, and Route 750, and it extends westward to the ridgeline of the Waianae Range. Elevations in the SBMR range from about 660 feet above mean sea level (amsl) along the eastern boundary to about 3,000 feet amsl on the ridgeline of the Waianae Range.



Geology

SBMR is underlain by the Koolau Basalt member of the Koolau formation, which abuts the older eroded surface of the Kamaileunu and Lualualei (lower and middle) members of the Waianae formation (USAG-HI 2004). The Koolau Basalt flowed in thin, nearly horizontal layers, on which soils developed and alluvial sediments were deposited between flows during the various eruptions of the Koolau Volcano. The Koolau basalts are overlain by recent alluvial sediments eroded from the Waianae Range, which account for the surficial deposits that cover most of the SBMR (Oki, 1998).

Soils

Four of the seven soil associations found on Oahu occur within SBMR (USAG-HI 2004). Soils of the Tropohumults-Dystrandepts association occur in largely inaccessible deep V-shaped drainages and narrow ridges on very steep east-facing slopes above an elevation of about 1,500 feet amsl. These are thin, well drained, light soils derived from volcanic ash that are high in organic matter, can contain more water than soil when saturated, and are strongly to extremely acidic. The surface layer is generally dark colored silty clay (friable in the case of Dystrandepts), while the subsoil has a strong blocky structure underlain by saprolite. Because of their occurrence on steep slopes, potential friability at the surface, and fine silty texture, the soil erosion hazard by wind and water is high for this association, especially in areas where vegetation has been depleted. Kolekole silty clay loam and Manana silty clay loam are two major soil groups found on the lower gently to moderately steep slopes of the range at elevations ranging from 500 to 1,200 feet amsl. Kolekole soils are moderately rapidly permeable to the depth of about 2 to 3 feet. Runoff is slow, and erosion hazard is slight. Kunia silty clay is found on the flatter lands of SBMR, on nearly level ground in upland terraces and fans at elevations of 700 to 1,000 feet amsl. Kunia soils are well drained and moderately permeable, exhibiting slow runoff and slight erosion hazard. Soils of the Helemano and Kawaihapai series are found in the gulches and drainageways on alluvial fans. Helemano soils are well-drained silty clays that exhibit severe to very severe erosion potential. Kawaihapai soils are well drained, and the erosion hazard is slight.

Hydrogeology

The uneven distribution of rainfall has implications for surface water runoff and groundwater recharge. The upper portion of each watershed can receive significantly more rainfall in a given storm than the lower portion. Many of the watersheds on the islands are small, and there is often little storage capacity, resulting in rapid runoff and common flooding. Streams on Oahu are generally perennial at higher elevations, where there is greater precipitation, and at lower elevations, where the topography intercepts the groundwater table (Nichols et al., 1996). At intermediate elevations, streams tend to be intermittent due to a combination of high infiltration, diversion of the flows, and high evaporation rates at low elevations (USAG-HI, 2004). There are two streams crossing the impact area at SBMR. These are intermittent and only provide significant runoff during heavier rainfalls.

Surface Water Occurrence

The average annual precipitation at SBMR is 43.75 inches. Monthly averages range from 1.63 to 3.78 inches during the dry season (April through October) and from 4.14 to 6.21 inches during the wet season. SBMR lies within an area in which the 100-year 24-hour rainfall is estimated to be about 16 inches. Streams in this area are primarily intermittent.

Groundwater Occurrence

The groundwater resources on Oahu are well developed, yielding more than 635 million gallons per day from numerous hydrogeologic units and aquifer basins. Approximately 50 percent of the fresh water used in Hawaii and about 99 percent of the drinking water is from groundwater (Nichols et al., 1996). Groundwater on Oahu occurs in basal aquifers, perched aquifers, and dike-impounded zones. The basal aquifer is a freshwater lens occupying porous and permeable volcanic rocks beneath the island. The freshwater lens is thickest near the center of the island and tapers off toward the edges of the island. Fresh water also occurs at higher elevations in perched aquifers and in dike-impounded zones, both of which are classified as "high-level" groundwater. Dike-impounded water is groundwater trapped behind vertical dikes. Perched aquifers are saturated permeable layers or fractured zones that occur above the basal lens and are separated from it by unsaturated deposits (USAG-HI, 2004).

SBMR is in the Schofield groundwater area of the central Oahu groundwater flow system, the largest and most productive flow system on Oahu (Oki, 1998). The central flow system is bounded on the north and south by coastal sedimentary deposits, known as caprock, because they overlie rocks that are more permeable and can confine the groundwater contained in those rocks within the coastal zone (USAG-HI, 2004).

The Schofield sub-area is bounded on the north and south by vertical low permeability features that reduce or prevent groundwater flow. These features might be dike intrusions or possibly depositional features (Oki 1998). Because the groundwater elevation inside the "dams" is higher than outside, the groundwater in the Schofield Plateau is called high-level groundwater. Rift zones associated with the Waianae and Koolau volcanoes contain clusters of vertical or nearly vertical dikes that bar groundwater flow. The eastern and western sides of the Schofield sub-area are bounded by dike zones of the Koolau and Waianae volcanoes, respectively.

Beneath the Schofield Plateau, groundwater occurs in the Schofield High-Level Groundwater Body, where depth to groundwater is approximately 600 feet or more, depending on the ground surface elevation. Additionally, groundwater occurs in the basal aquifer and dike-impounded groundwater system associated with the dike intrusions within the Waianae volcanics.

2.0 PATHWAY ANALYSIS

Schofield Barracks Military Reservation Studies

According to the *Archives Search Report* (ASR) *On the Use of Cartridge, 20MM Spotting M101 For Davy Crockett Light Weapon M28, Schofield Barracks and Associated Training Areas, Islands of Oahu and Hawaii* (USACE, 2007), training with the Davy Crockett weapon system was likely conducted at Schofield Barracks between 1962 and 1968. Historical documents contained no reference explicitly identifying a specific range used for Davy Crockett system training. Available shipment records indicate that 714 rounds (approximately 298 lbs of depleted uranium [DU]) were shipped to Hawaii for use either at SBMR or the nearby Pohakuloa Training Area (PTA). The

number of rounds used at each SBMR and PTA is unknown, but the combined number of rounds fired at these areas cannot exceed 714. In the interest of being conservative and to ensure that modeling represents worst-case estimates, it is assumed that the full shipment of 714 rounds (298 lbs) of DU was used on each range.

In August 2005, a tail assembly and partial spotter round body from the Cartridge, 20mm Spotting M101 associated with the Davy Crockett Light Weapon M28 were discovered by SBMR personnel during routine activities. DU fragments were found at several locations throughout the range area. This discovery prompted a scoping survey in 2007 (Cabrera, 2008) and a full characterization survey in 2008 (Cabrera, 2008).

DU fragments have been observed throughout SBMR as discrete metal fragments and as smaller particulate matter. The characterization survey found that the uranium concentration in the majority of the samples was representative of background (less than 3 pCi/g) with approximately 3 percent containing DU concentrations above background.

While conducting a surface water study at SBMR, DU was added as a contaminant of concern. DU was not detected in the surface water samples collected during this study. The uranium alpha spectroscopy isotopic results were less than their respective minimum detectable concentrations for most of the samples, and the ^{234}U / ^{238}U activity ratios calculated were inconclusive for either DU or natural uranium. Therefore, there is no evidence that DU in soil has migrated to surface water bodies located in or adjacent to the SBMR. In addition, potential contamination of groundwater was considered, but not used in the risk assessment because the underlying aquifer (located at a depth of approximately 500 ft below ground surface) is not recharged from water from the SBMR.

Because controlled burns are routinely conducted at SBMR to control grass fires, a study was performed to evaluate potential releases of DU to the environment during these events. There was no evidence of DU in the particulates generated during these prescribed burns.

Human Health Risk Assessment

A baseline human health risk assessment (BHHRA) was performed to evaluate the potential risk posed by DU at SBMR (Cabrera, 2008). Reported concentrations of uranium and progeny (decay products) in soil were evaluated to assess both toxicological and radiological risks from DU. Based on information obtained during site visits, review of historical records, and comparison of sampling results with respect to U.S. Environmental Protection Agency (USEPA) Region 9 Preliminary Remediation Goals (PRGs), DU was identified as the potential contaminant of concern (PCOC). For the purposes of this risk assessment, it was assumed that all uranium present at SBMR was depleted, and therefore DU was the sole contaminant considered in making the risk calculations in the BHHRA.

Four exposure scenarios were evaluated for the purpose of quantifying risks to potential on-site receptors: current and future maintenance worker, future construction/remediation worker, future adult cultural monitor/visitor, and future site worker. Complete exposure pathways were evaluated for each scenario and included a combination of the following: incidental ingestion of soil, inhalation of windblown fugitive dust, dermal contact with site contaminants, and direct exposure to external gamma radiation. Exposure point concentrations were calculated based on sample data from the soil.

Health risks were estimated for DU based on the chemical toxicity of uranium. The maximum hazard index (HI) of 0.2 was calculated to quantify the non-carcinogenic effects of exposure for a future construction/remediation worker. This is below the USEPA's acceptable risk limit for non-carcinogenic effects of 1.0. These results for non-carcinogenic risks indicate that there are no adverse impacts expected due to chemical exposure to DU.

The *RESidual RADioactivity* (*RESRAD*) computer code, Version 6.3, developed by Argonne National Laboratory (ANL, 2005), was used to estimate risk due to the radiological toxicity of DU for each of the potential receptors. A maximum risk of 3E-5 was calculated to quantify the excess lifetime cancer risk. This value falls within USEPA's acceptable risk range of 1E-4 to 1E-6, indicating that there are no likely adverse impacts expected from DU exposure based on its radiological toxicity, and the DU levels are safe (USAEPA 1989..

An additional dose and risk evaluation was performed to evaluate the potential health impacts to an off-site subsistence farmer living 1500 meters from the SBMR. This is a highly conservative exposure scenario that would be considered the Maximally Exposed Individual for offsite receptors. RESRAD-OFFSITE, Version 2.1 (ANL 2007) was used to estimate radiological dose and risk, and USEPA's standard Risk Assessment Guidance for Superfund equations were used to determine the chemical risk due to the presence of DU at the site. The results of the dose and risk assessments showed that both the radiological and chemical risks are within the USEPA's acceptable risk range. Hence, there are no likely adverse effects to off-site receptors resulting from the presence of DU at the SBMR and the DU levels are safe.

Potential Source-Human Interaction Pathway Analysis

There are no known potential source-human interaction pathways associated with the surface water exiting the McCarthy Flats and Kolekole Road range regions. There are no known recreational areas or surface water intakes along the North Fork of the Kaukonahua Stream, and it is not classified as a designated fishery. Release mechanisms include erosion of soils and surface water runoff. Surface water pathways were identified for the active ranges within the McCarthy Flats and Kolekole Road regions. Soils found within these areas are generally well drained, have high clay content, a moderately rapid permeability, and slow to rapid runoff, depending on

topography. The soil pH in this region ranges from 4.3 to 6.5, usually increasing with depth (USACE, 2004).

Surface water and sediment may be a source via runoff or erosion. The degree of slope, combined with the soil characteristics of the area, proximity to streams, and annual rainfall quantities indicate that potential contaminants can be transported hydraulically and deposited in streams. The McCarthy Flats and Kolekole Road regions contain tributaries to the North Fork of Kaukonahua Stream. This surface water body flows along the eastern border of the McCarthy Flats and Kolekole Road regions before moving down-gradient and discharging into the Kaiaka-Waialua Bay.

Potential Source-Ecological Interaction Pathway Analysis

Surface water draining the McCarthy Flats and the Kolekole Road regions flows off of the range areas, then northwest via the North Fork of Kaukonahua Stream to Waialua. Along this pathway, the surface water encounters habitat for several damselfly and dragonfly species as well as the O'ahu 'elepaio. The damselfly and dragonfly species are classified as Hawaiian arthropod species of concern and may be impacted through dermal contact during the developmental cycle. The endangered forest bird, O'ahu 'elepaio, may ingest or bathe in contaminated surface water.

Summary

Site characterization data (Cabrera, 2008) demonstrates that DU mobility is restricted and remains localized. DU was not detected in surface water or in air samples during burn studies. Except for samples taken underneath or immediately adjacent to DU fragments, soil samples were consistent with background levels of DU. Ground water is not considered a viable pathway for DU exposure. Wind erosion and surface water transport, while unlikely, are considered the most feasible method of transport off the range.

3.0 SAMPLING PLAN

Periodic Sampling Program

All sampling, analysis and resulting actions performed under this plan will adhere to the requirements outlined in the *U.S. Army Installation Management Command Environmental Monitoring Plan for Depleted Uranium from the M101 Spotting Round*. Quality control procedures and responsible individuals are identified in the IIMCOM *Generic Environmental Radiation Monitoring Plan*.

The DU on SBMR is contained within the impact area of the range which contains other hazards such as unexploded ordnance (UXO). Access to this area is tightly controlled and only trained personnel are authorized access. Range control personnel control access to all ranges, including those with residual DU.

Site characterization work has defined the area in which the DU is located. In addition, additional surveys with subsequent removal of DU occurred in support of potential construction activities on contaminated areas of the range. This reduced the source term and therefore reduced the amount of DU available to migrate from the range. This effort is ongoing at the time this plan was written, so the actual amount of DU removed is unknown at this time. The purpose of the periodic sampling program is to verify that DU is not migrating off the training/firing range. To achieve this, soil, surface water, and sediment samples will be taken annually at specified locations on the perimeter of the range.

Direct Radiation Measurements. The characterization survey demonstrated that over most of the range, the external exposure is consistent with background (approximately 7 μR/hr). Hot spots were detected during the characterization survey as high as 70 μR/hr; DU was removed from many of these areas, eliminating the hot spots. Access to the range is limited and personnel access to these areas is extremely limited; therefore, direct radiation exposure is not considered a credible exposure scenario and direct measurements will not be performed as part of this ERM Plan.

Soil Samples. To determine whether or not soil containing appreciable concentrations of DU is being impacted by sedimentation and erosion mechanisms which lead to off-site transport, soil samples will be taken at five areas along the perimeter of the range. These points correspond to likely transport locations and completely bound the range. Three of these locations are adjacent to established water/sediment locations, but will be taken in areas not impacted by the intermittent steam.

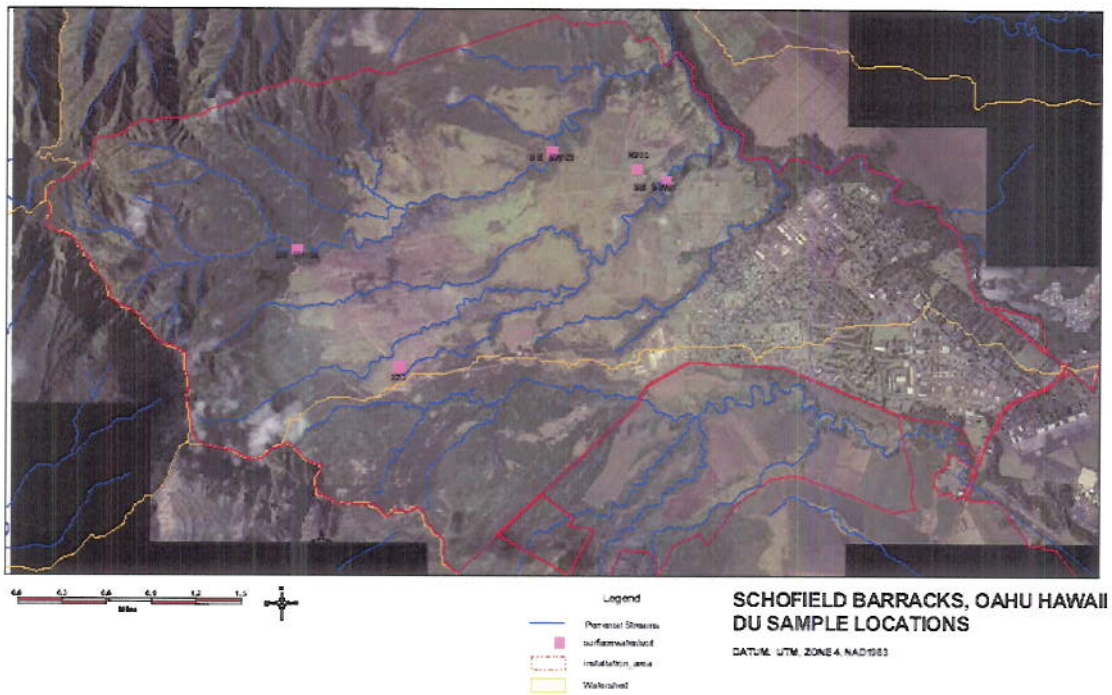
Soil sample Locations	
Sample Identifier	MGS Coordinates
SW-01	594941.2378393
SW-03	593823.2378703
SW-04	591077.2377646
KR-3	592247.2377608
MF-01	594729.2378419

See map identifying soil sample locations

Sediment/ Water Samples. There has been an ongoing surface water monitoring project to determine if munitions constituents, including DU, have been washed off the range. DU concentrations were indistinguishable from background levels. Although this monitoring effort has ended, the sampling locations are ideally suited to detect contaminants that have migrated off the range and accumulated in surface water drainages in the area, so they will be used for DU monitoring as part of this ERM Plan. Sediment samples will be collected on an annual basis at the four locations identified below. Three of the sampling locations are at locations where streams exit the range and the fourth, SW-04, is located where a stream enters the range to serve as a background sample. The rainy season typically occurs from December through March, so the sampling will occur during this timeframe to provide

the best opportunity to collect surface water. But, because of the intermittent nature of the streams, if this is not possible, only sediment samples will be taken. Otherwise both surface water and sediment samples will be taken at each of the identified locations.

Sediment/Water Sample Locations	
Sample Identifier	MGS Coordinates
SW-01	594941.2378393
SW-02	596083.2377958
SW-03	593823.2378703
SW-04	591077.2377646
See map identifying soil sample locations	



Analysis of Samples. Sample analysis will be by USEPA method 200.8, *Determination of Trace Elements in Waters and Wastes by Inductively Coupled Plasma - Mass Spectrometry (ICP-MS)* or equivalent procedure and USEPA Method 6020 *Inductively Coupled Plasma - Mass Spectrometry.* Alternatively, samples may be analyzed using an equivalent method for alpha spectroscopy; the use of this method may be warranted under circumstances where the activity concentration of uranium is not sufficient to provide accurate isotopic identification using ICP-MS. Results will be reported in terms of activity per gram for each isotope and total activity for uranium. The analysis may be performed by any Army or contract laboratory capable of performing the required analysis.

Action Levels. The purpose for analyzing the soil, sediment, and water is to ensure that releases of material to the environment are as low as reasonably achievable. Action levels are provided to establish a limit which if exceeded, will require

a mitigative investigation be initiated. Based on the results of the investigation, the radiation safety officer will recommend corrective actions to be undertaken. The NRC will also be notified when action levels are exceeded. Action levels are defined in the table below.

Environmental Media	Action level
Soil	**35 pCi/g**
Sediment	**35 pCi/g**
Water	**150 pCi/l**

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