LA-UR- 94-1838

Title: ENVIRONMENTAL RADIATION MONITORING PLAN FOR DEPLETED URANIUM AND BERYLLIUM AREAS, YUMA PROVING GROUND

Author(s): Michael H. Ebinger
Wayne R. Hansen

Submitted to: Project Report

Los Alamos
NATIONAL LABORATORY

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Form No. 836 R5
ST 2629 10/91

ENVIRONMENTAL RADIATION MONITORING PLAN FOR DEPLETED URANIUM AND BERYLLIUM AREAS, YUMA PROVING GROUND

Prepared for the Test and Evaluation Command,
U. S. Army

Michael H. Ebinger
and
Wayne R. Hansen

Environmental Science Group (EES-15)
Los Alamos National Laboratory

11 May 1994

TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

This Environmental Radiation Monitoring Plan (ERM) discusses sampling soils, vegetation, and biota for depleted uranium (DU) and beryllium (Be) at Yuma Proving Ground (YPG). The existing ERM plan was used and modified to more adequately assess the potential of DU and Be migration through the YPG ecosystem. The potential pathways for DU and Be migration are discussed and include soil to vegetation, soil to animals, vegetation to animals, animals to animals, and animals to man. Sampling for the GP 17A and GP 20 areas includes establishing transects perpendicular to the lines of fire. Sample collection along the transect will show DU deposition and will be used to estimate DU migration. The number of samples from each area varies and depends on if the firing range of interest is currently used for DU testing (GP 17A) or if the range is not used currently for DU testing (GP 20). The number of annual soil and vegetation samples for inactive ranges is 12, whereas the number of samples from active ranges is 76 each of soils and vegetation. Twenty to thirty-five individual mammals or lizards will be sampled from each transect will also be collected and analyzed. Air samples and samples of dust in the air fall will be collected in at least three locations in the active ranges. Thirty to forty-five sediment samples will be collected from different locations in the arroys near the impact areas.

DU and Be sampling in the Hard Impact and Soft Impact areas changed only slightly from the existing ERM. The modifications are changes in sample locations, addition of two sediment transport locations, addition of vegetation samples at the same locations used for soil samples, ten to twenty mammal samples, and air sampling from three to five positions on the impact areas. A total of 25 to 42 samples will be collected from the Hard Impact and Soft Impact Areas.

Analysis of samples for DU or total U by inductively-coupled mass spectroscopy (ICP\MS), α spectroscopy, neutron activation analysis (NAA), and kinetic phosphorimetric analysis (KPA) are discussed, and analysis for Be by ICP\MS are recommended. Establishing the source of U in samples is an important aspect of the sampling and analysis program. Acquiring total U (no isotope data) from a large number of samples and analysis of those samples with relatively high total U concentrations results in fewer isotopic identifications but more information on U distribution. From previous studies, total U concentrations greater than about 3 times natural background are usually DU by isotopic confirmation. Finally, we recommend the use of chain of custody forms to document sample handling and analysis from the point of collection to the time when the data are reported. The data should be stored electronically on a personal computer-based data base for ease of tracking and simplified reporting of environmental data.

INTRODUCTION

This Environmental Radiation Monitoring (ERM) Plan is intended to update the ERM currently used at Yuma Proving Ground (YPG) for collecting soil, sediment, and air samples (U. S. Army, 1990). Our recommendations are to modify the existing ERM sampling in order to sample the compartments and processes that most affect DU behavior in the YPG environment. Previous ERM reports show DU and Be data from 50 to over 100 samples of soils and arroyo sediments each year and approximately 300 samples from continuous air monitors each year. We suggest modifying sample collection to more adequately cover the soils, sediments, vegetation, and biota of the environment based on the field and modeling study.

The updated ERM incorporates the work conducted by Los Alamos from 1990 through 1994 at YPG on the environmental fate of depleted uranium (DU). In that work, ecosystem modeling and field sampling were conducted to evaluate the environmental pathways that are important to DU migration through the ecosystem. The modeling and field sampling suggest that previous ERM sampling of soils, sediments, and air should be modified to more fully monitor the important pathways and processes responsible for DU migration. In particular, more soil samples should be collected from the impact areas, and the frequency of sampling could be changed to twice yearly instead of quarterly; arroyo sediments should be collected closer to impact areas, and more samples should be collected; additional, periodic air sampling is suggested and should be conducted on the impact areas; and biological samples should be added to the ERM sampling in order to assess DU and beryllium (Be) contamination of small mammals in the food chain. We extended the existing ERM plan, incorporating as much of it as possible in the modifications. The proposed modifications of the existing ERM plan, however, should not cause large scale changes in the way ERM sampling is conducted at YPG. The details of these suggestions will be discussed below.

Sampling in support of previous ERM plans is documented in several reports that show little DU was detected in the environment except at known impact areas. The rationale behind the sampling reported in previous reports was sound, although the data could not be used directly for assessing risk of the DU testing program to the environment. Information about the YPG ecosystem obtained through ecological modeling and field sampling by staff from Los Alamos and Colorado State University suggest several modifications to the existing environmental sampling. Since the ecosystem modeling was designed to identify parameters that most affect the amount of DU transport in the ecosystem, ERM sampling is most cost effective when those parameters are sampled and reported. The most sensitive parameters identified in the ecosystem modeling can be considered "indicator processes" or "indicator species." Indicator processes refer to physical or chemical transformations that control the migration of DU in the environment, whereas indicator species refer to animals and plants that show effects of DU in the environments. Indicator processes or compartments should be the first affected parts of the YPG ecosystem and should show the highest DU concentration according to the ecosystem models and field sampling. These recommendations account for and utilize the information about transport pathways discussed below, and will provide data that can be used in the future to assess the effects of DU in the YPG environment.

The previous ERM plan (U. S. Army, 1990) and several ERM sampling reports provide the background on the YPG impact areas, geological setting, climatological summary, and the use patterns of the YPG area. These reports are left as references and should be consulted if further information on the overall YPG area is needed. The present ERM plan will discuss the importance of pathway analysis in assessing the impact of DU testing on the environment and the specific impact areas and environmental monitoring required in each impact area. A section on analytical methods that should be used for the analysis of the ERM samples is included, as well as guidance on the types of

samples to collect at different sites. Finally, we discuss the number of samples that should be collected and the locations for these samples.

Depleted uranium is found in two areas at YPG. First, DU penetrators are tested at GP 17A and GP 20 on the west end of the Kofa firing range. DU testing at GP 17A will also include programs moved from Jefferson Proving Ground as part of BRAC. A new catchment facility will be constructed on GP 17A for the former JPG testing, and the sampling plan below includes the new catchment facility. The second area where DU is found and the only area where Be is found is the eastern portion of the Kofa Range used for testing nuclear artillery mock-ups. Testing of the mock-ups began about 1954 and continued sporadically until about 1990. The geographic areas of interest for this ERM are shown in Figure 1.

ENVIRONMENTAL PATHWAYS FOR DU AND BE

The 1990 ERM document (U. S. Army, 1990) showed the following pathway for DU migration in the environment: Source → Soil → Run off → Vegetation → Animals → Predators → Humans. This pathway will be discussed in the context of the conceptual model shown in Figure 2, and the present ERM plan for YPG will be developed. Transfer of DU and Be through the ecosystem involves many interactions between different parts of the ecosystem as depicted in Figure 2. The linear approach to DU transfer in the 1990 ERM plan approximates the migration from source through the ecosystem, but does not show the interactions between components such as runoff (erosion) and differences in DU ingestion by small herbivores and large herbivores.

The source of DU on the Kofa Range is from testing of tank munitions against soft targets at GP 17A and GP 20. The source of DU and Be in the artillery impact areas is from testing of the mock nuclear artillery rounds. The two sources are different in terms of total amount of DU and Be placed in the environment as well as in the mode of DU and Be dispersal through the ecosystem. The amount of DU on the Kofa Range is

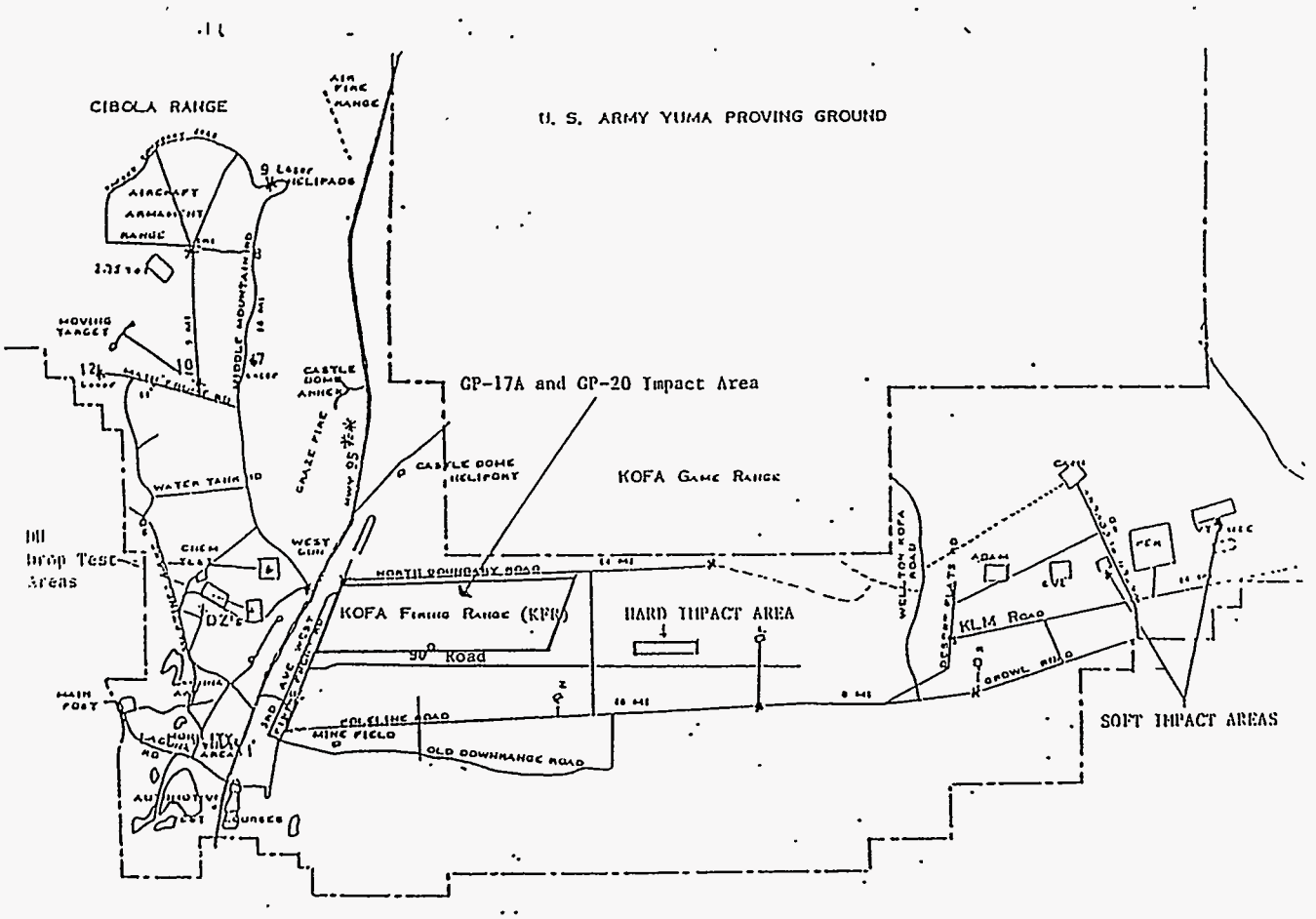


Figure 1. Map of YPG showing the areas of interest for this ERM.

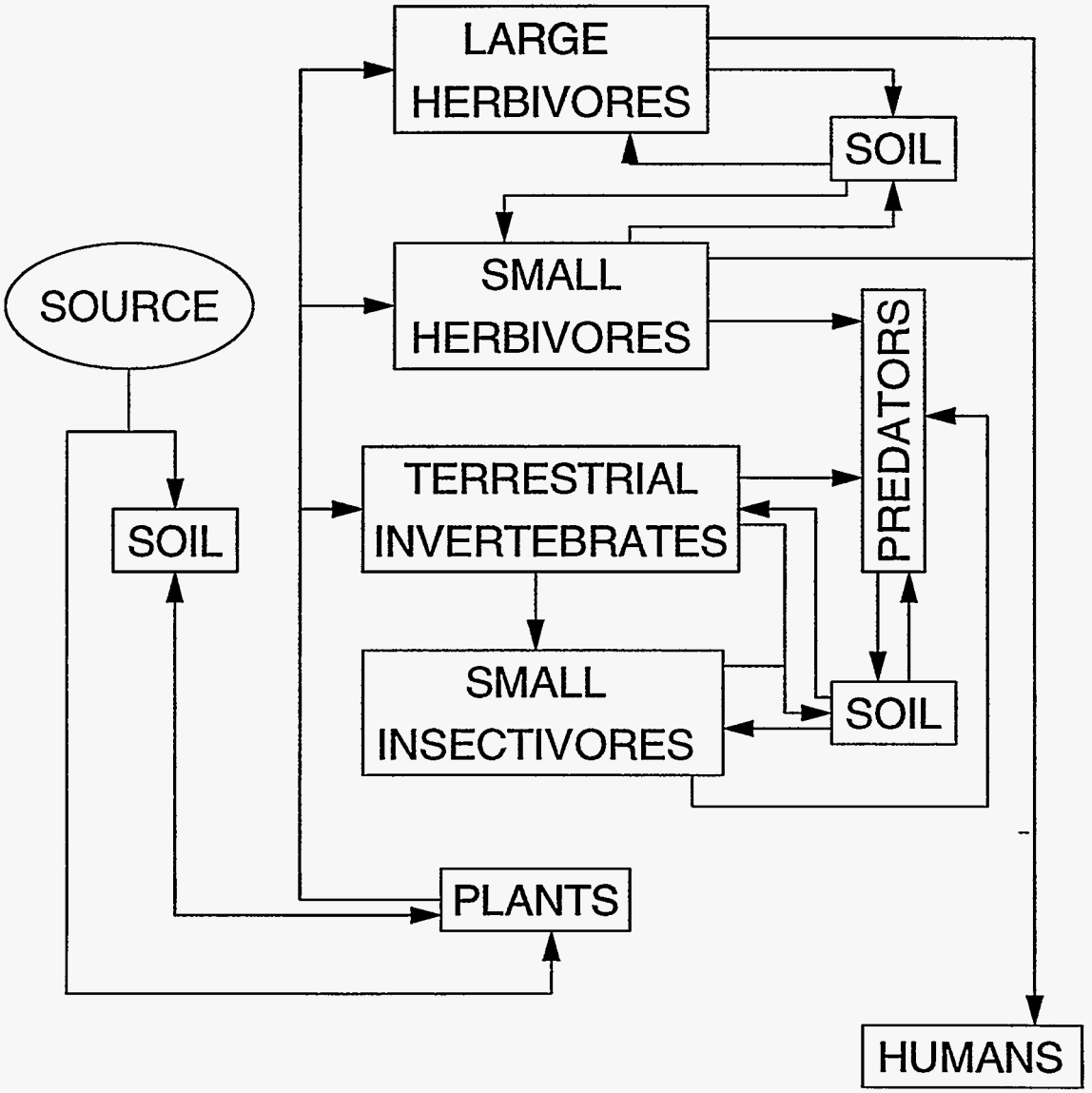


Figure 2. YPG ecosystem model. Arrows indicate transfer of DU from different compartments.

much greater than the amount fired in the he artillery tests. Furthermore, recovery of the artillery rounds after impact was originally part of the testing plan, whereas recovery of each round fired at GP17A or GP20 is impractical and would hinder testing efforts.

Potential Pathways for Contaminant Migration

There are several potential pathways for DU and Be introduction to and transport through the food web that include small insects, reptiles, small and large mammals, and humans (Figure 2). However, not all of these pathways contribute equally to the DU that could be transferred to humans. Modeling of DU transfer shows that small herbivores (*e.g.,* kangaroo rats) accumulate DU from soil ingestion and consumption of DU-contaminated vegetation, but large herbivores, while exposed by these pathways do not accumulate DU. DU accumulation in small herbivores is due to their close proximity to contaminated soils and vegetation in the impact areas. Transfer of DU in soils accounts for most of the DU in the small herbivores and controls the amount of DU available for transfer to the food chain. Examination of the different environmental pathways shows the ecosystem components that should be sampled in order to demonstrate the effects of DU migration on the YPG environment and on humans.

Soil to Plants. The soil to plant pathway consists of two means of DU transfer: 1) incorporation of DU through plant roots into plant tissue (incorporation); and 2) deposition of DU-contaminated soil on plant surfaces (surface deposition). The vegetation is sparse at YPG as a whole, but there are areas where significant plant growth occurs. One such area is to the west of the Hill and Birm area at GP 20; another is along the arroyos that dissect the entire Kofa Range.

DU is available to plant roots when plants grow in soils contaminated with DU. Uptake of DU (or U) by plant roots and incorporation within plant tissue is documented (Whicker and Ibrahim, 1987; Ibrahim and Whicker, 1988). Ratios of U concentrations in plants to the U concentrations in the soils in which the plants grow range from about 3 x

10^{-4} to 8×10^{-1} and depend on the concentration gradient of DU from soil to roots, DU particle size, and the chemical form of the particles. The areal distribution of DU is also an important factor in DU incorporation. Where low concentrations of DU are found in soils, plant roots will not be able to incorporate the DU as readily as when plants grow in soils with higher DU concentrations. Because of the sparse vegetation and small area (100 to 500 m^2) contaminated by high concentrations (>35 pCi/g-soil), incorporation of DU into plants is of minor importance.

Deposition of DU is significant from wind-born soil, soil ejected as a result of penetrator impacts, or, to a small degree, from raindrop splash (Dreicer *et al*, 1984). Price (1990) shows that vegetation in the impact area tends to have higher DU than background, and field measurements at YPG show that DU-containing dust on the surface of plants is significantly greater than background. DU on plant surfaces, while not affecting plant metabolism or growth observably, is available for ingestion by animals.

There is not enough DU on or inside the plants to cause noticeable toxicity to plants, but transfer of DU from soil to plants by air fall, resuspension, or actual DU uptake must be measured to estimate the effects of DU on ecosystems and humans. The animal pathway will be discussed below.

Soil Erosion. Erosion of DU from the surface of desert pavements and soils is the main mode of DU transport at YPG. Little vertical movement of DU was observed in soils at YPG (Ebinger *et al*, 1990), but tens to hundreds of mg-U/g-soil were found in arroyos adjacent to impact areas and in soils subject to penetrator impacts. Water erosion of DU fragments, mostly of particles less than 2 mm in diameter, increases the area of DU contamination beyond the immediate impact area. Plants and animals that range outside the impact areas can be affected by DU from testing after deposited DU erodes from the impact area. Transport of DU via water erosion also dilutes or decreases the concentration of DU in the sediment or soil, and the dilution increases as the distance

from the impact area increases. Water erosion of DU fragments is considered important with regard to the ecosystem near the impact areas but less important as distance from the impact areas increases. The largest effects of DU on plants and animals will be in the contaminated areas closest to the impact areas.

Water erosion is the most likely process to cause removal of DU from YPG to the uncontrolled environment south of the YPG reservation boundary. However, the effects of DU erosion on human health are small, less than 1 cancer death in 10^6 cases (1 in 1,000,00) according to the ecosystem model results. Sampling Castle Dome Wash at the southern YPG boundary should be conducted to show if DU is present at the boundary. DU concentration is expected to be background at the boundary because of the extreme amount of dilution with "clean" sediments as distance from the source area increases. Samples from arroyos that flow into Castle Dome Wash and drain the impact area should also be collected to determine the amount of DU that is removed from the impact areas before it is diluted to less than detection levels by uncontaminated arroyo sediments.

DU is also transported by wind erosion, and deposition onto plant surfaces of DU-contaminated soil is significantly above background in the vicinity of initial impact locations. The important aspect of wind erosion is the resuspension of DU particles into the air and subsequent deposition of the particles either on soils, desert pavements, plants that are used as a food source, or directly onto animal pelts. Inhalation of DU by animals and humans also becomes a consideration, especially to workers in the impact area and in and around the new catchment facility scheduled for construction at GP 17A. Redeposition of DU particles from wind to plant surfaces significantly changes the amount of DU that is available for ingestion by animals. One study of the GP 20 and GP 17A areas shows elevated DU on vegetation samples (Price, 1991). Field observations and measurements with a portable radiation detector also indicated that dust coating the leaves of trees and shrubs contained DU. While analyses were not made before or after washing, the field sample information (Price, 1991) suggests that DU-contaminated dust

increased the apparent DU concentration of the plants by coating the outside of the plants. The transport of DU through resuspension and redeposition is considered a major pathway and influences the amount of DU in the food web and the amount of DU that could be inhaled. Modeling results also suggest that wind-borne, DU-contaminated soil is a significant source of DU to the YPG ecosystem, although it a smaller effect than from DU transport via water erosion.

Soil to animals. Soil ingestion by animals is also a significant pathway for DU migration. Ingestion of tens to hundreds of grams of soil per kg of body mass is common in animals including deer, coyote, mice, and lizards. Modeling DU transfer through the food web showed that soil ingestion was one of the largest factors influencing the DU ingested by animals. In the model, the largest DU concentrations appear in the small mammals, specifically in the kangaroo rat (*Dipodoyms* sp.), and one of the largest contributions of total DU in kangaroo rats was from ingested soil.

Contaminated soil also adheres to the pelts of animals. While the amount of DU that would be transported on pelts is small, there is no reliable data on external dosimetry for animals of interest at YPG. Thus, the effects of radiation exposure from pelt-borne DU are unknown but expected to be small because similar skin exposure to humans is small. Of more importance is DU ingestion by predators when they consume prey with DU-contaminated pelts. Modeling the effects of predators ingesting DU-contaminated pelts showed that about 10% of the total DU concentration in predators could come from DU-contaminated pelts. The elevated levels of DU predicted were less than the soil concentrations and less than DU concentrations in prey animals. Animal sampling should be done in a manner that isolates pelt DU from internal DU.

Plants to Animals. Animal ingestion of DU by way of plant consumption is the major pathway of consideration at YPG. DU incorporation by plants is a minor pathway for DU transport for reasons mentioned previously, but ingestion of DU deposited on the surface of plants is significant. Impact areas where DU dust contamination is greatest

provide the highest potential for DU ingestion by animals from plants. Sampling vegetation will show the amounts of contaminants ingested by the animals that use the vegetation as a food source. A more detailed sampling scheme would show the contributions of surface-deposited DU on vegetation in relation to DU taken up by the plant roots. Analysis of vegetation samples that have been washed will provide data on the amount of DU crossing in to the root membranes, and analysis of the wash water will show the amount of DU that is on the surface of the plants.

Animals to Animals. Consumption of primary consumers by animals at higher trophic levels accounts for another pathway of DU migration at YPG. DU ingested by predators from plants and animals that carry DU is less than the DU ingested by primary consumers (*i.e.*, kangaroo rats). Thus, animals at higher trophic levels (predators, large herbivores) are inherently at lower risk of adverse health effects due to DU contamination than the small herbivores. The potential for DU transport via the predator pathway, however, is large enough to warrant continued monitoring of this pathway.

Animals to Humans. This pathway becomes significant only when animals that contain DU are consumed by humans. No farming or ranching occurs within the reservation boundary, and there is only minimal hunting of animals that live in or migrate through impact areas. While the potential exists for DU transfer to humans through consumption of animals, the probability of this occurrence is low as long as human access to the firing areas of interest is controlled. There is no evidence that DU migrates off site in sufficient quantities to elevate the health risk to humans south of YPG toward Yuma.

Summary of Pathways. There are several environmental pathways and processes that are important in controlling the amount of DU transferred into and through the YPG food web. Plant uptake and incorporation from soil, while small, provides one means of introducing DU to the food web. More important is DU-contaminated soil that is deposited on the surface of plants. The DU coating then becomes a means of introducing mg-U/kg concentrations into the food web.

Inhaled DU dust is one potential pathway to humans. Inhalation of DU through routine work at YPG is not expected, but inhalation due to dust-creating activities on the firing sites could occur. An inhalation pathway also exists for animals, especially the small herbivores that live near the soil surface and burrow into soils. Soil ingestion by animals is another potentially important pathway for DU transfer into the food web, and is correlated with the inhalation pathway for small herbivores. Soil erosion by water and wind controls most of the DU transfer through the ecosystem.

Redeposition of eroded DU-containing soil is also an important process and results in small concentrations (10-100 mg-U/kg-soil) of DU in many of the arroyos at YPG near impact areas and is the source of measurable quantities of DU dust found on plant surfaces in the impact areas. These pathways and processes stand out as the most sensitive parameters in the ecosystem models. Therefore, the present ERM plan will be concerned with modifying the existing ERM plan to incorporate the YPG ecosystem information.

KOFA RANGE (GP 17A, GP20, AND GP 4)

Testing of DU penetrators at GP 17A and GP 20 began in 1982 and continues at present. The impact areas of these firing positions and the surrounding environment are presently being studied for the environmental fate of DU fragments deposited as a result of the testing (Price, 1991; Ebinger *et al,* 1990). The study in progress shows that there are several pathways by which DU can migrate and be incorporated into food chains or redistributed in the environment.

Environmental Pathways and Processes

DU deposition. First, DU is deposited when penetrators strike the ground after being fired from either GP 17A or GP 20. The penetrators tend to skip along the ground for several hundred to several thousand meters after the initial impact before coming to

rest downrange. Fragments of DU are sheared or ground off by friction each time the penetrator hits the ground. Fragments ranging in size from sub-millimeter to several kg have been observed in the impact areas. It is also common to see "spray zones" of DU-contaminated dust that is ejected from an impact crater, carried by the wind, and redeposited on undisturbed desert pavement, soil, and vegetation 10 to 50 meters from the impact site. Field measurements have shown that DU-contaminated dust maintains DU concentration significantly above background in the spray zones.

Fragments too large for wind transport tend to be buried in the soils of the impact area or remain on the surface. These fragments are subject to transport by water erosion and weathering due to oxidation of the DU metal. The weathering products are the brightly-colored yellow rinds and fine particles that are regularly observed in the impact areas. Small penetrator fragments and the yellow weathering products can be moved by water that flows over the impact area as a result of summer rainstorms of high intensity and short duration or by low intensity, long duration winter storms. Intense thunderstorms are common in the summer, and infrequently result in extensive flooding of the YPG area. The present environmental fate studies suggest that significant DU, especially the weathered products, are relatively easily transported by the intermittently running water that comes from yearly precipitation. Small DU particles are moved into washes by water moving in gullies or overland, then is mixed with arroyo sediments and "flushed" through the system of successively larger drainages. The arroyos that drain the impact areas coalesce and flow into Castle Dome Wash within a few miles of the impact areas. DU redistributed by water erosion is extremely difficult to track because of the complex mixing that occurs as the DU is incorporated into the bed load of the successively larger arroyos.

Data from DU fragment recovery show that most of the fragments are recovered from about 3500 m to about 6500 m down range (Figure 3). About 100 kg of DU fragments have been collected between 3500-4000 m down range from GP 17A and GP

20. This location is the area where many of the DU penetrators strike the ground after passing through soft targets. The area is clearly gouged as the penetrators impact then skip off the ground and fly farther down range. Analyses of soil and vegetation samples along the GP 17A and GP 20 firing lines show that most of the DU dispersal in soils and vegetation is found between 3500 and 5500 m. There are significant though small DU concentrations (10 to 100 pCi/g) at about 3500 m (Figures 4 - 7). Deposition of larger DU fragments is most likely down range from 3500 m, and deposition of small fragments and DU dust is likely beginning in the area of first impacts at about 2000 m. The areas with concentrations of DU-contaminated dust, such as at 3500 m would be the most likely areas to show redistribution of DU by wind or by the energy imparted when penetrators strike the area repeatedly. These observations from the Kofa firing areas indicate some complexity in the DU source term that adds uncertainty in predictions of the effects of DU on the ecosystem and humans. Therefore, the areas of highest DU concentration and the areas of highest probable dust redistribution should be sampled as part of the environmental monitoring.

Incorporation by Plants: As discussed above, plant uptake of DU from soil is expected to be small. Analysis of vegetation samples suggests that the DU concentration associated with plants is mainly DU dust and not DU that has been absorbed by the plants. Figures 6 and 7 show DU from vegetation and represent the sum of incorporation and surface deposition.

Ingestion by Small Animals: Consumption of plants and the intermittent surface water that contain DU will result in small amounts of DU ingestion by animals such as the kangaroo rat. The largest source of ingested DU at YPG will be from vegetation coated with DU-dust and soil ingestion, and the smallest source will be from DU in surface water. While most DU carried on pelts is not ingested by the animals carrying it, predators who consume the smaller animals will ingest the pelt-borne DU. Thus, small animals can redistribute DU by ingestion of food, occasionally through drinking surface

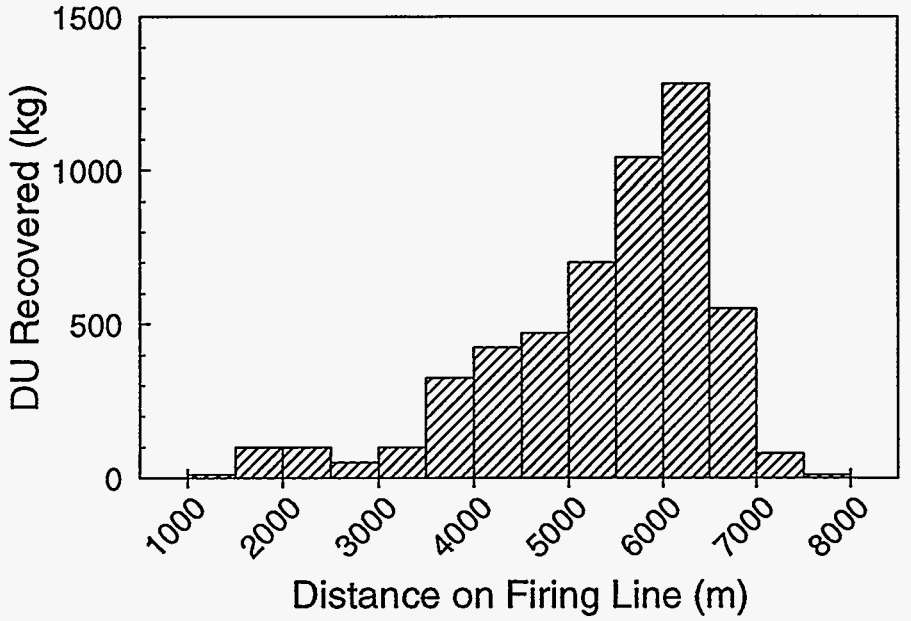


Figure 3. DU recovered at GP 17A and GP 20 as of December, 1992 data. Total DU recovered was 5489 kg.

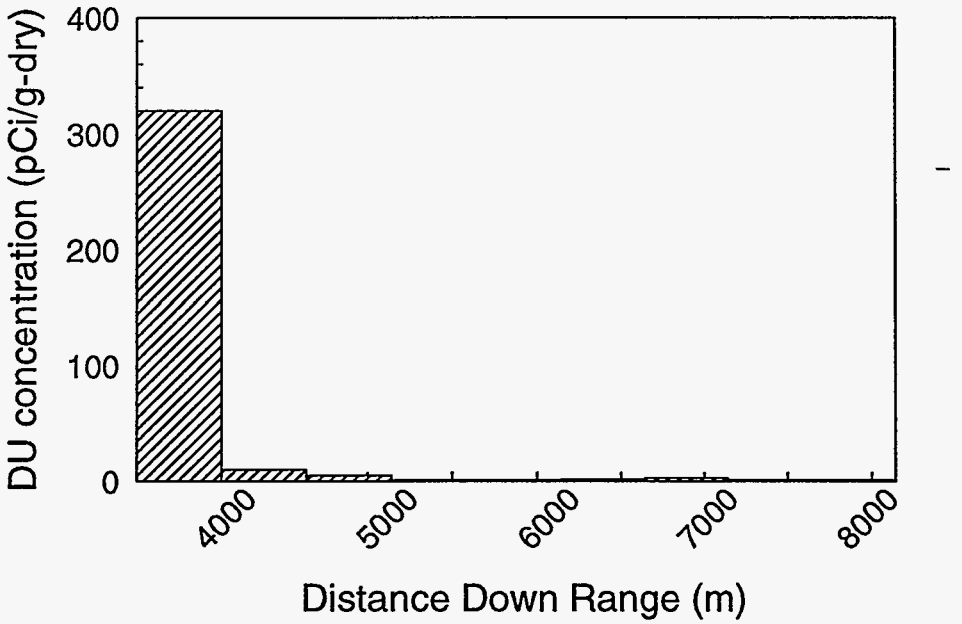


Figure 4. DU concentration in soils at GP 17A. Data from grids north of the firing axis (Price, 1991).

Figure 5. DU concentration in soils at GP 20. Data from grids north of the firing axis (Price, 1991).

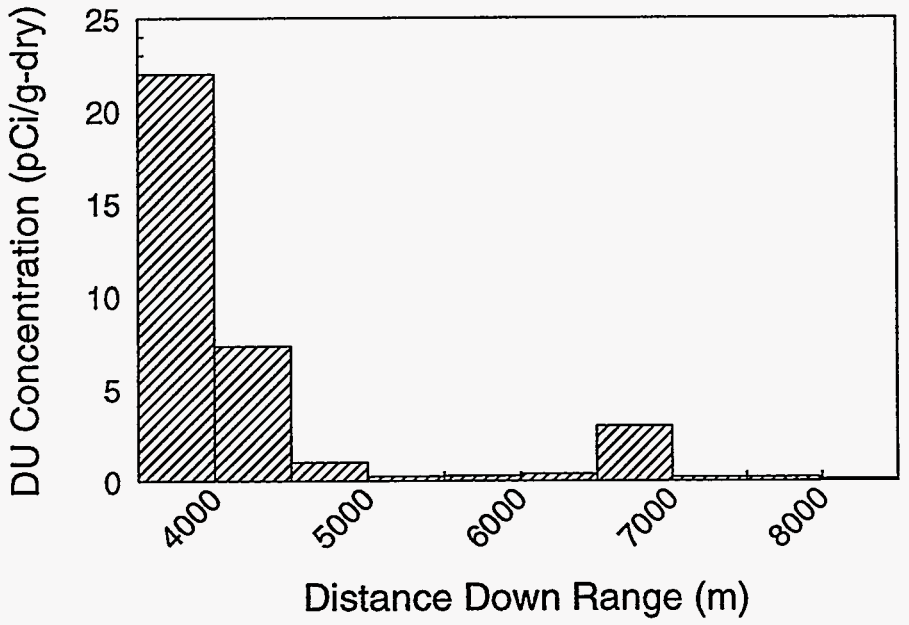


Figure 6. DU concentrations of vegetation at GP 17A. Data from grids north of the firing axis (Price, 1991).

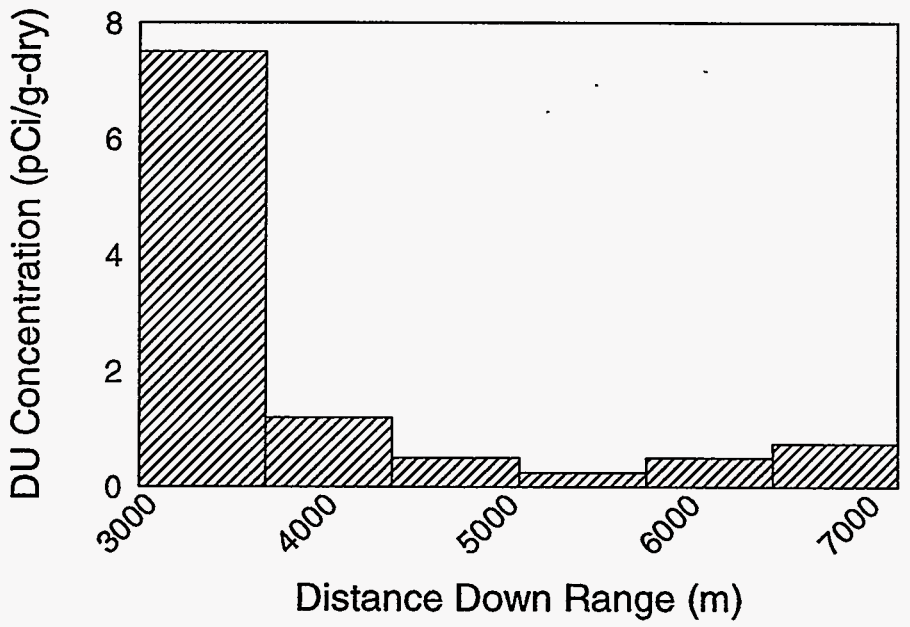


Figure 7. DU concentrations of vegetation at GP 17A. Data from grids north of the firing axis (Price, 1991).

water, or by carrying DU on their pelts. Mammals, reptiles, small snakes, and insects could all be responsible for redistribution of DU in this manner.

Ingestion by Larger Animals. Larger animals include birds, larger snakes, coyotes, deer, and rabbits. Ingestion of DU by larger animals includes the consumption of contaminated vegetation, small amounts of drinking water, and predation of smaller animals. Larger herbivores tend to contain elevated DU concentrations when DU redistribution is modeled, but the DU concentration is much lower in the animals than in soils. In the models, DU in large predators is usually from consumption of smaller animals that ingested DU from vegetation in contaminated areas or carried DU on their pelts.

Humans. Human consumption of animals that contain DU from the firing areas is infrequent at present. The pathways for human consumption include hunting and consuming animals that have ingested DU, and consuming vegetation contaminated in the DU firing areas. Human consumption of vegetation is unlikely because of the paucity of edible materials on the firing ranges. Ingestion of DU from drinking water is unlikely because surface water at YPG is ephemeral, and groundwater is about 600 ft below the surface. Rabbit, deer, dove, and quail hunting could be responsible for DU consumption by humans. However, the animals hunted would have ranged more widely than the impact areas, thereby diluting the DU concentration by ingesting "clean" foods from other sources. Transfer of DU to man through the animal pathway should be periodically assessed even if there is trivial DU ingestion by humans.

Contaminated dust transported by wind could lead to significant inhalation and/or ingestion of DU by humans, especially where penetrators initially impact the ground and dust is ejected from the soil into the air by repeated penetrator testing, or where dust is disturbed as a result of human activity (*e.g.,* recovering DU fragments). Dust devils and strong winds are frequent in the area especially in summer and could provide adequate wind velocities to suspend large quantities of DU-laden dust into the air. Since DU is

known to coat leaves and rocks close to the initial impact zone, the suspension of dust by wind or human activities, including collection of ERM samples, is likely in those areas. Measuring suspended DU dust is suggested in the impact areas.

External exposure from DU on the soil surface is another potential exposure pathway for humans. Calculations based on the total inventory of DU at GP 17A and GP 20 indicate that external exposure is much less than (<0.01%) the smallest contribution from the other pathways mentioned above. Because of the minimal contribution to human exposure, surface exposure is not considered an important aspect of this ERM.

Summary of Pathways. The pathways above indicate that small animals (*e.g.*, kangaroo rats) living in the impact areas and the plants consumed by kangaroo rats would be the first ecosystem components other than soil to show concentrations of DU, and thus, DU migration. The soil and arroyo sediments should act as sinks for most of the DU deposited on the firing site, thus the capacity of the soil for DU and the potential for DU flushing through arroyos should be considered. Sediment eroded from the soils and/or desert pavements is one of the largest redistribution mechanisms at YPG, thus the sediment concentration of DU should be considered. Ingestion of DU dust deposited on plants is a significant pathway for animal exposure to DU and should be quantified. Dust inhalation is a potentially large source of dose to humans and animals, but only during windy conditions or when human activity disperses large amounts of soil in the impact areas, or when animals burrow and groom.

Environmental Sampling, Kofa Range

The exposure pathways of interest indicate that soils, arroyo sediments, vegetation, and small mammals that live in the impact area should be sampled. Sampling these endpoints should indicate the magnitude of DU movement and shows approximately how long after depositions DU spreads from the impact areas. Periodic monitoring will also show needs of remediation if any is required. Sampling of the

endpoints such as predators and large herbivores would provide valuable data about DU transport through the food chain. Sampling of the predator and large herbivore endpoints, while lower in priority than small herbivores, soils, sediments, and vegetation, would also show the extent of DU migration through the ecosystem. This sampling could be used to show potential effects to human health and the environment.

Soil Sampling. Soils under and adjacent to desert pavements will also show DU contamination from penetrator impacts or the result of penetrators coming to rest on them. Previous soil profile sampling showed only a few centimeters of vertical DU movement in the soil (Ebinger *et al,* 1990). Thus, soils from surface to about 10 cm depth should be sampled periodically. Environmental sampling should also be designed to determine the areal distribution of DU contamination, not only the DU concentration at particular points in the field through time. Sample sizes for soil samples should be 1000 g of bulk soil or 500 g of < 2mm sieved soil. Soil sampling will show the DU concentration in soils at the impact area, and indicate the areas affected by DU fragments and DU-containing dust. Since soil concentration of DU is the determining factor in the quantity of DU migrating through the ecosystem, soil DU concentration should be measured regularly.

The 1990 sampling plan (U. S. Army, 1990) calls for annual soil samples at four locations at GP 4, GP 17A, and GP 20. We recommend maintaining the existing sampling frequency and number of samples on inactive DU ranges. On active DU ranges, though, increasing the number of soil samples is recommended. Penetrators impact the soil several times daily or at least weekly on active ranges, and significant redistribution of DU fragments (including DU-contaminated dust) results. Our recommendation is to add two 1000 m transects to the yearly sampling regime on active ranges. Ideally the transects would extend 500 m north and 500 m south of the firing line. One transect should begin at the point where initial impact of the DU penetrators occurs because of the high probability of DU particle redeposition. The other transect

should be established where the largest amount of DU is recovered (Figures 3 & 4) and should be sampled in the same manner as the first. Data from the transects will show the variability in the DU soil concentration with time during firing operations. Appendix A shows the number of samples required in this Environmental Monitoring Plan.

The number of samples from each firing site depends on if the range is being used for DU testing. Active ranges will require 76 samples per year if 100 m transect sampling is used. Inactive ranges require only 12 samples per year.

Sampling GP 17A after construction of the DU catchment facility should be modified from the above sampling scheme. Ten samples should be collected semi-annually from within a 30 m radius of the center of the catchment facility (Figure 8, attached separately). A large proportion of the area within the 30 m radius circle will be bituminous pavement or graded and covered with gravel. Soil samples shall not be collected from the paved or graveled areas, only from the soils beyond the pavement and within the 30 m radius. These samples will show the amount of DU ejected from the catchment facility during munitions testing. The area affected by material ejected from the catchment facility will be much less than the area currently affected on the GP 17A range. The area outside the catchment facility, *i.e.*, down range from the catchment facility, should be sampled as an inactive site as discussed previously.

Soil Erosion. Soil eroding from desert pavements and areas not affected by desert pavements will be responsible for significant redistribution of surface-deposited DU. Undisturbed desert pavements are stable with respect to erosion. Soil between rocks of the desert pavement, however, is easily eroded by water from rainfall events. Disturbed desert pavements also provide an erosional pathway because the protective cover of the pavement has been removed and the erosive soils have been exposed. The present DU ecological study shows that DU migrates across desert pavements when rainfall occurs at a rate and intensity similar to the events that lead to 50 or 100 year floods. In a laboratory test conducted as part of the ecological study, movement of millimeter-sized DU particles

from desert pavements was demonstrated. Relatively large DU fragments were also found along gullies that are cutting into soils at the Hill and Birm area of GP 20.

Erosion of large DU fragments is expected only as a result of rainfall events of high rate and high intensity. Erosion of smaller, sub-millimeter particles, however, requires much less severe conditions. Particles of this size are common in soils of YPG impact areas. Monitoring the amount of DU eroded from specific locations on the impact areas will show the DU contribution to different parts of the YPG environment (*e.g.*, the habitat of the arroyo bottoms) as well as the mass of DU leaving the YPG reservation via the large arroyos such as Castle Dome Wash.

Since GP 17A and GP 20 have tributaries that eventually empty into Castle Dome Wash, samples of erosion sediment should be collected at the impact areas. Inexpensive, passive flumes or small water control structures can be used to retain sediments resulting from any storms over a sampling interval. The flumes or structures could be located along flow paths (small gullies) that drain the impact areas of interest and are relatively isolated from high flow areas such as the main arroyos. Sampling in the flow paths would reduce the probability of losing a sampling station to flood waters in a larger arroyo and would ensure that DU-contaminated sediments are collected. Periodically sampling sediment trapped by flumes or control structures would provide an estimate of DU mass transfer from the impact area.

DU recovery at YPG as well as soil and vegetation sampling (Price, 1991) indicate several locations of interest for erosion sediment sampling. Most of the DU recovered at GP 17A and GP 20 is from between 3500 m and 6500 m down range. Assuming the amount recovered correlates with the amount deposited, the areas of highest recovery would be the areas that could contribute the most DU to erosion and subsequent redeposition at other locations along flow paths. Recent soil and vegetation sampling along the firing lines of GP 17A and GP 20 (Price, 1991) indicates that the areas where penetrators initially impact the ground, especially at about 3500 m, have

relatively large concentrations of small DU particles but low total DU inventories. Desert pavements in these impact areas have been opened to erosion because of penetrator impacts, and could contribute DU to nearby tributary arroyos. Sampling down-gradient from the desert pavements will show the amount of DU being moved away from the impact locations and available to other parts of the YPG environment.

Erosion Sampling. The sampling frequency and number of samples at the current water transport locations (Figures 9, 10; Figures 9 - 12 attached separately) should not be changed; annual sampling will show the amount of DU transported by the arroyo that includes Castle Dome Wash. However, we recommend additional annual samples from arroyos immediately adjacent to impact areas, especially the areas of initial impacts where DU-contaminated soil is ejected from impact traces, and in the portion of the impact area where most of the DU fragments are found. Sample sizes should follow the guidelines above for soil samples.

Sediment sampling locations 2A, 9A, 2B, 9B, and 3B (Figure 9) were used prior to 1990 and could be used for continued erosion sampling, or new sample locations could be established closer to the impact areas. The ecological risk study presently underway shows that water flowing over the desert pavements during rainfall events can move several kg of soil/m^2 of desert pavement when storms are intense. Because of these findings, five samples from arroyos near the locations of the two transects used for the soil samples should be collected and analyzed. The sediment locations should be sampled after rainstorms intense enough to cause flow in the arroyos as discussed in the current ERM (U. S. Army, 1990) or concurrently with the soil samples if there are infrequent rainstorms to produce channel flow for the twelve month period prior to the sampling date. The number and frequency of the water transport samples will be used to estimate the amount of DU eroding from the impact areas. The amount of DU measured in this way is also the amount of DU that could migrate off the YPG boundary.

Erosion samples from GP 17A should be sampled differently after the construction of the catchment facility. The water transport samples should be collected in the wash closest to and down gradient from the catchment facility. The samples at the catchment facility location will show the amount of DU available for migration from the catchment facility. The sampling frequency of GP 17A after the catchment facility is constructed should be the same as for the water transport samples discussed above.

DU Resuspension. Soils containing DU particles are also the source of DU-laden dust that is transported by wind or suspended in the air after deposition by repeated penetrator impacts. DU particles deposited from wind-borne or ejected dust is a significant source of DU to the ecosystem based on the current Los Alamos study of DU in the environment. Sampling the dust blowing from impact areas should be conducted to estimate the contribution of dust deposition on soils and plants and thus, to the food chain from this pathway. Passive dust collectors could be installed for known periods of time that consist of large-diameter Whatman filters (*e.g.*, Whatman #42, 6-inch diameter) in petri dishes or other suitable holders. Large-volume, portable air samplers could also be used, especially for sampling the cloud of soil ejected during and after penetrator firing. At least three samplers of either type should be placed within 10 to 15 m of the actual impact areas and at different locations downwind form the impact area to a distance of 100 m. The samples should be collected within the 30 m radius of the catchment facility (Figure 8). These data will show the maximum expected concentration of DU and the duration or frequency of the DU dust-yielding events. Dust sampling will also reveal if DU moves due to wind, repeated penetrator impacts, or both. The data on DU in dust should be used to assess its effects on human health and exposure of different ecosystem components. Samples should be collected for four to eight hours to ensure enough material is collected for analysis. Sample size will depend on the method of analysis and detection limits. Sampling should be conducted yearly and will include samples during firing and separate samples collected when no firing occurs. Replicate samples should be

collected for each. The total number of samples needed is 12 to 20 depending on the number of samplers.

Vegetation. Vegetation plays an important role in DU transfer from soil deposition to the food chain. Vegetation, while sparse in the GP 17A and GP 20 impact areas, occurs frequently in areas such as the arroyos at about 3500 m on the GP 17A range (Figure 6). Vegetation in these contaminated areas should be sampled where animals could consume potentially contaminated plant tissue. Samples of the vegetation should be collected during early growth of new leaves during the spring and from mature plants in the fall. The seasonal range in samples allows for weathering of any deposited DU dust over the course of a growing season. Samples should be collected along the same transects used for soil sampling or from the same place as soils sampled at other locations. Vegetation samples immediately adjacent to soils should be collected when ever possible so that the plant/soil DU concentration ratio can be calculated. These measurements can also be used to periodically assess the amount of DU transferred to animals in the food chain. As discussed above, DU can be absorbed into the plant through the roots and/or be deposited on the surface of leaves as DU-contaminated dust.

Analyses of vegetation will show the amount of DU available from consumption of vegetation. However, the source of DU on plants, whether incorporated form soil via roots or surface deposition from air, remains unknown. If there is reason to differentiate surface DU from incorporated DU, samples of YPG vegetation must be collected then subsampled. One subsample is to be washed of any surface coatings, the other is to be analyzed without washing. The two analyses will give the amount of DU that is absorbed as well as the amount deposited form the air. Total DU available from the vegetation source is the sum of both measured concentrations, assuming that the whole plant is utilized by animals. Samples of 500 g to 1000 g fresh or wet weight are needed to allow for splits and drying before analysis.

Currently there is no vegetation sampling required in the ERM plan (U. S. Army, 1990). Sampling vegetation in the locations specified will show the effects of DU incorporation and surface deposition. The number of vegetation samples will be the same as the number of soil samples. The number of vegetation samples within the 50 m radius of the catchment facility can be a minimum of 5 and a maximum of 10, depending on the density of the vegetative cover.

Biological Samples. Assessing the DU concentration of different animals in the impact areas will be accomplished through collecting kangaroo rats (*Dipodoyms* sp.) or field mice (*Perognathus* sp.) and analyzing tissue and organs from each individual. The rats and mice are considered indicator species of DU contamination based on the results of the ecosystem models. Lizards, kangaroo rats, and mice should be collected near the soil sample locations in order to correlate DU in the animals with DU in soils. Biological samples are a modification from the existing ERM plan and should demonstrate the low DU concentration expected in the field. Sampling and analysis of animals that are likely hunted near YPG, including rabbit, deer, dove, and quail, should be conducted. DU concentration in these samples will provide a more complete assessment of all pathways for DU ingestion by humans, even though the contribution to possible adverse health effects will be small.

Locations where the penetrators initially strike the ground at GP 17A and GP 20 are of primary interest because of the relatively high concentrations of DU in the soil (10 to over 100 pCi/g) and the potential for resuspension and redeposition of small DU particles. We recommend annual collection of 10 to 20 individual animals from the initial impact locations or from within 30 m of the GP 17A catchment facility, five to ten individuals from locations further down range and in the vicinity of the downrange soil transect, and up to five individuals from an area that is not affected by DU testing. These data will show the amount of DU entering the food chain at YPG and will give information about possible stress on the rats due to DU ingestion. The data from the

different sections of the impact area will also show if there is a difference in DU ingestion related to the amount of DU available as redistributed particles. The sampling also provides background or baseline data for comparison with impact-site samples.

The kidneys and the carcass of each animal should be separately analyzed for DU. Kidney data will indicate possible biological stress due to DU in the diet, and carcass DU will show the amount of DU that is available for transfer through the food chain. Sampling of additional animals such as birds and snakes is recommended as supplemental data.

DU AND BE AT THE HARD IMPACT AND SOFT IMPACT RANGES

Nuclear artillery mock-ups (*e.g.*, XM 753) were tested from 1954 to 1990 east and south of the Kofa Range in the Soft Impact and Hard Impact areas (Figures 9 - 12). One of the objectives of the testing programs involving these munitions was to recover the inventory of materials that was fired. This objective was partially met during the course of testing. Some DU and Be remain in the soils and should be monitored. There is an active agricultural area about 10 km from the southeast reservation boundary that could be significantly affected by DU and/or Be migrating off the site. It is expected that sampling at the nuclear artillery area will demonstrate that health and safety in the agricultural area are not jeopardized by the past artillery testing.

ERM sampling in FY 1990 reports no evidence of DU or Be migrating from the eastern section of the Kofa Range. In the Hard Impact and Soft Impact areas DU concentrations are elevated slightly above background in some cases; measured Be in the air and soils of the impact areas is well below action levels (U. S. Army, 1990). Originally there was an extensive air sampling program associated with the nuclear artillery test program, but the monitoring data showed low Be concentrations in the air. The air sampling program was discontinued in later tests because there was no or extremely low concentrations of Be detected at the impact areas.

Sampling DU and Be at YPG

Sampling for DU in the Hard Impact and Soft Impact areas will be similar to sampling in the GP 17A/GP 20 areas discussed above. Thus, soil sampling in the impact areas and in areas that collect erosion and runoff from the impact areas will be important. Sediments from arroyos that drain the DOE impact areas, vegetation, and large and small mammals should also be sampled in the same manner as at GP 17A and GP 20.

Be Sampling

Naturally occurring Be, while no less a potential health threat when compared to Be introduced during artillery testing, should be distinguished from Be left in the field after the DOE shots. Be from beryl and other minerals could have locally high concentrations due to weathering of rocks and soils that contain Be minerals. Unlike U isotopes, Be isotopic ratios are of limited value in determining the source of Be in the samples discussed above. Be occurs as ^{9}Be in nature almost exclusively. Small quantities of ^{10}Be and ^{7}Be occur as a result of cosmic irradiation of atmospheric nuclei (neutron capture and/or nuclear spallation) and from atmospheric testing of nuclear weapons. The ^{7}Be isotope is short-lived with a half life of about 53 days, whereas the ^{10}Be isotope has a half-life of 2.5 to 2.9 million years. Spatial and/or temporal variation in the amount of cosmic radiation received at a particular area could alter the Be isotopic ratio independently of Be deposited by testing, and such alteration would render Be isotopic ratios ambiguous.

Air sampling in the impact areas should be considered even if low Be concentrations are expected. Confirming low Be concentration in air samples at present and demonstrating this trend from previous sampling could support decreasing the frequency of Be monitoring and could show that long-term monitoring is not necessary from a technical standpoint. A similar argument can be made for Be in soils. If soil concentrations show low values, the frequency of soil sampling for Be could be modified. However, sampling for DU and Be provides a public record of results even if insignificant concentrations are found.

The pathways of importance in both the Be and DU sampling are similar to the pathways considered for the Kofa Range at YPG. Because of the chemical hazard to lung tissue of Be, however, additional emphasis on Be inhalation should be considered in the DOE impact areas. The air sampling done previously and additional air sampling done

under the modified ERM plan will help determine the presence or absence of inhalation risks for humans and animals.

Environmental Sampling, Hard Impact and Soft Impact Areas

Soil Sampling. The soil sampling locations shown in Figures 9-12, the number of samples, and the sampling frequency adequately cover the Hard Impact and Soft Impact areas. Moving sampling site 2946 (Figure 11) approximately 1000 m south would provide samples from soils more likely affected by the impacts between grid squares 2746 to 2946.

Water Transport Sampling. We recommend two new water transport sampling locations, one at the Soft Impact area and the other at the Hard Impact area. Location 6943 (Figure 10) could be moved south of the Hard Impact area to the 7241 (Figure 10) grid square in order to provide one of the two new sampling locations. Alternatively, locations 7241 could be established in addition to location 6943 (Figure 10) in order to provide improved coverage. The second new sampling location should be located in grid 4349 (Figure 12) near the Soft Impact area. Location 4349 will be used to monitor the DU and/or Be that is eroded from the soft impact site. Both new locations should be sampled annually with the other water transport samples.

Vegetation Sampling. Sampling vegetation in both the Soft and Hard Impact areas is needed. The vegetation samples should be collected at the same time and from the same locations as the random soil samples; if no vegetation sample can be collected at each random soil location, find an area where there is vegetation and sample there. A total of ten yearly samples will be collected. If DU surface deposition and incorporation are to be differentiated, vegetation samples should be split and treated as discussed for vegetation samples from the Kofa Range. The vegetation sample data and the soil data from a given collection date should be reported together so that soil to vegetation concentration ratios can be calculated if DU and Be is found in either.

Air Sampling. Yearly air sampling within the Soft Impact and Hard Impact areas is recommended. Three to five samples from portable air samplers will provide data on the total amount of dust and the DU and Be concentration in the dust. Continuous air monitoring at the Soft and Hard Impacts areas is not recommended because of the extremely low concentrations of DU and Be reported in previous ERM reports. Air sampling from the two areas could be conducted simultaneously with the soil, water transport, and vegetation sampling.

Biological Sampling. Five to ten kangaroo rats (*Dipodymus spp.*) should be sampled yearly from the Hard Impact and Soft Impact areas (total of 10 to 20 animals). Analysis of the lung contents for Be and the kidney and carcass for DU is recommended. The data from the animals should be compared with the data on similar animals collected from an area not affected by DU or Be testing. Animals collected for comparison to the Kofa Range biotic samples could also be used for comparison to the Hard and Soft Impact samples. We recommend live trapping of the rats, followed by cervical dislocation and dissection to recover the necessary portions of each animal. Biological sampling can be conducted at the same time as other sampling in these areas.

Additional YPG Environmental Sampling

The existing ERM (U. S. Army, 1990) lists several water transport samples down gradient from the Kofa Range and the Hard and Soft Impact areas. We recommend no changes in locations, frequency, or number of samples from these locations. These monitoring locations will address DU and Be transport off the YPG reservation.

Continuous air sampling at the YPG boundary and at locations on the Kofa Range shows DU and/or Be concentrations well below action levels (U. S. Army, 1990). Intermittent air sampling, such as sampling for two weeks per month, would also provide air concentration data that could be acceptable to the Nuclear Regulatory Commission and other organizations with oversight authority. Modification of existing continuous air sampling might also make resources available for additional sampling recommended in this ERM plan. However, modification of the continuous air sampling record could draw unwarranted scrutiny of the air concentration data and may not be a wise action with regard to providing a public record of sampling.

Periodic sampling of animals hunted near YPG should be conducted to show the amounts of DU and Be that could enter the human food chain. Yearly sampling is too frequent because of the minimal hunting pressure at YPG. However, five to ten samples of tissue and internal organs every two to three years would provide data on DU and Be in animals near YPG. Caution should be exercised because data from a small number of samples could lead to false conclusions about the source of DU and Be in the animals. The small number of samples and the uncertainty about if and how long each animal was in an impact area should be considered when making conclusions about possible DU and Be in hunted animals. Animals to collect include deer, dove, quail, and rabbit. Road kills would provide an additional sampling opportunity to estimate the DU and Be available to humans through consumption of different animals. Data from tissue and organs of these animals could provide valuable data on potential exposure to DU and/or Be.

Analytical Methods for DU and Be

DU Analysis. α-Spectroscopy is frequently used to determine the concentrations of ^{234}U, ^{235}U, and ^{238}U in soil, vegetation, and biological samples (*e.g.*, Price, 1991). Continued use of this method of analysis is advised because of its availability and relative wide use. Isotopic ratios determined by α-spectroscopy are subject to relatively large variation due to sample preparation and analysis of the instrumental data. These data are not necessarily the best analytical tool for determining total and/or isotopic U in samples. Inductively-coupled plasma/mass spectroscopy (ICP-MS), instrumental neutron activation analysis (NAA), and kinetic phosphorimetric analysis (KPA) are three other analytical techniques that could be used to measure total U and/or U isotope ratios in samples.

ICP-MS is currently gaining acceptance for the analysis of U and DU in different media. Detection limits tend to be similar to α-spectroscopy, sample preparation is simplified compared to α-spectroscopy, and ICP-MS is less expensive per sample, on average, than α-spectroscopy. Isotope mass ratios and total U mass-based concentrations are obtained from ICP-MS, and mass concentrations are easily converted to activities based on the measured isotope ratios. Isotope ratios determined from ICP-MS tend to have less analytical error than the same ratios calculated from α-spectroscopy. Thus, determination of the source of U in a sample is more certain using ICP-MS data. ICP-MS was successfully used in previous work with YPG soil and sediment samples as well as APG soil, sediment, and water samples (Ebinger *et al*, 1990). Sizes of samples from soils, vegetation, and biota required for analysis range from about 1 to 5 g of dried sample (10-20 g wet, depending on the nature of the sample), or roughly the same size as for α-spectroscopy.

The ICP-MS analysis involves some sample digestion in order to render the analyte into a form compatible with the technique. Standard methods of preparation and analysis should be adopted before the first samples are analyzed so that all total U and U

isotope analyses can be compared. Standard EPA methods (*e.g.,* 200.7) for metal extraction from soil and vegetation samples for ICP-MS analysis could easily be adopted for use in this ERM with little or no modification.

Instrumental neutron activation analysis (NAA) involves excitation of U nuclei in a sample, then measuring the radiation emitted from the excited nuclei (Gladney *et al* 1976, 1978, 1980; Gonzales *et al,* 1988). Radiation from different nuclei identify the element that produced a specific radiation. ^{238}U and ^{235}U produce radiation of characteristic energies that are proportional to the amount of each isotope in a sample. The energies emitted from the ^{238}U and ^{235}U give quantitative estimates of the isotopic ratio, thus the source of U is established. NAA also quantifies the total concentration of U in a sample, and this quantity is converted to an activity-based concentration similarly to ICP-MS data.

NAA requires little sample preparation but does require slightly larger sample sizes than ICP-MS or α-spectroscopy. Preparation of most samples consists of oven drying for 24 hours at about 110^{o} C. Some biological samples may need to be dried and ashed, but there are no chemical digestions or extractions to perform. The main drawback of NAA is the need for a research nuclear reactor facility or accelerator source for neutrons. Brookhaven National Laboratory, the University of Arizona, the University of Missouri, and Texas A & M University are potential providers of NAA capability. The requirement of a reactor facility may limit the number of samples that could be submitted for analysis. Despite the drawbacks, however, NAA is a method that should be considered.

Kinetic phosphorimetric analysis (KPA) is an instrumental method that uses a tunable laser to excite the U or DU in a sample. The excited sample then luminesces in direct proportion to the concentration of U or DU in the sample (Brina and Miller, 1992). KPA is another method that requires little to no sample preparation and can be used to

determine total U in soil, sediment, biological, human urine, and water samples. KPA, like ICP-MS, is gaining popularity in the analytical market place.

KPA is a sensitive method of analysis with reported detection limits for U of 1 to 5 ng/L (3.9×10^{-4} to 1.95×10^{-3} pCi/l) in water and 1 to 3 ng/g (3.9×10^{-4} to 1.17×10^{-3} pCi/g) in soils. Reported data agree favorably with data obtained using other methods and tend to show higher precision (Brina and Miller, 1992). Commercial KPA also tends to be less expensive per sample than ICP-MS or α-spectroscopy, therefore providing one possible means to increase cost effectiveness of environmental sampling. However, KPA is not a technique that can be used to obtain the isotopic distribution of U (or other analytes) in samples. The reported data are total U with no information about the possible sources of the U. The low cost of the method, ease of sample preparation and analysis, increasing availability for commercial use or for on-site installation, and the high accuracy and precision of the method indicate that KPA could be used as a quantitative screening method for samples to obtain initial information on which samples would be likely candidates for isotopic analysis using different methods. The high accuracy and precision of the data obtained from KPA screening would also provide a cost effective means to augment the environmental sampling by analyzing more samples per dollar. A two-stage analysis of environmental samples is suggested. The first stage would use KPA to detect U in samples. The second stage would be triggered by samples above a specified concentration, such as 10 μg/g-soil. Samples exceeding the specified concentration would be analyzed again with a different method. ICP-MS or α-spectroscopy will be used in the second phase to determine the isotopic ratio of the U in the sample, thereby providing activity or isotopic ratios of the U. Analysis of environmental samples in two stages would be a powerful and cost-effective tool for monitoring the fate of DU in the YPG environment.

Be Analysis. ICP-MS is the most reliable method of analysis for Be from samples in the Hard Impact and Soft Impact areas at YPG. Detection limits are low enough that

Be can be detected routinely, and sample preparation for Be analysis is similar to preparations for other analyses and would not, therefore, require significantly more manpower to prepare. As discussed above, analysis of isotopic ratios of Be, while interesting, may not be of direct relevance to the ERM sampling. Instead, the concentrations of Be in impact areas should be statistically compared to "background" Be concentrations, *i.e.*, Be concentrations obtained from samples collected from remote locations. Remote locations should be chosen carefully to ensure that Be concentrations reported come from geological settings similar to those of the impact areas.

Sample preparation of soils, vegetation, and biotic samples will be similar to that discussed above for ICP-MS analysis of other YPG samples. Care should be taken to account for Be in the samples extracted from rocks and minerals, *i.e*, background Be. Analysis of samples outside the areas affected by DU and/or DU and Be testing should be included in the routine ERM sampling in order to establish local background Be concentrations. Statistically comparing samples from the impact areas to background samples will indicate the origin of detected Be.

Quality Control/Quality Assurance (QA/QC)

Formal quality assurance/quality control (QA/QC) procedures should be developed in order to ensure that samples are collected and prepared in a consistent manner, sample handling is tracked, and the results from analytical laboratories are the best possible (NRC, 1979). Submitting blanks, multiple samples, and samples with known amounts of DU (*i.e.*, certified standards) are recommended. If submitted to analytical laboratories as regular samples, the analytical results of blanks, multiple splits, and certified standards will be checks on the quality of the methods used by the laboratories. QA/QC considerations, *e.g.,* chain of custody for all samples, also apply to sample collection, storage, and treatment before analysis. Formal procedures must be used to ensure consistent collection of samples in the field and sample preparation before

analysis in the laboratory. There should be a set of written procedures for all environmental sampling and analyses, and the procedures should show control of samples from the time of sample collection through the time the sample is sent to the laboratory and data are returned from the laboratory. AEHA Form 235 (Chain of Custody) was successfully used for sample tracking during the study conducted by Los Alamos and could be used as is for the environmental sampling. NRC Guide 4.15 (NRC, 1979) provides detailed discussions about QA/QC related to sample handling and chemical analysis.

Tracking the status of samples via personal computer-based databases would provide a relatively simple means of recording sample information. Sample status information can be easily added to a database, and data from the analytical laboratory can be incorporated after data are received. Information stored on a database would facilitate reporting of DU concentrations as required and would centralize the available data on DU in the YPG environment. Log books for recording field observations, lab notes, and deviations from written procedures should also accompany any electronic database. Log books would be the primary record for any sample, treatment, or analysis, and information in the log books would be transcribed to the electronic database. Log books would be a permanent record for all ERM activities as would the electronic database and backups. Finally, an annual date for publishing an account of the preceding year's data and interpretations should be established. Yearly publications of ERM sampling results would provide a record that could be referenced and would be a readily available resource on the YPG environment.

REFERENCES

Brina, R.; Miller, A. G. Direct Detection of Trace Levels of Uranium by Laser-Induced Kinetic Phosphorimetry. *Analytical Chemistry*. 641413-1418; 1992.

Driecer, M., Hakonson, T. E., White, G. C., Whicker, F. W. Rainsplash as a Mechanism for Soil Contamination of Plant Surfaces. *Health Physics*. 46:177-187; 1984.

Ebinger, M. H., Essington, E. H., Gladney, E. S., Newman, B. D., and Reynolds, C. L. *Long-Term Fate of Depleted Uranium at Aberdeen and Yuma Proving Grounds, Final Report: Phase I: Geochemical Transport and Modeling*. Los Alamos National Laboratory Report LA-11790-MS, 1990.

Gladney, E. S., Hensley, W. K., Minor, M. M. Comparison of Three Techniques for the Measurement of Depleted Uranium in Soils. *Analytical Chemistry*. 50652-653; 1978.

Gladney, E. S., Owens, J. W., Starner, J. W. Determination of Uranium in Natural Waters by Neutron Activation Analysis. *Analytical chemistry*. 48973-975; 1976.

Gladney, E. S., Owens, J. W., Starner, J. W. Determination of Uranium in NBS Biological Standard Reference Materials by Delayed Neutron Assay. *Journ. Radioanalytical Chemistry*. 59249-251; 1980.

Gonzales, E. R., Gladney, E. S., Boyd, H. A., McInroy, J. F., Muller, M., Palmer, P. D. Determination of U in Human Tissues by Delayed Neutron Activation Analysis. *Health Physics*. 55927-932; 1988.

Ibrahim, S. A., Whicker, F. W. Comparative Uptake of U and Th by Native Plants at a U Production Site. *Health Physics*. 54:413- 419; 1988.

NRC. Quality Assurance for Radiological Monitoring Programs (Normal Operations)--Effluent Streams and the Environment. Regulatory Guide 4.15, February, 1979.

Price, K. R. The Analysis of Soil and Vegetation Samples Collected from the Yuma Proving Ground. Pacific Northwest Laboratory report TD 2761, 1991.

U. S. Army. *Environmental Radiological Monitoring Plan: Depleted Uranium Munitions*. U. S. Army, Yuma Proving Ground, 1990.

Whicker, F. Ward; Ibrahim, Shawki A. *Radioecological Investigations of Uranium Mill Tailings Systems*. Report DOE\EV\10305-18, 1987.

APPENDIX A

Number of Samples for ERM

List of sample numbers and locations for YPG ERM plan.

	Active	Inactive
Kofa Soil		
GP 4	24	4
GP 17A	24	4
GP17A , with Catchbox	10	4
GP 20	24	4
Total	72 (58 with Catch Box)	12
Sediments		
GP 4 (+ 4 south of GP4)	10	5
GP17A (with 5 south of GP 17A)	10	5
GP 20 (with 6 north of GP 20)	10	5
Totals	30+15	15+15
DU-Contaminted Dust		
GP 4	3-5	
GP 17A	3-5	
GP 20	3-5	
Totals	9 to 15	
Vegetation		
GP 4	24	4
GP 17A	24	4
GP 20	24	4
Totals	72	12

Biological Samples (Mammals, Lizards)

GP 4, GP17A, and GP20 (per site)	10-20 at 1st impact	5
	5-10 at 2nd transect	
	5 from background	5
Totals (per site)	20 to 35	10

Hard Impact and Soft Impact Areas

	Hard Impact	Soft Impact
Soil	10	8
Sediment	7	1
Vegetation	10	8
Air Sampling	3-5	3-5
Biological	5-10	5-10
Totals	35 to 42	25 to 32

says that elements in addition to uranium may be used to suggest the origin of uranium in geochemical samples. If other element concentrations are high, the uranium may be derived from an orebody rather than merely being *leached from rocks*.

The geochemistry of ground water associated with uranium deposits is complex. The following is a discussion of that part of the geochemical model which is most useful for the interpretation of reconnaissance sampling like this survey.

Uranium, itself, is generally considered the best trace element indicator of uranium mineralization. In the ore roll model the axis of maximum uranium concentration in ground water is parallel to, and on the oxidized side of, a redox front. Thus, one should not lease and drill the axis of maximum uranium concentration, which is the zone of uranium mobilization, but an adjacent area down the hydrologic gradient from this trend where uranium is precipitated. Uranium concentrations in groundwater from reduced ore deposits are in the range of background values.

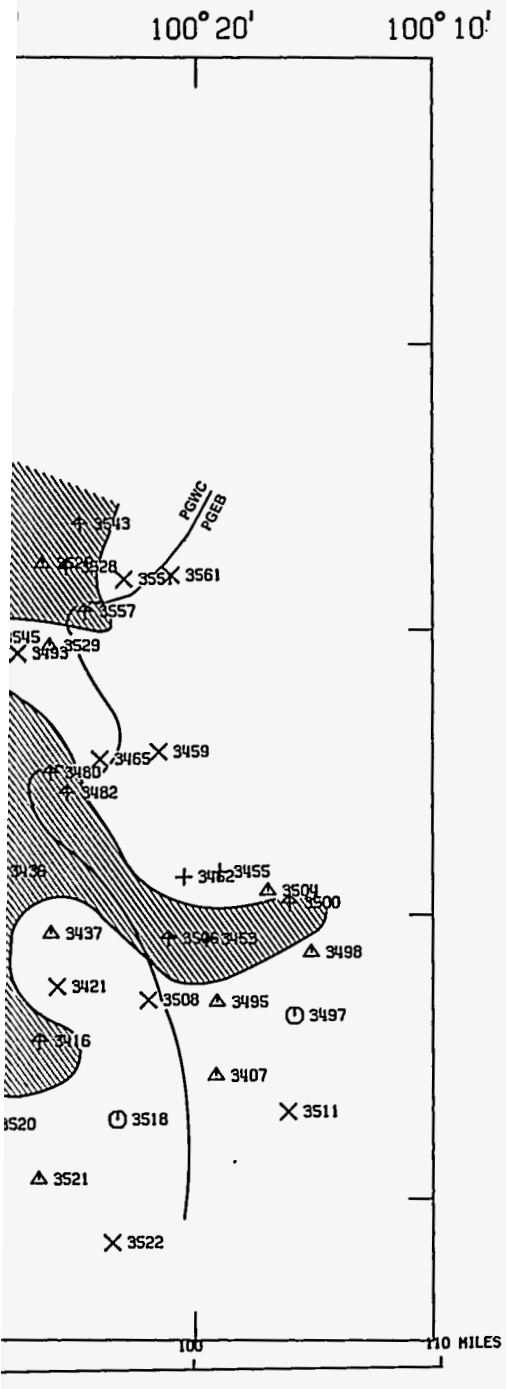
A consideration of other elements associated with ore roll deposits improves the accuracy and confidence in locating favorable trends. In geochemical cell theory, sulfate concentration and conductivity increase toward the redox front and then decreases down the hydrologic gradient primarily owing to precipitation of iron sulfide and then calcium carbonate. In the author's experience, molybdenum concentrations are normally associated with sandstone deposits but haloes in the groundwater may be to the side of, or farther down dip than, the center of the geochemical cell. Arsenic is most valuable for its regional halo around areas of mineralization. High values of bicarbonate and selenium may contribute to identifying the zone of uranium mobilization.

CLUSTER PLOT OF WELL WATER

An attempt was made to sample water wells at a spacing of approximately 3 mi in areas of about 200 mi^2 for each of the 5 major stratigraphic units of this study. The most complete pattern was obtained in the area of the Ogallala Formation.

Clusters selected from weighted and unweighted dendrograms are plotted in Figures C-19 and C-20. The weighted plot, which appears to associate the well water samples in a more meaningful manner for assessing uranium potential, is chosen for this discussion. Weights are assigned to 11 variables of which uranium is the most important. The weight of naturally-associated variables like sulfate and conductivity or bicarbonate and total alkalinity may be considered added together for many samples. For example, values for conductivity and bicarbonate, which are normalized by dividing by the standard deviation, are similar in many samples.

Figure 4 is a plot of an 8-cluster grouping of variables. Cluster 5, with a mean of 73 ppb uranium, is located in 3 groups of 2 sample sites each and individual site. Areas where other clusters dominate are also designated



CLUSTER CRITERION -- MINIMUM (WITHIN-CLUSTER) STANDARD DEVIATION

NORMALIZATION -- EACH VARIABLE IS DIVIDED BY STANDARD DEVIATION AND MULTIPLIED BY AN INPUT WEIGHT

WEIGHT	VARIABLE
0.334	L- U
0.111	L-SO
0.037	L-AS
0.037	L- B
0.037	L-BA
0.037	L-MO
0.037	L- V
0.111	PH
0.111	LCYL
0.074	BC
0.074	T-AK

		MEAN U	NO. SPLS.
⏲	CLUSTER 1	0.9	3
△	CLUSTER 2	4.5	17
+	CLUSTER ③	9.7	43
×	CLUSTER ④	29.	33
◇	CLUSTER ⑤	73.	7
⏄	CLUSTER ⑥	15.	18
X	CLUSTER 7	< 0.2	1
Z	CLUSTER 8	< 0.2	1

PROSPECTS REPORTED BY HAYES (1956)

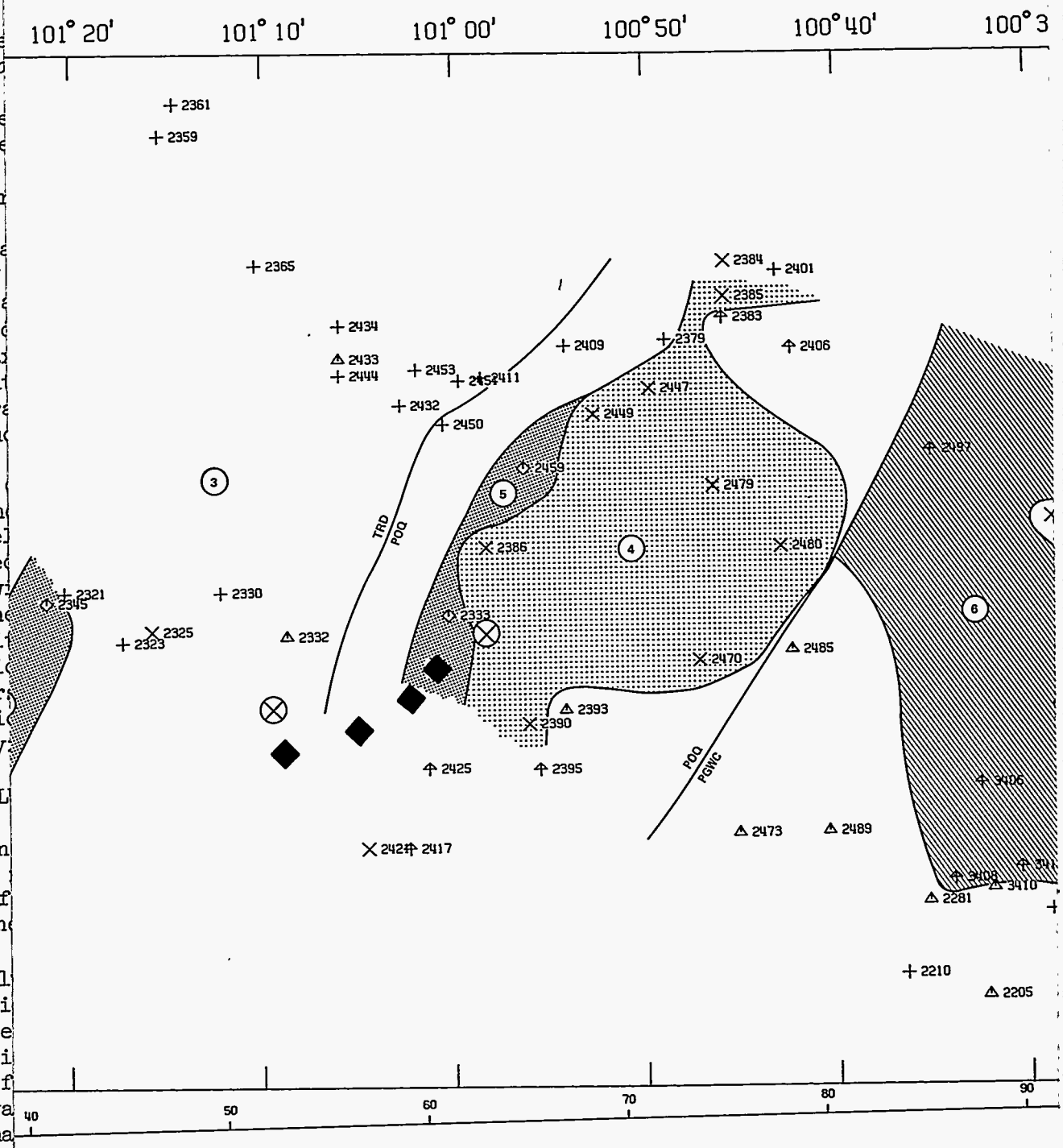
⊗ DEPOSIT/PROSPECT

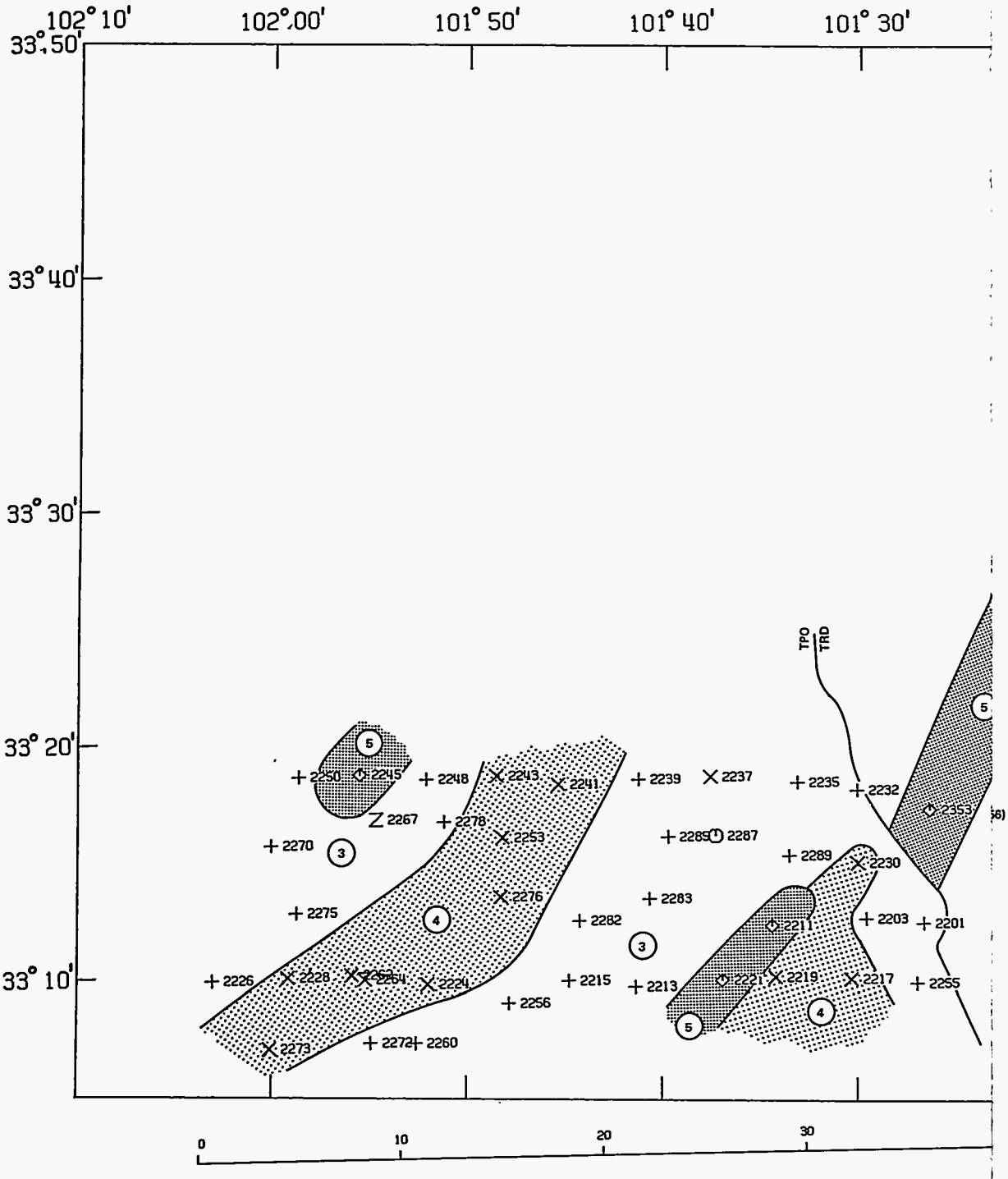
◆ EXPLORATORY DRILLING

WELL DATA
NORTHWEST TEXAS
PILOT SURVEY
09-24-76

Figure 4

CLUSTER PLOT OF WELL WATER WITH WEIGHTED VARIABLES


101° 20'
101° 10'
101° 00'
100° 50'
100° 40'
100° 3
2361
2359
2365
2434
2433
2444
2453
2411
2409
2384
2401
2385
2383
2379
2406
2432
2450
2447
2449
2459
2479
2497
3
5
4
6
TRD
POQ
2386
2480
2321
2345
2330
2325
2323
2332
2333
2470
2485
2393
2390
2425
2395
POQ
PGWG
2473
2489
2406
2417
2281
2210
2205
40
50
60
70
80
90


102° 10'
102° 00'
101° 50'
101° 40'
101° 30'
33° 50'
33° 40'
33° 30'
33° 20'
33° 10'
TPO
TRD
5
3
4
2250
2245
2248
2243
2241
2239
2237
2235
2232
2353
2267
2278
2253
2270
2289
2287
2289
2230
2276
2283
2275
2282
2211
2203
2201
2226
2228
2224
2215
2213
2221
2219
2217
2255
2256
2273
2272
2260