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# *Baseline Radionuclide Concentrations in Soils and Vegetation Around the Proposed Weapons Engineering Tritium Facility and the Weapons Subsystems Laboratory at TA-16*

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# ASELINE RADIONUCLIDE CONCENTRATIONS IN SOILS AND VEGETATION AROUND THE PROPOSED WEAPONS ENGINEERING TRITIUM FACILITY AND THE WEAPONS SUBSYSTEMS LABORATORY AT TA-16

**by**

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## ABSTRACT

**A preoperational environmental survey is required by the Department of Energy (DOE) for all federally funded research facilities that have the potential to cause adverse impacts on the environment. Therefore, in accordance with DOE Order 5400.1, an environmental survey was conducted over the proposed sites of the Weapons Engineering Tritium Facility (WETF) and the Weapons Subsystems Laboratory (WSL) at Los Alamos National Laboratory (LANL) at TA-16. Baseline concentrations of tritium ($^{3H}$), plutonium ($^{238Pu}$ and $^{239Pu}$) and total uranium were measured in soils, vegetation (pine needles and oak leaves) and ground litter. Tritium was also measured from air samples, while cesium ($^{137Cs}$) was measured in soils. The mean concentration of airborne tritiated water during 1987 was 3.9 pCi/m3· Although the mean annual concentration of $^{3H}$ in soil moisture at the 0-5 cm (2 in) soil depth was measured at 0.6 pCi/mL, a better background level, based on long-term regional data, was considered to be 2.6 pCi/mL. Mean values for $^{137Cs}$, $^{238Pu}$, $^{239Pu}$, and total uranium in soils collected from the 0-5 cm depth were 1.08 pCi/g, 0.0014 pCi/g, 0.0325 pCi/g, and 4.01 mγ/g, respectively. Ponderosa pine (P*inus ponderosa)* needles contained higher values of $^{238Pu}$, $^{239Pu}$, and total uranium than did leaves collected from gambel's oak (Q*uercus gambelii)*. In contrast, leaves collected from gambel's oak contained higher levels of $^{137Cs}$ than what pine needles did.**

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## I. INTRODUCTION

In 1981, Los Alamos National Laboratory (LANL), a Department of Energy (DOE) funded research facility, proposed the construction of two new facilities, the Weapons Engineering Tritium Facility (WETF) and the Weapons Subsystems Laboratory (WSL) (Browne 1981, Merryman 1986, Merryman and Nolen 1987). Prior to new construction, however, a preoperational environmental survey is required by DOE for new facilities or operations that will process, release, or dispose of radioactive materials (DOE 1991).

In general, a preoperational environmental survey will establish a site specific data base useful for interpreting environmental impacts from facility operations. Specifically, these studies shall serve to characterize, (1) the physical, chemical and biological conditions of potentially affected media, (2) establish background (baseline) levels of radionuclides

and chemicals to be processed, released, or disposed of, (3) characterize pertinent environmental and ecological parameters, and (4) identify potential pathways for human exposure or environmental impact, as a basis for determining the nature and extent of future environmental protection and monitoring programs. Thus, from subsequent routine monitoring programs, the evaluation of potential radiation exposures to man, trends, or rapid-changes of radionuclide concentrations in the environment, adequacy and effectiveness of containment and effluent control systems, and compliance with applicable requirements and regulations can be determined (Ahlquist and Wenzel 1984). This report describes baseline radiological concentrations in soil and vegetation (as well as other environmental conditions) located around these proposed facilities at TA-16.

## II. POTENTIAL IMPACTS

T***he Weapons Engineering Tritium Facility.*** Based on the maximum amount of $^{3}H$ on-site (250 g), the total amount of $^{3}H$ that could potentially be released from routine operations from the WETF was conservatively estimated at 400 Ci/year (Dewart 1987). Using a standard Gaussian plume model, the maximum on-site 50 year committed effective dose equivalent (CEDE) from an annual release of 400 Ci of $^{3}H$ was estimated to be 0.094 mrem, and the maximum off-site CEDE was estimated to be 0.084 mrem (Table 1). Consequently, the estimated off-site CEDE (to individual members of the public) resulting from activities at the WETF is lower than the 10 mrem/y limit established by the EPA for the air pathway (EPA 1989) and the 100 mrem/y for all pathways set by DOE (DOE 1990). Air inhalation and the direct absorption of tritium vapor (HTO) through the skin (cloud submersion) are the two major pathways of concern for tritium exposure.

T***he Weapons Subsystems Laboratory.*** Plutonium and uranium are not expected to be released from routine operations at the WSL. Tritium emissions, on the other hand, are expected to occur, albeit in small quantities, at the WSL. The annual routine release of $^{3}H$ from the WSL was estimated to be less than 120 Ci per year. Using a standard Gaussian plume model, the estimated CEDE from an annual release of 120 Ci of $^{3}H$ to the maximally exposed individual on-site and off-site was 0.072 and 0.025 mrem, respectively (Table 1) (Dewart 1985). Again, based on DOE and EPA radiation limits for the air pathway, estimated on-site and off-site CEDE is far less than 10 mrem/y (EPA 1989), and the 100 mrem/y limit for all pathways set by DOE (DOE 1990).

**Table 1. Fifty-year committed effective dose equivalent of expected releases of $^{3}H$ from the Weapons Engineering Tritium Facility (WETF) and the Weapons Subsystems Laboratory (WSL).1**

| | Maximum on-site (mrem) | Maximum off-site (mrem) |
|---|---|---|
| WETF2 | 0.094 | 0.084 |
| WSL3 | 0.072 | 0.025 |
| Total | 0.166 | 0.109 |

1Data from Dewart (1985, 1987); based on inhalation and skin absorption pathways.
2Routine releases were assumed to be 400 Ci/y.
3Routine releases were assumed to be 120 Ci/y.

C***umulative Impacts From Both Facilities.*** Total estimated CEDE from routine tritium releases by both facilities to off-site areas was only 0.1 mrem (Table 1). These data are 1% of the 10 mrem, upper limit, via the air pathway, from releases by DOE facilities (EPA 1989), and 0.1% of the 100 mrem limit for all pathways set by DOE (DOE 1990). Again, the major pathways of primary concern from a release of $^{3}H$ from these facilities are from the inhalation of air and the absorption of tritiated water vapor on the skin. Other pathways such as the ingestion of $^{3}H$ from contaminated water, locally grown produce, milk and meat are highly unlikely for the following reasons: (1) the possibility of $^{3}H$ contamination in water is extremely unlikely, as there are no hydrological connections between the alluvium or perched water to the main aquifer (the main aquifer ranges from 600 ft to 1200 ft below the surface, and is recharged from the Jemez Mountains west of the site) (ESG 1988), (2) doses from the ingestion of tritium would be about the same as doses from inhalation if 25% of the produce ingested by people living in the town site were to be locally grown (the main townsite of Los Alamos is 5,000 m away) (Tom Buhl, HSE-8, LANL, personal communication), and (3) dairies and stockyards do not exist in the immediate vicinity of LANL (DOE 1979). For these reasons, the level of $^{3}H$ in these foodstuffs would be very low.

## III. MATERIALS AND METHODS

Mesa soils at TA-16 are primarily Tocal and Frijoles very fine sandy loams (Nyhan et al. 1978). The Frijoles series consists of deep (45-150 cm to bedrock), well drained soils on nearly level to moderately sloping mesa tops. The Tocal series includes very shallow to shallow (approximately 36 cm to bedrock) well drained soils on gently to moderately sloping mesa tops.

TA-16 is a partially wooded area dominated by ponderosa pine, gambel's oak, mountain mahogany and mountain muhly (Raymer 1993). Local fauna consists primarily of small seed eating birds, field rodents, and large browsers such as mule deer and rocky mountain elk. Threatened, endangered and sensitive species, such as the northern

goshawk, spotted bat, Jemez Mountains salamander, meadow jumping mouse and sothwestern willow flycatcher have a moderate to high potential for occurring within TA-16 (Raymer 1993).

The area is classified as a semiarid temperate mountain climate with annual precipitation of nearly 45 cm (18 in) (DOE 1979). Most of the precipitation (75%) falls between May and October. Temperatures throughout the year are moderate. In summer, for example, daytime temperatures are generally below 32_X, while nightime temperatures vary from 12 to 15_X. In winter, temperatures range from -11 to 10_X in the daytime to -9 to 4_X in the night time.

Wind speed and direction also show strong diurnal and spatial variations. Based on data collected from the closest meteorological tower (TA-59 is located approximately 4,400 m away from TA-16), winds were generally light with an annual average wind speed of 2.9 m/s. Wind directions were SE to SSE during the day, and NW and WNW during the night. Cumulatively, winds come from the NW and from SW directions.

Based on the type and magnitude of the anticipated effluents (mostly tritium), meteorological information, and pathway analysis, the maximum ground-level radionuclide air concentrations in the environment from routine releases would be about 350 m northeast of the site (Buhl and Dewart 1981). Thus, most sampling locations (numbers 3 through 9) were located counterclockwise along a 160_ arc east and north of the site at distances ranging from 300-600 m (Figure 1) (Ahlquist and Wenzel 1984). Sample location #1 (main sample site) was placed 75 m east of the proposed building site, and locations #2 and #10 were placed 300-600 m south and west of the proposed site, respectively.

In addition to these sampling sites, an air monitoring station for tritium was established at TA-16. The sampler, part of LANL's routine on-site air monitoring newwork (AIRNET), pumps air through a tube of desiccant which absorbs tritiated moisture (HTO) from the air (Buhl and Scoggins 1987). At the end of each month, the desicant is collected and a 5 mL aliquot of water distilled from it is counted in a liquid scintillation counter. Tritium concentrations were reported as $^{3}H$ per unit volume of air.

Soil sampling programs are important in a facility's preoperational monitoring program, serving to establish accurate baseline concentrations of radionuclides, and are necessary later for the evaluation of environmental contamination resulting from

operational releases (Nyhan et al. 1981). Therefore, in June of 1985, soil samples were collected from each of the ten sampling stations for $^{137}Cs$, $^{238}Pu$, $^{239}Pu$, and total uranium. At each sample site, three soil samples approximating 500 cm3 each were collected in the following manner: a 27 x 3 cm ring was used to sample the 0-1 cm depth (resuspension layer), a 14 x 5 cm ring was used next to collect soil at the 1-5 cm depth, and a 25 x 5 cm PVC tube was used to collect soil at the 5-20 cm soil level (Wenzel et al. 1985). Before soil samples were collected the litter layer was carefully removed. Additionally, at sample location site #1 soil samples were taken at the A (1-20 cm), B (20-80 cm) and at the C (80-100 cm) soil horizon depths. All soil samples were placed in double plastic bags, labeled, packed in ice, and submitted to the Health and Environmental Chemistry Group (HSE-9) for chemical analysis. Analysis consisted of gamma counting to determine $^{137}Cs$, radiochemical seperation and alpha spectoscopy to determine Pu isotopes, and delayed neutron activation analysis that was used to determine total uranium.

Soil samples for $^{3}H$ analysis were intially collected in June of 1985. However, results from the first sampling period were inconclusive. Therefore, soil samples were collected again in last October of 1987. Sampling included placing soil from the 0-5 cm depth into one quart screw-cap glass jars; the jars were then placed into plastic Ziploc bags to protect against moisture loss. The samples were placed into ice chests for transport to the laboratory and kept frozen until analysis. Tritium concentrations were determined by distilling a soil sample until 5 mL of water was collected. The water sample was mixed with a liquid scintillation cocktail to a total volume of 15 mL, which was then measured on a liquid scintillation counter. Tritium was reported as activity per unit volume of soil moisture.

Ground litter was collected from sample locations #1 (four total samples), #7 (two total samples), #8 and #10 (one total litter sample from each). At each sample location, all ground litter, which consisted of a mixture of pine, oak, forb, and grass debris, was collected within a 0.25 x 0.25 m quadrant. Vegetation samples (pine needle and oak leaves) were collected from four permanently located transects (numbers 126, 15, 209 and 71) at sample location #1. Ponderosa pine needles were collected at two transects (#126 and #15), while gambel oak leaves were collected at the other two transects (#209 and #71). Each sample consisted of approximately 1200 to 1400 grams of vegetation. All sample materials (litter, needles, and leaves) were bagged individually into plastic Ziploc bags, marked for identification, and immediately placed in an ice chest for transport to the laboratory. At the laboratory, samples were ashed at 500_X for approximately 120 hours. Aliquots of ashed samples were submitted to the Health and Environmental Chemistry Group (HSE-9) for analysis. The same analytical procedures that were described for the

soils were performed on the plant ash materials.

## IV. RESULTS AND DISCUSSION

A***ir.*** Concentrations of $^{3}H$ at the TA-16 air sampling station during 1987 averaged 3.9 pCi/m3 (Table 2). The mean of regional background stations in 1987 was 4.1 pCi/ m3 (ESG 1988). Levels of $^{3}H$ at TA-16 are within regional concentrations; and thus are considered to be a reliable baseline value.

**Table 2. Mean concentrations (_σtd dev) of tritium in air during 1987.**

| | | |
|---|---|---|
| Mean (TA-16)1 | 3.9 (_11.5) | |
| Mean (on-site)2 | | 21.7 (_51.5) |
| Mean (off-site)3 | | 4.1 (_17.0) |

1Data from Environmental Surveillance Group (1988).
2Sampling stations are within LANL boundaries.
3Sampling stations are outside LANL boundaries.

S***oils.*** Tritium concentrations in soil collected from the 0-5 cm level at TA-16 ranged from a low of 0.1 to a high of 1.1 pCi/mL (Table 3). Overall, mean soil concentration of $^{3}H$ was 0.6 pCi/mL. These data were generally below those values reported for other on-site soils (1.9 pCi/mL) and from off-site soils (3.6 pCi/mL) collected in 1987 (ESG 1988). Lower soil $^{3}H$ concentrations observed at TA-16 in October of 1987 as compared to on-site and regional data collected in April and May of 1987 may have been due to the differences in collection times. For example, the month of October experienced warmer and dryer conditions than the months of April and May, when the temperatures were lower and rainfall was recorded as being twice the norm. Thus, increased evaporational losses of $^{3}H$ from soils collected in the month of October as compared to the wetter months of April and May, may have been responsible for the lower $^{3}H$ concentrations recorded. Therefore, a more reasonable baseline $^{3}H$ value to apply to TA-16 would be 2.6 pCi/mL (Purtymun et al. 1987). This is the mean concentration of $^{3}H$ in soils from regional background sites over the years 1978 through 1986.

Soil concentrations of $^{137}Cs$, $^{238}Pu$, and $^{239}Pu$ were higher in the resuspension layer (0-1 cm) than in the 1-5 and 5-20 cm soil layer depths (Table 4). Concentrations of these radionuclides in the top 5 cm of soil, however, were not significantly different from concentrations in soils collected at off-site regional stations (ESG 1986, Purtymun et al.

**Table 3. Mean concentrations of tritium in soils collected at the 0-5 cm depth from TA-16 on October 12, 1987.**

| Sample location | pCi/mL (_σtd dev) |
|---|---|
| #1-126 | 0.5 (0.4) |
| #1-15 | 0.5 (0.3) |
| #1-209 | 0.9 (0.1) |
| #1-71 | 0.3 (0.2) |
| #2 | 0.4 (0.3) |
| #3 | 0.7 (0.4) |
| #4 | 0.8 (0.3) |
| #5 | 0.1 (0.2) |
| #6 | 0.5 (0.4) |
| #7 | 0.9 (0.2) |
| #8 | 1.1 (0.2) |
| #9 | 0.6 (0.2) |
| #10 | 0.7 (0.1) |
| Mean (TA-16) | 0.6 (0.3) |
| Mean (on-site)1 | 1.9 (3.0) |
| Mean (off-site)2 | 3.6 (5.2) |

1Sampling stations are within LANL boundaries; data from ESG (1988).
2Sampling stations are outside LANL boundaries; data from ESG (1988).

1987). This suggests that fallout may be the common source of these radionuclides. Asexpected, the deposition of $^{239}$Pu has been occurring at a higher rate than that of $^{238}$Pu. Uranium levels, on the other hand, were significantly higher in soils collected at TA-16 than in soils collected at regional locations. Uranium's relative immobility in soil (Whicker and Schulz 1982), and its homogeneous distribution between soil layers at this site (Table 4), indicate that uranium was a product of soil formation and not a result of Laboratory activities. Soil uranium concentrations at TA-16, for example, were within worldwide background levels of 3-4 mγ/g (Russell 1966). Thus, all radionuclide and total U levels were considered to be reliable baseline values.

V***egetation.*** Concentrations of radionuclides in litter and vegetation (pine needle and oak leaf) samples are shown in Table 5. In general, radionuclides and total uranium were in much higher concentrations in litter than in vegetation materials. Radionuclides in litter represent deposition that has occurred over many years, whereas radionuclides found on standing vegetation are a result of the current year's deposition. For example, the ratio of litter to vegetation was 35:1 for $^{137}$Cs, 8:1 for $^{238}$Pu, 25:1 for $^{239}$Pu, and 14:1 for total uranium. Also, more $^{238}$Pu and $^{239}$Pu were found on the needles of ponderosa pine trees than on oak leaves, while oak trees appear to have accumulated more $^{137}$Cs than pine needles. Uranium concentrations in litter and in vegetation, on the other hand, are from naturally occuring uranium in soil. Pondersoa pine needles contained more uranium than

did oak tree leaves (Table 5). Uranium levels in plants have been reported to range from 0.1 to 0.01 mγ/g ash (Rickard et al. 1977). Plant materials collected from ponderosa pine and oak contained uranium levels just above this range.

**Table 4. Concentration of radionuclides in soil collected from TA-16 on October 12, 1985.**

| Sample location (soil depth cm) | | | $^{137}Cs$ | $^{238}Pu$ | $^{239}Pu$ | Total Uranium |
|---|---|---|---|---|---|---|
| | | | ----------pCi/dry g---------- | | | mγ/dry g |
| #1-126 | | | | | | |
| 0-1 | 1.66 | 0.0044 | 0.0355 | 3.87 | | |
| | | | 0.281 | 0.0021 | 0.0048 | 0.02 |
| 1-5 | | | 1.60 | 0.0051 | 0.0387 | 4.17 |
| | | | 0.26) | 0.0028 | 0.0058 | 0.30 |
| 5-20 | | | 0.34 | 0.0006 | 0.0112 | 3.94 |
| | | | 0.08 | 0.0014 | 0.0028 | 0.30 |
| #1-15 | | | | | | |
| 0-1 | 2.12 | 0.0010 | 0.0636 | 4.13 | | |
| | | | 0.34 | 0.0018 | 0.0063 | 0.30 |
| 1-5 | | | 0.43 | 0.0007 | 0.0103 | 3.77 |
| | | | 0.10 | 0.0011 | 0.0020 | 0.30 |
| 5-20 | | | 0.00 | 0.0000 | 0.0015 | 3.93 |
| | | | 0.06 | 0.0005 | 0.0011 | 0.30 |
| #1-209 | | | | | | |
| 0-1 | | | 4.68 | 0.0071 | 0.1780 | 4.87 |
| | | | 0.72 | 0.0032 | 0.0129 | 0.30 |
| 1-5 | | | 0.19 | 0.0000 | 0.0244 | 3.98 |
| | | | 0.07 | 0.0005 | 0.0036 | 0.30 |
| 5-20 | | | 0.29 | -0.0006 | 0.0018 | 4.32 |
| | | | 0.10 | 0.0010 | 0.0013 | 0.30 |
| #1-71 | | | | | | |
| 0-1 | | | 1.16 | 0.0026 | 0.0252 | 3.80 |
| | | | 0.22 | 0.0018 | 0.0039 | 0.30 |
| 1-5 | | | 0.70 | 0.0005 | 0.0190 | 4.04 |
| | | | 0.13 | 0.0002 | 0.0040 | 0.30 |
| 5-20 | | | 0.08 | 0.0019 | 0.0006 | 4.14 |
| | | | 0.05 | 0.0021 | 0.0011 | 0.30 |

**Table 4. (Continued)**

| Sample location (soil depth cm) | $^{137}Cs$ | $^{238}Pu$ | $^{239}Pu$ | Total Uranium | |
|---|---|---|---|---|---|
| | | ----------pCi/dry g---------- | | | mγ/dry g |
| #1-horizons | | | | | |
| A (1-20) | | 0.09 | 0.0000 | 0.0670 | 3.98 |
| | | 0.08 | 0.0005 | 0.0076 | 0.30 |
| B (20-80) | | 0.03 | -0.0004 | 0.0013 | 4.18 |
| | | 0.07 | 0.0013 | 0.0013 | 0.30 |
| C (80-100) | | 0.07 | -0.0011 | 0.0005 | 3.41 |
| | | 0.07 | 0.0013 | 0.0012 | 0.30 |
| #2 | | | | | |
| 0-1 | | 0.50 | 0.0000 | 0.0815 | 4.45 |
| | | 0.15 | 0.0005 | 0.0062 | 0.30 |
| 1-5 | | 0.17 | -0.0006 | -0.0006 | 4.24 |
| | | 0.08 | 0.0010 | 0.0010 | 0.30 |
| 5-20 | | 0.05 | 0.0027 | 0.0240 | 3.97 |
| | | 0.05 | 0.0012 | 0.0050 | 0.30 |
| #3 | | | | | |
| 0-1 | | 0.57 | 0.0000 | 0.0212 | 4.19 |
| | | 0.11 | 0.0005 | 0.0037 | 0.30 |
| 1-5 | | 0.08 | -0.0013 | 0.0026 | 4.01 |
| | | 0.07 | 0.0013 | 0.0016 | 0.30 |
| 5-20 | | 0.25 | -0.0022 | -0.0011 | 4.09 |
| | | 0.12 | 0.0011 | 0.0008 | 0.30 |
| #4 | | | | | |
| 0-1 | | 0.96 | 0.0009 | 0.0169 | 4.28 |
| | | 0.17 | 0.0011 | 0.0030 | 0.30 |
| 1-5 | | na | na | na | na |
| 5-20 | | na | na | na | na |
| #5 | | | | | |
| 0-1 | | 1.00 | -0.0010 | 0.0319 | 4.14 |
| | | 0.18 | 0.0020 | 0.0044 | 0.30 |
| 1-5 | | 0.02 | 0.0000 | 0.0038 | 3.99 |
| | | 0.06 | 0.0005 | 0.0020 | 0.30 |
| 5-20 | | 0.28 | -0.0012 | 0.0075 | 4.06 |
| | | 0.09 | 0.0009 | 0.0024 | 0.30 |
| #6 | | | | | |
| 0-1 | | 1.92 | 0.0023 | 0.0412 | 4.18 |
| | | 0.32 | 0.0015 | 0.0047 | 0.30 |

**Table 4. (Continued)**

| Sample location (soil depth cm) | $^{137}Cs$ | $^{238}Pu$ | $^{239}Pu$ | Total Uranium | |
|---|---|---|---|---|---|
| | | pCi/dry g | | | mγ/dry g |
| 1-5 | 0.81 | 0.0017 | 0.0173 | 4.29 | |
| | | | 0.15 | 0.0024 | 0.0034 | 0.30 |
| 5-20 | | | 0.07 | 0.0010 | 0.0015 | 3.86 |
| | | | 0.06 | 0.0016 | 0.0011 | 0.30 |
| #7 | | | | | | |
| 0-1 | | | 1.31 | 0.0002 | 0.0292 | 3.99 |
| | | | 0.21 | 0.0008 | 0.0028 | 0.30 |
| 1-5 | | | 0.14 | 0.0011 | 0.0150 | 3.87 |
| | | | 0.06 | 0.0009 | 0.0022 | 0.30 |
| 5-20 | | | 0.03 | -0.0007 | 0.0003 | 4.01 |
| | | | 0.08 | 0.0005 | 0.0006 | 0.30 |
| #8 | | | | | | |
| 0-1 | | | 1.77 | 0.0035 | 0.0308 | 4.24 |
| | | | 0.28 | 0.0013 | 0.0036 | 0.30 |
| 1-5 | | | 0.01 | -0.0013 | 0.0047 | 3.77 |
| | | | 0.06 | 0.0010 | 0.0022 | 0.30 |
| 5-20 | | | -0.01 | 0.0008 | 0.0179 | 3.74 |
| | | | 0.06 | 0.0008 | 0.0029 | 0.30 |
| #9 | | | | | | |
| 0-1 | | | 2.06 | 0.0028 | 0.0467 | 3.25 |
| | | | 0.32 | 0.0016 | 0.0051 | 0.25 |
| 1-5 | | | 0.33 | 0.0000 | 0.0044 | 3.14 |
| | | | 0.11 | 0.0005 | 0.0016 | 0.25 |
| 5-20 | | | 0.05 | 0.0003 | 0.0000 | 3.15 |
| | | | 0.06 | 0.0006 | 0.0005 | 0.25 |
| #10 | | | | | | |
| 0-1 | | | 2.64 | 0.0047 | 0.0628 | 3.93 |
| | | | 0.41 | 0.0024 | 0.0064 | 0.30 |
| 1-5 | | | 0.24 | -0.0006 | 0.0081 | 3.70 |
| | | | 0.08 | 0.0014 | 0.0024 | 0.30 |
| 5-20 | | | -0.01 | 0.0006 | 0.0025 | 4.01 |
| | | | 0.06 | 0.0011 | 0.0016 | 0.30 |
| Mean of 0-1 cm depth | | | 1.72 | 0.0022 | 0.0511 | 4.10 |
| | | | 1.092 | 0.0000 | 0.0018 | 0.14 |
| Mean of 1-5 cm depth | | | 0.39 | 0.0004 | 0.0123 | 3.91 |
| | | | 0.21 | 0.0000 | 0.0001 | 0.09 |

**Table 4. (Continued)**

| Sample location (soil depth cm) | $^{137}Cs$ | $^{238}Pu$ | $^{239}Pu$ | Total Uranium | mγ/dry g |
|---|---|---|---|---|---|
| | | ----------pCi/dry g---------- | | | |
| Mean of 5-20 cm depth | 0.12 | 0.0003 | 0.0056 | 3.94 | |
| | | 0.01 | 0.0000 | 0.0000 | 0.09 |
| Mean of 0-5 cm depth | 1.08 | 0.0014 | 0.0325 | 4.01 | |
| | | 1.07 | 0.0022 | 0.0368 | 0.35 |
| 1985 mean of on-site 0-5 cm depth[3] | 0.47 | 1.1900 | 0.0570 | 6.30 | |
| | | 0.30 | 3.7500 | 0.0820 | 7.50) |
| 1985 mean of off-site 0-5 cm depth | 0.45 | 0.0010 | 0.0100 | 2.60 | |
| | | 0.30 | 0.0010 | 0.0090 | 0.70 |

[1] Analytical uncertainty.
[2] Std dev.
[3] On-site and regional data from ESG (1986).

**Table 5. Concentrations of radionuclides in vegetation and litter collected at TA-16 in June of 1985.**

| Plant Material (Sample #) | $^{137}Cs$ | $^{238}Pu$ | $^{239}Pu$ | Total U | |
|---|---|---|---|---|---|
| | | ----------pCi/g ash---------- | | | mγ/g ash |
| **VEGETATION** | | | | | |
| **P**ine needles | | | | | |
| (1-126) | -0.47 | 0.0029 | 0.0088 | 0.62 | |
| | | 0.621 | 0.0020 | 0.0033 | 0.06 |
| 1-15 | | 0.40 | 0.0013 | 0.0056 | 0.38 |
| | | 0.52 | 0.0023 | 0.0024 | 0.04 |
| *Mean* | | 0.03 | 0.0021 | 0.0072 | 0.47 |
| Oak leaves | | | | | |
| (1-209) | 0.49 | 0.0006 | 0.0029 | 0.18 | |
| | | 0.36 | 0.0017 | 0.0019 | 0.02 |
| (1-71) | | 0.75 | 0.0004 | 0.0058 | 0.12 |
| | | 0.37 | 0.0007 | 0.0018 | 0.01 |
| M*ean* | | 0.62 | 0.0005 | 0.0044 | 0.15 |
| T*otal mean* | 0.30 | 0.0013 | 0.0058 | 0.33 | |
| (*std dev)* | | 0.53 | 0.0011 | 0.0024 | 0.23 |
| L**ITTER2** | | | | | |
| **(**1-126) | 2.35 | 0.0034 | 0.0519 | 3.06 | |
| | | 1.26 | 0.0025 | 0.0082 | 0.30 |
| (1-15) | | 7.91 | 0.0077 | 0.0947 | 4.32 |
| | | 1.46 | 0.0022 | 0.0071 | 0.40 |
| (1-209) | | 15.30 | 0.0345 | 0.2390 | 5.67 |
| | | 2.49 | 0.0037 | 0.0122 | 0.60 |
| (1-71) | | 3.72 | 0.0029 | 0.0595 | 3.94 |
| | | 0.74 | 0.0013 | 0.0051 | 0.40 |
| (7a) | | 16.60 | 0.0044 | 0.1780 | 4.66 |
| | | 2.66 | 0.0026 | 0.0135 | 0.50 |
| (7b) | | 19.20 | 0.0104 | 0.2260 | 4.67 |
| | | 3.20 | 0.0030 | 0.0136 | 0.50 |
| (8) | | 9.62 | 0.0120 | 0.2170 | 5.46 |
| | | 1.55 | 0.0029 | 0.0141 | 0.60 |
| (10) | | 5.31 | 0.0041 | 0.0852 | 4.41 |
| | | 0.87 | 0.0012 | 0.0052 | 0.40 |

**Table 5. (Continued)**

| Plant Material (Sample #) | $^{137}$Cs | $^{238}$Pu | $^{239}$Pu | Total U | |
|---|---|---|---|---|---|
| | ----------pCi/g ash---------- | | | | mγ/g ash |
| *Total mean* | 10.00 | 0.0099 | 0.1439 | 4.52 | |
| (*std dev)* | | 6.33 | 0.0105 | 0.0791 | 0.83 |

[1] Analytical uncertainty.
[2] Litter is a mixture of pine, oak, forb, and grass debris collected from a ponderosa pine dominated plant community.

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