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NATURAL BACKGROUND RADIATION AND ^{137}Cs INVENTORIES IN SOUTHERN NEVADA - PRELIMINARY REPORT ON FALLOUT

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ABSTRACT

External radiation measurements and soil sampling were performed at 28 sites in southern Nevada as part of an extensive radiological survey to determine residual levels of fission products and transuranic nuclides in Utah and Nevada as a result of nuclear weapons tests at the Nevada Test Site (NTS) during 1951-58. The natural background exposure rate was found to vary by about a factor of two. The ^{137}Cs inventories tended to be lower than expected indicating the effects of wind erosion. Cobalt-60 and ^{241}Am were detected at several sites which were reported to be hotspots in post-shot radiological surveys. Planned isotopic analysis of plutonium in the soil samples should help to determine the NTS fraction of total fallout. Estimates of the magnitude of wind erosion may provide upper limits to the original NTS deposition at each site.

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INTRODUCTION

Controversy has arisen over the magnitude and extent of radiation exposures in the southwestern U. S. that resulted from the nuclear weapons tests carried out during 1951-58 at the Nevada Test Site (NTS). One study reported excess cases of childhood leukemia in residents of Utah living closest to the test site and suggested a connection with the weapons tests.[1] Another attributed the deaths of sheep which grazed in areas downwind from the NTS during the Spring of 1953 to locally heavy fallout from a particular test series.[2] Although the radiological survey measurements and dose estimates made following these tests are being re-examined, there is some lack of confidence in the quality of these data. However, valuable corroborative data can still be obtained by examining the residual levels of certain long-lived fallout radionuclides (e.g. ^{137}Cs, $^{239-240}Pu$) present in the soil. An extensive survey of the populated areas of Utah was made in 1979 to determine the ambient natural background radiation levels and total ^{137}Cs inventories, and to estimate the infinite time dose in the St. George area attributable to the NTS tests.[3-5]

The present smaller-scale survey was performed in southern Nevada during May 19-27, 1980. The main objective was to verify the radiation measurements and dose estimates made after the tests at certain reported hotspots by comparing the residual fallout levels to those at neighboring areas. Twenty-eight sites were surveyed, seven of which were in areas of reported heavy fallout following one or more tests and could be classified as possible hotspots. The remaining sites were in areas associated with more typical levels of fallout, several being in the general vicinity of sheep grazing lands.

This report presents the results of in situ measurements and soil sample analyses for ^{137}Cs and other trace fallout products, along with the natural background radiation component for each site. The relative contributions of NTS and global fallout to the total measured inventory of ^{137}Cs, as well as mechanisms relating to redistribution, are discussed. Plutonium isotopic analyses on several of the samples may permit reasonably accurate estimates of the NTS fraction of ^{137}Cs to be made so that comparisons of the inferred radiation exposure from all fission products and historical "post-shot" measurements can be reported.

EXPERIMENTAL METHODS

The measurement sites chosen were generally near highways or secondary roads, since these were where the radiological teams performed surveys after the tests and their data suggested elevated fallout levels.[6-8] In order to fulfill our standard requirement that a measurement or sampling site be undisturbed for the past 30 years, a relatively flat open area 50 or more meters from the road was

usually selected. Ideally this area would contain a vegetative cover to insure minimal erosion, however, the terrain throughout the region did not conform to the usual conditions. In order to provide some consistency with previous inventory measurements made in Utah and Nevada[4, 9] where appropriate ground cover was present, a few sites were selected for comparison. The 28 sites are shown on a map in Figure 1 and identified in Table 1.

An in situ gamma-ray spectrum was accumulated over a 20-50 minute period using a 130 cm^3 coaxial Ge(Li) diode at a height of about one meter above the ground[10, 11] and analyzed on a desktop computer.[12] A high pressure argon ionization chamber (HPIC) was used for the total penetrating ionization rate[11] and a barometer for the atmospheric pressure readings to determine the cosmic-ray secondary component. At all but two of the sites, three cores of soil were taken to a depth of 15 cm and fractionated in 0-2.5, 2.5-5 and 5-15 cm segments. The three cores were spaced about 120° apart and 5-10 meters from the Ge(Li) detector. The total surface area of soil represented by these cores was 186 cm^2. The main function of these samples was for determining the depth distribution of ^{137}Cs in order to convert the 662 keV uncollided flux measured by the Ge(Li) detector in the field to an estimate of the ^{137}Cs inventory. An independent inventory estimate was also obtained from soil sample data.

Due to the dry and powdery nature of the soil, it was removed from the core tool by carefully spooning out the three separate layers. This procedure was sometimes performed with the corer in the ground to avoid spillage. All samples were packaged in heavy polyethylene bags immediately after collection.

Each sample was weighed and air dried in the laboratory. The samples were then reweighed and any large rocks and stones were scraped clean of adhering soil, weighed and discarded. Each sample was pulverized to a fine powder and about 100-180 g analyzed by gamma-ray spectrometry.

The homogeneity of the prepared samples and the precision of aliquoting and counting were tested with duplicate aliquots from six samples. In all cases, the ^{137}Cs concentration of the duplicates agreed to within 2 standard deviations of the counting error. In general, homogeneity and aliquoting were not critical in this study because a large fraction of the collected sample was actually used in the analysis.

The radiation sources used for calibration for the spectral analyses of the soils are traceable to standards from the National Bureau of Standards and the International Atomic Energy Agency. The calibration and sample analyses include appropriate corrections for variations in soil density and composition. The overall systematic error in the analysis is estimated to total less than 5%.

The ^{137}Cs inventory was inferred from the in situ measurement of primary photon flux using a conversion factor derived elsewhere.[4, 10, 12] The conversion

factor is a function of α/ρ, the depth distribution parameter for an assumed exponentially decreasing profile,

$$S = S_o e^{-(\alpha/\rho)\rho z}, \qquad (1)$$

where

S is the activity per cm^3 at depth z cm,
S_o is the activity per cm^3 at the soil surface,
α is the reciprocal of the relaxation length in cm^{-1}, and
ρ is the in situ soil density

The cumulative activity, or inventory I, integrated to depth z' is, then,

$$I = \int_o^{z'} S dz = \frac{S_o}{\alpha}\left[1-e^{-(\alpha/\rho)\rho z'}\right] = I_o\left[1-e^{-(\alpha/\rho)\rho z'}\right], \qquad (2)$$

where I_o is the total inventory in mCi/km^2 integrated to infinite depth.

Although the measured depth profile may not follow an exact exponential function, an accurate estimate of the total inventory with reasonable precision can be made by choosing a value of α/ρ which gives the best fit to the fractional activity profile in the top 5 cm of soil. This procedure works since over 75% of the primary photon flux at the detector comes from sources < 6 g/cm^2 below the surface of the soil, which at a density of 1.5 g/cm^3 corresponds to a depth of 4 cm.

For this study, a value of α/ρ was selected based on a fit to the fraction of the total inventory measured in the 0-2.5 and 2.5-5 cm cuts using Equation 2. By using the fractional activity, the determination of α/ρ becomes independent of systematic errors in the soil sample data. Although it is based on the assumption that the sampling depth was large enough to collect all of the activity, the value of α/ρ will not be substantially affected if a small fraction of the inventory is missed. The only radical departure from this case for this data set occurred at site 3. For this case a total activity was assumed and a fit was applied to the fractional activity in all three cuts. By iteration a total activity was arrived at which gave the best fit and the corresponding value of α/ρ was used.

Soil samples were not collected at sites 1 and 11. Site 1 had some grass cover and was, therefore, similar to sites 2 and 3. Rather than estimate a single α/ρ value, a range of values was chosen based on the other two sites. Site 11 was between sites 8 and 9. Since the depth profiles were quite similar at these two sites and the character of the land the same at all three, the average value of α/ρ was used for site 11.

RESULTS

The natural background exposure rates for each site are shown in Table 2 and illustrated in Figure 2. The sum of the individual contributions from each nuclide, as measured by the spectrometer, and the cosmic-ray secondary component, as inferred from the barometer readings, agrees well on the average (1.4%) with the HPIC measurement of the total exposure rate. Differences at any particular site can be attributed to statistical error for the most part. The exposure rate from ^{222}Rn daughters in the air was estimated from the average relationship between soil radium and ground level ^{222}Rn concentrations in the air.[13]

Using the HPIC data, the average exposure rate for the southeastern sites (1-11) is 11.7 μR/h ± 1.8 (1σ). The other sites averaged 17.1 ± 2.0. Although part of this difference is due to the generally lower altitude of the southeastern sites and the resultant lower cosmic-ray component, there is also an apparent difference in the average abundance of natural emitters in the soil between the two groups. The Utah survey performed in 1979 indicated fairly uniform external exposure rates (9-13 μR/h) across the state. One exception, however, was a 20 μR/h value recorded at Modena in western Iron County, Utah. It appears that this site is in the same geographical pattern of sites 12-28 in this study. This pattern appears to extend up into Beaver County, Utah as well, as seen in Figure 2.

Although the measurements in this survey were not performed within the towns as they were in Utah, the consistently higher ambient exposure rates recorded at the more northerly locations are probably representative of the actual natural background dose to the population there since the residential areas are on land of similar soil type. As such, these data are of some significance to any study involving radiation produced health effects, since external background radiation constitutes a large fraction of man's normal radiation exposure.[14]

The only man-made radionuclide detected in the field spectra was ^{137}Cs. Based on the depth profiles measured in the soil samples, the appropriate conversion factor was applied to yield the exposure rate contribution.[12] The current (1980) values are seen to vary between 0.1 and 0.3 μR/h.

Table 3 lists the pertinent soil sample data along with the concentrations of fallout emitters detected. Aside from the ^{137}Cs, several samples contained measurable amounts of ^{60}Co and ^{241}Am and one sample contained ^{106}Rh. Traces of ^{125}Sb, ^{144}Ce and ^{106}Ru were also detected in many of the surface soil samples, however, these nuclides have been seen in soils from other parts of the U. S. in the past few years and can be attributed to global fallout from recent Chinese weapons tests.[15]

With the exception of site 3, the data show that the 15 cm sampling depth was sufficient to collect nearly all of the deposited activity. Site 3 was an

old lawn at a private residence which had been flood irrigated. As was found in Utah last year, heavy application of water apparently acts to drive the cesium more deeply into the soil. Sites 4 through 28 were pristine locations where the depth profiles were found to be quite shallow, reflecting the small amount of precipitation in this area. A distribution of the measured depth profiles in histogram form is shown in Figure 3.

Table 4 lists the ^{137}Cs inventories inferred for each site from both the in situ and soil sample methods. The total absorption peak count rate for the 662 keV primary flux measured in the field and the value of α/ρ, the depth parameter derived from the soil samples, is also listed. This same depth parameter was used with Equation 2 to estimate the fraction of the total activity collected in the soil samples. The estimate of the total inventory using the soil sample data was made by correcting the measured value based on this fraction. Excepting site 3, these corrections were small.

Measurements have shown that the in situ method for determining inventory is as accurate but somewhat less precise (12% vs. 8%, 1 S.D.) than the soil analysis method based on 10 cores.[4] The precision of the sample method includes the statistical errors associated with collection, preparation and analysis. The major source of error lies with the collection, that is, whether the number of cores or surface area sampled is representative of the total area. As a first approximation, the statistical error would vary inversely with the square root of the number of cores. The 8% precision associated with the 10 core method would, therefore, be modified to about 15% for the 3 core method.

Although the in situ method involves using the soil sample data to determine the depth parameter, it is less sensitive to errors in the soil sample data particularly when the depth profile is shallow, as was encountered for most sites in the present study. Consequently, it is expected that the precision in the inventory estimates is about the same for both methods used in this study.

If a distribution of the percent differences between the in situ and 3 core soil sample inventory estimates is constructed for the 24 pristine sites, it would be expected to have a standard deviation about the mean of

$$\sigma = \sqrt{15^2 + 15^2}$$

$$= 21\% .$$

The fact that 15 out of the 24 cases (63%) lie within 20% of the mean lends confidence to the precision estimates of both methods.

That on the average the in situ inventory estimate is 18% higher than the soil sample estimate for the pristine sites can be attributed to a blowsand effect. Although there was little or no grass cover at most of the locations,

scattered brush such as sage was common. Wind blown soil particles tend to build up around the bases of such plants, thus higher concentrations of fallout products can be expected to reside there. The detector in the field "sees" this additional source whereas the soil samples were taken in the open areas among the brush where a depleted source would exist. At Site #9 the magnitude of this effect was checked by taking a grab sample of blowsand from under several clumps of brush. As shown in Table 3, the concentrations of both ^{137}Cs and ^{60}Co were found to be about double that of the 0-2.5 cm cut. If the ^{137}Cs was distributed essentially uniformly in the blowsand and 5% of the ground surface covered to a depth of 0-15 cm (a reasonable estimate based on visual examination) by these mounds of enhanced activity, the contribution to the peak area measured in the field would have been about 6 counts per minute, 26% of the total. Subtracting this contribution would lower the inventory from 35 to 26 mCi/km^2. The later value would, therefore, represent the open area away from the brush where the soil samples were collected. Conversely, if the blowsand was distributed evenly across the ground, the inventory would increase by 4-12 mCi/km^2 as compared to 29 mCi/km^2 measured in the samples collected away from the brush. These values are consistent with the 21% difference seen at this site. The magnitude of the blowsand effect at this site is illustrative of the effect at other sites. However, due to differences in depth distribution, ground cover and local wind conditions, no single correction factor can be applied to all sites. Nonetheless, one can probably conclude that based on the measurements at Site 9, the effect would not grossly distort the inventory estimates presented in Table 4.

A grab sample of sediment from a small wash was taken at Site 24 to check for any water erosion effects. Since sediment is generally comprised of fine particles it might also tend to accumulate fallout products washed off the ground surface. However, the ^{137}Cs concentration in the sediment was on the same order as the average concentration in the soil for the 0-15 cm sampling depth. If the particular wash sampled was representative then no major effect of runoff is apparent for this site.

A standard EML soil sample (10 cores, 0-30 cm) was taken at Site 21. The difference between the estimate of 44 mCi/km^2 for this set and the 64 mCi/km^2 found for the 3 core sample is not inconsistent with the estimated precisions (8 and 15%) and is indicative of the variable nature of deposition over land with poor ground cover. The soil sample inventory value shown in Table 4 for this site is the average of the two sets, weighted by their corresponding surface areas.

DISCUSSION

The contribution of global fallout to the total ^{137}Cs inventory can be estimated using the relationship between precipitation and ^{137}Cs deposition reported in the 1979 Utah study.[4] Although this relationship is crude and may not be valid for southern Nevada, it nonetheless provides a general idea of the magnitude of global fallout levels. Climatological data for the state of Nevada indicate on the order of 10 to 20 cm of precipitation for the southern Sites 1-11 and 28 and between 20 and 30 cm for the more northerly Sites 12-27.[18] Assuming a constant 15 mCi/km^2 dry deposition and a 2.5 mCi/km^2 per cm of rain wet deposition, the corresponding global ^{137}Cs levels would be about 40-65 mCi/km^2 for the southern sites and 65-90 mCi/km^2 for the northern sites.

The total ^{137}Cs inventory would be higher still when the U.K. component is included. The NTS contribution was estimated to be 29 mCi/km^2 in the St. George area and 18 mCi/km^2 near Enterprise in the Utah studies last year.[4,5] A similar or higher contribution would be expected at many of the sites in this study. Although the total inventory measured at the grass covered Site 2 is consistent with the values seen in neighboring southwestern Utah while the inventory at the grass covered Site 3 is exceptionally high, it is apparent that the poorly covered Sites 4-28 exhibit much lower inventories than expected. This inconsistency is explainable by the difference in the character of the sampling sites. The Utah inventory estimates represent a better estimate of actual deposition because the measurements were performed on grassy surfaces where the fallout would tend to remain. The inventories measured at Sites 4-28 in the present study are merely the current or 1980 values. The data indicates that some fraction of the original fallout has been redistributed, probably via wind erosion.

Further evidence of the effects of wind erosion can be seen at Sites 13 and 22. A nearby former EMI sampling sites that possessed vegetative cover, the ^{137}Cs inventory was 130 mCi/km^2 for both sites in June 1974.[19] Correcting for radioactive decay, 113 mCi/km^2 would be present at the time of this survey, whereas the average of in situ and soil sample measurements indicated 45 mCi/km^2 for Site 13 and 47 mCi/km^2 for Site 22. These are about a factor of 2.5 lower. If this same factor was applied to the other erosion-prone sites, the inventory estimates would range between 40 and 163 mCi/km^2. These values are more consistent with those found at Sites 2 and 3 and in Utah. However, applying a correction such as this is probably only valid on the average since the degree of erosion at any particular site would depend upon local winds, topography, vegetative cover and the blowsand effect previously discussed.

A major question not yet resolvable with the present data set is whether there is any difference in the behavior of dry and wet fallout once deposited on the ground. The NTS fallout was generally dry whereas most of the global was associated with precipitation. As such, it is possible that different fractions

of the NTS and global fallout were dispersed by wind. It is apparent, however, that not all of the NTS fallout was dispersed since ^{241}Am and ^{60}Co were detected in soil samples from several of the sites. These nuclides were not detected in the gamma-ray analysis of samples from southwestern Utah last year and are not normally seen in environmental samples from other parts of the U. S.

Although no direct relationship between ^{137}Cs and ^{60}Co can be assumed because of their probable different rates of fallout as a function of distance downwind from NTS, the fact that the ^{60}Co could be detected may indicate a higher than average NTS deposition for that area or deposition from a test relatively rich in ^{60}Co. Most of the sites identified in Table I as possible hotspots did show the presence of ^{60}Co whereas the other sites associated with more typical fallout levels generally did not. The highest ^{60}Co concentration was found at site 21 (also the only site with ^{87}Rb) and although not identified as a hotspot, this site probably received an enhanced cumulative fallout from several tests due to its elevation (~1500 m). The hotspot west of Site Valley (Site 5) identified after the Holtzman test also showed a comparatively high concentration of ^{60}Co. The lower values of ^{137}Cs, ^{60}Co and ^{241}Am found at the surrounding sites 2% in the same valley, although not in the same proportion to the surface beta activity measured during the post shot radiological survey, are at least consistent with the direction of the gradient.[6]

The >200 mCi/km^2 ^{137}Cs inventory estimates for Site 1 are due to excess fallout from runoff. A similar anomaly was seen at Hurricane, Utah last year.[4] Although this was substantially the highest inventory found in this survey, no ^{60}Co or ^{241}Am was detected in the soil samples. In addition, the Cesium profile was unusually deep and since the soil sample only extended to 15 cm, the errors in the inventory estimates are large. It is hoped that analysis of ^{210}Pb, a natural fallout nuclide found in rain, as well as Pu isotopic information, will help to better determine whether the excess cesium is from NTS or global fallout.

SUMMARY AND CONCLUSIONS

This report presents natural background exposure rates and ^{137}Cs inventories for 28 sites in the vicinity of the Nevada Test Site. The concentrations of fallout emitters in soil is also given for 26 of these sites. The natural background exposure rates varied by about a factor of two and tended to be higher at the more northern sites in this study. The ^{137}Cs inventories varied considerably but were in general lower than expected for this area. The data suggests that some fraction of the original fallout has been redistributed at sites with insufficient ground cover.

The presence of enhanced NTS fallout was indicated by small amounts of ^{60}Co and ^{241}Am in the collected soil samples, however, the corresponding ^{137}Cs inventories at these sites were not unusually high when compared to neighboring locations. In order to verify the original post-shot radiation measurements, estimates of the NTS component in the total ^{137}Cs inventory must be made and corrections applied to account for any wind erosion since the time of the shot. This matter is complicated by the possibility that dry NTS fallout may be affected to a different degree by the wind than wet global fallout. In view of this, accurate estimates of the original NTS deposition and resultant radiation doses may not be possible. It is hoped, however, that plutonium isotopic analyses of the soil samples will help to determine the NTS fraction of the total fallout now present and point out any differences in the redistribution of wet and dry fallout. If the magnitude of wind erosion effects can be estimated for the NTS fallout, upper limits to the post-shot radiation levels can be established.

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TABLE 1

MEASUREMENT SITE LOCATIONS

Site No.	Location	Remarks
1	Mesquite, private residence	
2	Mesquite, open field	
3	Bunkerville, private residence	
4	Riverside	
5	Route 168 (7) 2 miles NW of I-15 interchange	
6	7 miles N of Moapa on road to Carp	875 $\mu Ci/ft^2$, shot Simon[8]
7	14 " " " " " "	
8	US-93, 4.8 miles N of Butler Ranch	1260-2770 $\mu Ci/ft^2$, shot Smoky[7]; 3-5 R infinite dose, shot Harry[8]
9	Kane Springs Rd., 0.8 miles E of Butler Ranch	1260-2770 $\mu Ci/ft^2$, shot Smoky[7]; 3-5 R infinite dose, shot Harry[8]
10	I-15, 8.8 miles E of Glendale	740 $\mu Ci/ft^2$, shot Simon[8]
11	US-93, 2.4 miles N of Butler Ranch	1260-2770 $\mu Ci/ft^2$, shot Smoky[7]; 3-5 R infinite dose, shot Harry[8]
12	US-93, 5 miles N of Alamo	
13	Lincoln County Airport (Panaca)	near former EML sampling site[8]

TABLE 1 (Cont'd)

Site No.	Location	Remarks
14	Route 322 (85), 2.1 miles E of US-93 junction (Pioche)	
15	US-93, 3.2 miles E of Oak Spring Summit	
16	US-93 20.5 miles E of Crystal Springs	
17	Route 318 (38) 21.5 miles N of Crystal Springs	
18	Route 375 (25), 2.2 miles W of Crystal Springs	
19	6 miles N of Route 375 (25) and Cunderson Rd. junction (Sand Spring Valley)	4-5 R infinite dose, shot Nancy[6]
20	2.6 miles N of Route 375 (25) on road to Tempiute	
21	Route 375 (25), Queen City Summit	
22	2.9 miles NW of US-6 on road to Tybo	Near former EML sampling site[8]
23	Route 375 (25), 18.9 miles E of Warm Springs (Railroad Valley)	
24	US-6, 7.2 miles W of Warm Springs	1310 μCi/1t^2, shot Boltzmann[7]
25	US-6, 13.6 " " " " "	
26	US-6, 1.5 miles E of Route 376 (8A) junction	
27	US-95, 4.5 miles N of Goldfield	
28	US-95, 8 miles S of Beatty	

NOTE: Surface activities quoted are total beta corrected to H+12 hours.

TABLE 2

EXTERNAL RADIATION LEVELS

Location No.	Date	Exposure Rate (μR/h) Cosmic	^{40}K	Th	U	Rn	^{137}Cs	Total Natural Gamma Ray	Σ	HPIC
1	5-19-80	4.2	1.7	1.3	0.9	0.1	0.1	4.0	8.3	9.8
2	5-20-80	4.1	2.0	2.0	1.7	0.2	0.3	5.9	10.3	10.0
3	5-20-80	4.1	2.0	2.0	1.2	0.1	0.3	5.3	9.7	11.4
4	5-20-80	4.1	2.6	2.6	1.1	0.1	0.2	6.4	10.7	11.4
5	5-20-80	4.2	3.0	3.3	1.9	0.2	0.1	8.4	12.7	12.4
6	5-21-80	4.2	3.7	4.3	2.5	0.3	0.2	10.8	15.2	14.5
7	5-21-80	4.2	3.6	4.6	2.2	0.2	0.1	10.6	14.9	14.6
8	5-21-80	4.6	2.4	2.9	1.5	0.2	0.3	7.0	11.9	11.0
9	5-21-80	4.6	4.0	4.1	1.8	0.2	0.2	10.1	14.9	13.6
10	5-22-80	4.4	2.1	2.0	1.3	0.1	0.2	5.5	10.1	9.8
11	5-22-80	4.6	1.2	2.1	0.9	0.1	0.2	4.3	9.1	10.2
12	5-22-80	5.1	4.6	4.7	2.1	0.2	0.2	11.6	16.9	16.6
13	5-22-80	5.9	3.5	3.1	1.4	0.1	0.2	8.1	14.2	13.5
14	5-22-80	6.3	3.3	3.8	2.2	0.2	0.3	9.5	16.1	14.9
15	5-23-80	6.6	4.7	5.6	2.1	0.2	0.3	12.6	19.5	18.9
16	5-23-80	6.0	4.3	5.3	2.5	0.3	0.3	12.4	18.7	17.2
17	5-23-80	5.7	4.3	5.4	2.3	0.2	0.2	12.2	18.1	17.2
18	5-23-80	5.5	4.1	5.5	2.2	0.2	0.3	12.0	17.8	17.3
19	5-24-80	6.0	5.3	5.9	*	-	0.2	-	-	20.8
20	5-25-80	6.3	1.9	2.6	1.6	0.2	0.3	6.3	12.9	13.2
21	5-25-80	6.6	5.0	4.9	2.1	0.2	0.3	12.2	19.1	18.9

*Measurement negated by radon daughter washout.

Th - ^{232}Th + daughters

U - ^{238}U + daughters

Σ = sum of individual nuclides plus cosmic

HPIC = high pressure ionization chamber

TABLE 2 (Cont'd)

Location No.	Date	Exposure Rate (μR/h) Cosmic	^{40}K	Th	U	Rn	^{137}Cs	Total Natural Gamma Ray	Σ	HPIC
22	5-26-80	6.2	3.8	4.2	2.4	0.2	0.3	10.6	17.1	16.5
23	5-26-80	6.0	4.1	3.9	2.0	0.2	0.3	10.0	16.5	16.3
24	5-26-80	6.7	4.4	4.3	2.1	0.2	0.3	11.0	18.0	18.1
25	5-26-80	6.4	5.2	4.4	2.2	0.2	0.2	12.0	18.6	18.3
26	5-26-80	6.2	4.8	3.9	2.4	0.2	0.2	11.3	17.7	17.2
27	5-27-80	6.2	4.2	6.0	3.6	0.4	0.3	14.2	20.7	19.5
28	5-27-80	4.7	4.6	5.4	2.3	0.2	0.2	12.5	17.4	16.8

TABLE 3

SOIL SAMPLE DATA

Site	EML I.D. No.	Depth (cm)	Wet Wt.* (g)	Dry Wt.** (g)	H_2O (%)	Concentration (pCi/g-dry) ^{137}Cs	^{241}Am	^{60}Co	^{106}Rh
2	S-2751	0-2.5	854	653	23	1.009±.010	-	0.004±.002	-
	52	2.5-5	839	638	24	0.958±.029			
	53	5-15	2823	2091	26	0.230±.013			
3	54	0-2.5	416	415	0	0.692±.008	-	-	-
	55	2.5-5	502	498	2	0.709±.017			
	56	5-15	2597	2432	6	0.611±.007			
4	57	0-2.5	846	817	0	0.857±.007	0.016±.011	0.011±.002	-
	58	2.5-5	530	509	0	0.493±.013			
	59	5-15	2933	2738	1	0.040±.008			
5	60	0-2.5	640	628	0	0.439±.008	-	-	-
	61	2.5-5	702	668	0	0.056±.013			
	62	5-15	2983	2826	1	0.008±.004			
6	63	0-2.5	761	711	0	0.412±.006	-	-	-
	64	2.5-5	549	560	0	0.159±.010			
	65	5-15	2841	2707	2	0.099±.010			
7	66	0-2.5	656	650	1	0.403±.007	-	-	-
	67	2.5-5	607	601	0	0.071±.010			
	68	5-15	2612	2538	2	0.006±.003			
8	69	0-2.5	694	653	0	1.056±.008	-	0.013±.003	-
	70	2.5-5	703	634	0	0.279±.012			
	71	5-15	3033	2609	2	0.022±.007			
9	72	0-2.5	692	637	0	0.611±.008	-	0.005±.003	-
	73	2.5-5	704	629	1	0.127±.016			
	74	5-15	2727	2577	3	0.023±.009			
	75f	Blowsand	3473	3473	0	1.081±.009	-	0.011±.003	-
10	76	0-2.5	881	740	0	0.949±.007	0.16±0.11	0.011±.002	-
	77	2.5-5	660	564	0	0.118±.014			
	78	5-15	2694	2348	2	0.021±.007			
12	79	0-2.5	877	875	0	0.615±.008	-	-	-
	80	2.5-5	680	667	0	0.060±.010			
	81	5-15	2876	2752	4	0.007±.004			
13	82	0-2.5	677	647	1	0.801±.009	-	-	-
	83	2.5-5	601	541	4	0.376±.013			
	84	5-15	2657	2273	7	0.035±.008			
14	85	0-2.5	407	389	2	1.073±.010	-	0.003±.002	-
	86	2.5-5	442	395	10	0.835±.037			
	87	5-15	2395	2023	15	0.18 ±.01			
15	88	0-2.5	731	719	1	0.657±.009	-	-	-
	89	2.5-5	651	600	4	0.203±.012			
	90	5-15	2884	2657	7	0.013±.008			

TABLE 3 (Cont'd)

Site	EML I.D No.	Depth (cm)	Wet Wt.* (g)	Dry Wt.** (g)	H$_2$O (%)	^{137}Cs	Concentration (pCi/g-dry) ^{241}Am	^{60}Co	^{106}Rh
16	S-2791	0-2.5	727	715	1	0.610±.009	-	-	-
	92	2.5-5	617	587	4	0.085±.010			
	93	5-15	2811	2659	5	0.006±.007			
17	94	0-2.5	705	686	0	0.626±.008	-	-	-
	95	2.5-5	750	704	2	0.230±.019			
	96	5-15	2633	2421	5	0.050±.009			
18	97	0-2.5	882	769	1	0.815±.009	-	-	-
	98	2.5-5	593	561	3	0.096±.014			
	99	5-15	2468	2262	6	0.012±.007			
19	S-2800	0-2.5	704	677	1	0.603±.012	0.088±.026	0.026±.006	-
	01	2.5-5	696	664	2	0.273±.020			
	02	5-15	2590	2342	4	0.025±.009			
20	03	0-2.5	841	629	10	0.212±.009	-	-	-
	04	2.5-5	691	554	13	0.075±.019			
	05	5-15	2240	1889	11	0.050±.008			
21	06	0-2.5	638	501	12	1.286±.009	0.124±.013	0.075±.004	0.040±.003
	07	2.5-5	814	650	14	0.498±.007	0.047±.013	0.029±.004	0.012±.003
	08	5-15	2919	2327	14	0.094±.010			
	09†	0-30	22563	19909	12				
22	10	0-2.5	711	655	6	0.910±.012	-	0.003±.003	-
	11	2.5-5	677	629	7	0.129±.013			
	12	5-15	2914	2611	8	0.005±.006			
23	13	0-2.5	610	548	5	1.131±.009	-	0.007±.003	-
	14	2.5-5	720	655	7	0.485±.020			
	15	5-15	3088	2801	7	0.008±.006			
24	16	0-2.5	805	751	3	1.496±.011	0.020±.013	0.032±.004	-
	17	2.5-5	651	612	5	0.293±.020			
	18	5-15	2486	2294	7	0.013±.005			
	19†	Wash Sediment	5293			0.320±.008			
25	20	0-2.5	726	678	1	0.427±.006	0.010±.009	0.006±.003	-
	21	2.5-5	650	624	2	0.155±.018			
	22	5-15	2816	2565	5	0.060±.010			
26	23	0-2.5	865	791	0	0.561±.008	-	-	-
	24	2.5-5	654	616	1	0.156±.010			
	25	5-15	2485	2335	3	0.019±.004			
27	26	0-2.5	846	696	0	0.739±.008	-	-	-
	27	2.5-5	687	656	2	0.154±.012			
	28	5-15	2458	2262	5	0.006±.003			
28	29	0-2.5	772	714	0	0.550±.025	-	-	-
	30	2.5-5	649	617	0	0.122±.015			
	31	5-15	2664	2408	2	0.018±.009			

*% by weight of in situ material including rocks.
**Excludes rocks.
†Grab sample, undefined area; all samples 186 cm^2 in area unless otherwise noted.
‡620 cm^2 area.

NOTE: Uncertainties are 1 σ Poisson counting errors.

TABLE 4

CESIUM-137 INVENTORIES (MAY 1980)

Site No.	Field Spectrometry cpm	Field Spectrometry α/β	Field Spectrometry mCi/km²	Soil Sample Measured, mCi/km²	Soil Sample Fraction of Total	Soil Sample Corrected, mCi/km²
1	12.1±1.3	0.11±.03E	35±110	-	-	-
2	29.4±1.2	0.11	88±13	94	0.92	102±15
3	23.6±1.8	0.03	209±31*	117	0.43	272±41*
4	20.0±1.4	0.23	37±6	57	1.00	57±9
5	9.6±0.9	0.43	13±2	18	1.00	18±3
6	25.4±1.2	0.15	61±9	35	0.96	36±5
7	10.8±1.2	0.44	15±2	17	1.00	17±3
8	36.0±1.5	0.36	54±8	50	1.00	50±8
9	22.8±1.3	0.36	35±5	29	1.00	29±4
10	23.6±1.0	0.35	36±5	44	1.00	44±7
11	24.1±1.6	0.35E	37±6	-	-	-
12	24.8±1.7	0.44	34±5	32	1.00	32±5
13	28.6±1.3	0.29	47±7	43	1.00	43±6
14	31.3±1.6	0.21	61±9	60	0.97	62±9
15	34.5±1.7	0.34	53±8	34	1.00	34±5
16	34.3±1.7	0.52	44±7	27	1.00	27±4
17	29.5±1.4	0.24	53±8	40	0.99	40±6
18	32.7±1.5	0.44	45±7	39	1.00	39±6
19	27.4±1.5	0.25	49±7	35	1.00	35±5
20	36.6±1.5	0.33	52±9	33	1.00	33±5
21	35.2±1.5	0.22	67±10	49	1.00	49±7
22	30.6±1.4	0.33	49±7	44	1.00	44±7
23	35.2±1.4	0.31	56±8	52	1.00	52±8
24	41.1±1.5	0.40	59±9	71	1.00	71±11
25	20.8±1.6	0.15	50±8	42	0.97	43±6
26	24.4±1.4	0.27	42±6	30	1.00	30±5
27	32.1±1.5	0.37	48±7	34	1.00	34±5
28	23.0±1.3	0.33	36±5	27	1.00	27±4

NOTE: E = value estimated Precision estimates are ± 1 S.D.

*Values may be overestimated due to insufficient sample depth.

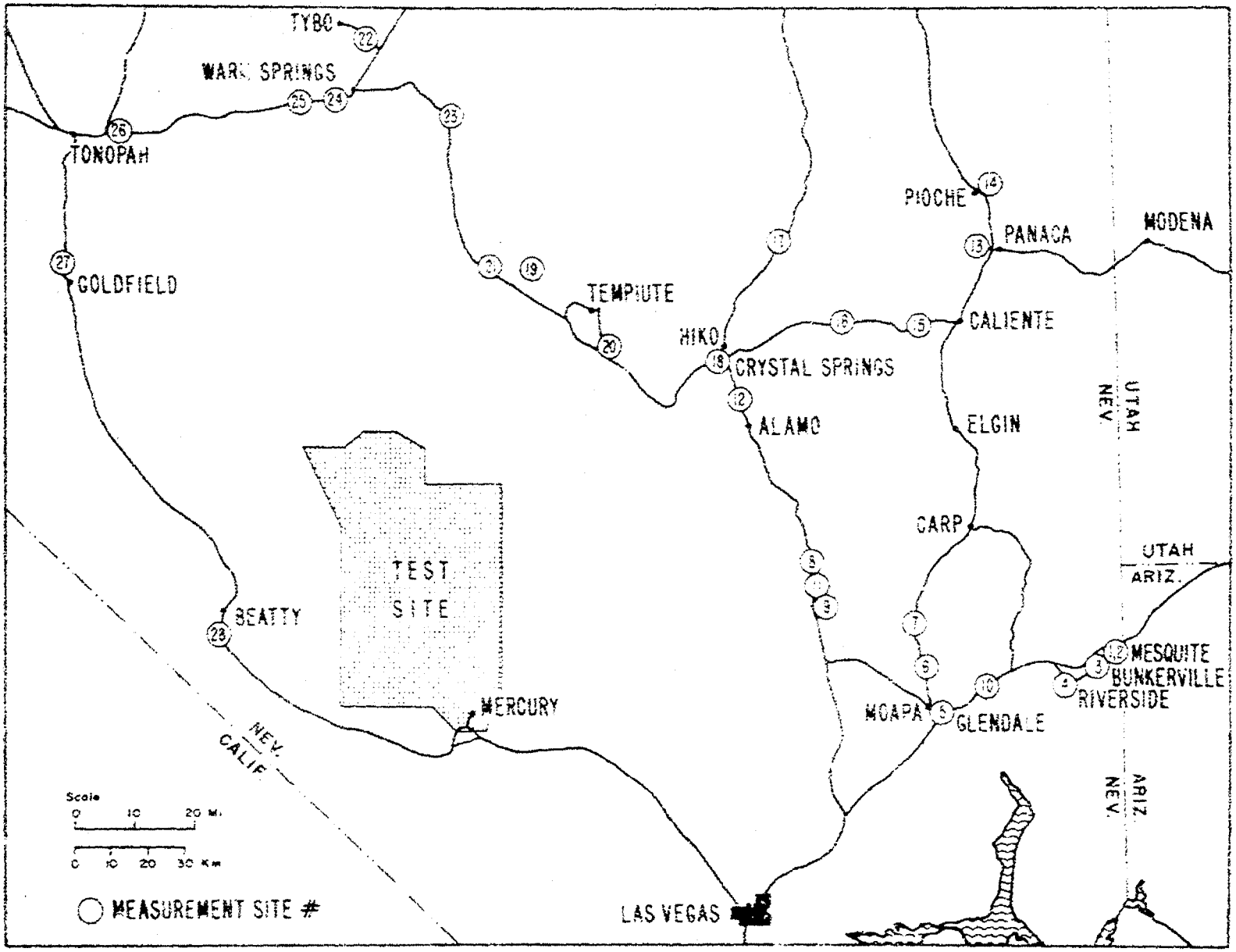

Figure 1. Location of measurement sites in this study.

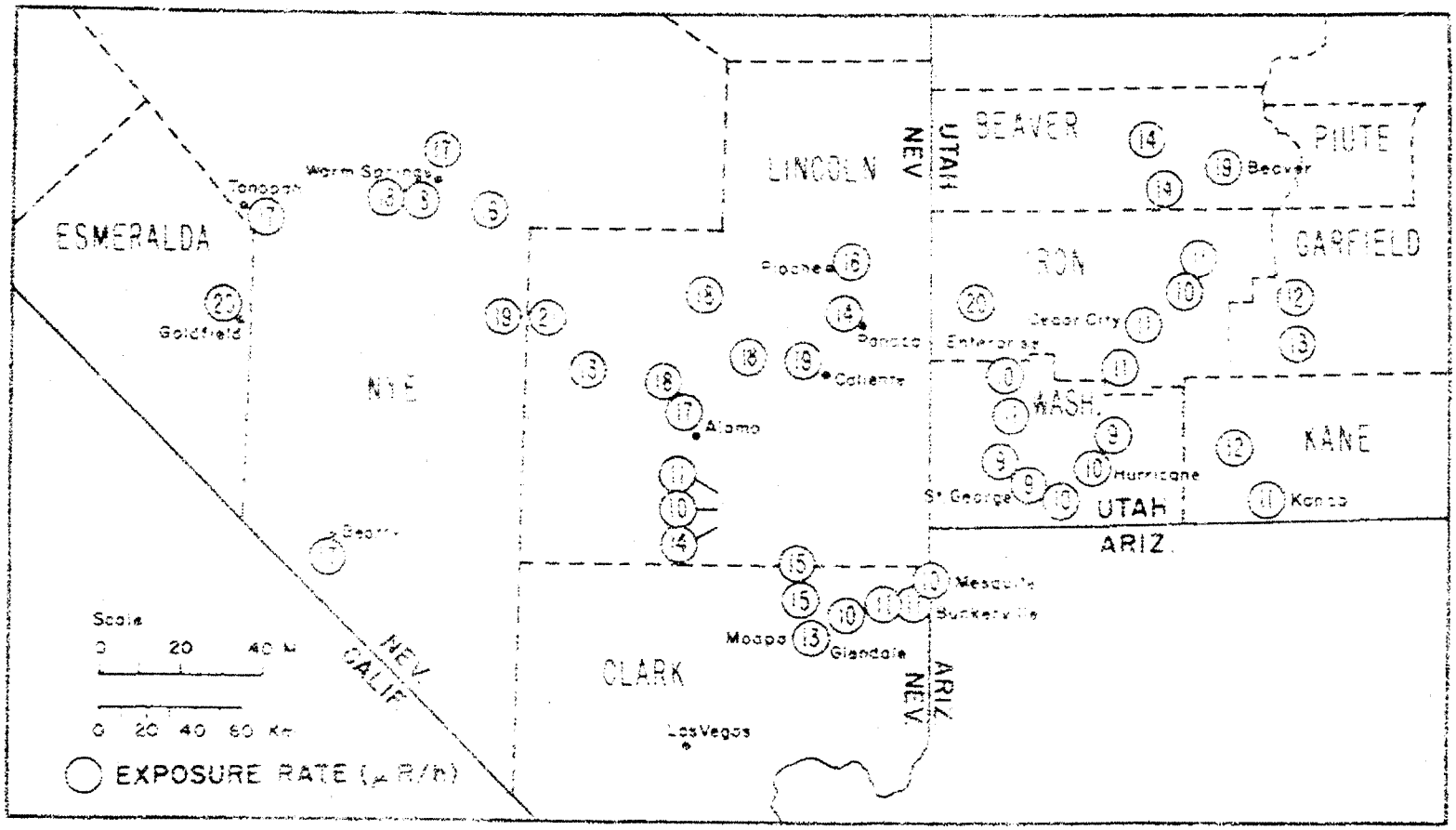

Figure 2. Typical background exposure rates in southern Nevada (this study) and southwestern Utah (Reference 3).

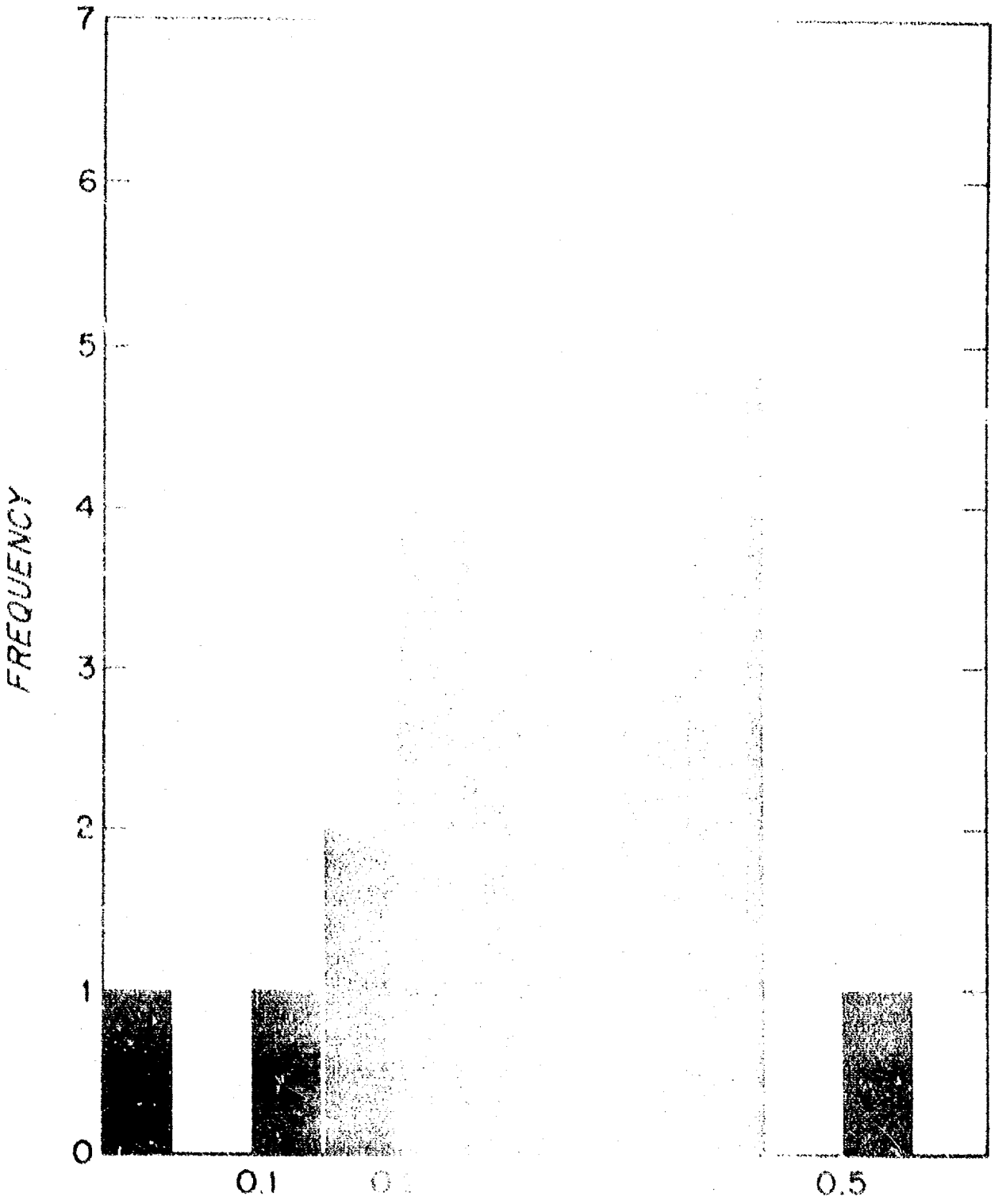

Figure 3. Frequency [illegible] depth parameter, α/p, [illegible]