August 16, 1973

Members of the Radiological Assessment Review Group

PREDICTED EXTERNAL EXPOSURE DOSES TO RETURNING ENIWETOK POPULATION

By memorandum of July 19, 1973, we sent you a copy of a preliminary draft of a report on predicted external exposure doses. We have received a new draft embodying Harold Beck's calculations, and a copy is provided for your information. This copy reflects the benefits of discussions with LLL and EG&G staff.

Original Signed By
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Enclosure:
As stated

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D/C - Navy. Re - Settlement @ Eniwetok

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Members of the Radiological Assessment Review Group - memo dtd 8/16/73

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HLB/JEM (AEC-LASL) 7/27/73

PREDICTED EXTERNAL EXPOSURE DOSES TO RETURNING ENIWETOK POPULATION

Utilizing the comprehensive aerial survey data reported by EG&G supported by ground level TLD measurements and other information inferred from the soil sample radionuclide analyses, we estimated free air doses from gamma-ray emitting radionuclides present in the soil on the various islands at Eniwetok Atoll to which the returning population might be subject.

Integral doses for 5, 10, 30 and 70 years beginning in 1973 were calculated for the five different living patterns presented in Table I. These cases were chosen to bracket the probable range of doses which would be received by any sizable segment of the population. Almost any other reasonable pattern can be inferred by combining the results from two or more of these cases.

For example, averaging the calculated doses for either I_a or I_b, II, III and IV should give a reasonable estimate of the average dose to the entire returning population, assuming half live on Engebi and half on Eniwetok and

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that trips to islands in the South or North are equally likely for either group. The choice of fractional times for the various population groups are based on J. Tobin (this report) and the comments of the Eniwetok Magistrate at the May meeting. Case I_b differs from case I_a in that more time is allotted to temporary occupation of islands other than Engebi while less time is spent in the Engebi village area. Case I_b probably leads to upper limit doses for a sizable fraction of the population. Case IV represents the least exposed population group. No attempt was made to break down the time spent on other islands into specific areas. Such a breakdown would appear to over complicate the calculations unnecessarily.

The estimated mean exposure rates at the present time for each of the locales treated, and for each major source, are given in Table II. The average ^{137}Cs and ^{60}Co exposure rates for each island were taken from the EG&G summary table given in their section of this report. A mean for all the northern islands (excluding Yvonne) was obtained by weighting the individual island averages by their land area. The estimates for specific regions of Janet were obtained by examination of the EG&G ^{137}Cs and ^{60}Co

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contour maps for that island. To an estimated 3.3 μR/h mean cosmic ray exposure rate at this latitude was added 0.2 μR/h to account for naturally occurring nuclides in the soil and sea water. The minor contamination of the southern islands is relatively uniform and the mean ^{137}Cs and ^{60}Co exposure rates were chosen by inspection of the individual EG&G contour maps.

There are wide variations in exposure rates on many of the northern islands and in a few areas the exposure rates may be as high as 400-500 μR/h. An examination of the data indicates that the exposure rates given in Table II are reasonable estimates of the area weighted means values. (If anything they may be slightly conservative since we suspect that although the EG&G aerial data agrees well with the TLD data, the latter may overestimate somewhat because of the minimal beta-ray shielding of the TLD device.) Thus the integrated values determined from these measurements should be reasonable estimates of the average doses to population groups although some individuals might well receive much higher doses.

The relative gamma-ray exposure rate contributions from ^{60}Co and ^{137}Cs inferred from the EG&G data agrees well with values independently inferred

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from the soil activity and depth profile measurements. Although the soil data indicate trace amounts of other gamma emitters, such as ^{125}Sb, ^{155}Eu and ^{241}Am, calculations of exposure rates based on the observed soil concentrations indicate that these nuclides contribute at most an additional 3-5% to the exposure rate, and they were therefore neglected. Local anomalies, for example due to scrap, were also ignored under the assumption that they will be removed before resettlement and will probably contribute little more to eventual integrated total doses.

Integral 5, 10, 30 and 70 year gamma-ray doses for each age group were calculated for each case shown in Table 1. These results were then combined by folding in the present population distribution (Table III). Corrections were made for radioactive decay but no corrections were made for possible weathering and consequent deeper penetration of radionuclides into the soil. The results of these calculations are given in Table IV and are labeled "unmodified". Additional calculations were made to ascertain the effect of carrying out various reasonable actions to reduce exposure rates on the Atoll.

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The first modification, labeled "village graveled" in Table IV reflects the effect of covering the village areas with 1 to 2 inches of coral gravel. Tobin indicated this practice was common throughout Micronesia (Private Communication). This action can be expected to reduce the gamma exposure levels in the village area by approximately a factor of two.

The second and third modifications are based on the assumption that clearing the islands for agricultural use and housing will result in some mixing of the top soil. It would appear that it would not be impractical during this period to also plow many of the more contaminated islands to a depth of about one foot. Assuming that plowing results in mixing rather than burying the top soil, we estimate average reductions in exposure rates of about a factor of three would be obtained. This reduction factor is based on the present 3-5 cm relaxation lengths for radionuclide depth distribution in the uppermost soil layers of the more contaminated areas (this mean value varies considerably from site to site). The reduction was then calculated from exposure rate versus depth distribution data (HASL-258). Modification

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(2) indicates the effect of plowing Engehi only while modification (3) reflects the additional effect of plowing all the northern islands. Deeper plowing or turning over the soil rather than mixing it would of course result in even greater exposure rate reductions. For example mixing to a depth of two feet would reduce gamma exposure levels by an additional factor of two, while covering the sources with approximately a foot of uncontaminated soil would essentially reduce the eventual integral gamma-ray doses from ^{137}Cs and ^{60}Co to negligible values, i.e. doses everywhere similar to those calculated for case IV. Removing the first 6 inches of top soil which now usually contains over two thirds of the activity, rather than plowing, would result also in about a factor of three reduction in gamma exposure rates.

Based on the result given in Table IV, however, extensive modifications may not be necessary. If we compare the unmodified integrated exposures with values calculated for typical U. S. sea level locations which are also given in Table IV, we see that even for Cases I_a and I_b the 70 year integral dose is only slightly greater than the comparable "typical" U. S. value.

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The unmodified expected mean population doses obtained by averaging cases I_b, II, III and IV are all quite comparable with typical USA values. At most, implementation of modifications 1. and 2. should be sufficient to assure mean population exposures well below U. S. mean levels.

Because of the low amount of natural radioactivity normally present in coral atolls, these levels would still of course be higher than levels found elsewhere in the Marshall Islands (essentially case IV). The results for cases II and IV indicate restricting the permanent villages to "clean" southern islands at least temporarily would also result in lower exposures, recalling that the calculations are based on an immediate return. Note that for case I_b almost as much exposure is accumulated in the first 10 years as in the succeeding 20 years. As illustrated in Table V for case I_a differences in radiation exposure of the various population groups are minor, particularly for the longer time periods. Similar results were obtained for the other cases indicating that the exact time breakdown among age groups is not highly important. The fact that the doses for cases I_a and I_b do not differ substantially indicates the exact time breakdown among geographical areas is also not critical.

Table VI illustrates the distribution of dose with respect to geographical area for each of the cases. The large fraction from working in the interior or on other islands reflects of course the higher exposure rates present in these areas.

All of the results discussed so far are free air gamma plus cosmic ray exposures. The effect of shielding by structures or the body itself on gonadal or bone doses has been ignored. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) presently recommends a body shielding factor of 0.8 to convert from free air dose (rads) to gonadal dose (rem). The free air dose will be additionally enhanced by the presence of beta rays, primarily from ^{90}Sr-^{90}Y in the soil. We estimate the ^{90}Sr-^{90}Y beta one meter free air value will be about four times that due to ^{137}Cs gammas. This is based on unpublished HASL ~~data~~ calculations assuming $^{90}Sr/^{137}Cs$ soil activity ratios [redacted] consistent with the present soil analyses. We would thus expect free air beta dose rates to average about 150 μrad/hr in the interior of Engehi and about 50 μrad/hr in the village area. Although the skin dose would be about one half and

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the eye lens dose about one fourth the free air values, the gonadal dose would probably be at most about 1% (Private Communication, O'Brien, HASL). Thus we expect the additional contributions to the gonadal dose from beta rays to be at most about 5 mrem/yr. Gonadal or bone beta-ray doses are thus insignificant compared to gamma-ray contributions. As discussed previously, however, the high free air beta-ray ionization may have elevated the field TLD data adding some conservatism to the mean exposure rates used in the model.

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Table I

ASSUMED GEOGRAPHICAL LIVING PATTERNS

Case Description	Group	Village	Beach	Interior	Lagoon	Other Islands
I_a						
Village on Engebi (Janet), visits to other northern* islands only.	Infants	85	5	0	0	10
	Children	55	10	15	5	15
	Men	50	5	15	10	20
	Women	60	10	10	0	20
I_b						
Village on Engebi (Janet), visits to other northern* islands only.	Infants	70	5	5	0	20
	Children	50	5	15	10	20
	Men	40	5	20	10	25
	Women	50	5	15	5	25
II						
Village on Eniwetok (Fred), visits to northern* islands only (excl. Janet).	Infants	Same as Case I_B				
	Children					
	Men					
	Women					
III						
Village on Engehi (Janet), visits to southern** islands only.	Infants	Same as Case I_a				
	Children					
	Men					
	Women					
IV						
Village on Eniwetok (Fred), visits to southern** islands only.	Infants	Same as Case I_b				
	Children					
	Men					
	Women					

*Northern islands include Alice, Belle, Clara, Daisy, Irene, Janet, Kate, Lucy, Mary, Nancy, Olive, Pearl, Sally, Tilda, Ursula, Vera, Wilma.

**Southern islands include all islands from Tom thru Leroy proceeding clockwise around atoll.

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Table II

ESTIMATED MEAN EXPOSURE RATES (μR/h) USED FOR DOSE CALCULATIONS*

Enjebi (Janet)

Village Area:	^{137}Cs	13
	^{60}Co	7
	Cosmic + natural	3.5
Interior:	^{137}Cs	40
	^{60}Co	20
	Cosmic + natural	3.5
Beach:	^{137}Cs	1.0
	^{60}Co	0.5
	Cosmic + natural	3.5

Eniwetok (Fred)

Village Area:	^{137}Cs	0.4
Interior:	^{60}Co	0.6
Beach:	Cosmic + natural	3.5

Lagoon

All Areas:	Cosmic + natural	3.5

Northern Islands

Weighted mean over surface area of estimated average exposure rates (see EG&G Section) on following islands: Alice, Belle, Clara, Daisy, Edna, Irene, Kate, Lucy, Olive, Pearl, Sally, Tilda, Ursala, Vera, Wilma.

^{137}Cs	17	Excl.	^{137}Cs	26	Incl.
^{60}Co	30	Janet	^{60}Co	26	Janet

Southern Islands

Includes all islands from Tom thru Leroy proceeding clockwise around atoll.

^{137}Cs	0.4
^{60}Co	0.6

*Based on mean values for various islands reported under EG&G aerial survey discussion.

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Table III

POPULATION DISTRIBUTION - ENIWETOK

Age Groups		Percent of Total Population
Infants (0-5 years)	Male	12
	Female	10
Children (6-18 years)	Male	21
	Female	21
Adults (19-50 years)	Male	18
	Female	14
Adults (over 50)	Male	2
	Female	2

Total Population 432

On Ujelong Now 340

Source - Jack Tobin

Table IV

ESTIMATED INTEGRAL EXTERNAL FREE AIR GAMMA DOSES (Rads)

	Time Interval - Years			
	5	10	30	70
Unmodified	.99	1.80	4.03	6.68
I_a 1. Village graveled	(.78)	(1.54)	(3.28)	(5.58)
2. + Janet plowed	(.50)	(1.00)	(2.12)	(3.81)
3. + Northern islands plowed	(.35)	(0.74)	(1.63)	(3.03)
Unmodified	1.08	1.93	4.34	7.14
I_b 1. Village graveled	(.90)	(1.63)	(3.76)	(6.31)
2. + Janet plowed	(.59)	(1.08)	(2.50)	(4.38)
3. + Northern islands plowed	(.38)	(0.73)	(1.81)	(3.41)
Unmodified	0.47	0.83	1.92	3.35
II 3. Northern islands	(0.26)	(0.48)	(1.23)	(2.38)
Unmodified	0.77	1.42	3.27	5.58
III 1. Village graveled	(0.55)	(1.06)	(2.52)	(4.48)
2. + Janet plowed	(0.27)	(0.52)	(1.36)	(2.71)
IV Unmodified	0.15	0.29	0.87	1.89
Mean population dose (see text) Unmodified	0.62	1.12	2.60	4.49
1. Village graveled	(0.52)	(0.95)	(2.27)	(4.01)
2. + Janet plowed	(0.37)	(0.68)	(1.66)	(3.08)
3. + all Northern plowed	(0.27)	(0.51)	(1.32)	(2.60)
Sea level U.S.A. (80 mrad/yr)* Typical	0.40	0.80	2.40	5.60

*See HASL-170, ORP/SID 72-1

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Table V

ILLUSTRATION OF DOSE BREAKDOWN AMONG POPULATION GROUPS
(CASE I_a - UNMODIFIED)

Group	Total Integrated Dose (rad)			
	5 years	10 years	30 years	70 years
Infants	.85	1.65	3.86	6.51
Children	1.02	1.83	4.07	6.71
Men	1.06	1.89	4.16	6.84
Women	1.03	1.84	4.04	6.65

Table VI

% OF UNMODIFIED EXPOSURE RECEIVED FROM VARIOUS LOCALES*

Case	Village	Beach	Interior	Lagoon	Other Islands
I_a	47	2	27	1	23
I_b	36	1	33	2	28
II	22	2	8	4	64
III	58	2	33	1	5
IV	50	5	17	8	20

*For 30 year intervals averaged over population distribution, percentages for other time periods are similar.

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