5/10/79

401201

RADIOLOGICAL IMPLICATION FOR RESETTLEMENT OF ENEU ISLAND

SUMMARY

Unless imported food is a substantial and continuing part of the diet of the Eneu population for about 20 years, unless the Eneu population can effectively be prevented from access to Bikini Island for several years, and unless no food from Bikini Island is eaten for about 30 years, it is unlikely that radiation doses to people living on Eneu Island would be in compliance with federal radiation protection guidance[1]. Based upon previous experience and past practices, however, it is doubtful whether imported food will be a part of the daily diet and that access to Bikini Island can be restricted. Therefore, a return to Eneu Island should be delayed for close to 20 years if radiological dose is the only governing factor unless a firm commitment can be made which will guarantee that adequate imported food will be available and used by the people, and that residence can be restricted to Eneu Island. If the Enewetak radiation exposure criteria[2] are to be applied to the Eneu population, it is unlikely that the radiation doses to the people would be in compliance with the criteria for approximately 20 years, even if imported food is available and if mobility is restricted. Under either criteria, a return to Bikini Island would be delayed even longer because of the higher levels of radionuclides in the soil.

[1]The Federal Radiation Council (FRC) recommended exposure limits of 500 mrem/yr to individuals, 170 mrem/yr to average population groups, and 5000 mrem/30 yrs to the average population of the U.S.

[2]Enewetak criteria are one half of the FRC exposure limit for individuals and 80 percent of the FRC 30-year exposure limit.

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BACKGROUND

In August 1978 the residents of Bikini Island left their Atoll because measurements of radiocesium made in April 1978 showed accumulations in the bodies of 13 out of 101 people; if this level were maintained for one year, it would result in an annual radiation dose equal to or greater than the 500 mrem/yr federal radiation protection criteria for exposure of individuals. The dose rate might have increased further had those people continued to live on Bikini Island. At that time the question was raised about whether or not the Bikini people could relocate on Eneu Island. Information then available on the radionuclide content of test plantings of food crops on Eneu was inadequate, and there were insufficient samples of coconuts grown on Eneu Island to answer the question. In the Congressional Committee hearings[3] held on July 25, 1978, it was agreed that priority would be given to collecting and analyzing available data to update radiation exposure estimates for use by those who are considering whether the Bikini people should return to live on Eneu Island. In early 1979, new information was obtained so that dose predictions for residence on Eneu Island could, for the first time, be based upon data from analysis of actual food items of the diet grown on the island rather than on theoretical predictions derived from soil concentrations.

RADIATION SOURCES

People living on Eneu Island receive radiation exposure from two sources: 1) external irradiation from natural background radiation

[3]Interior and Related Agencies Subcommittee, Committee on Appropriations, House of Representatives.

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(which is very low) and from radionuclides remaining in the soil from nuclear tests at Bikini Atoll; 2) internal irradiation from radionuclides deposited in the body as a consequence of eating foods from the island area (including foods grown in the contaminated soil and marine life from the lagoon) and from inhaling airborne radionuclides. Because of the metabolic characteristics of the predominant radionuclides (cesium-137 and strontium-90) at Eneu, bone marrow doses are expected to be slightly greater than whole body doses, and will be the limiting exposure.

The external radiation dose rate has been determined from data obtained during a recent aerial radiological survey. The external doses to whole body and bone marrow for Eneu residents were calculated using measurements of external radiation and estimates of time spent in various areas of the island (e.g., village, island interior, on the lagoon, etc.).

The internal radiation doses were calculated from estimates of the amounts and kinds of food in the diet (with and without imported foods) and from measurements of the radionuclide content of these foods and of drinking water (see Attachments 1, 2, 3, and 4). Levels of radioactivity in food shown in these attachments were obtained from analysis of samples collected on Eneu Island, except for pandanus which was not yet available. Since pandanus would be a diet constituent, the contributed dose is calculated from uptake coefficients and soil concentrations of radionuclides. The 30-year dose commitment is calculated assuming only radioactive decay with no reduction from other possible mechanisms.

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It is expected that some individuals on Eneu Island will receive doses higher or lower than the predicted average dose. This may result from: 1) eating a larger or smaller quantity of food than that shown in the assumed diet, 2) eating more or less of certain foods containing the highest radioactivity levels, and 3) eating foods grown from areas on the island having soil concentrations higher or lower than the average. In this regard it should be noted also that the former "...Federal Radiation Council suggests the use of the arbitrary assumption that the majority of individuals do not vary from the average by a factor greater than three."[4] This factor of three is used in establishing and distinguishing between guidance for the maximum annual dose to the average individual within that population and guidance for the potentially highly exposed individual within that population.[5]

FEDERAL GUIDANCE

Radiation Protection Guides for the U.S. were approved by the President and are used by federal agencies in their radiation protection activities. These guides specify the radiation dose that should not

[4]Report No. 1, Background Material for the Development of Radiation Protection Standards, Staff Report of the Federal Radiation Council, U.S. Department of Health, Education and Welfare, May 13, 1960, pg. 27.

[5]The "maximum annual dose" refers to the dose in that year in which the exposure of the average individual is greatest, taking into account the buildup and the removal and decay of radionuclides in the body. The majority of the highly exposed individuals within this population are assumed not to receive an annual exposure more than a factor of three greater.

be exceeded without careful consideration of the reasons for doing so,[6] and that every effort should be made to encourage the maintenance of radiation doses as far below these guides as practicable. To comply with these standards, certain conditions must be met. First, the basic FRC recommendation is "...that the yearly radiation exposure to the whole body of individuals in the general population...should not exceed 0.5 rem."[7] The FRC recognized, however, that exposure of individuals may be difficult to monitor under some circumstances; thus they suggested that the limit to individuals may be met by the use of average limits to the popualtion. Second, therefore, the FRC indicated that: "Under certain conditions, such as widespread radioactive contamination of the environment, the only data available may be related to average contamination or exposure levels. Under these circumstances, it is necessary to make assumptions concerning the relationship between average and maximum doses. The Federal Radiation Council suggests the use of the arbitrary assumption that the majority of individuals do not vary from the average by a factor greater than three. Thus, we recommend the use of 0.17 rem for yearly whole-body exposure of average population groups... It is critical that this guide be applied with reason and judgment. Especially, it is noted that the use of the average figure, as a substitute for evidence concerning the dose to individuals, is permissible only when

[6]The Federal Radiation Council, in Report No. 1 (see footnote 4, pp. 26-27), stated that the guidance should not be exceeded unless "...a careful study indicates that the probable benefits will outweigh the potential risk."

[7]See Note 4, p. 26.

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there is a probability of appreciable homogeneity concerning the distribution of the dose within the population included in the average."[8] Third, "When the size of the population group under consideration is sufficiently large, consideration must be given to the contribution to the genetically significant population dose. The Federal Radiation Council...recommends the use of the Radiation Protection Guide of 5 rem in 30 years...for limiting the average genetically significant exposure of the total U.S. population. The use of 0.17 rem per capita per year, as described (above) as a technique for assuring that the basic Guide for individual whole body dose is not exceeded, is likely in the immediate future to assure that the gonadal exposure Guide is not exceeded."[9] Therefore, the whole body dose is considered to be the equivalent of the genetically significant dose.

Because of the absence of radiation protection guides specific for the Marshall Islands, criteria were developed from the basic Federal guidance for evaluating land use options for use in planning the cleanup and rehabilitation of Enewetak Atoll.[10] These criteria are presented here since they were developed subsequent to the decision regarding the cleanup and rehabilitation of Bikini Atoll. It was

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[8]See Note 4, p. 27.

[9]See Note 4, p. 27.

[10]Cleanup, Rehabilitation, Resettlement of Enewetak Atoll - Marshall Islands, Environmental Impact Statement, Defense Nuclear Agency, April 1975.

recognized that decisions on land use involve consideration of predicted radiation doses which have inherent uncertainties. To make allowance for this, radiation criteria were chosen that are 50% of the annual Federal guidance for individual whole body and bone marrow doses and 80% of the 30-year whole body dose for population exposures. Therefore, the Enewetak criteria limits the dose to the whole body or the bone marrow of individuals to 250 mrem/yr and the dose to the average individual within the population to 4000 mrem/30 yr. (It should be noted that use of a percentage of the FRC values "... is not to be viewed as an attempt to establish new standards but is considered to be a necessary precaution in the application of current standards."[11] The adoption of limits for Enewetak equal to one-half the FRC guide for individuals and 80 percent of the FRC guide for 30-year limits is a result "... of the uncertainty concerning dose estimates which depend greatly on the foods people will choose to eat and the way they will choose to live."[12] While dose estimates are to be compared to these percentages of the FRC guides, actual exposure levels monitored after the people return should be compared to the 100 percent values of the FRC guides.[13])

CALCULATED DOSES LIVING IN ENEU

The calculated doses[14] shown below are for two living patterns and for two assumed diets. The diets are based on the recent experience

[11]See footnote 10, Vol. II., Sec. B, p. III-10.

[12]See footnote 10, Vol. I., Sec. 5, p. 5-7.

[13]See footnote 10, Vol. I., Sec. 5, p. 5-7 and Vol. II., Sec. B, p. III-11.

[14]All dose estimates are rounded off and are based upon information contained in "An Updated Radiological Dose Assessment of Eneu Island at Bikini Atoll," Robison, W. L. and Phillips, W. A., UCRL-52775, 1979, in draft.

and observations of the scientific teams who have been working on Bikini Atoll.[15]

Calculated Maximum Annual Dose (Average for Population)

(Federal guidance is 170 mrem/yr)

A. People live 100% of the time on Eneu Island.

	With Food Imports	Without Food Imports
Whole Body	120 mrem/yr	210 mrem/yr
Bone Marrow	140 mrem/yr	260 mrem/yr

B. People live 80% of the time on Eneu Island and visit Bikini Island 20% of the time, and assuming no food from Bikini Island is eaten.

	With Food Imports	Without Food Imports
Whole Body	170 mrem/yr	260 mrem/yr
Bone Marrow	190 mrem/yr	300 mrem/yr

NOTE: On attachments 5-9 it is assumed that the maximum exposed individuals would be three times these values as per the FRC guidance.

Calculated 30-Year Dose (Average Whole Body)

(Federal guidance is 5000 mrem/30 yrs.)

A. People live 100% of the time on Eneu Island.

With Food Imports	Without Food Imports
2700 mrem	4700 mrem

B. People live 80% of the time on Eneu Island and visit Bikini Island 20% of the time, and assuming no food from Bikini is eaten.

With Food Imports	Without Food Imports
3700 mrem	5700 mrem

NOTE: People who recently lived on Bikini Island already have received a dose of about 1000 mrem. This has not been included in the above estimates.

[15]The dietary parameters are important factors in the calculation of dose estimates, and the diet is continually being refined as additional information becomes available. To the extent that the diet used in this document (Attachment 1) may be refined, the dose estimates also may change accordingly.

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If there is increased utilization of Bikini Island, the projected doses can be estimated by applying the finding that the respective Bikini doses would be about eight times the doses for Eneu residence shown above (maximum annual and 30-year doses).[16]

If return to Eneu and Bikini is delayed, the above dose estimates would be reduced by a factor of two for every 30-year period the return is delayed. This is due to the fact that the radioactivity of the two radionuclides (cesium-137 and strontium-90) that contribute most to whole body and bone marrow doses, decays in the environment with an effective half-time of 30 years.

Attachments 5 and 6 present estimates of the maximum annual whole body and bone marrow doses for the average population if, starting with 1979 as the zero time, a return to live on Eneu Island (the six lower curves) or on Bikini Island (the two highest curves) is delayed. Attachments 7 and 8 present similar information for the individuals receiving the highest doses. Attachment 9 shows the predictions for 30-year doses.

DISCUSSION

The predicted maximum annual whole body and bone marrow doses for the average Eneu Island population in Attachments 5 and 6 can be compared with the 170 mrem/yr federal guidance. If a monitoring program

[16]The basis for this estimate is that the concentrations of radionuclides in the soil and in coconuts on Bikini are about eight times greater than those on Eneu.

is in place, doses to the highest individuals can be compared with the standard for individuals which is 500 mrem/yr (see Attachments 7 and 8). Doses for the highest individuals can also be compared with the Enewetak criterion which is 250 mrem/yr.

Whether annual doses (for the population or for individuals) and 30-year doses for people living on Eneu or Bikini Islands meet or exceed federal guidance and/or the recently developed Enewetak criteria depends upon the amount, kind, and source of local foods that are eaten, the availability of imported foods, the proportion of residence time on Eneu Island and on Bikini Island, and the time interval between now and the date of rehabitation.

Attachments 5 through 9 illustrate the estimated dose (vertical axis) to the population or to an individual in the population if the people are returned to Eneu or to Bikini in any particular year (horizontal axis, beginning in 1979). Moreover, the attachments illustrate estimated doses for eight separate living patterns as identified on Attachment 5. Federal guidance and Enewetak criteria levels also are indicated. If any particular curve does not go above the guidance or criteria level, a return of the people could be accomplished that year without expecting to exceed the guidance or criteria, providing residence conforms to the conditions upon which the doses are estimated. If a curve goes above the guidance or criteria, the point at which it crosses the guidance or criteria, as read from the horizontal axis, is the approximate number of years that return should be delayed so that the radiation dose would not be expected to exceed the guidance or criteria.

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For example, if the Bikinians returned in 1979 to Eneu, if the diet consists of both local and imported foods as shown in Attachment 1, and if they spend no time on and consume no food from Bikini Island, (Attachments 5-9, Curve 1) their predicted maximum annual whole body and bone marrow doses and their 30-year whole body doses (average for the population) would be within the federal guidance of 170 mrem/yr and 5000 mrem/30 yr. Under these same conditions, exposures of the highest individuals would be within the 500 mrem/yr federal guidance for whole body and bone marrow but would exceed the 250 mrem/yr Enewetak criterion. Without imported food (Attachments 5-9, Curve 3) both predicted average population and highest individual doses exceed the 170 and 500 mrem/yr federal guidance, while the 30-year estimate of 4700 mrem/30 yr just meets the 5000 mrem/30 yr federal guidance but exceeds the 4000 mrem/30 yr Enewetak criterion.

Furthermore, it must be recognized that there is a significant degree of uncertainty in the dose estimates because of the need to predict lifestyles of peoples. For most situations it is estimated that these values may be realistic to within a factor of two; under unusual circumstances they may be within a factor of three.[17] These, then, would be the approximate error bands associated with the curves in Attachments 5-9.

A summary comparison of these curves with the federal guidance and with the Enewetak criteria is given in Attachment 10.

[17] Robison, W.L. and Phillips, W.A., "An Updated Radiological Dose Assessment of Eneu Island at Bikini Atoll, UCRL-52775, 1979, in draft.

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OTHER CONSIDERATIONS

In evaluating radiological conditions on Eneu and Bikini Islands, there are certain other factors which should be taken into account:

1. Exposure to any radiation is believed to involve some risk which is proportionally greater as the radiation exposure increases; therefore, any unnecessary radiation exposures should be avoided and all exposures kept as low as is reasonably achievable.

2. The benefits and risks inherent in the Federal guidance are those applicable to persons living outside of restricted access areas in the U.S. under normal peacetime operations.

3. There appear to be difficulties associated with the practicality and reliability of applying administrative controls over long periods of time with the intent to limit exposure.

4. The need to apply a safety factor where there are uncertainties in the predicted dose estimates, resulted in the use of a factor of 2 in applying Federal guidance to the Enewetak situation.

5. The marketability for copra produced from coconuts grown on Bikini and Eneu Islands is questionable at the present time.

There are also nonradiological factors which have not been considered. Among these are:

1. The benefits to be derived by the Bikini people in returning to their Atoll according to their own decisions and preferences.

2. Resettlement options at locations other than Bikini Atoll.

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DIETS

FOOD ITEM	ENEU ISLAND FOODS ONLY INTAKE G/DAY	ENEU ISLAND AND IMPORTED FOODS INTAKE G/DAY
FISH	600	300
DOMESTIC MEAT	50	20
PANDANUS FRUIT	75	15
BREADFRUIT	200	100
WILD BIRDS	10	-
BIRD EGGS	5	-
COCONUT FLUID	300	200
COCONUT MEAT	100	50
CLAMS	25	15
GARDEN FRUITS AND VEGETABLES	50	30
TOTAL	1415	805
IMPORTED FOODS		825
TOTAL		1630

Attachment 1

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CONCENTRATION OF ^{137}Cs IN SUBSISTENCE CROPS AND FISH AT ENIU ISLAND

Attachment 2

FOOD PRODUCT	NO. OF SAMPLES	AVERAGE CONCENTRATION pCi/g WET WEIGHT	RANGE OF CONCENTRATION pCi/g WET WEIGHT
Coconut Meat (Green)	6	22.7	3.5-48
Coconut Meat (Intermediate)	9	16.5	4.8-32
Coconut Meat (Mature)	31	30.9	5.3-117
Coconut Meat (Sprouted, Springy)	8	27	16-52
All coconut meat	54	27	3.5-117
Coconut Fluid	28	13.5	1.2-44
Breadfruit	2	6.5	5.2-7.8
Squash	12	8.5	1.6-20
Papaya	18	14	1.6-31
Banana	3	0.92	0.54-1.3
Sweet Potato	2	3.6	2.3-5
Watermelon	17	2.6	0.26-7.2
Garden Fruits and Vegetables (Average of Squash, Papaya, Banana, Sweet Potato, Watermelon)		5.9	
Fish (Mullet)+	6	0.026+	
Domestic Meat		15*	

+ From V. Noshkin

* Estimated from Bikini pig data

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Attachment 3

CONCENTRATION OF ^{90}Sr IN SUBSISTENCE CROPS AND FISH AT ENEU ISLAND

FOOD PRODUCT	NO. OF SAMPLES	AVERAGE CONCENTRATION pCi/g WET WEIGHT	RANGE OF CONCENTRATION pCi/g WET WEIGHT
COCONUT MEAT	9	0.021	0.0033 - 0.052
COCONUT FLUID*	-	0.021*	-
BREADFRUIT	2	1.9	0.47 - 3.4
WATERMELON	8	0.031	0.012 - 0.063
SQUASH	6	0.064	0.024 - 0.15
PAPAYA	5	0.29	0.052 - 0.39
SWEET POTATO	1	0.13	-
GARDEN FRUITS AND VEGETABLES (AVERAGE OF WATERMELON, SQUASH, PAPAYA, SWEET POTATO)		0.13	
FISH (MULLET)		0.076+	
CLAMS		0.005+	
DOMESTIC MEAT		0.011**	

* ASSUMED TO BE THE SAME AS COCONUT MEAT

\+ FROM V. NELSON AND B. SCHELL

** FROM 1975 BIKINI DOSE ASSESSMENT

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Attachment 4

CONCENTRATION OF $^{239+240}Pu$ IN SUBSISTENCE CROPS AND FISH AT ENEU ISLAND

FOOD PRODUCT	NO. OF SAMPLES	AVERAGE CONCENTRATION PCi/G WET WEIGHT	RANGE OF CONCENTRATION PCi/G WET WEIGHT
COCONUT MEAT	9	2.8×10^{-5}	4.1×10^{-6}-5.3×10^{-5}
COCONUT FLUID	-	2.8×10^{-5}*	-
BREADFRUIT	1	1.7×10^{-5}	-
WATERMELON	8	1.3×10^{-5}	4.4×10^{-6}-2.0×10^{-5}
SQUASH	6	8×10^{-6}	3.5×10^{-6}-1.9×10^{-5}
PAPAYA	3	8.3×10^{-6}	6.5×10^{-6} - 1.1×10^{-5}
GARDEN FRUITS AND VEGETABLE (AVERAGE OF WATERMELON, SQUASH, PAPAYA)		9.8×10^{-6}	
FISH (MULLET)+	6	1.3×10^{-4} +	

* ASSUMED TO BE THE SAME AS COCONUT MEAT

\+ FROM V. NOSHKIN

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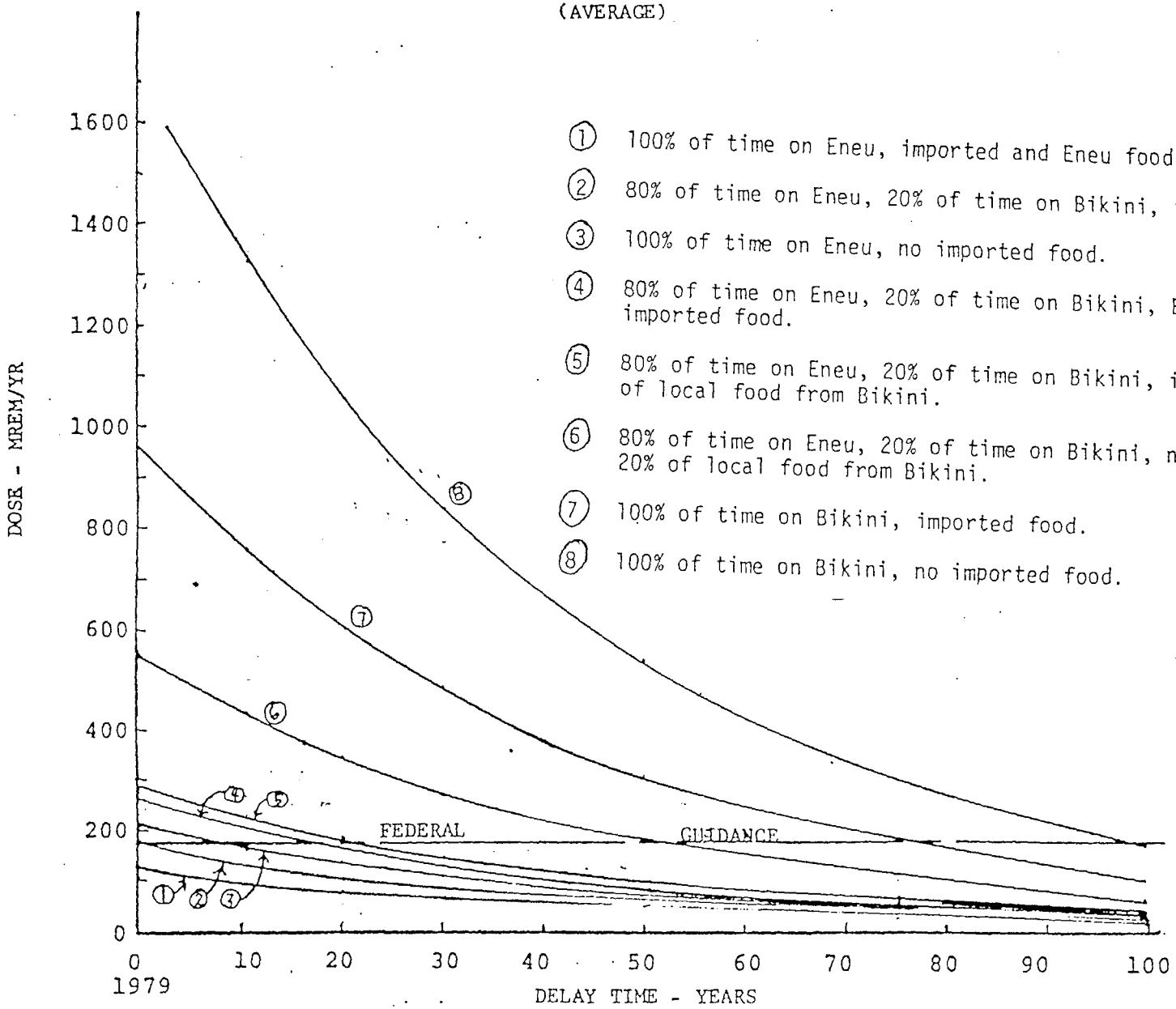
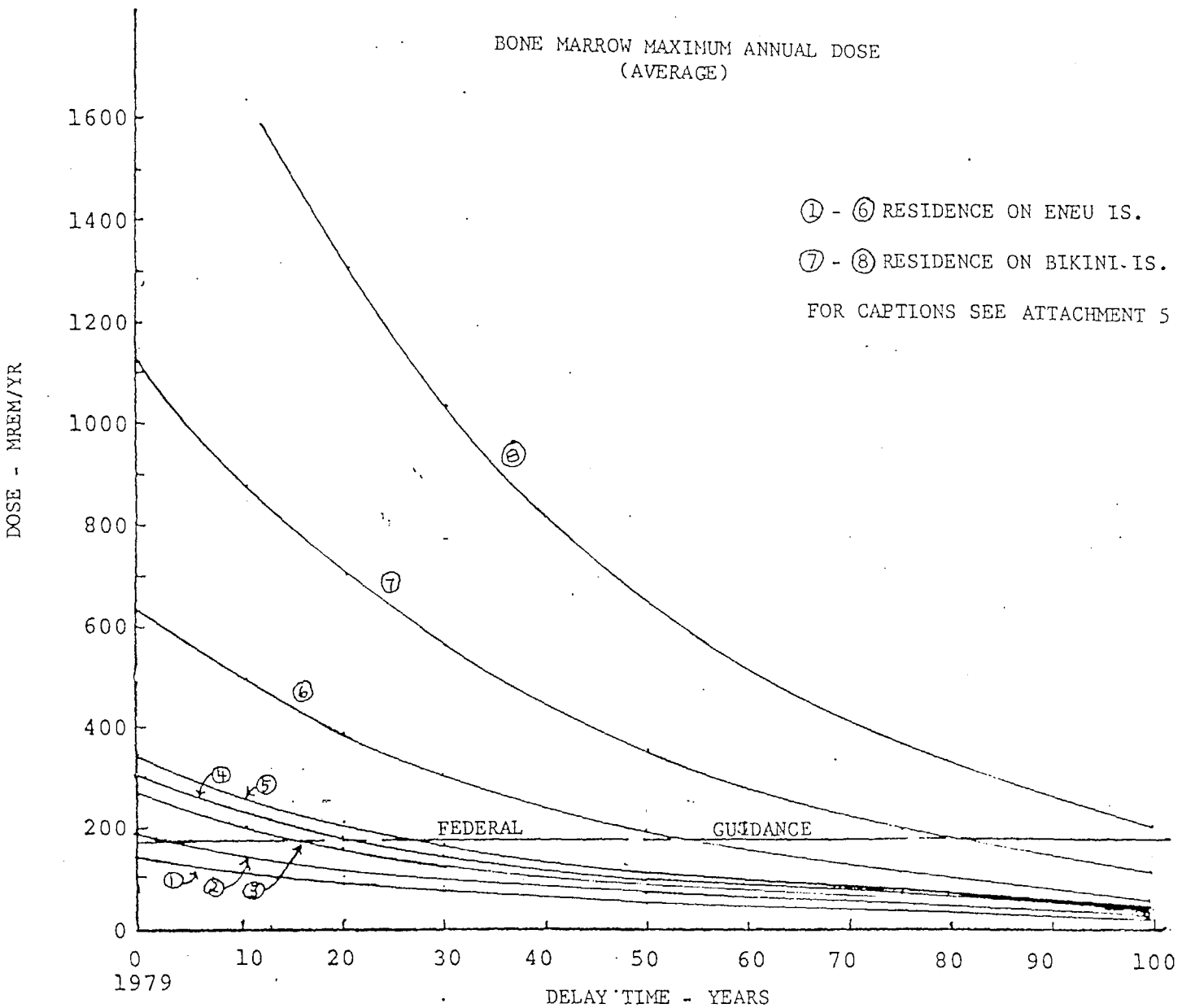
WHOLE BODY MAXIMUM ANNUAL DOSE
(AVERAGE)



Attachment 5



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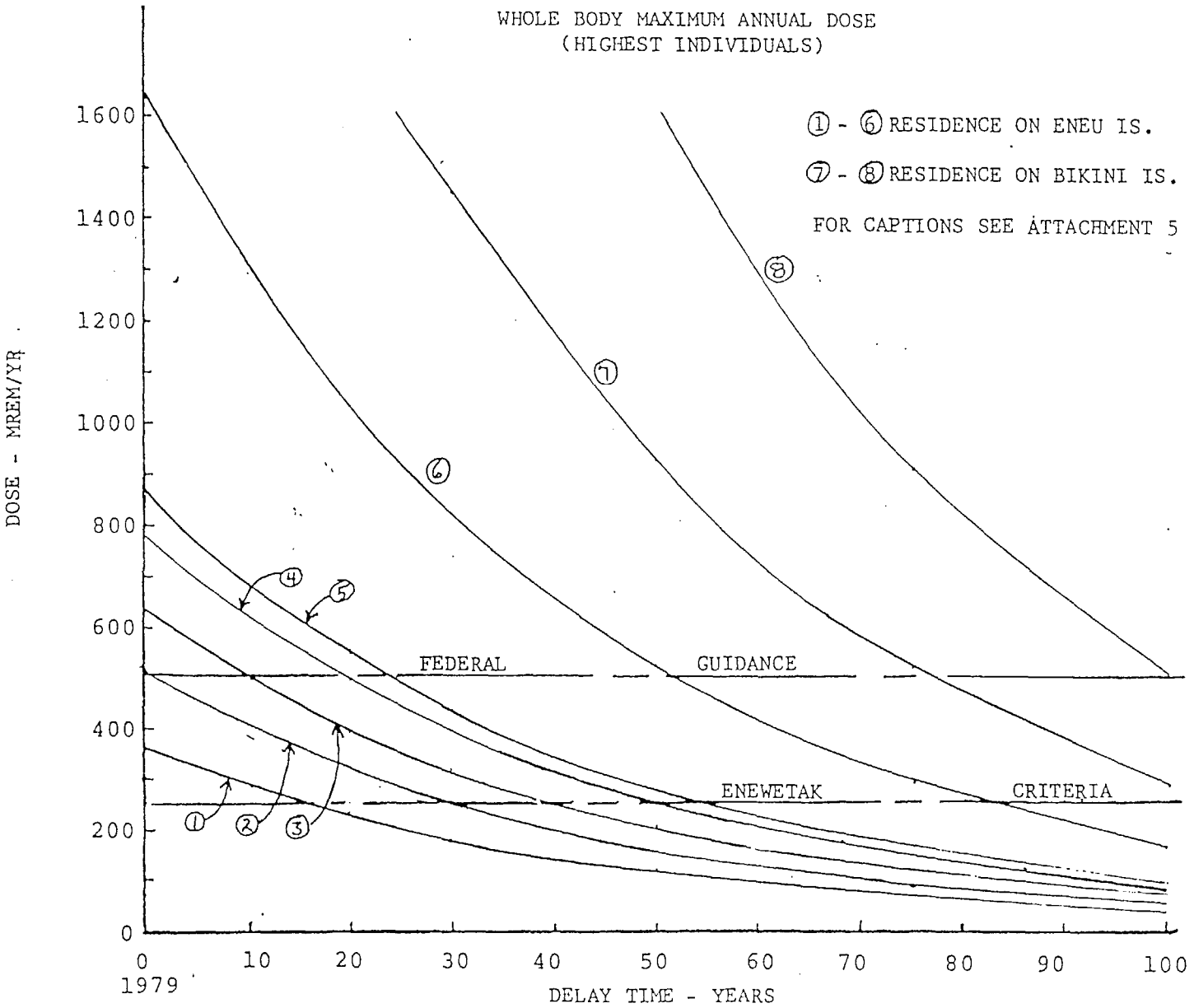

Attachment 7

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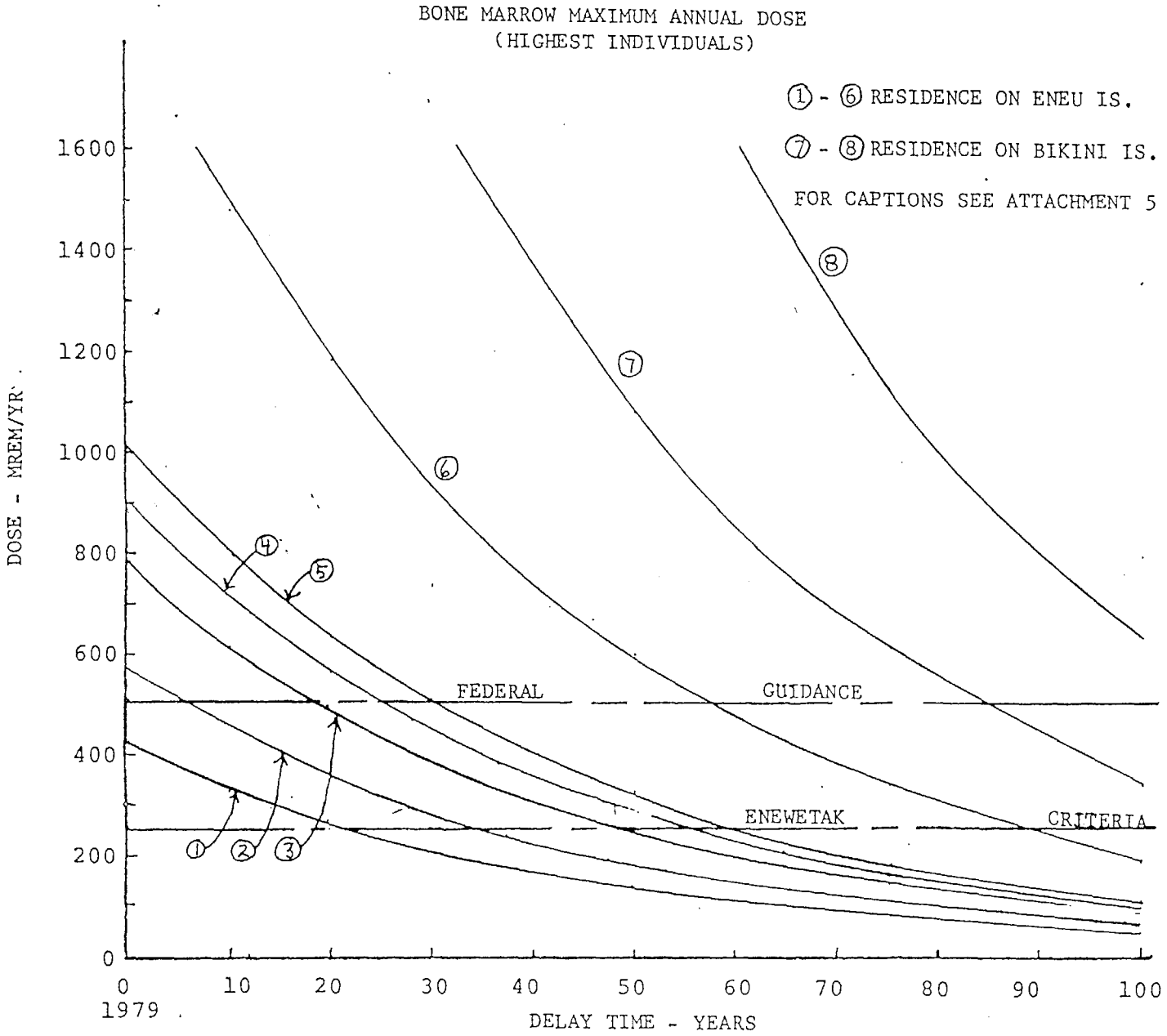

Attachment 8

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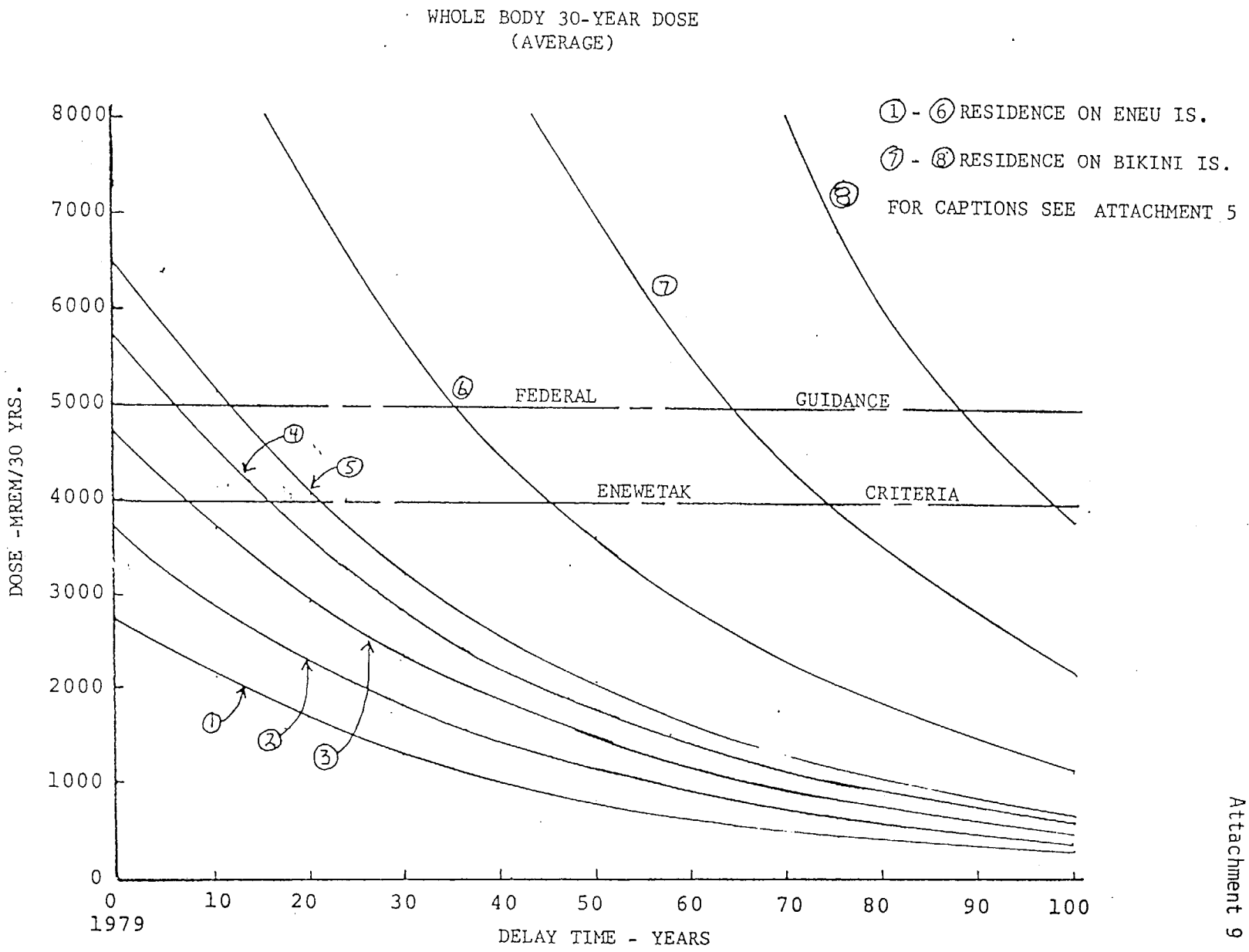

Attachment 9

Living/Eating Pattern	COMPLIANCE OF ESTIMATED DOSES* TO FEDERAL GUIDELINES Population 170 mrem/Yr	FEDERAL GUIDELINES Population 5000 mrem/30 Yrs	FEDERAL GUIDELINES Individual 500 mrem/Yr	ENEWETAK CRITERIA Individual 250 mrem/Yr	ENEWETAK CRITERIA Individual 4000 mrem/30 yrs
With Food Imports Plus Eneu Food					
100% of Time on Eneu	YES	YES	YES	NO (~20-25 Yrs)	YES
80% of Time on Eneu, 20% on Bikini	Borderline (up to 5 Yrs)	YES	NO (~5-10 Yrs)	NO (~30-40 Yrs)	YES
With No Food Imports; Eneu Food Only					
100% of Time on Eneu	NO (~15-20 Yrs)	YES	NO(~15-20 Yrs)	NO (~45-50 Yrs)	NO (~5-10 Yrs)
80% of Time on Eneu, 20% on Bikini	NO (~20-25 Yrs)	NO (~5-10 Yrs)	NO(~20-25 Yrs)	NO (~50-60 Yrs)	NO (~15-20 Yrs)

*Number in parentheses is the approximate range of the number of years until the indicated living/eating pattern is estimated to be in compliance with the guidance/criteria.

ATTACHMENT 10