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APPENDIX III

REVIEW OF RADIATION PROTECTION STANDARDS

The Task Group has considered a number of concepts in devising an approach to guidance for cleanup and rehabilitation of Enewetak Atoll, accepting some and rejecting others. Notably, the concept that AEC recommendations should consist of a series of alternatives or fall back positions with the degree or level of radiation exposure reduction ultimately determined by some later deliberation based on factors such as availability of funds was rejected. The consensus of the Task Group opinion was that these recommendations should be specific and unequivocal, and should establish a clear position on what is needed. To do less would be unfair to the Federal agencies who have accepted responsibilities to perform the rehabilitations and to the Enewetak people who are looking to this agency for advice.

The judgement of the Task Group is that rehabilitation must conform with current radiation standards applicable for normal operations (not for accidents or for radiation workers) and with good health physics practice in implementing these standards. A summary of current radiation protection standards and material related to health risks that may be associated with the standards reviewed and radiation criteria recommended by the Task Group follows.

A. Federal Radiation Council (FRC)

Basic FRC numerical guidance and health protection philosophy are similar to those of the ICRP and NCRP. Radiation Protection Guides (RPG's) are provided which deal with exposures of individuals and of population groups. Actions are to be directed primarily toward control of the sources of radioactivity to restrict entry into the environment but also toward control of radioactive materials after entry into the environment in order to limit intake by humans. The RPG's express the dose that should not be exceeded without careful consideration of the reasons for doing so. Every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable. The RPG's are intended for use with normal peacetime operations. There should be no man-made radiation exposure without expectation of benefits from such exposure. Considering such benefits, exposure at the level of the RPG is considered as an acceptable risk for a lifetime. The RPG's for the population are expressed in terms of annual exposure, except for the gonads, where the ICRP recommended value of five rems in 30 years is

used. FRC states that the operational mechanism described for application of criteria to limit the whole body dose for individuals to 0.5 rem per year and to limit exposure of a suitable sample of the population to 0.17 rem per year is likely to assure that the gonadal exposure guide will not be exceeded.

The child, infant, and unborn infant are identified as being more sensitive to radiation than the adult. Exposures to be compared with the guidance are to be derived for the most sensitive members in the population. The guide for the individual applies when individual exposures are known; otherwise, the guide for a suitable sample (one-third the guide for the individual) is to be used. This operational technique may be modified to meet special situations.

The FRC primary numerical guides, expressed in rem, are provided in two reports, FRC Nos. 1 and 2, summarized in Table I. Secondary numerical guides developed by FRC are expressed in terms of daily intake of specific radionuclides corresponding to the annual RPG's. Consideration is given to all radionuclides through all pathways to derive a total annual exposure for comparison with FRC guides. However, for many practical situations, relatively few radionuclides yield the major contribution to total exposure; by comparison, exposures from others are very small.

TABLE I

FRC RADIATION PROTECTION GUIDES [1/]

	INDIVIDUAL	POPULATION GROUP
Whole body	0.5 rem/yr	0.17 rem/yr
Gonads	-	5 rems/30 yrs
Thyroid [2/]	1.5 rems/yr	0.5 rem/yr
Bone marrow	0.5 rem/yr	0.17 rem/yr
Bone	1.5 rems/yr	0.5 rem/yr
Bone (alternate guide) [3/]	0.003 μg of ^{226}Ra in adult skeleton	0.001 μg of ^{226}Ra in adult skeleton

1/ For conditions and qualifications see FRC Report Nos. 1 and 2.

2/ Based upon a child's thyroid, 2 gms in weight and other factors listed in paragraphs 2.10-2.14 of FRC Report No. 2.

3/ Or the biological equivalents of these amounts of ^{226}Ra.

B. The International Commission on Radiological Protection (ICRP)

The ICRP originated in the Second International Congress of Radiology in 1928. It has been looked to as the appropriate body to give general guidance on widespread use of radiation sources caused by rapid developments in the field of nuclear energy. ICRP recommendations deal with the basic principles of radiation protection. To the various national protection bodies is left the responsibility for introducing the detailed technical regulations, recommendations, or codes of practice best suited to their countries. Recommendations are intended to guide the experts responsible for radiation protection practice.

ICRP states that the objectives of radiation protection are to prevent acute radiation effects and to limit the risks of late effects to an acceptable level. It holds that it is unknown whether a threshold exists, and it is assumed that even the smallest doses involve a proportionately small risk. No practical alternative was found to assuming a linear relationship between dose and effect. This implies that there is no wholly "safe" dose of radiation.

Exposure to natural background radiation carries a probability of causing some somatic or hereditary injury. However, the Commission believes that the risk resulting from exposures received from natural background should not affect the justification of an additional risk from man-made exposures. Accordingly, any dose limitations recommended by the Commission refer only to exposure resulting from technical practices that add to natural background radiation. These dose limitations exclude exposures received in the course of medical procedures. (These same qualifications with regard to natural background and medical procedures are applied to NCRP and FRC recommendations.)

ICRP developed the concept of "acceptable risk." Unless man wishes to dispense with activities involving exposures to ionizing radiation, he must recognize that there is a degree of risk and must limit the radiation dose to a level at which the assumed risk is deemed to be acceptable to the individual and to society in view of the benefits derived from such activities.

For planned or controlled exposures of individuals and populations, the ICRP has recommended the term "dose limit." Recommended dose limits are thought to be associated with a very low degree of risk. For unplanned exposures from uncontrolled sources

the term "action level" is recommended. In general it will be appropriate to institute countermeasures only when their social cost and risk will be less than those resulting from the exposure. Setting of action levels is the responsibility of national authorities.

It is not desirable to expose members of the public to doses as high as those considered to be acceptable for radiation workers because children are involved, members of the public do not make the choice to be exposed, and members of the public are not subject to selection, supervision and monitoring, and are exposed to the risks of their own occupations. For planning purposes, dose limits for members of the public are set a factor of ten below those for radiation workers.

The ICRP dose limits for individual members of the public are presented in Table II. No maximum "somatically significant" dose for a population is given. The genetic dose to the population should be kept to the minimum amount consistent with necessity and should not exceed 5 rems in 30 years from all sources other than natural background and medical procedures. No single type of population exposure should take up a disproportionate share of the total of the recommended dose limit.

TABLE II

ICRP DOSE LIMITS [1/]

	Individuals	Population
Gonads, red bone-marrow	0.5 rem/yr	-
Skin, bone, thyroid	3.0 rems/yr [2/]	-
Hands and forearms; feet and ankles	7.5 rems/yr	-
Other single organs	1.5 rems/yr	-
Genetic dose [3/]	-	5 rems/30 yrs

1/ For conditions and qualifications see ICRP Publication 9.

2/ 1.5 rems/yr to thyroid of children up to 16 years of age.

3/ See paragraphs 84, 85, and 86, ICRP Publication 9.

C. National Council on Radiation Protection and Measurements* (NCRP)

The NCRP position is that the rational use of radiation should conform to levels of safety to users and the public which are at least as stringent as those achieved for other powerful agents. Continuing and chronic exposure attributable to peaceful uses of ionizing radiation are assumed.

The NCRP has adopted the assumption of no-threshold dose-effects relationship and uses the term "dose limits" in providing guidance on population exposures. All radiation exposures are to be kept as low as practicable. The numerical values of exposure as presented are to be interpreted as recommendations, not regulations. Use of the no-threshold concept involves the thesis that there is no exposure limit free from some degree of risk.

To establish criteria, NCRP uses the concept of "acceptable risk" (where the risk is compensated by a demonstrable benefit) broken down to fit classes of individuals or population groups exposed for various purposes to different quantities of radiation. Numerical recommendations for dose limits are necessarily arbitrary because of their mixed technical value-judgement foundation. The dose limits for individual members of the public and for the average population recommended by NCRP represent a level of risk considered to be so small compared with other hazards of life, and so well offset by perceptible benefits when used as intended, that public approbation will be achieved when the informed public review process is completed.

For peaceful uses of radiation, NCRP provides yearly numerical dose limits for individual members of the public, considering possible somatic effects, and strongly advocates maintenance of lowest practicable exposure levels, especially for infants and the unborn. NCRP also recommends yearly dose limits for the average population based upon somatic and genetic considerations and recommends the same value as ICRP of 5 rems in 30 years for gonadal exposure of the U.S. population. Table III contains a summary of recommended values. NCRP Report No. 39 entitled, "Basic Radiation Protection Criteria," dated January 15, 1971, contains the most recent updating of NCRP recommendations for protection of the public.

*Formerly known as the National Committee on Radiation Protection and Measurements.

TABLE III

NCRP DOSE LIMITS [1/]

	Individual	Population
Whole body	0.5 rem/yr	0.17 rem/yr
Gonads	-	0.17 rem/yr [2/]
Gonads (alternative [3/] objective)		5.0 rems/30 yrs

D. Criteria Against Which Survey Findings and Alternative Measures Will Be Evaluated

The Task Group approached the question of radiation dose criteria from two directions. First, FRC, ICRP, and NCRP recommendations reviewed above were judged as to applicability in this situation. Second, a risk approach was reviewed using information from ICRP, UNSCEAR, and the National Academy of Science BEIR Committee. The results of this latter effort are summarized in Part F which follows.

The radiological survey of Enewetak Atoll provides a comprehensive data base needed to derive recommendations relative to the radiologically safe return of the Enewetak people. These recommendations are to be based on an evaluation of the significance of all radioactivity on the Atoll in terms of the total exposure to be expected in the returning population, and on consideration of those reasonable actions and constraints which, where made, will result in minimum exposures.

The guidelines used in deriving these recommendations can be summarized as two interdependent considerations:

1. Expected exposures should be minimized and should fall in a range consistent with guidance put forward by the Federal Radiation Council (FRC).

1/ For conditions and qualifications on application, see NCRP Report No. 39, "Basic Radiation Protection Criteria."

2/ To be applied as the average yearly value for the population of the United States as a whole. See paragraph 247, NCRP Report No. 39.

3/ See paragraph 247, NCRP Report No. 39.

2. Actions taken to reduce exposures should be those which show promise of significant exposure reduction when weighed against total expected exposures and the "costs" of the actions. "Costs," in this context, are measured primarily in terms of costs to the Enewetak people as constraints on their activities or as dollar costs for cleanup or remedial action.

In these evaluations, it should be emphasized that dosages through various pathways are estimated on the basis of environmental data and considerations of expected living patterns and dietary habits. While "radiation standards" do not exist for environmental contamination levels in substances such as soil and foodstuffs, there is general agreement in terms of conservative models of these pathways and the relationships between a certain level in the environment and the likely dose to result from the pathway exposure.

The area of plutonium in soils, however, is one for which there is no general agreement as to the quantitative relationship between levels in soils and dosages to be expected through the inhalation pathway, the primary one through which man can receive a significant dose from plutonium. The ICRP recommends a maximum permissible average concentration (MPC) of 1 picocurie per cubic meter (pCi/m^3) of air for "insoluble" plutonium and 0.06 pCi/m^3 for "soluble" plutonium for unrestricted areas. While the plutonium in the soil at Enewetak is thought to be typical of world-wide fallout, and therefore insoluble, 0.06 pCi/m^3 will be used for the sake of conservatism.

Appendix A of Enewetak Radiological Survey, NVO-140, presents two possible methods for deriving the exposures that may occur through the inhalation pathway for plutonium in soil. (This is the pathway of interest for the present although it is recognized that for the very distant future, ingestion may become more important by comparison. Table 250 of Appendix II shows that exposure to bone, liver, and lung from ^{239}Pu is expected to be a few hundredths of a rem in 30 years for pathways other than inhalation.) This material is produced as Attachment I of this section. The two methods presented are the "resuspension-factor" approach and the "mass-loading" approach. Soil concentrations of ^{239}Pu that would be associated with the standard for ^{239}Pu in air (0.06 pCi/m^3) by the two methods are:

Resuspension-factor approach ..... 1,000 pCi/g

Mass-loading approach ..... 600 pCi/g

A recent report, A Proposed Interim Standard for Plutonium in Soils LA5483-MS, presents recommendations derived from estimates of exposure through inhalation considering the concentration of ^{239}Pu in the very top surface soil.

The following values were recommended:

400 pCi/g - For all particle sizes provided no more than 200 pCi/g in < 100/mm size fraction.

A revised Maximum Permissible Concentration, MPC, of 0.3 pCi/m^3 for individuals was used in these determinations. The estimates apply to large area contamination. Levels several times larger could be permitted for localized deposition.

The Task Group recognizes that the islands of Enewetak Atoll are small and that the areas of highest ^{239}Pu in soil on these islands are smaller still. On the other hand the people live close to the soil. It is also recognized that experts are not in agreement as to the critical organ for inhaled plutonium, whether to use an average dose for this organ, or the model to be used to predict dose. It is the view of the Task Group that available biological and environmental information is not adequate to establish general guidance for cleanup of plutonium contaminated soil. However, guidance for a particular set of circumstances or conditions can be developed on a case-by-case basis using conservative assumptions and safety factor. The following guidance is recommended only for use in making decisions concerning plutonium cleanup operations on islands of Enewetak Atoll:

1. Any areas or locations where soil concentrations of ^{239}Pu are greater than 400 pCi/g should receive corrective action with contaminated soil removed for disposal.

2. Situations with soil levels in the 40 to 400 pCi/g range may receive corrective action with each area or location evaluated on a case-by-case basis.

The following guidance is provided for this evaluation:

a. Islands with soil levels in the above range may be divided into two categories, those of sufficient size for construction of permanent houses, and those that are not.

b. Removal of ^{239}Pu contaminated soil is better justified within the range above for the larger islands such as JANET or SALLY where permanent housing may someday be located and for near surface locations on the larger islands.

c. The smaller islands may be considered of less concern. Their long-term outlook is uncertain since they are sometimes increasing in size and sometimes erroding away. Small islands may be washed over by storm waves and are not a safe site for permanent housing. From that viewpoint, they are in the same category as unnamed sandbars along the reef where other islands may have disappeared or be forming.

d. The amount of effort that properly may be given to soil removal in this range increases as the soil concentration increases.

e. Once an action is taken, the objective is to achieve a substantial reduction in plutonium soil concentrations, and further, to reduce concentrations to the lowest practicable level, not to reduce them to some prescribed numerical value.

3. Areas or locations showing less than 40 pCi/g do not require corrective action because of the presence of plutonium alone.

E. Recommended Guides

The standards issued by FRC are recommend as the basic guidance for evaluation of exposures to individuals to Enewetak.

This is recommended with provisos that:

1. The full amount of the numerical values should not be used for evaluating exposures from a single man-made source, in this case radioactivity from weapons tests. This is applied so that the Enewetak people will not be denied benefits of future nuclear technology because they are receiving exposures from man-made radiation at the maximum level of acceptable standards.

2. Environmental followup surveys and studies of radioactivity levels in people are performed such that the full range of radiation exposures of individual members of the Enewetak population will be known.

3. Exposures of the Enewetak people are kept to the minimum practicable level.

Survey, Cleanup, and Rehabilitation Evaluation

It is recommended in this context that:

1. The FRC Radiation Protection Guide (RPG's) for individuals should be used as the basic standard. The requirement is to assure that exposures for continuous residence in Enewetak Atoll will be well within the annual and 30-year criterion. While these are conservative standards from a health view point, there is no built-in conservatism to account for uncertainty in prediction of annual exposures to individuals. Because of the complex circumstances of exposure and the many pathways, each with its uncertainty, the Task Group recommends use of 50 percent of the FRC annual standards for evaluation of the many cleanup and rehabilitation alternatives at Enewetak Atoll. This 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. The following values apply for evaluation of alternatives:

Whole body	0.25 Rem/yr
Bone marrow	0.25 Rem/yr
Bone	0.75 Rem/yr
Thyroid	0.75 Rem/yr

2. The Task Group recommends use of 100 percent of the FRC RPG's to evaluate post-cleanup and rehabilitation and post-return conditions wherein direct measurement of levels of radiation and radioactivity in foods and in people are made. Under such conditions, dose estimates should be subject to much less uncertainty. The requirement is to assure that exposures are well within the FRC standards. See Section A. of this Appendix for the FRC RPG's.

3. The criteria for evaluating gonadal exposures at Enewetak Atoll should be 4 rems in 30 years. The requirement is to assure that long-term exposures will be well within this criteria. The Task Group feels justified in using 80 percent rather than 50 percent of the FRC standard since there will be ample time to verify exposure estimates using actual sampling of the diet and time to follow the changing pattern of exposures of people.

4. The recommended guidance for cleanup of ^{239}Pu in soil at Enewetak Atoll is:

   a. < 40 pCi/g - corrective action not required.

   b. 40 to 400 pCi/g - corrective action may be needed. Action to be taken should be determined on a case-by-case basis.

   c. > 400 pCi/g - corrective action required.

   In applying the criteria for bone and bone marrow in part 1 above, it is assumed that if annual exposures do not exceed the applicable criteria in the year of highest dose, there will not be a requirement for limiting longer term cumulative exposures. On the other hand, implementation of the "lowest practicable" concept will require considerations of effectiveness of remedial measures to reduce both annual and longer term exposures to the extent practicable.

F. Risk Considerations

The Task Group and its technical advisors have reviewed the available information from ICRP, UNSCEAR, and the National Academy of Science BEIR Committee that could be used to

estimate the health risk that may be associated with long-term exposures at the level of the radiation dose and soil removal criteria being recommended. It is clear from this review that knowledge of the relationship between radiation dose and effects of that dose on man as characterized in dose-effect curves is incomplete even for external radiation exposures. For internal emitters and particularly for plutonium, the situation is even less satisfactory. UNSCEAR has summarized their findings by stating that one should not extrapolate in a linear fashion from effects seen at high doses and dose rates to effects at low doses and dose rates since there is strong likelihood of recovery and repair. The BEIR Committee, using only human data, concluded that since the low dose data were incomplete, one should conservatively assume a linear no-threshold dose-effect curve drawn through data obtained at high doses and dose rates. The committee further suggested that if this linear no-threshold curve is assumed to be correct, it follows that 6,000 cases of cancer would be produced each year in a population of 200,000,000 people exposed at a rate of 0.17 Rem/yr. (This is the FRC RPG for population groups - see Table I.) For the Enewetak population of less than 500 exposed at the same level, one can make the following estimate:

$$\frac{6 \times 10^{3} \text{ cases/yr} \times 500 \text{ people}}{2 \times 10^{8} \text{ people}} = 1.5 \times 10^{-2} \text{ cases of cancer/yr}$$

Using a linear dose-effect curve, exposure at the level of the recommended criterion of 0.25 Rem/yr would give 2.2×10^{-2} cases per year. The Task Group views this as a pessimistic upper limit of risk. It could be inferred that there may be between zero and three cases of cancer in 100 years if the entire Enewetak population were continuously exposed to 0.25 Rem/yr over that time period.

Most of the exposure to whole body, at Enewetak, and in fact, to all organs will come from internal emitters. The shape of the dose-effect curve for exposures from internal emitters is most uncertain because of lack of experience and lack of confidence in extrapolation of high dose and dose rate effects into the very low dose and low dose rate situation. A lack of confidence in

the statistics and risk estimate drawn therefrom has therefore led the Task Group to have serious reservations about their validity. The Task Group holds the opinion that such estimates cannot be used in any definitive way to draw conclusions on whether current radiation standards are too high or too low or as a basis for decision-making relative to resettlement of Enewetak Atoll. While the risk associated with doses at the level of current standards is possibly not zero, it is viewed as being very low as described by FRC, ICRP, and NCRP. The basic FRC standards, conservatively applied, are viewed as suitable for Enewetak rehabilitation provided there is also a serious and concerted effort to keep exposures as low as practicable.