Environmental Monitoring, Research and Dose Assessment Program

Plan for P.L. 96-205

Prepared by the Department of Energy

for the

Department of Interior

November, 1980

Outline of Environmental Monitoring, Research and Dose Assessment Program Plan for P.L. 96-205

1. Introduction

The United States Congress passed, and President Carter signed in March of 1980, Public Law No. 96-205, which provides that:

> The Secretary of the Interior (hereinafter in this section referred to as the "Secretary") shall provide for the people of the atolls of Bikini, Enewetak, Rongelap, and Utirik and for the people of such other atolls as may be found to be or to have been exposed to radiation from the nuclear weapons testing program, a program of medical care and treatment and environmental research and monitoring for any injury, illness, or condition which may be the result directly or indirectly of such nuclear weapons testing program. The program shall be implemented according to a plan developed by the Secretary in consultation with the Secretaries of Defense, Energy, and Health, Education, and Welfare and with the direct involvement of representatives from the people of each of the affected atolls and from the government of the Marshall Islands. The plan shall set forth, as appropriate to the situation, condition, and needs of the individual atoll peoples:
>
> "(1) an integrated, comprehensive health care program including primary, secondary, and tertiary care with special emphasis upon the biological effects of ionizing radiation;
>
> "(2) a schedule for the periodic comprehensive survey and analysis of the radiological status of the atolls to and at appropriate intervals, but not less frequently than once every five years, the development of an updated radiation dose assessment, together with an estimate of the risks associated with the predicted human exposure, for each atoll; and

"(3) an education and information program to enable the people of such atolls to more fully understand nuclear radiation and its effects;

As part of this responsibility the Department of Interior (DOI) requested that the Department of Energy (DOE) prepare for consideration of the Secretary of Interior, a plan for part (2) of the above quoted law.

This plan is in response to the request from the Secretary of the Interior.

2. Background Information for the Northern Marshall Islands; Historical Development of Marshall Island Surveys and Programs.

The United States conducted the nuclear testing program at the Pacific Proving Grounds of Enewetak and Bikini Atolls from 1946 through 1958. As a result, both atolls were contaminated with a variety of radionuclides; Rongelap and Utirik atolls were also contaminated by radioactive fallout. In addition to these 4 atolls, other atolls downwind of the proving grounds, as well as other geographical areas (i.e. Hawaii, Mainland U.S., Europe (etc.) received low levels of radioactive fallout.

A U.S. moratorium on testing started on October 31, 1958 and marked an end to nuclear testing in the Marshall Islands. Since that time short-lived radionuclides (half-lives less than about 4 years) have essentially disappeared from the atoll environment. Also in the 22 years since the conclusion of the testing program, the atolls and islands have been subject to natural environmental processes and the concentration of some radionuclides has decreased in the marine and terrestrial ecosystems. However, concentrations of longer-lived fission products such as ^{137}Cs and ^{90}Sr plus other activation products such as ^{60}Co and the transuranic

radionuclides ^{239}Pu, ^{240}Pu, ^{241}Pu and ^{241}Am, are still present in concentrations which could be of a concern from a public health point of view and needed to be evaluated in order to form a basis for decisions on resettlement options at the atolls.

A limited number of radiological surveys were conducted at Enewetak, Bikini, Rongelap, Utirik and other atolls prior to 1966. These surveys generally inventoried the quantities of radionuclides in specific geographical locations or those associated with different classes of organisms or substances. They were not usually supported by basic physical, chemical or biological modeling of the systems.

Examples of such studies are those by Welander[1] who reported ^{137}Cs, ^{90}Sr and some Pu concentrations in various marine and terrestrial biota at Enewetak and Bikini; and those by Welander [2,3] and Held [4] for radionuclide concentrations in environmental components from Bikini Atoll.

In late 1966 the Secretary of the Interior requested that the Atomic Energy Commission (AEC) determine the condition of Bikini Atoll and make an evaluation of whether the Bikini people could safely return to their atoll.

In 1967 a survey was conducted of Bikini Atoll and a dose assessement was completed;[5] a committee was appointed by the AEC to review the results of the survey and assessment and to make recommendations thereon. The committee recommended certain cleanup, rehabilitation and follow up actions to guide Federal agencies involved in the assessment. On Aug. 12, 1968, President of the United States, Lyndon B. Johnson, announced, in a letter to the Secretary of Defense, a major federal program to prepare for the return of the people to Bikini.

In 1969 the Department of Defense and the AEC commenced the cleanup of debris and equipment from Bikini. At this time agricultural reclamation was also begun with the removal of scrub vegetation and the planting of coconut

seedlings. Eight Bikini men returned to the Atoll to assist in the initial stages of the resettlement program and in December of 1969 an additional crew of 23 workers arrived from Kili. Families followed shortly thereafter.

Construction of 40 houses along the lagoon road was started. The resettlement program as planned called for an additional 38 houses, school, church, store, and dispensary before the 1977 target completion date.

Also during this period, (1969), the Enewetak people petitioned the United States for assistance to return to Enewetak Atoll. Discussions and meetings were held with government officals during the next three years and in April 1972 the Marshall Island District Administrator was informed by High Commissioner Edward E. Johnston and Ambassador F. Haydn Williams that Enewetak Atoll would be returned to its former inhabitants. As a result, in Sept. 1972 it was decided to conduct a comprehensive radiological survey of Enewetak Atoll to gain a sufficient understanding of the total radiological environment and assess whether all or any part of the Atoll could be safely reinhabited and if so, under what constraints.

The radiological survey and description of Enewetak and the dose assessment were published in 1973.[6] Data from the report was useful to describe the radiological conditions at the atoll for one point in time. One of the principal findings was the identification for the first time of the significance of the terrestrial food chain in contributing a potential dose to a returning population. The terrestrial pathway was predicted to contribute the major share of the potential dose for most living patterns but the survey results also showed that, although small, the dose from transuranic radionuclides was highest in the marine food pathway.

As a result of the assessment work at Enewetak, it was apparent that more data were required on radionuclide concentrations in subsistence crops, residence time of radionuclides in the atoll ecosystem and the controlling

features in the cycling of the key radionuclides in both the terrestrial, groundwater and marine environments. Consequently, field research programs were implemented between 1972 and 1975 with support from Atomic Energy Commission (AEC) and one of its successor agencies, the Energy Research & Development Administration, (ERDA) and, since 1977, from the Department of Energy (DOE) to provide more reliable data for dose assessments for alternate living patterns at the atoll and to define transport mechanisms determining the fate of the radionuclides within the environment.

Meanwhile in 1974, a master plan had been developed for Bikini that contained plans for the Phase II housing construction to begin sometime in the future. The planning was stopped awaiting advice from AEC on the best locations for the phase II housing. In November 1974 the AEC informed the Dept. of Interior of more recent radiological findings [7] and of the desirability of conducting a "follow-on" radiological survey since it appeared from the additional available data that the locations planned for some of the Phase II housing should be carefully evaluated in order to minimize external exposure. On March 7, 1975 the Secretary of Interior, Rogers Morton, outlined a survey plan to ERDA Administrator Roger Semans, Jr.

A comprehensive radiological survey of Bikini and Eneu Islands was conducted to produce more precise information on external radiation levels in areas identified for additional housing and to provide data for estimating doses from the food chains for future residents of Bikini.

The assessment based on the results of this survey indicated that Bikini Island living patterns could lead to doses that far exceeded the federal guidelines and that Eneu Island living patterns were very near the guidelines. [8,9,10,11,12] However, no subsistence crops were available on

Eneu Island, very few on Bikini Island, and coconut trees planted by the Trust Territory in 1970 were not yet producing nuts.

As a result of the Bikini peoples' desire to relocate to Eneu Island if possible, test plots of subsistence crops were established on Eneu Island in order to develop a data base on radionuclide concentrations in subsistence crops, concentration ratios, residence times, etc. This was done in August of 1977 and is part of the continuing field research program supported by DOE. The only transuranic data in the marine environment at Bikini prior to 1972 were published by Welander [3]; Pu concentrations in 2 entire fish samples collected from Bikini in 1964 were rather high. A complete assessment of transuranic concentrations in marine species and the marine ecosystem was warranted and the marine research program being conducted at Enewetak was extended to Bikini atoll.

Because the preliminary dose estimates from the 1975 survey at Bikini Island predicted that as local foods became available doses would exceed federal guidelines and body burdens of ^{137}Cs and ^{90}Sr would increase, a whole body counting and urine bioassay program was expanded to the Bikini people living at Bikini Atoll. As predicted, many of the residents were found to have body burdens of ^{137}Cs approaching the federal guidelines.[13] As a result, the Bikini people were once again removed from Bikini Atoll and relocated at Kili Island and other atolls in August of 1978.

In 1973 an AEC Task Group was established to develop cleanup criteria for Enewetak Atoll. Based upon recommendations of this group and other information, a cleanup program was initiated in 1977 and completed in 1980. The cleanup was directed toward removal of scrap and debris from the entire atoll and toward soil removal to reduce transuranic radionuclide

concentrations on several islands. Subsequent to cleanup, an updated data bank was developed including external gamma exposure rates and radionuclide concentrations in the soil on all islands. An updated assessment has been completed for Enewetak Atoll which includes radiological dose estimates for all proposed living patterns at the atoll.[14]

In addition to resettlement options at Bikini and Enewetak Atolls, the U.S. Government had an interest in evaluating the radiological condition of 10 additional atolls and 2 islands (together with Bikini Atoll this is referred to as the northern Marshall Island Multi-Atoll Survey) downwind of the proving grounds prior to termination of the Trust Territory Agreement in 1981. About half of these atolls such as Rongelap and Utirik are inhabited; some have had a minimum of environmental monitoring and others none at all.

A radiological survey of the external gamma exposure rates and the terrestrial and marine environments was conducted at these atolls in late 1978 as part of the Northern Marshall Island Survey (NMIS) to assess the concentrations in different components of the environment. The data from this survey are being used to evaluate, in the form of radiological dose assessments, the probable consequenses of living on any of these atolls.

REFERENCES

1. A.D. Welander, K. Bonham, L.R. Donaldson, R.F. Palumbo, S.P. Gessel, F.G. Lowuan, and W.B. Jackson, (1966) Bikini-Enewetak Studies 1964 Part I, Ecological Observations. University of Washington Laboratory of Radiation Biology, Seattle, Rept. UWFL-93, Park I .

2. A.D. Welander, K. Bonham, R.G. Palumbo, S.P. Gessel, F.G. Lowua, W.B. Jackson, R. McClin, and G.B. Lewis, (1967). Bikini-Enewetak Studies, 1964 Part II, Radiobiological Studies. University of Washington Laboratory of Radiation Biology, Seattle, Rept. UWFL-93, Part II .

3. A.D. Welander, (1969). "Distribution of Radionuclides in the Environment of Enewetak and Bikini Atolls," in Proc. of Second National Symposium on Radioecology, Ann Arbor, Mich. 1967, p. 346.

4. E.F. Held, S.P. Gessel and R.B. Walker, (1965). Atoll Soil types in Relation to the Distribution iif Fallout Radionuclides, Univeristy of Washington Laboratory of Radiation Biology, Seattle, Rept. UWFL-92 .

5. P.F. Gustafson, Radiological Report on Bikini, Report to USAEC April 1968 (Appendix May, 1968).

6. Enewetak Radiological Survey, USAEC Nevada Operations Office, Las Vegas, (1973). Report NVO-140, Vol III. (1973)

7. O.D. T. Lynch, T.F. McCraw, V.A Nelson, and W.E. Moore, Radiological Resurvey of Food, Soil, Air and Groundwater at Bikini Atoll, 1972, ERDA-34, 1975.

8. P.H.Gudiksen, T.R.Crites, and W.L. Robison, (1976). External Dose Estimate for Future Bikini Atoll Inhabitants. Lawrence Livermore Laboratory,

Rept. UCRL-51879, Rev. 1.

9. M.E. Mount, W.L. Robison, S.E. Thompson, K.O. Hamby, A.L.Prindle, and H. B. Levy, (1976). Analytical Program-1975 Bikini Radiological Survey, Lawrence Livermore Laboratory, Rept. UCRL-51879, Pt. 2.

10. C.C. Colsher, W.L. Robison and P.H. Gudiksen, (1976). Evaluation of the Radionuclide Concentration in Soil and Plants from the 1975 Terrestrial Survey of Bikini and Eneu Islands, Lawrence Livermore Laboratory, Rept. UCRL-51879, Pt. 3.

11. V.E. Noshkin, W. L. Robison, K. M. Wong, and R.J. Eagle, (1977). Evaluation of the Radiological Quality of the Water on Bikini and Eneu Islands in 1975: Dose Assessment Based on Initial Sampling, Lawrence Livermore Laboratory, Rept. UCRL-51879, Pt.4.

12. W. L. Robison, W. A. Phillips, and C. S.Colsher, (1977). Dose Assessment at Bikini Atoll, Lawrence Livermore Laboratory, Rept. UCRL-51879, Pt. 5.

13. R.P. Miltenberger, N.A. Greenhouse and E.T. Lessard, (1980) Whole Body Counting Results from 1974 to 1979 for Bikini Island Residents Health Physics Vol. 39, 395-407.

14. W.L. Robison, W.A. Phillips, M.E. Mount, B. Clegg and C.L. Conrado,(1980). Preliminary Reassessment of the Potential Radiological Doses for Residents Resettling Enewetak Atoll, Lawrence Livermore National Laboratory, Report UCRL 53006 (In Press).

3. Rationale for Current DOE Environmental Programs in the Marshall Islands

The basic rationale for current DOE environmental monitoring research and dose assessment programs in the Marshall Islands is to develop a reliable data base for estimating radiological doses to populations on the northern atolls. This data base also provides a basis for information on resettlement options at Bikini and Enewetak Atolls and provides the necessary basic research data to allow predictions of dose beyond one point in time.

The data for the various parameters in the dose models are available as a range of values; a mean value for each of the parameters is determined from the available data. As a result, the average dose calculated from these parameters will represent a range of doses determined by the distribution of the data for each of the model parameters. Therefore, it is possible for a person to receive a dose which exceeds the average dose and for this reason it is essential to develop monitoring and research programs to refine the data base for making these dose assessments.

Programs conducted at the atolls prior to 1968 were not directed toward developing dose assessment capabilities. The programs had limited and specific goals, more of general academic interest, and were not directed toward providing an adequate data base upon which predictive dose assessments could be made.

The surveys conducted at Enewetak in 1972-1973 and Bikini in 1975 and 1978 were the first large scale efforts designed for this purpose. As a result of performing the dose assessments from the data generated in these surveys, it was possible to : (1) define the data required to improve the dose assessments (2) define areas of research which would delineate radionuclide cycling mechanisms in the atoll ecosystems, and (3) define experiments to evaluate methods of reducing either uptake of radionuclide into subsistence crops or the soil radionuclide inventory.

Field programs were initiated at both Enewetak and Bikini Atolls to specifically develop the data required to produce more precise radiological dose assessments and to define how the ecosystems operate. Major subsistence crops have been planted to determine the radionuclide concentration in the edible foods, define the time dependence of radionuclides in the atoll ecosystem, and develop concentration ratios (plant/soil) for predictive dose models. Additional research is designed to delineate the cycling of radionuclides to better understand the transport of elements in the atoll ecosystem and to evaluate potential remedial measures for reducing the uptake of critical radionuclides in the subsistence crops. Soil samples are analyzed as part of this program not only to develop concentration ratios but also to supply the necessary data to evaluate the inhalation pathway. Usable groundwater sites are identified and the radionuclide concentrations are carefully assessed since this water may be used in the future for drinking, household or agricultural purposes.

In the marine environment fish, water and sediment samples are collected to determine the concentration of radionuclides for use in the dose assessments; in addition, the data are also used to develop predictive models for the marine pathway for remobilization of radionuclides from the sediment, lagoon flushing rates, concentration ratios for fish and water, temporal variations of radionuclides in lagoon water, etc.

One of the critical variables in any Marshall Island dose assessment is the assumed dietary intake for the population. Published data on the average annual intake of locally grown foods is very sparse. The estimated dose is directly proportional to the intake of local food products grown on the atolls. It has, therefore, been essential to attempt to develop information on the dietary habits of the residents of the various atolls; these studies have been very limited to date and need to be included as a major effort under P.L. 96-205.

Whole body counting of people living at Bikini, Rongelap and Utirik has been conducted to determine whether or not body burdens for ^{137}Cs are within the federal guidelines and to directly estimate whole body doses.

4. Objectives of On-going DOE Monitoring, Research and Dose Assessment Programs in the Marshall Islands.

A. Terrestrial Program

The broad goals of this program are to develop the necessary data base for radionuclide concentration, transport and cycling in the terrestrial environment of northern Marshall Island Atolls. These data are the input for radiological assessments of alternate living patterns which serve as part of the information base for evaluating resettlement options at Enewetak and Bikini Atoll.

The specific objectives are to:

- Determine the concentration of radionuclides in local food products and assess the relative importance of currently used food products and proposed food products to the estimated food chain doses.

- Delineate the rates of uptake, redistribution and removal of radionuclides in the ecosystem, and develop or refine the concentration factors for the critical radionuclides;
- Develop further understanding of radionuclide cycling in the terrestrial foodchains and derive guidelines for agricultural practices that will minimize population exposure via terrestrial foods;

- Employ these new data and constants as input to the assessment program for refining the projected doses for Enewetak, Bikini and other atolls in the nothern Marshall Islands;
- Define the need and develop guidelines for any long-term radio-ecological surveillance on Enewetak, Bikini, Rongelap and Utirik atolls.
- Produce an ecological systems model for the long-lived radionuclides in these coral island environments including radionuclide transport, recycling, and fate;
- Evaluate the resuspension pathway as a potential source of transuranics exposure; and
- Add to the data base supporting the predictive dose assessment capability.

B. Marine-Groundwater Program

The goals of this program are to investigate the rates of movement, accumulation and turnover of the transuranics and other radionuclides in various components of the marine and groundwater environments of Enewetak and Bikini Atolls and open ocean areas in the Marshall Islands. Samples are collected for radiochemical analysis from these aquatic environments in order to:

- Determine the concentrations of radionuclides in different tissues and organs of marine species to develop recommendations for minimizing the passage of radionuclides to human populations from the marine food chain;

- Evaluate the rates and impacts of radionuclides remobilized from the benthic environment to the lagoon water mass and subsequently, to the open ocean;
- Develop a fundamental radionuclide data base and construct models at the Atolls that will be useful in predicting impacts on components of the aquatic environment;
- Furnish data to assist in locating usable sources of groundwater at the Atoll and determine correlations between radionuclide concentrations in the groundwater, soils and various edible plant species; and
- Evaluate the impact of marine plutonium labelled particulates resuspended on the ocean-side reef at the Atolls of Bikini and Enewetak.

C. Dose Assessment Program

The goals of this program are to:

- Develop accurate estimates of the maximum annual dose rate and the 30 year integral dose for alternate living patterns at Bikini and Enewetak Atolls. These assessments form a basis for decisions for land-use at the atolls and also serve as a basis for decisions by the people of each atoll. The dose assessments in the Marshall Islands must be as accurate as possible; they must neither seriously underestimate nor overestimate the potential radiological risks associated with resettlement of these atolls.

- Define the information and research projects that are required to improve the precision of the dose assessments. This important output of the assessment program helps focus the research on needed information and makes the research effort more responsive and efficient.

D. Dietary Studies Program

The goal of the dietary study program is to develop a data base for estimating the average annual intake of locally grown foods for each atoll. These data are critical for precise dose estimates because the radionuclide intake scales directly with the consumption of local food and limited available information indicates that average consumption of local foods may be very atoll specific. A secondary goal is to estimate the projected use of imported foods for each atoll. Studies to date have been very limited and conducted as add-on to other programs when possible. This has not provided adequate data and needs to be emphasized in the future.

E. Personnel Monitoring - Whole body Counting and Urine Bioassay Program

The goals of the personal monitoring program are to:

- Provide documentation that the doses and body burdens being received are within a range that is acceptable.

- Provide direct data on individual body burdens of ^{137}Cs via whole body counting and ^{90}Sr via urine bioassay to verify that the predictive models are in fact correctly estimating body burdens and doses.

F. Marshall Island Data Bank

The objective of this project within the Marshall Islands assessment program is to organize into one location the available radionuclide data which has been obtained in the Marshall Islands. The data bank is currently limited primarily to data collected in recent years by one laboratory but should be expanded to include all radionuclide data obtained prior to, during, and afte the U.S Nuclear Testing Program.

G. Revelant Publications

Publications relevent to current Marshall Island Programs are listed by program.

TERRESTRIAL PROGRAM

Colsher, C.C., Robison, W.L. and Gudiksen, P.H. (1976). Evaluation of the Radionuclide Concentration in Soil and Plants from the 1975 Terrestrial Survey of Bikini and Eneu Islands. Lawrence Livermore Laboratory Report UCRL-51879, Pt. 3.

Robison, W.L., Phillips, W.A. and Colsher, C.S. (1977). Dose Assessment at Bikini Atoll. Lawrence Livermore Laboraory Report UCRL-51879, Pt. 5.

Mount, M.E., Robison, W.L., Thompson, S.E., Hamby, K.O., Prindle, A.L., and Levy, H.B. (1976). Analystical Program - 1975 Bikini Radiological Survey. Lawrence Livermore Labortory Report UCRL-51879, Pt. 2.

Koranda, J.J., Robison, W.L., Thompson, S.E. and Stuart, M.L. (1978). Enewetak Radioecology Research Program: I. Ecological Studies on Engebi Island, 1975-1976. Lawrence Livermore Laboratory Report UCRL-52409-1.

Koranda, J.J. and Robison, W.L. (1978). Accumulation of Radionuclides by Plants as a Monitor System. In: Environmental Health Perspective, 27, 165-179.

Robison, W.L., Phillips, W.A., Mount, M.E., Clegg B.R. and Conrado, C.L. Assessement of the Potential Radiological Doses for Residents Resettling Enewetak Atoll. Lawrence Livermore National Laboratory, Report UCRL-53066, 1980.

Koranda, J.J., Martin, J.R., Thompson, S.E., Stuart, M.L., and McIntyre, D.R. (1973). Terrestrial Biota Survey,U.S.A.E.C. Enewetak Radiological Survey, NVO-140, p.225-348.

Clegg, B. and Wilson, D. (1973). Air Sampling Program Program, U.S.A.E.C., Enewetak Radiological Survey, NVO-140, p. 349-371.

Lynch, O.D.T., and Gudiksen, P.H. (1973). Terrestrial Soil Survey, U.S.A.E.C. Enewetak Radiological Survey, NVO-140, p. 81-116.

Greenhouse, N.A., Miltenberger, R.P. and Lessard, E.T. (1979). External Exposure Measurements at Bikini Atoll, Brookhaven National Laboratory, Report BNL-51003.

Clegg, B.R., Koranda, J.J., Robison, W.L., and Holloday, G. Remote Sensing of Soil Radionuclide Fluxes in a Tropical Ecosystem. IEEE Symposium, November 4-7, 1980, Orlando, Fla.

MARINE PROGRAM

Nelson, V. and Noshkin, V.E. (1973). Marine Program. In Enewetak Survey Report, USAEC Nevada Operations Office, Las Vegas, Rept. NVO-140, Vol. 1, pp. 131-224.

Noshkin, V.E., Wong, K.M., Eagle, R.J. and Gatrousis, C. (1974). Transuranics at Pacific Atolls I. Concentration in the Waters at Enewetak and Bikini. Lawrence Livermore Laboratory, Livermore, Rept. UCRL-51612, pp.1-30, June.

Noshkin, V., Wong, K., Gatrousis, C. and Eagle, R. (1975). Transuranics and Other Radionuclides in Bikini Lagoon: Concentration Data Retrieved from Aged Coral Sections. Limno & Oceano. 20, 729-742.

Marsh, K.V., Wong, K.M., Holladay, G., Noshkin, V.E. Buddemeier, R. (1975). Radiological and Chemical Studies of the Ground Water at Enewetak Atoll I. Sampling, Field Measurements, and Analytical Methods. Lawrence Livermore Laboratory, Rept. UCRL-51913, September.

Noshkin, V.E. Wong, K.M., Eagle, R.J. and Brown, G. (1975). Preliminary Evaluation of the Radiological Quality of the Water on Bikini and Eneu Islands. Lawrence Livermore Laboratory Rept. UCRL-51971, December.

Noshkin, V.E., Wong, K.M., Marsh, K., Eagle, R., Holladay, G. and Buddemeier, R.W. (1976). Plutonium Radionuclides in the Groundwaters at Enewetak Atoll. In Proc. of IAEA Symp. on Transuranium Nuclides in the Environment. IAEA SM-199/33, Vienna, pp. 517-543.

Noshkin, V.E., Eagle, R.J. and Wong, K.M. (1976). Plutonium Levels in Kwajalein Lagoon. Nature 262, 745-748.

Robison, W., Noshkin, V.E. (1976). Comparison of Pu Concentration in Dietary and Inhalation Pathways at Bikini and New York. Lawrence Livermore Laboratory, Livermore, Rept. UCRL-52176.

Noshkin, V.E., (1976). Coral as a Recorder of Radioisotope Concentrations. In Energy and Technology Review. (R.B. Carr, Ed.) Lawrence Livermore Laboratory, Livermore, Rept. UCRL-52000-76-5, pp. 16-20.

Noshkin, V.E., Robison, W.L., Wong, K.M., and Eagle, R.J. (1977). Evaluation of the Radiological Quality of the Water on Bikini and Eneu Islands in 1975: Dose Assessment Based on Initial Sampling. UCRL-51879, Part 4.

Buddemeier, R.W. and Holladay, G. (1977). "Atoll Hydrology: Island Groundwater Characteristics and their Relationship of Diagensis" in Proc. Third Intern. Coral Reef Symp., May 1977.

Levy, Y., Miller, D.S., Friedman, G.N. and Noshkin, V.E. (1978). Analysis of Alpha Emitters in the Coral, Favites verens, from Bikini Lagoon by Solid-State Track Detection, Health Physics, 34 209-217.

Wong, K.M., Brown, G. and Noshkin, V.E. (1978). A Rapid Procedure for Pu Separation in Large Volumes of Fresh and Saline Water by Manganese Dioxide Coprecipitation. J. Radioanal. Chem., 42 No. 1, 7-15.

Marsh, K.V. Jokela, T.A., Eagle, R.J. and Noshkin, V.E. (1978). Radiological and Chemical Studies of Groundwater at Enewetak Atoll. 2 Residence Time of Water in Cactus Crater. Lawrence Livermore Laboratory, Rept. UCRL-51913, Pt. 2.

Wong, K.M., Noshkin, V.E., and Jokela, T.A. (1978). Preconcentration of Plutonium Radionuclides from Natural Waters. In Selected Environmental Plutonium Research, Rept. of NAEG, White, M.G. and Dunaway, P.B., Eds. NVO-192 and as UCRL-80686.

Noshkin, V.E., Wong, K.M. and Eagle, R.J. (1979). Plutonium Concentrations in Fish and Seawater from Kwajalein Atoll, Health Phys. 37, 549-556.

Spies, R.B., Marsh, K.V., and Colsher, J., "Dynamics of Radionuclide Exchange in the Calcareous Algae, Halimeda, submitted to Limnol & Oceanogr. (1979).

Noshkin, V.E. and Wong, K.M. (1980). Plutonium in the North Equatorial Pacific, in, Processes Determining the Input, Behavior and Fate of Radionuclides and Trace Elements in Continental Shelf Environments, U.S. Dept. of Energy Rept. CONF-790382.

Wong, K.M., Jokela, T.A. and Noshkin, V.E. (1980), Problems Associated with Transuranium Determination of Suspended Solids and Seawater Samples, in Proc. 23rd Conf. on Anal. Chem. in Energy Technol., Gatlingburg, TN.

Noshkin, V.E. and Wong, K.M. (1980). Plutonium mobilization from sedimentary sources to solution in the Marine Environment, in Proc. Nucl. Energy Agency, 3rd NEA Seminar on Marine Radioecology, Tokyo, Japan.

Noshkin, V.E., Wong, K.M., Eagle, R.J. and Anglin, D.L. (1980), Concentration of ^{113m}Cd in the Marine Environment, Nature, 287, 221-223.

Noshkin, V.E. (1980) Transuranic Radionuclides in Components of the Benthic Environment of Enewetak Atoll, in Transuranic Elements in the Environment, W.C. Hansen, Ed., Dept. of Energy Publ., DOE/TIC 22800.

Noshkin, V.E., Eagle, R.J. Wong, K.M. and Jokela, T.A. (1981) Transuranic Concentrations in Reef and Pelagic Fish from the Marshall Island, in IAEA Symp. Series, "Impacts of Radionuclide Releases into the Marine Environment, IAEA, Vienna (to be published).

Noshkin, V.E., Wong, K.M., Eagle, R.J. and Anglin, D.L. (1981). Detection of Cadmium Radioactivity in the Marine Environment, in IAEA Symp. Series, "Impacts of Radionuclide Releases into the Marine Environment", IAEA, Vienna (to be published).

Noshkin, V.E., Eagle, R.J., Wong, K.M., Jokela, T.A. and Robison, W.L. (1981). Radionuclide Concentrations in Drinking and Groundwater at the Marshall Islands and Dose Assessment, Lawrence Livermore National Laboratory, UCRL-52853, part 2 (to be published).

DOSE ASSEMENT PROGRAM

Robison, W.L. (1973). Summary of Dose Assessment. Enewetak Radiological Survey. USAEC Nevada Operations Office, Las Vegas, Report NVO-140, Vol. 1, 612-625.

Robison W.L. (1973). Dose Estimates for the Marine Food Chain. Enewetak Radiological Survey. USAEC Nevada Operations Office, Las Vegas, Report NVO-140, Vol. 1, 526-541.

Robison, W.L., Phillips, W.A., Ng, Y.C., Jones, D.E. and Lowe, O.A. (1974). Report by the AEC Task Group on Recommendations for Cleanup and Rehabilitation of Enewetak Atoll. Appendix V, Annual Bone and Whole-Body Doses, pp. 1-12, Tables 1-10.

Robison, W.L., Ng, Y.C., Thompson, S.E. and Phillips, W.A. (1975). Bikini Dose Assessment. Report to ERDA Headquarters, 39 pages.

Wilson, D.W., Ng, Y.C., and Robison, W.L. (1975). Evaluation of Pu at Enewetak Atoll. Health Phys. 29, 599-611.

Gudiksen, P. and Robison, W.L. (1975). Preliminary External-Dose Estimate for Future Bikini Atoll Inhabitants. Lawrence Livermore Laboratory, Rept. UCRL-51879.

Gudiksen, P.H., Crites, T.R. and Robison, W.L. (1976). External Dose Estimates for Future Bikini Atoll Inhabitants. Lawrence Livermore Laboratory, Rept. UCRL-51879, Rev. 1.

Mount, M.E., Robison, W.L., Thompson, E.E., Hamby, K.O., Prindle, A.L. and Levy, H.B. (1976). Analytical Program-1975 Bikini Radiological Survey, Lawrence Livermore Laboratory, Rept. UCRL-51879, Pt. 2.

Colsher, C.C., Robison, W.L. and Gudiksen, P.H. (1976). Evaluation of the Radionuclide Concentrations in Soil and Plants from the 1975 Terrestrial Survey of Bikini and Eneu Islands. Lawrence Livermore Laboratory, Rept. UCRL-51879, Pt. 3.

Robison, W.L. and Noshkin, V.E. (1976). Comparison of Plutonium Concentrations in Dietary and Inhalation Pathways at Bikini and New York and Their Relevance to Plutonium Urine Concentrations and Body Burdens. Lawrence Livermore Laboratory, Rept. UCRL-52176.

Noshkin, V.E., Robison, W.L., Wong, K.M. and Eagle, R.J. (1977). Evaluation of the Radiological Quality of the Water on Bikini and Eneu Islands in 1975: Dose Assessment Based on Initial Sampling. Lawrence Livermore Laboratory, Rept. UCRL-51879, Pt. 4.

Robison, W.L., Phillips, W.A. and Colsher, C.S. (1977). Dose Assessment at Bikini Atoll. Lawrence Livermore Laboratory, Rept. UCRL-51879, Pt. 5.

Miltenberger, R.P., Lessard, E.T. and Greenhouse, N.A. (1980). Cobalt-60 and ^{137}Cs Long Term Biological Removal Rate Constants for the Marshallese Population, Health Physics, Vol 39, 6.

Dietary Studies Program

J. R. Naidu, N. A. Greenhouse, G. Knight and E. C. Craighead, Marshall Islands: A Study of Diet and Living Patterns, Brookhaven National Laboratory, Report BNL - , 1980.

W. L. Robison, W. A. Phillips, M. E. Mount, B. R. Clegg and C. L. Conrado, Reassessment of the Potential Radiological Doses for Residents Resettling Enewetak Atoll, Lawrence Livermore National Laboratory, Report UCRL-53066 (1980).

W. L. Robison (1973). Dietary and Living Patterns. Enewetak Radiological Survey. USAEC Nevada Operations Office, Las Vegas, Report NVO-140, Vol. 1, 492-498.

Whole body Counting Program

R.P. Miltenberger, N.A. Greenhouse and E.T. Lessard, Whole body Counting Results from 1974 to 1979 for Bikini Island Residents, Health Physics Vol. 39, 395-407, 1980.

5. Environmental Monitoring, Research and Dose Assessment Program Plan (EMRDAP) for P.L. 96-205.

A. Uniqueness and Purpose of the Plan; Cost Assumptions

The goal of this program plan (EMRDAP) is to define as precisely as possible what scientific and technical efforts will be required to implement the program, their cost, and to identify, where possible, influences which could alter, by either reducing or expanding, the scope of the EMRDAP. The preceding sections should help put the proposed program in context with past and current programs.

The program of environmental monitoring and research should be coordinated with the medical and educational programs where it is appropriate but the EMRDAP is very different in several respects from the other two programs. The context of any EMRDAP will be affected by living and land-use patterns currently in place, by living and land use patterns which may occur in the future, by results which will be produced from current DOE research programs in the Marshall Islands and by social and political decisions made in the Marshall Islands.

The required work, timelines and cost therefore can vary considerably depending upon many non-technical factors, and will be significantly affected by results from current DOE Marshall Island programs. Therefore, it is difficult to precisely define what will be required over the next several years other than in a general way relying extensively upon efforts necessary to generate past dose assessments and information from current DOE programs in the Marshall Islands. P.L. 96-205 will necessarily increase the time required to maintain monitoring and dose assessment efforts beyond that which would have occurred under the current programs.

The program costs for the EMRDAP described in this section are developed assuming that the implementation of the described program will be based on ongoing DOE programs in the Marshall Islands. If the described program were to be conducted independent of current DOE programs, the need to develop baseline data, necessary logistic support and additional manpower would lead to an estimated 250% increase in costs for implementing the program over the first 2 to 3 years; estimates of the cost for both continuing and new programs are included in Appendix A.

B. Direct Monitoring Requirements for Continued Dose Assessments

1.) Samples of Locally Produced Foods

The analysis of the radionuclide concentration in the locally grown dietary products is the most direct way to evaluate the potential dose to current or future inhabitants. Radionuclide concentrations in foods combined with information on average dietary intake (see section B 4) defines the pCi per day intake for an individual and provides the basis for calculating whole body and bone marrow doses when appropriate physiological and radiological models are employed.

Thus, samples of coconut meat and fluid, Pandanus fruit, breadfruit, papaya, banana, squash and other terrestrial food products (which may vary by atoll) should be collected at islands identified at present as residence or agriculture islands at Bikini, Enewetak, Rongelap and Utirik atolls to maintain a data base for updating dose assessments. In additon, reef fish, pelagic fish, clams, lobsters, birds, coconut crabs any other identified food products, cistern and ground water should be collected from the marine and terrestrial environment for radiological analysis.

These data provide not only a basis for dose assessment but they also provide a basis for evaluating the environmental residence time of radionuclides in food species. Based on the best results currently available from ongoing DOE programs, sampling at Rongelap and Utirik need be no more frequent than once every 4 years providing that historical and/or new data or altered agricultural practices do not indicate a more frequent sampling cycle. Sampling at Enewetak and Bikini Atolls should be conducted on an annual basis until a reasonable data base is established.

The sampling of both the terrestrial and marine environments should require no more than 8 people for 10 to 14 days at each atoll. To minimize man power and logistic costs the sampling for both marine and terrestrial environments should be carried out concurrently. Whenever possible, the local population will be relied on for advice and assistance in sample collection at their atoll.

The islands at the atolls which currently have subsistence crops available are:

Bikini Atoll - Bikini and Eneu Islands; these islands are sampled under the current program.

Rongelap Atoll - Rongelap, Naen, Kabell, Enjaetok, Mellu

Utirik Atoll - Utirik, Aon, Pigrak

Enewetak Atoll - Only about 4 coconut trees and 2 Pandanus trees are currently available in the contaminated northern half of the atoll but food crops will be collected where available from the current southern residence islands of Japtan, Medren and Enewetak. However, in 1980, 6 islands (Aomon, Bijire, Aej, Lujor, Lojwa, and Alembel), were planted with coconut. Therefore, by 1985 or 1986 coconut fruit

should be available and a major sampling program will be required. The purpose of this sampling will be to supply data for making dose estimates for people living at the atoll, to determine if foods are suitable for consumption and to provide the information to assess the potential use of the copra in the world market. If in the meantime other food crops such as breadfruit, Pandanus sp. etc., are planted on either of these 6 islands or on Enjebi Island, then they should also be included in the sampling program. Current programs are only capable of maintaining the monitoring of Eneu and Bikini Islands and Bikini lagoon at Bikini Atoll and Enjebi, Bokombako and Louj Islands and Enewetak lagoon at Enewetak Atoll. Monitoring at other islands and atolls would have to be accomplished under P.L. 96-205.

Kilogram quantities of each sample are required for transuranic analyses and this will provide sufficient sample for analysis of ^{137}Cs (and other gamma emitters) and ^{90}Sr. A minimum of 5 pooled samples of each selected food item should be collected per island. In the lagoon, 5 or 6 species of fish (mullet, goatfish, surgeonfish, parrotfish, etc.) should be collected from 5 different locations, and 3 sites should be sampled for invertebrates (clams, lobsters, etc.) and other marine organisms. This describes the minimum program required for the basic dose assessment if implemented as part of the ongoing DOE effort using, for the most part existing manpower and equipment. A program conducted independent of the current DOE program would require additional manpower, additional samples to establish a data base, training of personnel in sampling methods and sample processing techniques, familiarization of personnel with field work in atoll environments, additional equipment and analytical expertise in handling low-level radioactive samples.

2.) Soil Samples

Some atolls, and islands within atolls, which may have to be evaluated as possible residence or agriculture sites do not yet have growing terrestrial subsistence food plants. A predictive methodology is therefore required to estimate the expected concentrations of radionuclides in local foods and the subsequent radiological doses. This methodology is developed by determining the concentration ratio between the edible fruit and the soil (pCi/g fruit/pCi/g soil) for each radionuclide. These concentration ratios can then be multiplied by the average soil concentrations of an island with no existing crops to estimate radionuclide concentration in the foods.

Soil sampling is, therefore, required for two purposes: 1) soil profiles to a depth of about 40 to 60 cm (this encompasses the active root zone of most food plants observed at the atolls) must be collected through the root zone of each sampled tree to develop additional concentration ratio data to confirm and expand the previously established concentration ratio data base. 2) soil profile samples to depths of 40-60 cm must be collected on islands that are to be evaluated for residence or agriculture. The data developed from these samples, in conjunction with the concentration ratio data base, will form the basis of the dose assessment for each island. Profiles may have to be collected on a 50 m grid in some areas to provide sufficient resolution to evaluate changes in soil concentration across an island; all profiles should be collected in the following increments: 0-5 cm, 5-10 cm, 10-15 cm, 15-25 cm, and 25-40cm. A significant data base, developed from ongoing DOE programs, already exists for Enewetak Atoll but limited data are available for most other atolls. Supplemental data are necessary to expand the current information base to provide more reliable values for parameters in the predictive models.

The data derived from these samples can then be used not only to develop concentration ratios but to supply information on depth distribution of different radionuclides, supply data needed to estimate effects of soil removal on predicted radiological doses, supply information on surface soil (0-5 cm) concentrations for use in estimating exposure via the resuspension/ inhalation pathway and supply information on the depth of the humic containing soil. The soil radionuclide concentration data are also very important in helping to assess the environmental residence time of ^{137}Cs and ^{90}Sr.

The soil profiles and local subsistence foods for developing the concentration ratios will be sampled from the same islands where available. Other islands at the 4 atolls which may require additional soil sampling to develop data for the dose assessment are:

Bikini Atoll	- Bikini, Eneu, Nam, Enidrik, Eneman
Rongelap	- Rongelap, Naen, Kabell, Enjaetok, Mellu
Utirik	- Utirik, Am, Pigrat
Enewetak	- Aomon, Bijire, Aej, Lujor, Lojwa, Alembel

Additional soil sampling would be necessary at those island not included under the curent program.

Six persons at each atoll for 10 to 14 days would be required for sampling present and proposed residence and agriculture islands. This could be done concurrently with vegetation and marine sampling (see page 28 under B-1).

After the first 4 years the annual cost for soil sampling would probably be reduced for these atolls although it is possible that other islands might later be identified for agriculture and/or residence and would require similar attention. Therefore, an estimate for a continuous level of effort will be

included in the cost analysis although the effort may not be required or may be required at a level exceeding our estimate.

3.) Ground and Cistern Water Samples

Ground water and cistern water are both used for drinking and cooking although the preferred source of water is the rain water collected in the cisterns. Thus, it is necessary to sample these water supplies in conjunction with the vegetation, marine and soil sampling programs. Not only are the results of the analysis of these water samples used for direct input to the dose assessment but they also are very significant in delineating time dependence and cycling of radionuclides in the atoll ecosystem.

On current residence islands or agriculture islands where there are established wells, sampling could be done concurrently with other sampling efforts. On current and potential agriculture and residence islands without wells, 5 man days of effort would be required to establish a well site based on past experience. Cistern and ground water studies at Bikini and Eneu islands at Bikini Atoll and ground water studies at Enewetak Atoll are part of current programs. Studies at other islands or atolls would have to fall under P.L. 96-205.

4.) Dietary and Consumption Habits

A critical parameter in the dose models is the average annual (or daily) intake of local subsistence foods. The pCi intake of all radionuclides is directly related to the amount of contaminated food product consumed. Therefore, it is most essential to have accurate information on the average

diet and consumption patterns at each of the atolls. Current information is limited but indicates that dietary habits may be atoll specific and that application of dietary information developed at one atoll may not be appropriate for another atoll.

The Ujelang Diet Survey developed at Ujelang Atoll is the best information available on the dietary habits of the Enewetak people. However, it is not clear that this diet will accurately reflect the diet of the people who have (or will) returned to Enewetak. Similarly, the diet of the Bikini population should be evaluated if they return to Bikini Atoll; if return to Bikini Atoll will be delayed for some time then preliminary evaluation of the diet of the population at their current places of residence would be in order. The diets of the Rongelap and Utirik populations also need to be studied in more detail.

The data will have to be obtained in two ways: (1) have people live at the atolls for extended periods of time (months) and observe, estimate and measure where possible the dietary intake of the people; and (2) use questionnaires to help develop the information required on diet preferences and habits. One atoll per year would be an appropriate goal. Thus it would take 4 years to complete the initial work at the 4 atolls and some follow-up work in subsequent years would undoubtedly be required.

5.) External Gamma Exposure Rate Measurements

External gamma exposure rates at Bikini, Rongelap and Utirik were measured in late 1978 as part of the Northern Marshall Island Survey (NMIS); exposure rates at Enewetak were measured during 1979 and 1980 as part of the clean-up project. The data from the NMIS are being summarized and will be published in 1981. The external exposure rates at Enewetak are currently in press. These

data will be used in dose assessments for Enewetak and the 13 atolls of the NMIS and will be published during 1981; these assessments will provide the initial dose assessment for the atolls and a dose assessment will not be required again for another 5 years.

In order to ensure that the expected reduction in exposure at the atolls is occurring, and to provide external dose data for assessments, and to help evaluate the environmental residence time of ^{137}Cs, external gamma measurements should be made every 4 or 5 years beginning within the next 4 years at the residence islands and one agriculture island at each of the atolls. Measurements would be made using either hand held scintillation detectors or vehicle mounted scintillation or high resolution solid state detectors. No aerial surveys would be required.

Once an effective half-time of ^{137}Cs at the atolls has been determined, the frequency of external gamma measurements could be reduced or perhaps even eliminated. The first external radiation reassessment program, assuming one atoll per year, would begin in the next 4 years and the second reassessment, in the same sequence, would begin 5 years later. A decision on whether to continue the program at this frequency could be made at this point.

C. Research Requirements

1.) Environmental Residence Times for ^{137}Cs, ^{90}Sr, $^{239,240}Pu$ and ^{241}Am.

A key parameter in any dose assessment model is the effective half-time of the radionuclides in the environment being evaluated. The effective half-time is a combination of the radiological (physical) half-life of a radionuclide and the residence half-time of the radionuclide in the environment.

For example, ^{137}Cs and ^{90}Sr contribute by far the most significant fraction of the dose over the next several decades; both have radiological half-lives of about 30 years. Because the environmental residence half-lives for these 2 nuclides is not known, the 30 year radiological half-times are used in the dose models. However, if the environmental residence half-time for either or both of the radionuclides could be accurately determined, then it might be learned that the effective half-time might be less than 30 years. For example, if the environmental residence time were 10 years then the effective half-time would be 7.5 y; even if the environmental residence time of ^{137}Cs were 60 years the effective half-life would be 20 y. As a result the estimated doses would be less than those predicted using the 30 year radiological half-time and conclusions regarding resettlement options could possibly be altered.

Therefore, a very important part of the research plans in the Marshall Island is to determine the environmental residence time of the most significant radionuclides in the atoll ecosystems. This requires monitoring the soil and vegetation radionuclide concentrations in specific areas and in specific plants over extended periods of time. Use should be made of any historical samples if they can be precisly located and identified and be of value in the determining the residence time (see section E2).

The situation is similar in the marine environment. Radionuclides will be lost from the environment by a variety of processes and change accordingly in marine food products. A knowledge of the environmental residence time for each radionuclide is required to evaluate future impacts from the marine food chain.

Studies of the residence time of ^{137}Cs, ^{90}Sr and the transuranics are in progress at Enewetak and Bikini Atolls. These studies should be expanded to include Rongelap and Utirik Atolls.

2.) Cycling of Radionuclides in the Atoll Ecosystem

Radionuclides are still present in the atoll ecosystems because they are incorporated into plants and soil and are continuously cycled through the plant/soil system. Small fractions of the total radionuclide inventory on an island are slowly transported down the soil column into the ground water system.

Therefore, it is important to determine the mechanisms and controlling features of radionuclide cycling as a function of climatic conditions, season of the year and the agriculture and irrigation practices in order to better direct remedial actions for reducing radionuclide uptake and/or radionuclide inventory. Determining the movement of water in this ecosystem is a critical part of the study because it is essentially the soluble fraction of the total inventory that is available to the food crops and transport to the groundwater system.

Similarly, radionuclide transfer and cycling between the sediment, water column and marine species is of importance in the marine environment to predict the long term dose effects from that pathway and the ultimate turnover time of radionuclides in the marine ecosystem.

Some of this research is currently being conducted in DOE funded programs, at Enewetak and Bikini but these studies should be extended to include Rongelap and Utirik. Also with increased funding, expertise on the role of soil microorganisms in radionuclide accumulation and cycling could be included in ongoing studies. Any new studies conducted independent of the current programs would necessarily have to include the atolls of Enewetak and Bikini and at least partially duplicate or supplement the ongoing DOE programs at these atolls.

3.) Remedial Measures

An important feature of any future research program, especially at Enewetak and Bikini Atolls, should be an evaluation of methods for reducing the potential dose to residents resettling the atolls. There are two basic methods, other than abstention from eating local foods, for possibly reducing the dose and these are:

a.) To reduce the uptake of ^{137}Cs, ^{90}Sr into the edible food products and/or

b.) To reduce the radionuclide inventory in the soil.

Preliminary studies, limited by current funding and program obligations, are underway to evaluate the potential of both of these concepts. However, much more thorough and complete programs should be established under the P.L. 96-205 program.

For example, more complete and sophisticated studies could be conducted to evaluate various agriculture practices, using different high potassium and nitrogen fertilizer to the block the uptake of ^{137}Cs. Different types and amounts of fertilizer, different application rates, application of stable elements (Cs, Sr) and different irrigation practices should all be evaluated in a controlled, scientific manner to evaluate the effectiveness of the techniques to reduce radionuclide uptake by subsistence crops. These efforts should incorporate appropriate expertise where necessary such as tropical agriculturalists, soil scientists and hydrologists if necessary.

Also, experiments designed to evaluate possible means of reducing the soil radionuclide concentration should be expanded. Current 100 m x 100 m plots have been denuded of all vegetation and are being monitored to see if there is a reduction in the soil inventory, with a concurrent increase in radionuclide

concentration in the ground water. Irrigation of these plots will increase the "effective rainfall" and may decrease the time required to evaluate whether natural processes (rainy season) will reduce the radionuclide inventory in the root zone area. In addition the scale of the experiment could be expanded and encompass larger areas of land which currently have producing coconut trees where radionuclide inventories appear to be stable and are perhaps being reduced only by radiological decay.

Results from current programs would provide guidance for expanded projects directed at these 2 basic remedial action concepts. The acquisition of such information could be very significant for the people and makes such basic experiments a critical part of the long term research goals of the Marshall Island program.

4.) Radionuclide Distribution in Copra Products

The only cash crop for the northern Marshall Island atolls is copra. Cesium -137 and ^{90}Sr are absorbed through the root system of the coconut trees and incorporated into the coconut meat which can be used directly or dried (i.e. copra). Consequently, it is essential to know how the radionuclides are distributed in the products resulting from processing of the copra.

The common method of processing copra, and the method used at the large commercial plant in Majuro, is to squeeze the copra at high pressure and temperature to produce coconut oil and a dry residual pulp material which is commonly used for animal feed. Therefore, it is necessary to determine the concentration of the major radionuclides in the copra products in order to evaluate the possible use of the products in the world market and to provide the data base for assessing the potential dose to man from use of the products.

In addition, there are new methods proposed for processing copra which have different operating conditions and produce different by-products. The products from these new methods need to be evaluated because it maybe possible that the radionuclide distribution wil be different, prehaps with the results that the products using these methods, may be more acceptable on the world market.

The importance of copra on the economy of the Marshall Islands, and on the economy of Enewetak and Bikini Atolls in particular, is of such importance that the experiments to determine the radionuclide distribution in copra products from the different methods should be carried out. Only limited studies have been possible in current programs.

5.) Transuranics in Fish

The global experience in marine studies of the transuranics is too brief to model or to predict confidently concentrations of plutonium and other transuranics accumulated from the environment by marine organisms. It was recently found that the average concentration for $^{239+240}Pu$ in muscle of mullet from Rongelap Atoll was larger than the average concentrations in these fish from other atolls, including the more contaminated atolls of Bikini and Enewetak. This unanticipated finding can be resolved through additional research at Rongelap Atoll in order to describe the environmental links transferring transuranic radioactivity to man.

Of the transuranics, plutonium and americium to date have received the greatest attention in the radiological program at the Marshall Islands. Recently, however, curium has been detected in fish tissues from Enewetak and Bikini and may be, by analogy, present in higher concentrations in fish from Rongelap. The internal dose to man from curium by ingestion of marine foods

might be nearly half of the plutonium dose. A better understanding of the behavior of curium both in the marine and terrestrial environments of the atolls is warrented. Since ^{242}Cm decays to ^{238}Pu, there will be changing concentrations of this radionuclide in the environment and an evaluation of the increases of Pu^{238} in the local environments should be made.

There is still some uncertainity concerning what fish tissue and what quantity of tissue is consumed by the Marshallese in their diet. Doses from transuranics through ingestion of fish flesh are low but specific communities may also consume the liver, or parts of the intestinal tract or the entire fish wherein concentration levels are generally much higher. Until better dietary information is available, it will be necessary to analyze all fish parts to permit reconstruction of the radionuclide concentations for dose assessment in any subfraction of the entire fish. A better understanding of how the radionuclides are distributed among various tissues could circumvent the need for this continued long term analytical program. For example, if ratios of activity between various fish parts are determined and verified, it would then only be necessary to analyze one or two tissues of the fish and predict other concentrations from the developed tissue ratios.

6.) Ground Water

Groundwater studies at Enewetak and Bikini are progressing under the current DOE research program but little is known of the rates or cycling processes of radionuclides between the terrestrial soils and groundwater at Rongelap and Utirik. The water is fresh enough for human consumption and efforts should be made to protect this valuable resource and understand or predict any major changes in radionuclide concentrations with time. Understanding how radionuclides migrate to the water tables is closely linked

with assessing the residence time for specific radionuclides in the terrestrial environment. Groundwater and soil research studied should be conducted concurrently at the atolls.

7.) Enewetak Crater Disposal Site

In September of 1980 a monitoring program of the groundwaters and near shore lagoon water adjacent to the Cactus Disposal site on Runit Island was initiated with the anticipation that the program would eventually be incorporated into the EMRDAP. As now established, groundwater and lagoon water is sampled every 2 months from each of 3 sites around the waste disposal crypt. Twice every year, oceanside reef water samples will be collected and analyzed for plutonium, ^{137}Cs and ^{90}Sr. Once each year local reef fish will be collected and analyzed for radionuclide concentrations. Any indication of radionuclides leaching through the aquifer and entering the lagoon will be assessed by comparing the results with historical data. These collections must be made repetitively over a period of years to evaluate the integrity of the waste containment system on Runit Island.

8.) Other Radionuclides and Pathways

Although the major long-lived radionuclides in the environment and those critical in dose assessments have been identified, a continued search should be made to identify less obvious radionuclides and pathways which could contribute to the dose to man.

For example, it was recently determined that ^{113m}Cd is concentrated in the liver of fish from Bikini and Enewetak. Cadmium-113m is a low yield fission product, decays by energetic beta emission and has a 14.6 year

half-life, and is persistent in the environment. Since cadmium is concentrated in the liver and kidney of man, the radiological significances of ^{113m}Cd should be carefully evaluated at Bikini, Enewetak, Rongelap and Utirik Atolls. Additional cadmium measurements in the environment are needed since we have little information concerning this element.

There may be less obvious radiological pathways to man that could require evaluation. For example if the non-edible parts of fish of marine origin (gut contents with high concentrations of plutonium), are indiscriminatley recycled to the terrestrial environment, the levels of transuranics could be increased near future village or residence areas by refuse disposal. Thus, there may be other pathways yet to be identified which could require evaluation.

D. Radiological Dose Assessment and Risk Analysis

1.) Data Reduction

The reduction and evaluation of the data derived from samples collected at the atolls (see Section 5B) should be carried out in the dose assessment program. The data must be screened and evaluated and put into a format to be coordinated with other parameters in the dose assessment models. Data reduction and evaluation is a very critical phase of a dose assessment and a task that requires continual effort, not only to keep the data base updated for the assessment work but to evaluate the data in many ways to help define and focus additional field work, to determine environmental residence times for the radionuclides and to evaluate remedial measures. A most important factor in data reduction is the development of a computerized data bank (see next section D2).

2.) Data Bank

The objective of this project within the Marshall Islands assessment program will be to organize into one location all available radionuclide data which has been obtained in the Marshall Islands prior to, during, and after the U.S.Nuclear Testing Program. This will allow for data analysis heretofore impossible, will provide a central location for the U.S. Government to obtain information necessary to answer questions which arise over the next several decades, and will provide a means to transfer data as needed.

The data bank should include all the external gamma measurements and radionuclide concentration data obtained from soil, vegetation, animal, marine, air and water samples in the Marshall Islands from past and current programs. It must be possible to recall the data by date, sample type, radionuclide, atoll, island within an atoll, location on the island, source of the data (i.e., laboratory or university etc.) and the analytical laboratory. All data taken prior, during and after the test years at the atolls should be included. The purpose is to have all the data available in one location so that it may be evaluated for time dependent information and so questions which arise about the historical situation at the atolls can be more readily answered. Particularly important will be the fact that the U.S. Government will have one location to call upon when questions arise over the next twenty or thirty years concerning the radiological status of the atolls. Whole body counting data and urine bioassay data should be included so that environmental data and human data are tied together and in one data management system.

It would simplify matters if the data base format were consistent with those from current continuing DOE Marshall Island programs. In that way the first two years of this effort could be dedicated to entering all historical data into a system that would be compatible with current data.

3.)Dose Assessments

As spelled out in the P.L. 96-205 a radiological dose assessment at the 4 atolls is required at least once every 5 years. A dose assessment must include the evaluation of the following exposure pathways:

1. External gamma
2. Terrestrial foods
3. Marine foods
4. Drinking water
5. Inhalation

Maximum dose rates and 30 and 50 year integral doses should be calculated. The results should be broken down by pathway and also given as a total dose from all pathways. Annual body burdens should also be calculated for pathways 2 thru 4.

The dose models used to calculate the doses must be currently accepted models from the scientific literature. Specifically, because ^{137}Cs and ^{90}Sr contribute most of the dose, the whole body and bone marrow dose models for estimating doses from ingested ^{137}Cs and ^{90}Sr must be realistic. Inhalation pathway dose estimates must be based upon sound resuspension models for an atoll ecosystem.

The dose assessment methodology must also be able to generate predicted doses for islands and atolls where locally grown subsistence foods are presently not available. Many of the demands for dose assessments involve this kind of situation and there must be a predictive capability to estimate doses when only radionuclide concentrations in soil are available. This is a most essential feature of the required dose assessment methodology.

Although not required, it would be more efficient, both economically and scientifically, to have the data bank effort and the dose assessment effort carried out by the same organization. Even though the output of the data bank could be supplied to whoever is handling the dose assessment, it is most useful to be able to evaluate the data and design the input for the dose models in an integrated manner which would be more difficult if these two functions were separated.

The dose assessment requirements of P.L. 96-205 will be met for the first 5 year period with the dose assessments made in 1979 for Enewetak, 1980 for Bikini, and those for Rongelap and Utirik which will be published in 1981 from data generated in the Northern Marshall Island Survey. Five years subsequent to each of these dose assessments an updated published assessment will be made. This cycle will be repeated every 5 years, and continue on a similar cycle until it is determined that the frequency of the assessment period can be decreased or perhaps terminated.

4.) Risk Analysis

After the maximum annual doses and 30 and 50-year integral doses have been estimated, it will be necessary to estimate the increased genetic and somatic risk to the population.

The risk should be estimated using the best information available on the increased incidence of cancer and genetic defects caused by radiation exposure such as that presented in the National Academy of Science Reports on the Biological Effects of Ionizing Radiation (BEIR Report). A risk analysis should accompany each dose assessment for each atoll.

5.) Personal Monitoring - Whole Body Counting and Urine Bio Assay.

Whole body counting and urine bioassay of people ressettling Enewetak Atoll and any future populations at Bikini Atoll is the most direct means to verify ^{137}Cs and ^{90}Sr body burdens and doses predicted in the dose assessments and to determine if any individual receives an inordinate body burden and dose.

Residents of Rongelap and Utirik, who have been monitored over the last few years, should continue to be monitored to determine if body burdens are at acceptable levels and to assess if body burdens reflect any change observed in the environmental concentration of radionuclides.

Whole body counting and urine bioassay should be conducted on a bi-annual basis for residents of Rongelap and Utirik by visiting 1 of the 2 atolls each year. Annual visits should be made to residents resettling Enewetak Atoll and to residents of Bikini Atoll should resettlement occur. This could be reduced to bi-annual visits after a few years. With populations of the size currently on Rongelap and Utirik, and those projected for Enewetak and Bikini, about 2 to 3 weeks will be required for four (4) people in the field to complete the monitoring at each atoll.

E. Other Atolls

If other atolls are identified to fall within the scope of the P.L. 96-205, additional costs will be incurred to implement the program. Some phases of the program outlined above for Enewetak, Bikini, Rongelap and Utirik will not need to be duplicated in their entirety at other atolls. For example, the research studies to determine the mechanisms controlling radionuclide cycling, the research directed toward reducing uptake and

decreasing radionuclide inventory and detailed ground water studies will be focused at the 4 specified atolls and will be necessary only on a limited basis at other atolls.

Estimated incremental costs to conduct the program outlined for the 4 atolls specified in P.L. 96-205 at other atolls are listed in Appendix B. A general description of the required effort is listed by program.

1.) Requirements for Dose Assessments

a) Terrestrial and marine food sample collection.

Soil sample collection and ground-water and cistern-water sample collection will be required at each atoll which is included for monitoring and dose assessment.

b.) Diet and Consumption

Dietary and consumption habits will have to be evaluated for each added atoll in order to develop dose assessments that are atoll specific.

c.) External Gamma Measurements

External gamma exposure rates at other atolls are very low and need only to be measured once sometime after 1985 to verify the external measurements of the Northern Marshall Island survey and the expected decrease.

2.) Research Requirements

Most research efforts will be conducted at one of the 4 specified atolls (i.e. Enewetak, Bikini, Rongelap and Utirik). However, verification of some experiments may be in order and others may be required as a result of some of the monitoring at other atolls. Examples might be the transuranic concentrations observed in fish (see section 5 c.4), a different concentration ratio for different species of coconut or Pandanus, or vastly different radionuclide transport or cycling than observed at other atolls.

For planning purposes it might be prudent to assume an additional $100k per year for environmental research required at other atolls.

3.) Dose Assessment

Dose assessment at other atolls can be considered in two broad categories:

1. Predictive dose assessment and risk analysis as described in sections 5B and 5D, and
2. Personnel monitoring - whole body counting and urine bioassay as described in section 5D.

Both will be essential parts of a complete assessment of other atolls.

F. Shiptime Support

An adequate research vessel is an absolute requirement for the transportation of personnel and equipment to the Atolls and for support of personnel and the program during residency at any Atoll. There are no adequate vessels available for short-time charters in the Marshall Islands at the present time. Currently DOE provides support for its on-going programs through an annual lease arrangement. The current 1981 estimated annual operating costs for the vessel is $900,000. It is estimated that this cost will increase annually by at least 15% primarily because of rising fuel costs. The home port of the vessel is Kwajalein Atoll. This Atoll is a convenient staging area for scientists and equipment since it is accessable by air from the U.S. mainland.

Shiptime is a valuable commodity and presently there is little flexibility in the schedule to accomodate any significant additional use of the current vessel. Unless part of the on-going DOE programs in the Marshalls were reduced in effort, the present vessel would be inadequate to provide the support required for current programs and any additional program requiring several months of independent operation in the field. One option is to provide a separate vessel to support this EMRD. However, since charters are not available, it would cost approximately $1,000,000 annually to maintain an additional vessel at Kwajalein. During the first few years it is estimated that, with the program as described herein, the ship would not be used by any new group of investigators for more than 3 to 4 months of the year to collect baseline information and conduct regular sampling. It could be idle during the rest of the years unless supplementary charters could be found.

A more reasonable option is to integrate the operations required for PL 96-205 with DOE programs in the Marshalls currently utilizing the DOE supported vessel. As part of the on-going DOE effort, approximately 20% additional ship time support would be required during regular scheduled research cruises to Bikini on an annual basis. Two to three weeks of additional ship support would be necessary at Utirik and Rongelap every few years. These periods of time could be accomodated with some rearrangements and modifications in the current schedule. In the appendices two costs are indicated for ship support. In both cases it must be recognized that the costs are highly dependent on usage of the vessel; any modifications in the frequency of sampling required and non-predictable factor such as weather and equipment failure. One cost assumes an independent vessel is devoted entirely to work under this program. The second is the estimated shiptime cost for this program if the effort were implemented in conjunction with on-going programs.

If additional Atolls are included in this monitoring program it is probable that the present support capabilities of the current research vessel could be exceeded. An additional vessel might be required to support the additional effort at other Atolls. This support is indicated as a separate item in Appendix B - Table 1 which outlines the estimated 1981 annual costs if other Atolls are included with this plan.

Appendix A - Table 1.

Estimated Annual Costs in Thousands of Dollars for P.L. 96-205
for Enewetak, Bikini, Rongelap and Utirik Atolls
Assuming the Programs are Conducted In Conjunction with
On-going DOE Marshall Island Programs.

Program	Year 1*		Year 2		Year 3		Year 4		Year 5	
Sampling for Dose Assessment	350	(850)+	378	(700)	408	(771)	441	(850)	600	(600)***
Dietary Studies	120	(120)	130	(130)	140	(140)	151	(151)	60	(60)
External Dose Measurement (600)++									200	
Dose Assessment	30	(470)	33	(508)	36	(550)	39	(599)	42	(647)
Risk Analysis	70	(70)	76	(76)	82	(82)	89	(89)	96	(96)
Personnel Monitoring	**	(310)	**	(108)	**	(117)	**	(124)	**	(132)
Environmental Research Requirements	300	(950)	324	(1026)	350	(1108)	378	(1197)	408	(1293)
Data Bank	250	(500)	270	(540)	110	(110)	119	(119)	129	(129)
Shiptime Support	20	(900)	23	(1035)	75	(1190)	86	(1369)	75	(1574)
TOTAL	1140	(4170)	1233	(4023)	1201	(4068)	1303	(4498)	1610	(5131)

+ Number in parentheses are estimates for costs if the program was conducted by new groups independent of current DOE Marshall Island Programs.

++ Cost per atoll; plan for one atoll per year begining in 1985.

* Assumed to be 1981 dollars.

** Will be covered under current program.

*** Increased cost reflect the fact that subsistence crops on northern islands of Enewetak will be available.

Appendix A - Table 2
Breakdown of estimated first years costs in thousands of dollars

	Estimated costs if programs are conducted in conjunction with ongoing DOE Marshall Island programs	Estimated costs if programs are conducted independent of current DOE Marshall Island programs
A. Sampling for Dose Assessment	350	850
Manpower	70	200
Analytical	217	340
Logistics	28	60
Equipment	35	250 *
B. Dietary Studies	120	120
Manpower+	102	102
Logistics	18	18
C. External Gamma	200	600
Manpower+	160	160
Logistics	40	40
Equipment	0	400 *
D. Dose Assessment	30	470
Manpower+ & Computer Time	30	470
E. Risk Analysis	70	70
Manpower+ & Computer Time	70	70
F. Personnel Monitoring	0	310
Manpower+	-	85
Logistics	-	15
Equipment	-	210 *
G. Research	300	950
Manpower+	100	400
Logistics	0	60
Analytical	200	490
H. Data Bank	250	500
Manpower+ & Computer Time	250	500
I. Shiptime Support	20	900

* Equipment costs would be greatly reduced after initial purchase and in succeeding years would approach that listed for current DOE programs.

+Includes publication costs, report writing, etc.

Appendix B - Table 1.

Estimated annual costs in thousands of dollars for other atolls which may be included (i.e. other than Enewetak, Bikini, Rongelap and Utirik).

Program	Year 1*
Sampling for Dose Assessment	250 (250)+
Dietary Studies	120 (120)
External Gamma Measurement	200 (200)
Dose Assessment	30 (30)
Risk Analysis	30 (30)
Personnel Monitoring	100 (100)
Environmental Research	100 (100)
Data Bank	50 (50) +
Total	880 (880)++
Shiptime Support	900 (900)+++

* 1981 dollar costs per atoll; this would have to be adjusted for inflation for the actual year the program was begun at an atoll.
+ Numbers in parentheses are estimates for costs if the programs were conducted by new groups independent of current DOE Marshall Island Programs. The estimates are in addition to the program costs listed in Appendix A.
++ Cost-independent of shiptime.
+++ If an additional vessel were required to implement program beyond present capabilities.

APPENDIX C

Estimate of Time-lines for EMRDAP implementation at the 4 atolls (work that is in addition to the work currently performed under ongoing DOE Marshall Island Programs)**

Task	1979/1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Monitoring (Sampling) of Food Products and Water			Bikini	Enewetak	Utirik	Rongelap	Bikini	Enewetak	Enewetak	Bikini	Rongelap	Utirik	Evaluate need to continue the program	
Soil (Monitoring) Sampling			Bikini	Enewetak	Utirik	Rongelap	Bikini	Evaluate the need to continue the program						
Dietary Habits		Rongelap	Bikini	Utirik	Enewetak		Bikini	Enewetak						
External Gamma Monitoring Measurements				Enewetak	Bikini	Rongelap	Utirik		Enewetak	Bikini	Rongelap	Utirik	Evaluate need to continue the program	
Personnel Monitoring*		Utirik Rongelap Enewetak	Bikini Enewetak	Utirik Rongelap Enewetak	Bikini Enewetak	Utirik Rongelap Enewetak	Bikini Enewetak	Utirik Rongelap Enewetak	Bikini Enewetak	Evaluate what atolls should be continued and at what frequency.				
Research Requirements		Continued evaluation and implementation of necessary programs - all atolls →												
Data Bank and Data Reduction		All 4 atolls →												
Dose Assessment	Bikini Enewetak	Rongelap Utirik			Enewetak	Bikini	Rongelap Utirik			Enewetak	Bikini	Rongelap Utirik		
Risk Analysis	Bikini Enewetak	Rongelap Utirik			Enewetak	Bikini	Utirik Rongelap			Enewetak	Bikini	Utirik Rongelap		

* If resettlement should occur at Bikini Atol then annual monitoring would be necessary for the first few years.

** These schedules may be modified as necessary based on previous findings.

Appendix D

Tasks	Work currently in progress or planned as part of ongoing DOE programs				New or additional work required under P.L. 96-205				
	Bikini	Enewetak	Rongelap	Utirik	Bikini	Enewetak	Rongelap	Utirik	Other Atolls
Monitoring of Food Products	+	+	-	-	x	x	x	x	x
Monitoring of Soil and Water	+	+	-	-	x	x	x	x	x
Dietary Habits	-	-	+	+	x	x	x	x	x
External Gamma Monitoring	-	-	-	-	x	x	x	x	x
Personnel Monitoring	+	+	+	+	x	x	x	x	x
Research Requirements	+	+	-	-	x	x	x	x	x
Data Bank	+	+	+	+	x	x	x	x	x
Dose Assessment	+	+	-	-	x	x	x	x	-
Risk Analysis	+	+	+	+	x	x	x	x	x
									x

- Nothing current or planned independent of P.L. 96-205