ENVIRONMENTAL IMPACT STATEMENT

CLEANUP, REHABILITATION, RESETTLEMENT OF ENEWETAK ATOLL — MARSHALL ISLANDS

APRIL 1975

DEFENSE NUCLEAR AGENCY
Washington, D.C. 20305

Volume I of IV

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15 April 1975

MEMORANDUM FOR: SEE DISTRIBUTION LIST

SUBJECT: Environmental Impact Statement - Enewetak

1. Attached is the Environmental Impact Statement (EIS) for the proposed cleanup, rehabilitation and resettlement of Enewetak Atoll. This EIS has been prepared under the supervision of the Defense Nuclear Agency acting for the Department of Defense, with the assistance of the Atomic Energy Commission (now the Energy Research and Development Administration) and the Department of the Interior. The statement is intended to address the effects of the proposed project on the quality of the human environment, particularly that of the Enewetak people.

2. Comments of concerned federal agencies and the public were solicited on 6 September 1974. The proposed plan was presented to the Enewetak people and their counsel, the Micronesian Legal Services Corporation, at Enewetak on 7 September 1974. Substantive comments have been received, considered and are included in Volume IV of the EIS. Several comments, particularly those by the Natural Resources Defense Council, Inc. and the Micronesian Legal Services Corporation, have raised controversial issues concerning the degree of risk associated with the levels of plutonium which should be permitted to remain in the soil of the Atoll. The question cannot be resolved in this document. A more appropriate forum for the resolution of the controversy rests with the Federal agency charged with the establishment of standards for radiation protection. Consequently, it is planned to use the guidelines recommended by the Atomic Energy Commission in the proposed project.

3. This EIS was filed with the Council on Environmental Quality (CEQ) on 15 April 1975. The 30 day waiting period established by National Environmental Policy Act and the CEQ guidelines will run from the date that notice of availability is published in the Federal Register.

Warren D. Johnson

WARREN D. JOHNSON
Lieutenant General, USAF
Director

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SUMMARY SHEET
ENVIRONMENTAL IMPACT STATEMENT FOR CLEANUP, REHABILITATION, AND RESETTLEMENT OF ENEWETAK ATOLL, MARSHALL ISLANDS

1. This is an Environmental Impact Statement for the proposed cleanup, rehabilitation, and resettlement of Enewetak Atoll, the Marshall Islands. The statement is an administrative action in compliance with the National Environmental Policy Act (NEPA), (47USC4332).

2. This statement addresses a proposed project to remove and dispose of debris, structures, and soils which pose physical or radiation hazards or which pose obstructions to human habitation or the productive use of the land. The Department of Defense has been assigned responsibility to plan the cleanup phase of the proposed project. This statement also addresses the problem of the economic and social measures required to resettle the Enewetak people in the Atoll after 25-30 years of absence. The Department of the Interior, through the Trust Territory of the Pacific Islands, is responsible for this latter aspect of the proposed project.

3. During the post World War II period, the Atoll was used as a proving grounds for development testing of modern weapons and weapons systems, particularly nuclear weapons. This resulted in the relocation of the inhabitants from the Atoll, the creation of hazards, both physical and radiological, and the consequent loss of much of the productive capacity of the Atoll. The intent of this project is to remove or reduce those existing conditions which would be a bar to safe habitation of the Atoll and to return the Enewetak people to the Atoll. The effects of this proposed action are expected to be a permanent settlement of the people in a safe and productive environment. As the population grows from approximately 400 at present, the problems associated with a growing population on a small isolated land area may be expected to be magnified. The effects of the engineering operation to produce the results desired will of course create some adverse effects such as fish kill, loss of habitat for fauna, soil erosion and other like effects. These latter effects are expected to be minimal and temporary when compared to the resulting overall improvement of the condition of the atoll.

4. The Engineering Survey Report prepared for the Defense Nuclear Agency and the Enewetak Radiological Survey (NVO-140) prepared by the Atomic Energy Commission are essentially condition surveys which show the hazardous debris and structures and the radiological conditions of the Atoll. From these two source documents and the AEC Task Group Report, as well as from a Master Plan for the resettlement of the Atoll

prepared for the Trust Territory of the Pacific Islands. It is possible to visualize many alternatives which can be addressed in the evaluation of the many human, physical, and cost variables which are present. In order to obtain an overview of the possible solutions, a tabulation of twelve illustrative solutions has been made. These involve three separate cleanup procedures for each of four different habitation control plans. The consequences of all these combinations are tabulated. Factors involved in structuring these solutions are radiological conditions, living patterns, physical hazards, and the disposal of hazardous and radioactive materials and scrap. The tabulation analyses presented for these twelve particular solutions include possible radiation doses and cost-benefit comparisons. Based on this orientation, five solutions hereafter referred to as Cases 1 through 5, are selected for detailed discussion. Of these, two - Cases 1 and 5 - are considered to be outside of reasonable limits. Case 1 permits radiological doses greater than the protective guides and Case 5 results in unacceptable ecological damage to the land. The remaining three solutions are considered to illustrate the reasonable means to accomplish the objectives of the program.

Case 3 is considered to be the most responsive to the established goals and is a balance of the human, physical, and cost parameters which must be considered. It is planned to conduct the proposed cleanup, resettlement, and rehabilitation project as outlined by Case 3. The estimated radiological dose is well below the radiation protection guides recommended by the AEC Task Group; all physical hazards resulting from past construction and testing will be removed and the cost is well below the mid point between other viable solutions.

5. Under the conditions of Case 3, the Enjebi People could not expect to return to their ancestral residence island of Enjebi at an early time. This would require both the Enjebi and the Enewetak People to live on land formerly owned and occupied by only the Enewetak People. Thus, until natural decay processes reduce the exposure rates on the northern islands, there would be less land available for agriculture and some supplement to the people's diet may be needed. The people will be subjected to acceptable low levels of ionizing radiation with a relatively low risk. Some contend that the residual plutonium levels should be established in accordance with the hot particle theory. Since this theory is controversial, not currently accepted by existing standard setting authorities, and results in very severe if not impossible residual limitations for transuranium radionuclides, it has not been applied.

6. The Draft Environmental Impact Statement was made available to the Council on Environmental Quality, concerned federal agencies and the public on September 6, 1974. Substantive comments on the Draft Statement were received from the public and the following agencies, all of which were considered and are included as part of this Statement in Volume IV.

a. Environmental Protection Board, Department of Health Services, Trust Territory of the Pacific Islands.

b. Office of Environmental Affairs, Department of Health, Education and Welfare.

c. U. S. Coast Guard, Department of Transportation.

d. Biomedical and Environmental Research and Safety Division, U. S. Atomic Energy Commission.

e. Office of the Assistant Secretary of Defense for Health and Environment.

f. Region IX, U. S. Environmental Protection Agency.

g. Natural Resources Defense Council, Inc.

h. Micronesian Legal Services Corporation, Counsel for the Enewetak People.

i. Advisory Council on Historic Preservation.

7. This Final Environmental Impact Statement was filed with the Council on Environmental Quality on 15 April 1975.

1. SCOPE OF THE PROPOSED CLEANUP AND REHABILITATION PROGRAM

1.1 INTRODUCTION

This document is the environmental impact statement for a proposed project to clean up the Atoll of Enewetak and resettle the people of Enewetak on their native land. It is intended to be a joint project sponsored by the Defense Nuclear Agency (DNA), acting as agent for the Department of Defense (DOD), and the Department of the Interior (DOI). The Defense Nuclear Agency (DNA) has acted as the lead agency in the preparation of this statement and has fully coordinated this statement with the Office of Territorial Affairs, the Department of the Interior.

1.2 BACKGROUND OF THE OPERATION AND VIEWPOINT ADOPTED IN THIS IMPACT STATEMENT

The Enewetak people were relocated from the atoll in 1947 so that the islands could be used for the testing of various nuclear devices. The people were resettled on Ujelang Atoll, which is smaller than Enewetak in land and lagoon areas. High Commissioner Edward E. Johnston and Ambassador Franklin Haydn Williams, the President's personal representatives to the Micronesian Status Negotiations, announced in April, 1972, that the United States was prepared to release Enewetak Atoll to the Government of the Trust Territory of the Pacific Islands (TTPI) by the end of 1973, with the expectation that cleanup and resettlement could eventually take place.

Since the announcement, surveys have been conducted to determine the current condition of the atoll with respect to both physical and radiological hazards. Extensive discussions have been held with the Enewetak people to determine their desires with respect to land use, to the establishment of living and community facilities, to the use of facilities already present, and with respect to the possible short and long term economic development of the atoll. These surveys and discussions form, in part, the basis for the planning of the proposed operation described herein. (See Tab B, Volume II of this Environmental Impact Statement for AEC Task Group recommendations and Tab D, Volume II, for the Master Plan.)

This document differs from the usual environmental impact statement. In the usual case, the project being proposed may involve building something on land which is in a "natural" or relatively undeveloped condition. As a result, the impact of the project on the environment is critically scrutinized and weighed against the expected benefits. If the benefits sufficiently outweigh the adverse impacts, approval of the project can be expected.

In the case of the proposed Enewetak operation, the situation is reversed. The adverse environmental impacts are already present. The islands are already littered with debris and in some areas are contaminated with radioactivity. The proposed operation is one of eliminating these existing impacts and preparing the atoll for resettlement. It is true that the cleanup actions would, themselves, have impacts on the environment. Consequently, this report adopts the view that one must consider not only the impact of the proposed actions and the comparative weight of these actions balanced against existing radiological conditions, but also the impacts of any lack of action. This latter may include the continued denial of the islands to the Enewetak people and continued prevention of any economic use of the islands.

1.3 PHASES OF THE PROJECT

A major objective of the proposed operation is to be able to return the people to the islands as early as possible. Accordingly, for economic, political, and social reasons, it may be desirable to conduct cleanup and resettlement concurrently. For purposes of discussion, however, it is convenient to distinguish these elements as separate phases and, moreover, to identify four phases as follows.

1.3.1 Phase 1 - Cleanup

This phase consists of the removal of debris, structures, and soils which pose hazards or obstruction to human habitation. It also includes the definition of actions necessary to avoid harmful radiation exposures. During this phase, a maximum of 50 people of Enewetak will commence residing on Japtan Island including both those who may be employed to assist cleanup operations and some members of the Enewetak Planning Council. In addition, the representative of the District Administrator, and members of the representative's family, totalling 12 persons, will also be resident on Japtan.

1.3.2 Phase 2 - Rehabilitation

This phase consists of economic and social rehabilitation measures, such as provision of housing and replanting of coconut trees and other crops, to permit resettlement of the Enewetak people.

1.3.3 Phase 3 - Resettlement

The resettlement phase will take place after cleanup has been completed and the islands have been certified as safe. Housing will then be constructed, and the Enewetak people could occupy the newly built homes and cultivate the land. For the safety of the people concerned this phase would require mutually imposed controls to assure that the living patterns of the people conform to the limitations recommended by the AEC Task Group Report. The TTPI will have the responsibility for the enforcement of travel and residence restrictions.

1.3.4 Phase 4 - Long Term Development

Although not considered part of the current project, a fourth and continuing phase is identified. This phase would follow the cleanup, rehabilitation, and resettlement and would consist of the long range development of the economy and culture of the islands, as well as long term radiological monitoring.

1.4 ASSIGNMENT OF RESPONSIBILITIES

Three United States Government agencies have been involved in the testing and posttesting periods on Enewetak and are now involved in planning the proposed cleanup, rehabilitation, and resettlement of the atoll.

- The United States acquired Enewetak from the Trust Territory of the Pacific as a nuclear proving ground in 1946. The Department of Defense has been designated to carry out the proposed cleanup to make the atoll safe for human habitation.

- The United States Atomic Energy Commission (AEC) was responsible for the technical aspects of the nuclear testing program. The Energy Research and Development Administration (formerly the AEC) now has the responsibility of providing technical data and acting in an advisory capacity on all radiological matters during both the planning and operational phases of the cleanup program. The ERDA will also assume responsibility, including funding, for future periodic follow-up radiological surveys as necessary; and the maintenance of periodic monitoring of the health status of the resettled people and of the radioactivity in the environment subsequent to rehabilitation.

- The Department of the Interior has had nominal administrative jurisdiction over the Marshall Islands through the Trust Territory of the Pacific Islands, and has the administrative responsibility for the care of the Enewetak people, the resettlement of the atoll, and the enforcement of advisory controls.

- The DOD, ERDA, DOI, and TTPI have solicited the views of the Enewetak people in planning for their return to Enewetak Atoll.

2. SUMMARY OF IMPACTS

The program proposed for cleanup, rehabilitation, and resettlement has been designed to provide a safe and productive habitation for the Enewetak people. The expected positive effects of the proposed program on the people and the environment expressed in qualitative terms are as follows:

- The return of the Enewetak people to their homeland.
- The removal of dangerous debris, litter, and structures to permit the construction of habitations and community centers and the installation of agricultural areas.
- The rehabilitation of certain existing buildings and other facilities for use by the Enewetak people.
- The clearing and removal of undesirable vegetation.
- The reduction of some external gamma exposure through removal of contaminated scrap.
- The removal and disposal of that plutonium-bearing soil which exceeds AEC guidelines.
- The increase in economic independence of the Enewetak people by increasing their ability to provide products and services.
- The establishment of new artificial reefs for marine life.

On the negative side, the proposed cleanup and resettlement operation may have certain adverse impacts on the atoll environment and people. The more significant of these are listed below. These impacts and others are detailed in Section 5 and discussed in Section 8.

- The denial of Enjebi and the northern islands for resettlement by the driEnjebi, and the relocation of the driEnjebi on the southern part of the atoll for an extended period, because of the harmful radiological conditions existing on Enjebi and certain other northern islands.
- Increase in the projected population which may result in overcrowding in future years. This would result from the restriction of residential areas to the southern islands.

- The risk of detrimental economic, social, and physical effects as a result of cleanup operations or as a result of advisory controls which exclude some land from productive use.

- The necessity for maintaining periodic inspections of Cactus and/or Lacrosse Crater to insure integrity.

- The loss of some desirable vegetation and disruption of habitats for fauna of the atoll.

- The fish-kill resulting from blasting ship channels in the lagoon.

- A possible long term degradation of the atoll caused by reintroducing the Enewetak people in substantial numbers on a limited land area, which, for the most part, is now uninhabited.

- All of the adverse conditions associated with a growing and emerging culture newly exposed to modern western civilization, but living on a limited land area, such as pollutions from gasoline and other POL sources, maintenance of modern equipment, and reliance on new means and resources instead of traditional ones.

- The physical and emotional stresses to which the Enewetak people could be subjected as a result of their relocation to Enewetak Atoll. For a large number who have never seen the atoll, the adaptation process could present serious problems. Even though the TTPI would endeavor to ease the problems engendered by the move, the fact remains that adjustment to the new location would require a long time and a large amount of sympathetic assistance. Even the older people, who had once resided on the atoll, would require assistance in adjusting to the fact that the atoll is not the same as when they left and that certain restrictions on their normal living pattern would have to be observed. While the TTPI would provide expert assistance to aid in alleviating the uncertainties inherent in such a transition, consideration must be given to the certainty that they will remain with the people for some time to come.

- The risk of somatic effects from long term low level residual radiation.

3. ENEWETAK ATOLL - HISTORY AND STATUS

3.1 ENEWETAK ATOLL ISLAND NAMES

The Enewetakese names of most of the islands in the Enewetak Atoll are difficult for English speaking people to pronounce and spell. Consequently, code names were assigned to the islands during the nuclear testing operations. Site names were also given to several points in the lagoon and on the reef where scientific structures were erected. Nearly all documents and maps made subsequent to 1952 include these site names. In some cases the Enewetakese names are also shown in parentheses. Enewetakese names as listed in Table 3-1 will be used throughout this document, spelled in the manner indicated there.

Table 3-1 presents a comparison of site names with the names obtained from the Enewetak people themselves during the field trip to Ujelang in July 1973. It also contains the names obtained from the United States Hydrographic Office Charts. It is interesting to note the influence of Japanese pronunciation on the names as given in the hydrographic charts.

3.2 PHYSICAL DESCRIPTION OF ENEWETAK AREA

3.2.1 Geography

Enewetak Atoll is the most northwestern atoll in the Western (Ralik) Chain of the Marshall Islands which form the northern part of Micronesia in the central Pacific Ocean (Regional Map, Figure 3-1). Its location is 11° 21'N, 162° 21'E, approximately 550 nautical miles southwest of Wake Island, 189 nautical miles west of Bikini Atoll, and 2,380 nautical miles southwest of Honolulu (Airline Distances Map, Figure 3-2). The Eastern chain of the Marshalls is known as the Radak chain.

The atoll consists of 40 islands on an elliptically shaped reef approximately 23 by 17 nautical miles, with the long axis running northwest to southeast. The total land area is 2.75 square miles, with the land height generally averaging 10 feet above mean sea level. The Vicinity Map (Figure 3-3) shows the atoll configuration.

The lagoon, which is about 388 square miles in area, has three entrances: an east channel approximately 180 feet deep, between Medren and Japtan; a 6-mile wide channel to the south; and a shallow (approximately 4 fathoms maximum depth) channel to the southwest. Tidal currents vary from 1 knot in the south channel up to 2 knots in the deep channel.

TABLE 3-1: COMPARISON OF SITE AND ENEWETAKESE NAMES

Site	Names from U. S. Hydrographic Office Charts	Enewetakese Names**
ALICE	Bogallua	BOKOLUO
BELLE	Bogombogo	BOKOMBAKO
CLARA	Eybbiyae	KIRUNU
DAISY	Lidilbut	LOUJ
EDNA	*	BOKINWOTME
HELEN	Bogeirik	BOKAIDRIKDRIK
IRENE	Bogon	BOKEN
JANET	Engebi	ENJEBI
KATE	Mujinkarikku	MIJIKADREK
LUCY	Billee	KIDRINEN
PERCY	*	TAIWEL
MARY	Bokonarppu	BOKENELAB
NANCY	Yeiri	ELLE
OLIVE	Aitsu	AEJ
PEARL	Rujiyoru	LUJOR
RUBY	Eberiru	ELELERON
SALLY	Aomon	AOMON
TILDA	Biijiri	BIJIRE
URSULA	Rojoa	LOJWA
VERA	Arambiru	ALEMBEL
WILMA	Piirai	BILLAE
YVONNE	Runit	RUNIT
SAM	*	BOKO
TOM	*	MUNJOR
URIAH	*	INEDRAL
VAN	*	*
ALVIN	*	JINEDROL
BRUCE	Japtan	ANANIJ
CLYDE	Chinimi	JINIMI
DAVID	Muti	JAPTAN
ELMER	Parry	MEDREN
WALT	*	BOKANDRETOK
FRED	Eniwetok	ENEWETAK
GLENN	Igurin	IKUREN
HENRY	Buganegan	MUT
IRWIN	Bogan	BOKEN
JAMES	Libiron	RIBEWON
KEITH	Grinem	KIDRENEN
LEROY	Rigili	BIKEN
REX	Bogen	JEDROL
OSCAR	*	DREKATIMON
MACK	*	UNIBOR

*No Geographic Place Name.

**As Confirmed by the Enewetak People During the Ujelang Field Trip of July, 1973.

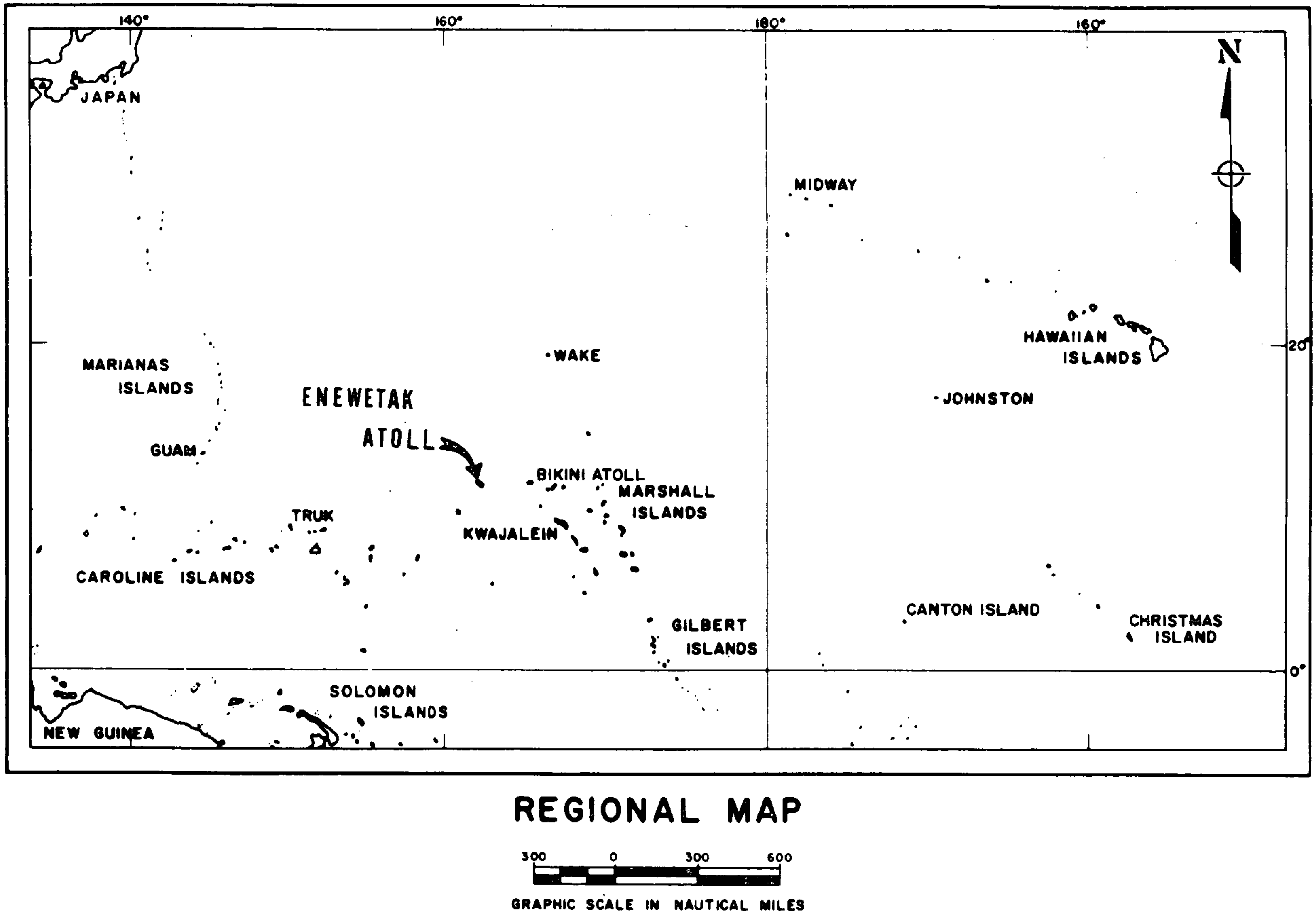
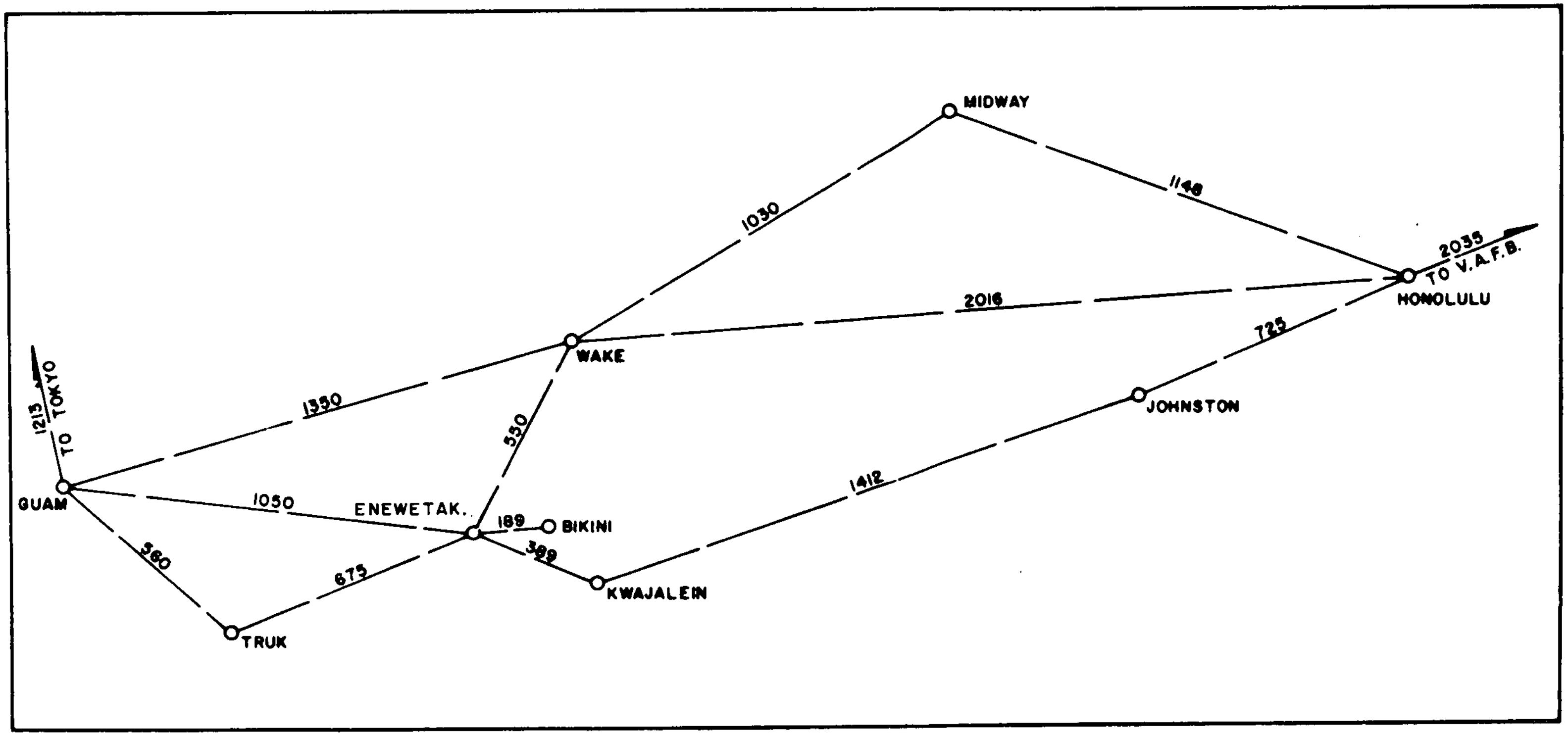


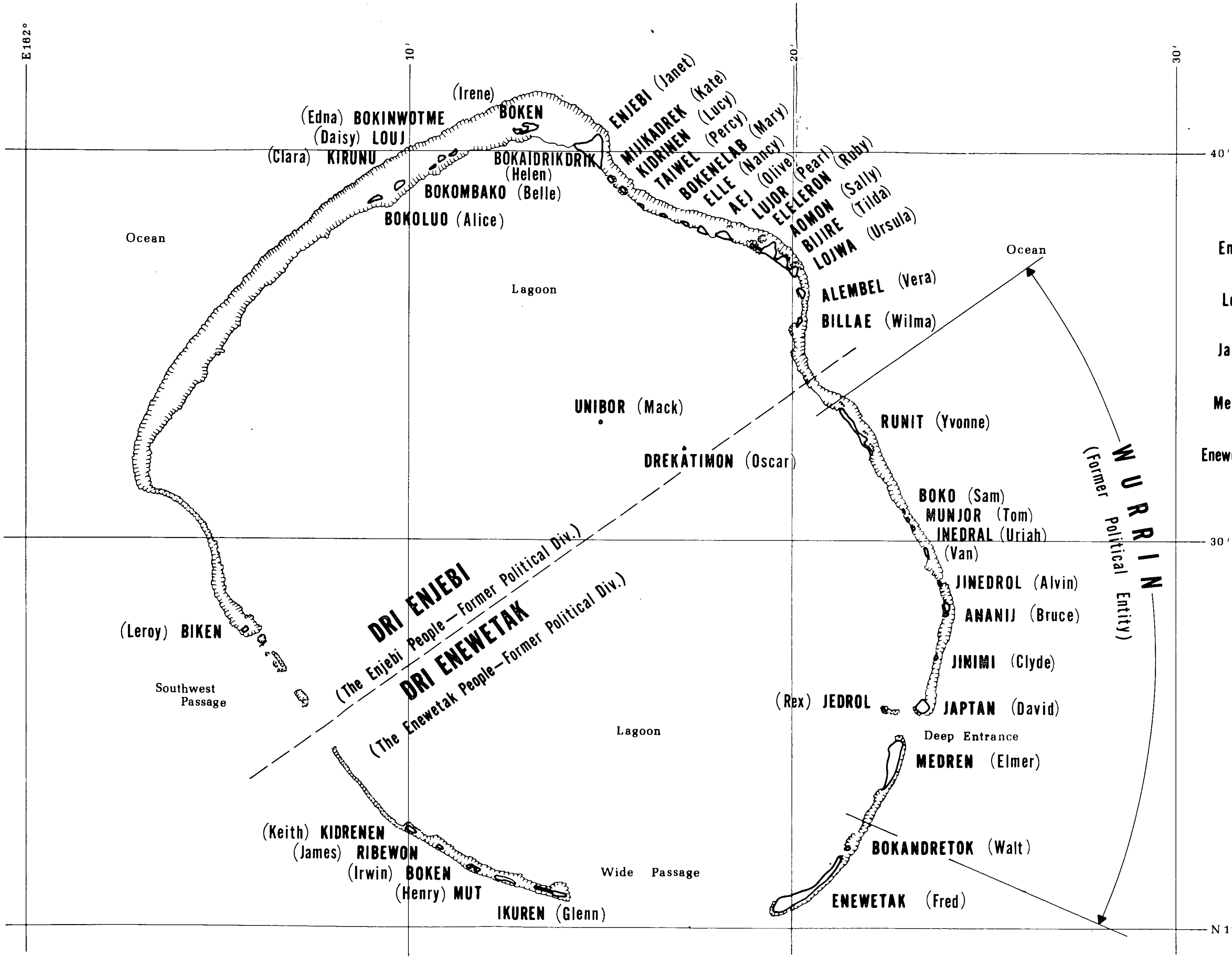
FIGURE 3-1: REGIONAL MAP



AIRLINE DISTANCES MAP

NO SCALE

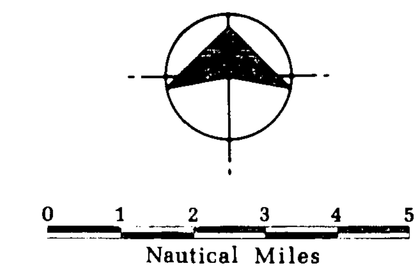
FIGURE 3-2: AIRLINE DISTANCES MAP



	Enjebi	Lojwa	Japtan	Medren	Enewetak
Enjebi		6	17	17	20
Lojwa	6		12	13	16
Japtan	17	12		2	6
Medren	17	13	2		5
Enewetak	20	16	6	5	

MILEAGE TABLE

(Nautical Miles From Dock To Dock)



ENEWETAK ATOLL

VICINITY MAP

FIGURE 3-3

3.2.2 Geology

Enewetak Atoll rises 15,000 feet above the ocean floor, while the top of the eroded volcano which forms the island base is approximately 4,200 feet below the surface. Steep coralline reefs reaching to the surface form a flat oval ring of reef and low-lying islands, within which is a shallow lagoon with a maximum depth of about 200 feet.

Enewetak is a classic example of the Darwinian concept of atoll formation in which an atoll is born when an oceanic volcano, surrounded by a fringing coral reef, begins to subside slowly below the ocean surface. As the coral and coralline algae (which require shallow, clear, warm, oxygenated marine waters) maintain an upward growth commensurate with the subsidence, the fringe of reef flourishes, particularly on the ocean side. As the volcano continues to subside, the fringe reef gives way to a barrier reef, and then to an atoll.

Since the northeast trade winds vary little in their direction, the reefs on the windward and leeward sides of the atoll are distinctly different. A greater volume of ocean water carrying nutrients necessary for coral growth flows over the windward side due to the wind-generated ocean currents. Therefore, more rapid growth occurs on the windward side, which has a slightly elevated ridge at the reef edge, while there is no ridge on the leeward side. The leeward side drops sharply to ocean depths up to 200 fathoms, whereas, the windward reef slopes seaward at a lesser angle.

Four near-surface geologic regions can be distinguished at Enewetak Atoll: island, interisland, ocean reef, and lagoon. Descriptions of the island and ocean reef geology can be given based on core samples from 50 holes drilled during the nuclear testing program (Cooper and Pratt, 1968). No records are available of the interisland and lagoon geology so that these can only be inferred.

The island geologic profile consists of unconsolidated coral sands and gravels, saturated below the water table and extending from the surface to a maximum depth of 150 feet. The water table varies with the tide, its distance below the land surface decreasing rapidly with distance from shore. Typical depths to the water (elevation of island above mean tide) are 5 to 8 feet. At the intertidal zone, a 1-foot to 5-foot layer of beach rock (calcium carbonate cemented coral sands and gravels) is usually found, the exposed portions of which form most of the shore line. The rock strength ranges from hand crushable to high strength sandstone, decreasing in strength and thickness from ocean to lagoon. Below the unconsolidated coral sands and gravels, there is an old reef horizon extending from the ocean to the lagoon side, at depths of 50 to 150 feet. This reef horizon is gradational and porous, consisting of large detrital and *in situ* coral fragments with fine sands and muds occupying the voids.

The ocean reef profile shows a similarity to the island profile except that the upper surface layer consists of a wave-planeated, dense, algal-limestone reef flat composed of detrital and *in situ* coral. The thickness of the upper reef horizon varies from 0 to 15 feet, progressing outward from the island, and is composed of a dense algal limestone. Of the two holes drilled into the Aomon reef proper (Ladd, 1969), one penetrated a 35-foot sand and gravel horizon between the upper and lower reefs, while the other did not. It is inferred, based upon limited drilling and general atoll physiography, that the ocean reef geology is more heterogeneous than the island geology, containing numerous large coral heads, caverns, etc.

The interisland geologic profile can be presumed to be similar to the island geologic profile, except for the possibility that the top 10 to 40 feet of rock and sand has been eroded away by the sea.

The lagoon geologic profile probably consists of soft, fine sediments to a depth of a few hundred feet, with intermixed and sporadic lagoonal coral heads. The depth to the lower reef horizon, if it exists, is probably not greater than a few hundred feet.

3.2.3 Climatology

Enewetak's climate is the tropical marine type, with temperatures ranging from 71° to 94°F and humidity in the 73 to 80 percent range. There is much cumulus cloud cover, moderate rainfall (57 inches mean annual rainfall), and, to a lesser extent, constant northeasterly trade winds of 0 to 30 knots. Most depressions or tropical storms occur during the months of September through December, although they are possible at any time of the year. Typhoons are uncommon but not unknown (Doran, 1959). A climatological summary of Enewetak Atoll for a 10-year period, as prepared by the United States Air Force Environmental Technical Applications Center, is shown in Table 3-2.

3.2.4 Hydrology

Enewetak Atoll relies on rainfall as its source of fresh water. Since the soil is extremely porous, drainage of rainfall by downward percolation through the ground is rapid. This "groundwater" makes contact at its lower face with marine water that has infiltrated through the porous rock from the sea and lagoon. Fresh water poured upon an open body of salt

TABLE 3-2: METEOROLOGICAL OBSERVATIONS FOR ENEWETAK ATOLL OVER A 10-YEAR PERIOD

Parameter Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Absolute Max Temp (°F)	88	88	89	90	91	90	92	91	93	91	94	88	94
Mean Max Temp (°F)	85	85	86	86	86	87	87	87	88	87	86	86	86
Mean Min Temp (°F)	78	78	78	78	78	79	79	79	79	79	79	78	79
Absolute Min Temp (°F)	71	73	73	72	73	73	71	72	72	71	72	71	71
Mean Rel Humidity (pct)	73	73	75	76	78	79	80	80	79	79	78	76	77
Mean Precip (in.)	1.03	0.85	1.73	2.47	5.65	4.06	7.12	6.67	6.76	9.76	7.26	3.61	57.0
Mean No. Days Precip ≥ 0.1 in.	3.4	2.5	4.3	5.3	9.2	9.6	13.0	13.1	13.1	14.0	13.0	7.2	108.3
Mean No. Days of Thunder-storms	0.0	0.0	0.0	0.0	0.2	0.4	1.3	0.9	1.4	1.9	0.5	0.2	6.0
P Freq. Wind Spd ≥ 17 knots	47.4	56.2	49.4	47.9	38.7	27.8	11.4	9.3	7.0	9.1	34.7	47.5	32.2
P Freq. Wind Spd ≥ 28 knots	0.2	0.3	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.7	1.5	0.3

water will quickly spread over the surface of the salt, and through currents and waves will become thoroughly mixed with the salt water. Porous rock, however, imposes an obstacle to this rapid spread and restricts the mixing of the fresh water with the denser salt water. The fresh water is only about 40/41 as dense as salt seawater and floats on the salt water, displacing 40 parts of seawater for each part of fresh water floating above the normal seawater level. That is, fresh water seeping to basal groundwater level on coral atolls and other porous islands has a depth that is about 40 times the head or elevation of its water table above sea level (Figure 3-4). This head or hydraulic gradient tends to seek sea level by lateral flow through the restricting rock. This principle of freshwater displacement of salt water in islands and coastal areas is known as the Ghyben-Herzberg law, after its first discoverers (Cox, 1951). As the head of water moves outward, the depth of the fresh water becomes less until at the edge of the shore, where the fresh water seeps into the sea, it is just about sea level, disregarding the fluctuations of the tide.

In a roughly round island of uniform permeability, the body of fresh water floating upon the salt water assumes the shape of a lens, the edges of which approximate the edges of the island, with the upper face of the lens only slightly convex compared with the deeply convex lower surface at the saltwater interface (Weins, 1962). A pictorial representation of an ideal freshwater lens is shown in Figure 3-4. It should be noted that the water shown in Figure 3-4 does not lie in a large pool beneath the island, but is trapped within the porous media making up the island. Ideally, the saltwater/freshwater interface would be clearly defined; however, this is the exception to the rule as the lens is a dynamic system rather than a static system. When the interface moves with respect to the porous fluid-containing medium, the sharpness is diffused, creating a transition zone in which the quantity of mixing is proportional to the rate of movement of the interface (Figure 3-5).

Normally, the interface moves constantly due to tidal action and seasonal changes in the amount of recharge (rainfall percolation) which affects the thickness of the lens. This movement of the interface up and down alternately brings the invasion of salt and the dilution of salt water with fresh water. Thus, the contact zone is not sharply defined in terms of salinity or freshness, but shows a transition in salinity. At the center of an island of uniform permeability, the tidal fluctuation is at a minimum, and the depth of fresh water is at a maximum. At the shore, the tidal range is at a maximum and there is a reverse gradient at high tide carrying salt water into the island. Therefore, all of the water emerging at the shore line is brackish (Weins, 1962). At present, there is uncertainty as to the existence of fresh (brackish) water lenses under some islands in the atoll. A comprehensive hydrological survey would be required to locate the lenses and determine their qualities.

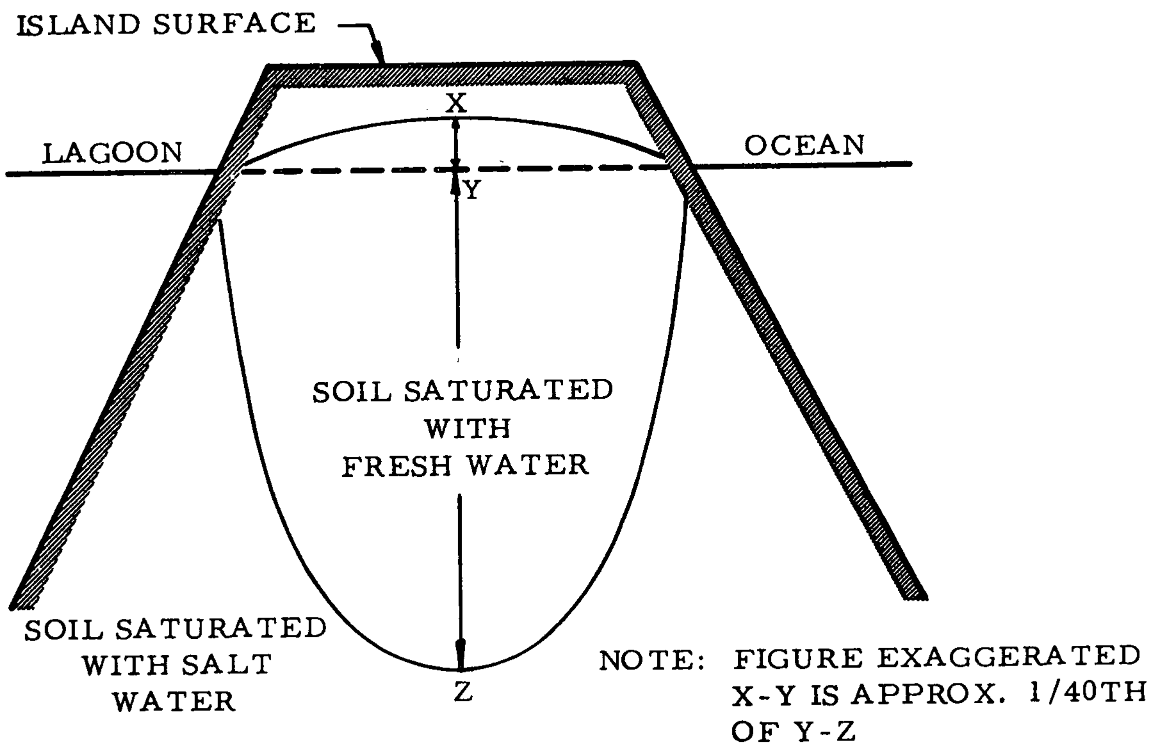


FIGURE 3-4: SCHEMATIC REPRESENTATION OF AN ISLAND FRESHWATER LENS

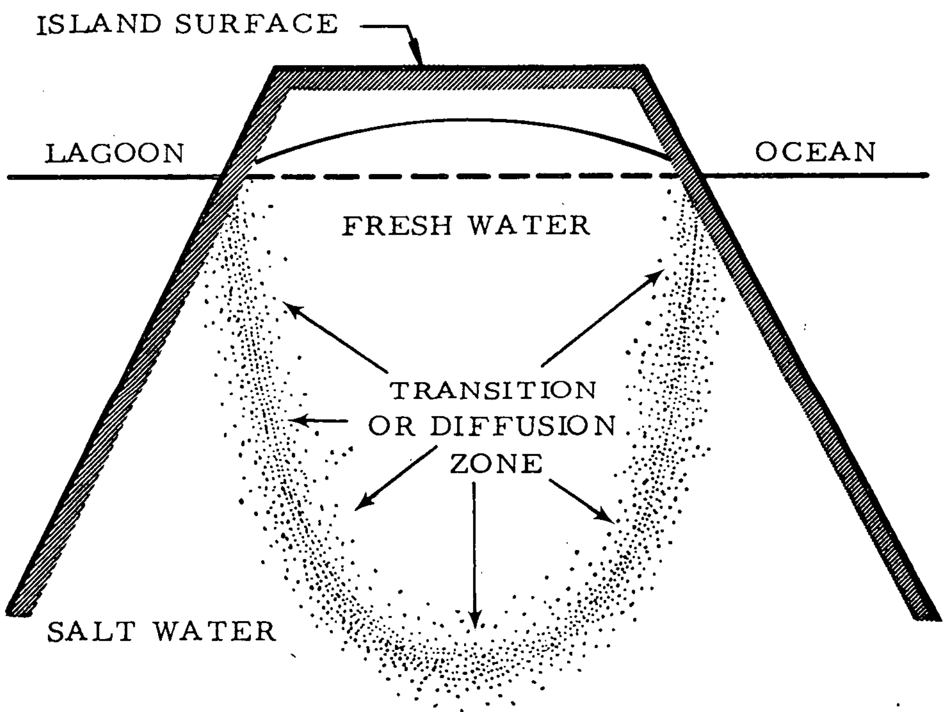


FIGURE 3-5: FRESHWATER LENS DIFFUSION ZONE

3.2.5 Ecology - Flora and Fauna

The activities of man have had a profound impact upon the ecology of Enewetak Atoll. The extent of impact caused by the small numbers of early inhabitants is unknown. However, historical records provide some information on the effects of man's more recent activities. The Germans introduced coconut plantations (and the consequent clearing of underbrush) and domestic fowl and animals, before the turn of the century. Soil, used for ship ballast, was transported from Europe to the atoll during this period. The Japanese, preparing for war, brought large numbers of people to the islands and engaged in massive construction projects. Heavy bombardments during World War II devastated portions of the reef and entire islands. During the nuclear testing program of 1948 to 1958, some islands were totally devegetated and two were destroyed. Although the majority of nuclear tests were conducted in the northern half of the atoll, the islands of the south were used for housing the thousands of test program personnel. Consequently, the southern islands were altered by the large scale construction of airstrips, housing and harbor facilities, and roads.

The following description of the present ecology of Enewetak Atoll is presented as the best data available at the present time.

3.2.5.1 Flora. Enewetak is in the northern and drier section of the Marshall Islands. As a consequence, it does not have, and probably has never had, dense, lush damp forests; nor is its flora large. St. John (1960) described the flora as follows.

Its indigenous flora totals 42 species, of which 4 are endemic, all of these four being in the genus *Pandanus*. The total of adventive weeds is 27 and that of cultivated plants, including both food crops and ornamentals, is 26. Species known only by drifted seeds on the beaches total seven. Altogether, the living flora totals 95 species (see Table 3-3).

Seeds or fruits found in the jetsam on the sea and lagoon beaches add an element in the flora. Many come from species growing on the islets of the atoll, but there are others from species unknown on the island and certainly floated on the sea currents or waves from distant regions. Of these, *Hernandia sonora* is the only one that is native to other islands of the Marshall group, those to the south in the wetter belt. Two species, *Caesalpinia bonduc* and *Aleurites moluccana*, are of wide occurrence and could have come from the northeast, south, or west. Both are abundant in Hawaii. Two species, *Mucuna urens* and *Sapindus saponaria*, must have come from the northeast, being abundant in Hawaii and absent in other parts of the tropical Pacific. Two species, *Dioclea reflexa* and *Entada phaseoloides*, must have come from the south or west. In sum, of the six

TABLE 3-3: THE FLORA OF ENEWETAK ATOLL
(As Reported by St. John, 1960)

Species			
Scientific Name	Common Name	Vernacular Name	Remarks
TREES			
Pandanus brachypodus	Pandanus	Punmusi	Pandanus leaves are utilized for weaving plaited goods and thatch. Some pandanus fruits are used as food.
Pandanus enchabiensis		Maok	
Pandanus korrorensis		Bop	
Pandanus odoratissimus var. novocaledonicus		Bop	
Pandanus odoratissimus var. novoguineensis		Bop	
Pandanus pulposus		Jilebar	
Pandanus rectangulatus		Anilip	
Pandanus rhombocarpus		Papparawa	
Pandanus utiyamai		Bop	
Cocos nucifera	Coconut Palm		Used for food making, artifacts, and copra production.
Artocarpus incisus	Breadfruit	Me	Of aboriginal cultivation. Tree, 9 m. tall, observed on Japtan, 1944.
Pisonia grandis		Kangae	Abundant, forming forests on better habitats.
Hernandia sonora		Bingbing	Fruits found on beaches, 1958.
Aleurites moluccana			Found only as seed on sea drift.
Sapindus saponaria			Found as seeds on beaches.
Carica papaya	Papaya	Keinapu	Recently introduced fruit tree. Observed, 1958.
Rhizophora mangle			Introduced tree, restricted to tidal salty shores.
Terminalia samoensis		Kugung	
Ochrosia oppositfolia		Kijebar	Tissues poisonous.
Cordia subcordata	Heliotrope	Kono	Evergreen tree to 16 m.
Messerschmidia argentea		Kirin	Small tree. Leaves may be eaten.
Guettarda speciosa		Wut	A tree to 8 m.
Morinda citrifolia	Indian Mulberry	Nen	Medicinal use.
LARGE SHRUBS			
Ximenia americana		Kalikelik	Sour, edible fruit.
Suriana maritima		Ngiungi	

TABLE 3-3 (continued)

Species			Remarks
Scientific Name	Common Name	Vernacular Name	
LARGE SHRUBS (continued)			
Ricinus communis			Introduced ornamental.
Pemphis acidula		Kungi	Hard wood. Leaves edible.
Nicotiana glanca	Tree Tobacco		Introduced weed.
Scaevola frutescens var. frutescens		Mar kinat	The most abundant shrub, especially near the shore. Leaves used medically; wood hard.
Scaevola frutescens var. sericca		Mar kinat	
Wedelia biflora		Marguegue	
SMALL SHRUBS			
Phymatodes scolopendria		Kino	Recorded only in 1944.
Cyperus javanicus		Wujoet in ion buil	Probably of aboriginal introduction.
Fimbristylis atollensis		Berelitchman	Native sedge, abundant on most habitats.
Achyranthes velutina			
Sida fallax		Kio	
Pluchea indica			Introduced weed.
VINES AND CREEPERS			
Caesalpinia bonduc			Found only as drift seeds on the beaches.
Canavalia microcarpa		Marlap	
Dioclea reflexa			
Entada phaseoloides			Known here only as seeds in the sea drift.
Muguna urens			Drift seeds on beach of Engebi.
Phaseolus vulgaris	String Beans		In gardens.
Vigna marina		Markinejojo	
Triumfetta procumbens		Adat	A trailing vine used in weaving.
Ipomoea pes-caprae		Marginejojo	
Ipomoea purpurea	Common Morning Glory		Cultivated ornamental.
Ipomoea tuba		Marbele	
Citrullus vulgaris	Watermelon		Once grown in gardens.
Cucumis melo	Cantaloupe		Once grown in gardens.

TABLE 3-3 (continued)

Species			Remarks
Scientific Name	Common Name	Vernacular Name	
VINES AND CREEPERS (continued)			
Cucurbita maxima			Observed in gardens, 1944.
GRASSES			
Cenchrus brownii			Introduced weed.
Cenchrus echinatus	Sandbur	Legalek	Introduced weed, abundant and troublesome in disturbed soils.
Chloris inflata			Introduced weed.
Cynodon dactylon	Bermuda Grass		Deliberately introduced as lawn grass and as sand binder.
Dactyloctenium aegyptium			Introduced weed.
Digitaria pruriens	Crab Grass		Introduced weed.
Eleusine indica	Goose Grass		Introduced weed.
Eragrostis amabilis	Love Grass	Wujoich	Common, but apparently an introduced weed.
Lepturus repens var. repens		Ujos aitok	The commonest native grass.
Setaria verticillata	Bristly Foxtail		Introduced weed, abundant in disdisturbed soil near settlements.
Sorghum bicolor var. technicum	Sorghum		Cultivated crop grain.
Thuarea involuta		Ujos maroro	Local, uncommon, found on or near the sea beaches.
Tricachne insularis			Introduced weed.
Tricholaena repens			An introduced weed.
Zea mays			Once cultivated, observed, 1944.
HERBS			
Cyperus odoratus	Sedge	Ujoet	Introduced weed, wet places.
Allium cepa	Onions		Onions reported in gardens in 1944.
Crinum asiaticum	Spider Lily		Observed in gardens, 1944.
Tacca leontopetaloides	Arrowroot	Mokmok	Tubers grated and washed to obtain edible starch.
Fleurya ruderalis		Nenkutkut	
Achyranthes aspera		Kaleklek	Introduced weed.
Amaranthus dubius			Introduced weed.

TABLE 3-3 (continued)

Species			Remarks
Scientific Name	Common Name	Vernacular Name	
HERBS (continued)			
Amaranthus viridis			Introduced weed.
Boerhavia diffusa var. diffusa		Matok aitok	Abundant.
Boerhavia diffusa var. tetrandra		Rabitchragai	
Mirabilis jalapa	Four-O'Clock	Emen aur	Introduced, probably as an ornamental.
Portulaca lutea		Kiran	
Portulaca oleracea			
Portulaca samoensis		Bujon	
Cassytha filiformis		Kenen	Parasitic entwining herb.
Brassica oleracea	Cabbage		Cultivated vegetable.
Brassica pekinensis			Cultivated vegetable.
Raphanus sativus	Radish		Cultivated vegetable.
Tribulus cistoides	Caltrop		
Euphorbia chamissonis	Spurge	Berol	
Euphorbia hirta	Spurge		Introduced weed.
Euphorbia thymifolia	Spurge		Introduced weed.
Phyllanthus amarus			Weed introduced from America.
Malvastrum coromandelianum			Introduced weed.
Physalis angulata	Ground Cherry		Weed introduced from North America.
Solanum lycopersicum	Tomato		Cultivated for its edible fruit.
Erigeron bonariensis			Introduced weed.
Lactuca sativa	Lettuce		In gardens, 1944.
Pluchea odorata			Introduced weed.
Vernonia cinerea		Senailing nagailing	Introduced weed.
Zinnia elegans	Zinnia		In American gardens, 1944.

drift species, four certainly floated from Hawaii on the Japan Current which regularly flows past Hawaii towards the Marshalls and the central Pacific. The two species of southern or western origin may have traveled eastward on the Equatorial Counter Current and have been wafted northward during a southerly storm.

Because of the dryness and the small, mostly narrow, islets, there is little diversity in the habitats. There are no good sand dunes or fresh ponds, or central hollows with rich, black humus topsoil. The only habitats are outer beaches of coral rock or coral gravel, inner beaches of coral sand, small coral sand dunes, coral gravel flats, and coral sand flats. Some of the plants seem restricted to a particular habitat, but the zones formed are rather indefinite. Their occurrence appears to be governed less by the soil than by the size of the islet and the distance of the zone from the sea. This seems to determine the degree of shelter from salt spray and the availability of fresh water in the water table.

Woodbury (1962) described ecological successions that occurred at Enewetak after the nuclear testing program. Extracts of this description are presented as follows:

"It is well known that many of the low coral islands on reefs show stages of development from mere piles of coral sand through successive stages of accumulation to well developed loamy soils bearing heavy forest stands. Examples could be selected that would illustrate the steps in succession through which the advanced islands probably passed to reach their present stage of development. Palumbo (1962) watched the recovery of plants on Bokombako (Belle) Island of the Enewetak Atoll after a nuclear explosion denuded the island and produced a secondary bare area. Later studies have been made of the distribution of vegetation on the islets by the crew from the University of Utah in the Spring of 1962.

"This pattern of recovery on Bokombako (Belle) showed quite a different pattern from that expected from a primary bare area which with the assistance of Palumbo, Held, Bushman and others, I have charted approximately as follows: When coral sands are piled sufficiently large and high to hold fresh rainwater, _Scaevola frutescens_ and/or _Messerschmidia argentea_ seeds from neighboring sources germinate and become established. Seeds may be carried by water or by birds, occasionally by wind or by man (Fosberg, et al, 1956:216). Their roots in the fresh water begin to bind the soil, the crowns shade the ground and reduce soil temperature, and the litter incorporated in the soil improves the organic content and helps to hold more moisture. The presence of plants helps to slow winds carrying sand or sediment and thus increases the size of the island. On some islands, the waves wear at one side while winds transport sand to the other side thus producing a slow migration of the island.

"After Scaevola or Messerschmidia have pioneered the first harsh environment (excessive salinity, strong sunlight, high temperature, scarce nutrients); a grass, such as Lepturus repens; and a sedge of the genus Fimbrystilus join these hardy pioneers and help in further ameliorating the environment. These are assisted by other sand binders, Suriana maritima, and the creeping morning glory, Ipomea tuba.

"Once established, this morning glory may extend its long runners over fresh sand surfaces and act as a sand binder that will hold the sand in place while other vegetation becomes established. In this way, it acts as a pioneer. The accident of dispersal may change this sequence in different ways and lead through different routes to a heavy cover of vegetation.

"With the advent of vegetative cover, some of the fish-eating birds, especially the terns, begin to use the vegetation for nesting purposes, some on the ground among the herbage or shrubs and others in the trees. Wherever they nest, the consequent guano brings much needed minerals from the sea, especially phosphorus, that add to the fertility of the soil. These extra minerals are incorporated into the plants, thence into the plant litter, and again into the soil to pave the way for the entry of additional plants that could not survive well as pioneers.

"When the cover is adequate to provide a more hospitable environment (reduced salinity, shaded soil, lower temperature, and better nutrition), certain secondary plants enter the vegetation, particularly the prostrate vines, Triumfetta procumbens and Boerhaavia tetrandra and the dodder-like parasite, Cassytha filiformis. Other species characteristic of later stages of the vegetation may be added as conditions become more favorable and their needs become available. These include woody trees that can become established in thick vegetation and push their way into dominant positions. In the thick wooded interior of the islets of the Enewetak Atoll, woody trees of Morinda, Pisonia, Cordia, Guettarda and the coconut, Cocos nucifera are common, while Pandanus, Termialia, Ochrosia, and others occasionally occur. On Japtan (David) islet, a small slightly brackish pond occurs on the southeast one-third of the island in a heavy stand of brushy vegetation, mainly Messerschmidia and Pisonia.

"On Bokombako (Belle) islet that was cleared of surface vegetation by a nuclear explosion, Palumbo (1962) found in general that most of the shrub vegetation produced new growth from subterranean parts or from stem stubs left standing after the foliage and limbs had been torn away by the blast. Such plants rapidly revegetated on that islet where the soil was left intact, but on Louj (Daisy) islet that lost most of its soil, pioneering had to begin from a primary bare area.

"The pattern of vegetational change in advanced states of development is not well understood and but few if any of the heavy stands at Enewetak have reached a stage that can be called mature in which a reasonable degree of stability has been attained in the direction of a dynamic equilibrium with the environment. This may be interpreted to mean that further natural changes are likely to occur in the stands of vegetation. In a native forest of Enewetak, introductions of new species may lead to further change.

"In such atoll native forests, vegetation holds the key to its own perpetuation. Nearly all of the fertility for plant growth is stored in the vegetation itself, its litter on the ground, and the dark colored top few inches of soil. When the organic matter in the soil is decomposed, the forest vegetation gathers plant nutrients as they become available and slows loss through leaching. Clearing of the forest cover and cultivation upsets this cycle and allows greater leaching losses, thus depleting fertility.

"The vegetation on the islets shows variation ranging through all of the successional stages of development. There are many bare sand spits that are covered and uncovered by the tide; others project above the highest tides. Permanently exposed above the water are many small points bearing small stands of Scaevola and Messerschmidia plants. Larger islets are usually covered with other types."

From observations, photographs, and field notes, of John Bushman and other members of the field expedition, the following ecological descriptions were obtained and described by Woodbury (1962).

- Bokoluo. A small islet, about 1/4 x 1/8 miles, with cover of Scaevola and Messerschmidia shrubs, from 2 to 8 feet in height, denser and taller on the west side, interspersed with patches of heavy grass, all of which has regrown since it was devestated by nuclear detonation. Stumps indicate that the islet formerly supported large coconut palms.

- Bokombako. This small islet, slightly larger than Bokoluo, has a denser cover of the same shrub types but taller (1 to 9 feet), and an occasional large-leaf Guettarda occurs. Much of the Scaevola is infested with the parasitic dodder.

- Kirunu. This islet, smaller than Bokoluo, is covered with a sparse stand of Scaevola and Messerschmidia shrubs, 4 to 8 feet tall, interspersed over two-thirds of the island with coconut palm stumps and hummocks of dry grass.

- Louj. This islet, much larger than the three preceding islets, was denuded of its vegetation and most of its soil by a nuclear detonation and now has a scattered stand of young Messerschmidia shrubs, mostly concentrated along the lagoon edge where the plants are more vigorous and taller.

- Bokinwotme. This islet, also badly battered by a nuclear detonation, has no vegetation except a few small Messerschmidia plants about 6 to 24 inches high. It is now mainly a narrow spit or sand dune.

- Bokaidrikdrik. This is a small islet with a causeway connecting it to the larger island, Boken. What is left after a nuclear detonation is an elongated spit or sandbar containing little vegetation, mainly small Messerschmidia plants from a few inches to 3 feet tall.

- Boken. This medium sized islet is ringed with a hedge-like row of shrubs, mainly Messerschmidia. The interior is more open with shrubs and trees widely spaced among a grass-sedge covering.

- Enjebi. This, the largest islet in the north end of the atoll, has dense growths of Messerschmidia up to 12 feet tall on the lagoon side and much sparser shrubs including clumps of Scaevola on other parts of the island. On the north end, the openings are filled with hummocks of dry grass. In other openings, vines of morning glory, Ipomoea and Triumfetta, crisscross the landscape.

- Mijikadrek. This small islet, with much loose sand on it, has a covering of low shrubs, mainly Scaevola, 6 to 8 feet tall, with scattering Messerschmidia.

- Kidrinen. Another small islet with a stand of Scaevola 6 to 10 feet tall, spotted with Messerschmidia and Guettarda. There was little, if any, grass to stabilize the loose dry sand scattered among the vegetation.

- Bokenelab. Similar in size to Mijikadrek and Kidrinen, this islet has two large and one small coconut palms growing among the sparse Scaevola and Messerschmidia shrubs, intermixed with grasses and vines on the loose sand among the brushes.

- Elle. This small islet has a dense stand of shrubs 8 to 12 feet tall, mainly Scaevola with scattering Messerschmidia and Guettarda interspersed and about 10 to 15 short coconut palms about 10 to 12 feet tall. No grass was observed.

- Aej. This pear-shaped islet, about 3/8 of a mile in length, has a mixed cover of Scaevola and Messerschmidia, 5 to 10, and occasionally 15, feet tall, the site of great nesting colonies of birds. On the west (lagoon) side, plants are fairly dense with little vegetation under them; but on the east side, the stand is more open with interspersed vines a foot or two in depth. At the narrow end of the islet, dry hummocks of grass are interspersed among the bushes.

- Lujor. This islet, larger than Aej, is ringed with a lush stand of Scaevola, 12 to 14 feet tall, and Messerschmidia, 10 to 12 feet. The more open interior has a grass sedge cover interspersed among the shrubs.

- Eleleron, Aomon, Bijire, and Lojwa. These four interconnected islets are sparsely covered with regrowth vegetation since the nuclear detonation of 1958 that seared nearly all of the plants. The coconut palms did not recover, but the Scaevola and Messerschmidia shrubs are now 10 to 15 feet tall. Grass hummocks occur in open spaces of the interior of the islets.

- Alembel. This small islet bears a dense stand of the usual shrubs, grasses, and vines interspersed with scattering palms in the interior.

- Billae. This small islet has the usual Scaevola and Messerschmidia shrubs with patches of grasses and Suriana vines.

- Runit. This is a dry, sparsely vegetated islet, mainly hummocks of grass, with occasional plants of Scaevola and Messerschmidia.

- Boko, Munjor, Inedral, and Van. Boko is a sand spit only. Munjor is very small containing sparse Messerschmidia trees up to 8 feet tall. Inedral and Van are larger and well vegetated with Scaevola shrubs up to 10 or 12 feet in height and Messerschmidia trees up to 15 feet.

- Ananij. The southern end of this islet bears a heavy stand of Scaevola. Farther north, coconut palms overtop a dense forest, 30 to 40 feet in height, containing Pisonia and Cordia trees with a mixture of Messerschmidia and Scaevola up to 15 or 20 feet. In places, Boerhaavia forms an understory and the morning glory vines grow in openings of the forest.

- Jinimi. This small islet is covered with Scaevola about 6 feet tall and Messerschmidia about 8 feet, interspersed with a grass mat under and between most of the shrubs.

- Jedrol. A long sandy spit from the west gradually yields to higher lands covered with grass and the usual Scaevola and Messerschmidia shrubs up to 15 feet tall and the less common Pisonia, 35 to 40 feet, two Guettarda trees and some Triumfetta vines with the high point at the east and about 12 or 15 feet above the waterline.

- Japtan. Much of this island has been disturbed by human use. On the undisturbed portions, there are many palms, Pisonia, Messerschmidia, and Scaevola trees and shrubs. The island has a rich avifauna.

- Medren and Enewetak. Both of these islands have been intensively developed for human use and there is little natural vegetation left on them.

- Ikuren. This island has been restricted from recent human use and shows the natural vegetation with little human disturbance. There is a dense jungle forest on the eastern part of the island giving way on the west to lower, more open trees, shrubs, and grasses. The prominent forms of the jungle are palms, Pisonia and Messerschmidia trees. The latter reaches heights of 30 to 40 feet, with trunks 6 to 10 inches in diameter. Prostrate vines are common in the jungle. Scattering Morinda and Guettarda trees are associated with the ubiquitous Scaevola shrubs.

- Mut. Heavy vegetation on parts of this islet is ringed with dense Scaevola between the beach and the palms, but on other parts there are open spaces.

- Boken. This islet is cut by a waterway and has more or less typical vegetation.

- Ribewon. No notes available.

- Kidrenen. This teardrop-shaped islet has the narrow end at the southeast dominated by Scaevola which yields in the wider portion to a taller forest of coconut palms with an understory of Messerschmidia trees, associated with a long strip of Pisonia trees, 30 to 45 feet tall and scattering Pandanus trees. The soil is loose and there is little grass.

- Biken. This islet showing much human activity is pitted with several large dry craters. Scaevola occurs generally around the edge of the islet but also inland where it is generally dominated by Messerschmidia, Pisonia, and palm trees. There are scattered Morinda and Guettarda trees among them and also considerable grass and Triumfetta and morning glory vines.

3.2.5.2 Fauna. On the reef and in the lagoon, there is an abundance of colorful plant and animal life in which the keen competition between different species for space and food is very evident. On every hand, there is evidence of rapid growth and simultaneous destruction. Masses of reef-building coral are competing with the corraline marine algae for space, one often overgrowing the other. Schools of green parrot fish gnaw wide scratches on the coral. Fleshy patches of algae are pressed tightly against the surface of the coral and thus hold against the surges of the water pushed across the reef by the crashing breakers. Sea urchins and clams grind niches into the hard coral; some of them constantly feed on the cover of bacterial and algal film which is constantly being replaced. The clams, the corals, some small fish, and other forms are ceaselessly removing from suspension in the water the small, often microscopic, plants, animals, and bits of debris which make up the plankton. In regions of quieter water, where sand has been deposited, sea cucumbers and spider snails, among the larger forms, turn the sand again and again in their gleaning for food (Donaldson, 1959).

Large schools of goatfish, mullet, surgeon-fish, and other plant and plankton feeders are a common sight. Preying on unwary or disabled members of these schools are the carnivorous fish -- the groupers, tuna, jacks, and sharks. Ultimately, the waste products and carcasses of these and other carnivores are returned to the lagoon and reef to complete the cycle. In the biological cycling of materials, there is not only an abundance of organisms, but also a wide variety of species, some 700 among the fishes alone (Schultz et al, 1953), so that whatever is not utilized by one is quickly taken by another. There is here a perfect economy of use of substance essential to life. The phytoplankton comprise the foundation of the food chain in the sea. By their diurnal vertical migration, plankton carry materials from the deeper waters of the lagoons to the surface or even up onto the reefs and eventually to the islands. Minerals as well as organic materials, concentrated and incorporated into the algae, are passed on in the food chain to the animals that feed upon them.

The invertebrates make up the great bulk of the animal life of an atoll. Sea cucumbers have been compared with earthworms in their ceaseless turning of the gravel and sand as they obtain their nutriment from bacteria and algae. Corals and clams remove microorganisms and particulate matter from the water and are eroded by algae and sponges, which bore holes in the skeleton or shell, thus contributing to a return of carbonates to the water. Crabs, sipunculid worms, and others also attack the skeleton of the corals. Some of the land crabs drag fish and algae ashore when feeding. In short, within the invertebrates and their symbionts alone, complete biological cycles occur from land to sea and back again, from inorganic substances to organic, and back again.

The fauna on the islands of Enewetak is represented by terrestrial and quasi-marine species. Invertebrates include mollusks, nocturnal crabs, centipedes, scorpions and spiders, and insects of considerable variety including cockroaches, scale insects, termites, fruit beetles, fruit flies, ants, and others (Fosberg, et al, 1956). The vertebrates consist of three species of rats, the polynesian rat, Rattus exulans; the roof rat, Rattus rattus; and the house mouse, Mus musculus (Tamarin, et al, 1971), 32 known species of birds (Amerson, 1969), 4 known species of lizards, and 2 turtles (Woodbury, 1962). In the following listings, only land animals have been included. Among marine animals, there are more than 700 species of fish alone.

3.2.5.2.1 Invertebrates. The invertebrates of Enewetak Atoll are represented by a much greater assortment of kinds than the vertebrates. The best available data on known invertebrates of Enewetak lists them by ascending phyla as follows:

- Molluska. Land mollusks are represented by five species of small terrestrial snails found on the islets. Specimens of these taken in the litter under vegetation are on record in the Bishop Museum. These snails, listed below, appear to be widespread inhabitants of Pacific Islands.

The list below gives the specimens from Enewetak Atoll and their museum numbers of record at the Bishop Museum (Woodbury, 1962).

- Pupillidae (family).

    Gastrocopta sp. Bishop Mus. Nos. 193, 184 and 193, 185.

        Collected under trees May 15, 1946, by E. Y. Hosaka.

- Achatinellidae (family).

    Lamellidea pusilla Moellendorff, Nos. 193, 187.

        Collected under trees May 15, 1946, by E. Y. Hosaka.

- Subilinidae (family).

    Lamellaxis oparanum Pfeiffer, Nos. 190, 241.

        Collected on Runit Islet, August 28, 1945, by Lt. G. A. Estep.

    Opeas pumilum Pfeiffer, Nos. 193, 188.

        Collected under trees, May 15, 1946, by E. Y. Hosaka.

- Truncatellidae (family).

    Truncatella sp., Nos. 193, 189.

        Collected under trees, May 15, 1946, by E. Y. Hosaka.

- Crustaceans. Since crustaceans are primarily marine organisms as insects are primarily terrestrial, it is to be expected that few crustaceans will be found on the land as few insects are inhabitants of the ocean, although many of both kinds are found in fresh water. Crustaceans with gills adapted for aquatic respiration have a difficult problem of keeping gills moist in air. Many species of the intertidal zone solve it by dipping the gills in seawater from time to time. Others have attained more independence by developing protective coverings over their gills and behavior patterns that in the adult stage keep them in humid microhabitats during the day and lead them into activity at night when humidity is high and danger of desiccation low. These marine crustaceans still reproduce in the ocean but not much is known of the early part of their life histories before they emerge onto the land in advanced stages.

At Enewetak Atoll, there are many species that show stages of terrestrial adaptation intermediate between those that live entirely in the water, through those that live entirely on the land. The following list was compiled by Woodbury (1962) in a review of the ecology of Enewetak.

ISOPODA (order) . . . Sowbugs

- Porcellionidae (family).

    Metapornorthus pruinosus (Brandt, 1833).

        Specimen taken on Enewetak Island, Enewetak Atoll, under edge of building, May 19, 1962, by John Bushman.

- Talitridae (family).

    Talorchestia spinipalma Dana . . . Sandhoppers or beach fleas.

        Reported taken at Enewetak, July 7, 1946, Barnard, 1960, 4(2):24-27.

DECAPODA (order) . . . Shrimps, crabs, and allies.

- Coenobitidae (family) . . . Hermit crabs.

    Typical hermit crabs with soft, twisted, wormlike abdomens are adapted to use empty snail shells, into which the abdomen is inserted for protection and which they carry around with them. They shift to larger and larger shells as they grow, if available; if not, they may use coconut shells or go naked. With projecting legs that can be withdrawn into the shell as needed, such crabs are well protected from desiccation and from some types of predation. The following records have been found:

Coenobita perlatus H. Milne-Edwards . . . Land hermit crab:

Range: Bokombako Islet, Enewetak (Held, 1960:18) over a 2-year period, 1954-1956; widespread in the Marshalls (Fosberg, et al, 1956:230-231).

Habits: Usually hides in daytime under rocks, under debris on the beach, shrubs, in crevices, or under bark of trees or litter on the ground; active at night on beaches and in vegetation.

Food: Primarily land plants and scavenger around detritus washed up on the beaches.

Birgus latro (L) . . . Coconut crab.

A hermit crab adapted to living on land without snail shells; its life history is poorly known but B. latro has been known from early times as a conspicuous animal on many islands.

Range: Throughout the Pacific Islands, especially in association with coconut palms; occurs on Japtan Islet (McQueen, Johnson).

Habitat: Chiefly coconut groves and associated vegetation.

Habits: It is known to climb coconut trees; it hides in burrows in daytime; young ones cover themselves with dirt in their burrows (Held).

Food: Chiefly coconuts on the ground which it husks with its large chelipeds and cracks the nuts to get at the meat inside; also known to catch young sea turtles on the beach.

- Xanthidae (family)

Zoozymus aeneus (Linn.) . . . Reef crab.

Range: From Red Sea to Hawaii, on record in Bishop Museum from Medren Islet. Occurs on reefs; collected at night.

Eriphia laevimana

Collected on Biken, November 5, 1952, and on Runit November 6, 1952, Bonham (1959).

Eriphia scabricula Dana

Is recorded from the Marshall Islands (Bryan letter).

- Grapsidae (family).

Grapsus grapsus (Linn.)

Reported from Gilbert and Marshall groups (Balss).

Metasesarma aubryi H. Milne-Edwards

Reported from Gilbert and Marshall groups (Balss).

- Ocypodidae (family) . . . Ghost crabs.

Pale, fast running crabs, numerous along the beach.

Ocypoda ceratophthalma (Pallas) . . . Lower beach crab.

Range: Widespread through Micronesia; occurs on Enewetak Islets (McQueen, Johnson, March 1962).

Habitat: Lower part of the beach where it burrows in the sand.

Habits: Ranges along lower part of beach at night; hides in burrows in daytime.

Ocypoda cordimana Desm . . . Upper beach crab.

Range: Widespread in Micronesia; occurs on Enewetak Islets (McQueen, Johnson, March, 1962).

Habitat: Upper part of beach and adjacent vegetation.

Habits: Hides in burrows in sand of upper beach in daytime; active at night mainly in vegetation.

- Insects. The insects are probably the most abundant of all animals at Enewetak. The following list, as compiled by Woodbury (1962) from collection records, is not complete since many species of insects at Enewetak have not yet been identified.

MALLOPHAGA (order) . . . Chewing lice.

- Menoponidae (family).

  Actornithophilus ceruleus

- Philopteridae (family).

  Quadriceps sp. Novo

HOMOPTERA (order) . . . Aphids, leafhoppers, and allies

- Aphididae (family) . . . Aphids.

  Aphis gossypii Glover

  Aphis medicagnis Koch

Fulgoroidea

Derbidae (family), Cenchreini.

Lamenia caliginea charon Fennah

Cicadellidae (family), Deltocephallnae

Euscelini . . . Leaf hoppers

Exitianus capicola Stal.

HETEROPTERA (order) . . . Bugs

- Cydnidae (family) . . . Negro and burrower bugs.

    Geotomus pyomaeus Dallas

    Asopinae

    Oechalia shellenbirgii

- Coreidae (family) . . . Squash bugs.

    Rhopsalinae

    Liorhyssus hyalinus G. F. Gross

- Lygaeidae (family) . . . Chinch bugs, plant bugs;

    Lygaeinae, Lygaeini

    Nysius Pulchellus Stal.

    Nysius picipes Usinger

    Rhyparochrominae, Myodochini

    Pachybrachius nigriceps Dallas

- Nabidae (family) . . . Damzel bugs

    Nabis capsiformis Germar

- Miridae (family) . . . Leaf and plant bugs

    Mirinae, Stenodemini

    Trigonotylus dohertyi Distant

NEUROPTERA (order) . . . Lacewings

- Chrysopidae (family) . . . Green lacewings, aphis lions

    Chrysopa ramburi Schneider

DIPTERA (order) . . . Two-winged flies.

- Ceratopogonidae (family)

    Midges, gnats, punkies

    Forcipomyia (Forcipomyia) tuthilli

    Dasyhelea esakii Tokunaga

    Dasyhelea flavibasalis Tokunaga

- Tephritidae (family), Dacinae

    Dacus (Strumeta) frauenfeldi Schiner

- Drosophilidae (family)

    Drosophila (Sophophora) ananassae

- Sarcophagidae (family) . . . Sarcophagids

    Phytosarcophaga gressittii Hall & Boh.

    Boettcherisca karnyi Hardy

    Parasarcophaga (Liosarcophaga) misera Walker

- Chironomidae (family) Clunioninae

    Clunio sp. nov., M. Tokunaga (Ms)

    Thalassomyia maritima Wirth

- Startiomyidae (family) Clitellariinae

    Brachycara ventralis Thomson

- Muscidae (family) Coenosiinae

    Atherigona flavipalpis Malloch

    Muscinae

    Musca (Musca) domestica Linneaus

- Calliphoridae (family) Calliphorinae

    Phaenicia _cuprina_ (Wiedemann)

  Chrysomyinae

    Chrysomya _megacephala_ (Fabricius)

COLEOPTERA (order) . . . Beetles

- Elateridae (family) . . . Click beetles

      Pachyderinae

    Simodactylus _fasciolatus_ Fairmaire

    Simodactylus _tasmani_ Candeze

    Conoderus _pallipes_ Eschscholtz

- Dermestidae (family) Dermestini . . . Skin or larder beetles

    Dermestes _ater_ DeGeer

- Ceramycidae (family) . . . Long-horned beetles

      Lamiinae, Niphonini

    Prosoplus _atlanticus_ _atlanticus_

- Tenebrionidae (family) . . . Darkling ground beetles

      Stenosini

    Gebieniella _carinata_ Eschscholtz

  Opatrini

    Gonocephalum _pottsi_ Kulzer, n. sp.

- Scolytidae (family) . . . Barkbeetles

    Hypothenemus _eruditus_ Westwood

- Anthicidae (family) . . . Ant-like flower beetles

  <u>Anthicus vexator</u> Werner, n. sp.

- Propalticidae (family)

  <u>Propalticus insularis</u> Von Hans, n. sp.

HYMENOPTERA (order) . . . Ichneumons, et al.

- Ichneumonidae (family) . . . Ichneumonid flies

  Ephialtinae, Ephialtini

  <u>Echthromorpha agrestoria insidiator</u> Smith

- Evaniidae (family)

  <u>Szepligetalla sericea</u> Cameron

- Arachnids. The list of arachnids is also incomplete. In addition to the ectoparasites, there are only three pseudoscorpion records available from Enewetak. They are probably found in rotting logs or deep humus and litter of the topsoil. Known specimens listed by Woodbury (1962), are as follows:

PSEUDOSCORPIONIDA (order) . . . Pseudoscorpions

- Chthoniidae (family)

  <u>Lechytia sakagamii</u> Morikawa

- Atamnidae (family)

  <u>Oratemnus samoanus whartoni</u> Chamberlin

- Chernetidae (family)

  <u>Haplochernes insulanus</u> Beier, n. sp.

ARANEIDA (order) . . . Spiders

- Salticidae (family) . . . Jumping spiders

  Specimens taken from nest of a white-capped noddy tern on Van Island, May 5, 1962, by John Bushman.

- Clubionidae (family) . . . Orb-weaver spiders

  Specimen taken from nest of a white-capped noddy tern on Ribewon Island, May 7, 1962, by John Bushman.

3.2.5.2.2 Vertebrates.

- Mammals. Three mammals have been reported at Enewetak. Of these, the polynesian rat, Rattus exulans, appears to be the only native mammal. The other two, Rattus rattus, the roof rat, and Mus musculus, the house mouse, are accidental introductions, probably arriving via ship.

- Birds. Amerson, 1969, reports 32 species of birds known from Enewetak Atoll. These include 17 seabirds, 12 shorebirds, 1 heron, 1 domestic fowl, and 1 cuckoo. Of these 32 species, 9 are definitely known to breed on the islands. Six additional species are suspected to breed on the islands but have not been observed doing so.

  The following checklist (Table 3-4) compiled by Amerson (1969), presents the recorded bird species from Enewetak Atoll. This list was compiled from: (1) POBSP field data, 1966; (2) Woodbury, 1962; (3) Pearson and Knudsen, 1967; (4) Carpenter, Jackson, and Fall, in prep.; (5) Baker, 1951; (6) Arnold Joseph, pers. corresp., September 1964; (7) Gleize and Genelly, 1945; (8) Richardson, unpublished MS; (9) Yale Cross-Cultural Survey, 1943; (10) USNM collection; (11) UUZM collection; and (12) BGSU collection. These sources are referred to in the checklist by the corresponding numbers and letters.

- Reptiles. In the northern Marshall Islands, the reptiles include at least four geckoes, a monitor lizard, three skinks, a blind snake, and two sea turtles (Woodbury, 1962). However, all of these species have not been identified at Enewetak. The following list describes only those reptiles known to occur at Enewetak.

TABLE 3-4: ENEWETAK ATOLL AVIFAUNA CHECK LIST

	Species	Status	Source
1)	Puffinus pacificus	Accidental ?	1, 2, 3, 4, 11, 12
2)	Puffinus griseus	Accidental	3
3)	Puffinus tenuirostris	Accidental	3
4)	Phaethon rubricauda	Resident breeder, March, April, July through September; few	2, 3, 4
5)	Phaethon lepturus	Resident breeder, April; few	2, 3, 4, 12
6)	Sula sula	Resident breeder ? ; few	5, 10
7)	Sula leucogaster	Resident breeder ? ; few to 300	2, 3, 4, 5, 10, 12
8)	Fregata minor	Resident breeder ? ; few to 300	2, 3, 4
9)	Egretta sacra	Resident breeder, June, July; common	2, 3, 4, 5, 6, 7, 10, 11
10)	Gallus gallus	Introduced breeder?	9
11)	Pluvialis dominica	Migrant	1, 2, 3, 4, 10, 11, 12
12)	Squatarola squatarola	Migrant	3, 5, 7
13)	Charadrius dubius	Migrant	3, 5, 7
14)	Numenius phaeopus	Migrant	2, 3
15)	Numenius tahitiensis	Migrant	2, 3, 4, 6, 12
16)	Limosa lapponica	Migrant	3, 4, 12
17)	Heteroscelus brevipes	Migrant	3, 4, 10
18)	Heteroscelus incanum	Migrant	2, 3, 4, 10, 11
19)	Arenaria interpres	Migrant	2, 3, 4, 6, 10, 11, 12
20)	Crocethia alba	Migrant	2, 3
21)	Erolia acuminata	Migrant	2, 3, 11
22)	Tryngites subruficollis	Accidental	3
23)	Sterna paradisaea	Accidental	2
24)	Sterna sumatrana	Resident breeder, March through May; 300	1, 2, 3, 4, 10, 11, 12
25)	Sterna lunata	Resident breeder ? ; few	2, 11
26)	Sterna fuscata	Resident breeder, March through May; July through September; few to 16,000+	2, 3, 4, 8, 10, 12
27)	Thalasseus bergii	Resident breeder, March ?	1, 2, 3, 4, 12
28)	Procelsterna cerulea	Resident breeder ?	2, 3
29)	Anous stolidus	Resident breeder, February through May, summer; 1,000's	1, 2, 3, 4, 10, 11, 12
30)	Anous tenuirostris	Resident breeder, February through May, summer; 1,000's	1, 2, 3, 4, 10, 11, 12
31)	Gygis alba	Resident breeder, February through May, 1000's	1, 2, 3, 4, 5, 6, 10, 11, 12
32)	Urodynamis taitensis	Migrant	2

SAURIA (suborder) . . . Lizards

<u>Lepidodactylis</u> <u>lugubris</u> (D&B) . . . Small house gecko

<u>Range</u>: Arno (Marshall, 1951); Onotoa Atoll, Gilbert Islands (Moul 1954:7).

<u>Specimen</u>: American Museum, Natural History, No. 66570, taken on Runit Islet by James Oliver, September 2, 1945, (C. M. Bogert).

Two specimens of an unidentified gecko taken on Bokombako on December 30, 1950, by Yoshio Oshiro are listed in the Bishop Museum, Catalog No. 899.

<u>Lipinia</u> <u>noctua</u>

Specimens of this lizard, taken on Runit Islet by James A. Oliver, September 2, 1941, are now in the American Museum of Natural History, Nos. 66571-72 (C. M. Bogert).

- Varanidae (family) . . . Monitor lizards

Varanus indicus . . . Terrible monitor

This largest of all living lizards was said to have been introduced by the Japanese onto Japtan Islet and was collected there in 1946 by J. P. E. Morrison (Fosberg, 1956:225). D. E. Johnson verbally reported seeing two of these lizards on that islet in March, 1962. A specimen collected on Japtan Islet in 1955 by a GI is now No. 78994 in the AMNH (C. M. Bogert).

- Scincidae (family) . . . Skinks

<u>Emoia</u> <u>cyanura</u> (Lesson) . . . Little blue-tailed skink

<u>Range</u>: Arno (Marshall, 1951); abundant on nearly all islets.

<u>Specimens</u>: AMNH Nos. 66573-74 and three untagged, taken on Runit Islet by James A Oliver, September 2, 1945, (C. M. Bogert).

CHELONIA (order) . . . Turtles

- Chelonidae (family) . . . Sea turtles

Chelonia mydas agassizii (Bocourt, 1868) . . . Pacific green turtle.

Range: Warm seas of the Pacific Ocean.

Habitat: Shoal waters with submarine vegetation.

Chelonia sp. (probably imbricata) . . . Hawkbill turtle

Range: Warm seas of the Pacific Ocean.

Habitat: Shoal waters.

Specimen: A live specimen was captured in the lagoon off Bijire Islet, May 20, 1962, by Larry McIntyre and kept in a pond on Enewetak Islet (Woodbury, 1962).

3.3 HISTORICAL BACKGROUND OF ATOLL

The recorded history of Enewetak dates from the sixteenth century and can be separated into four distinct periods: the discovery era from 1526 to 1885; the German Protectorate from 1885 to 1914; the Japanese Mandate from 1914 to 1944; and the United States Trusteeship from 1944 to the present time.

3.3.1 Discovery Era

The atoll was first reported sighted by Spaniards in 1526, three years before a landing was made by Alvaro de Saavedra in October 1529. Several other sightings were reported by the British from 1792 through the end of the 18th century. However, it appears that no significant contacts were effected prior to the 19th century although the first official survey and charting was made in 1798.

3.3.2 German Protectorate

In 1886, the Germans formally established a protectorate over the Marshall Islands, following some years of trading. The Marshallese, including the Enewetak people, accepted coconut seedlings from German traders and sold the resulting copra back to the Germans for trade goods and food. This involved the Enewetak people in a move from a subsistence economy to a mixture of a cash and a subsistence economy. The people of Enewetak were somewhat on their own as the Germans did not have a resident agent; nor were there other resident Europeans, and foreign visitors were kept to a minimum.

3.3.3 Japanese Mandate

The Japanese Mandate commenced with the seizure of Enewetak and all other German Micronesian possessions in 1914. As in the case of the Germans, visits to Enewetak were made by the Japanese Navy in 1920, as well as by Japanese traders, but no attempts were made to establish a full-time administration. Both Enewetak and Ujelang were administered from Ponape in the Carolines and the only foreign residents on Enewetak were a Japanese trader and his two assistants. Aside from a weather station established in the 1930's, Japanese contact with the atoll languished until the years 1939 to 1941. During this period, the Japanese decided to make Enewetak a strategic base in their conquest of the Pacific. The atoll was elaborately fortified and a large airfield was built on Enjebi Island, using both Marshallese and imported labor. Thousands of Japanese military personnel now occupied the atoll.

3.3.4 United States Trusteeship

Enewetak remained as a key bastion of the Japanese until it was captured by United States forces in February 1944. The United States occupied the atoll until the end of the war, using it as an advanced base for further operations to the west. The Enewetak people were moved to Aomon during the wartime occupation.

At the conclusion of the war, the United States was given the trusteeship of the Marshall Islands by the United Nations (Tobin, 1967).

3.3.4.1 Use as a Test Site. Between 1948 and 1958, the United States used Enewetak as a nuclear proving ground and conducted approximately 43 nuclear tests on the atoll (see Section 3.7).

The United States Coast Guard has maintained a LORAN station on the island of Enewetak for several years and is committed to continue its operation until at least 1979. Since the early 1950's, the University of Hawaii has operated the Enewetak Marine Biological Laboratory (now known as the Mid-Pacific Marine Laboratory) under the auspices of the United States Atomic Energy Commission (ERDA).

3.3.4.2 Relocation of Enewetak People. During the United States occupancy of the Enewetak Atoll, 136 people were in residence. "Prior to the 1944 invasion of Enewetak, the population of the Atoll was divided into two communities; one was located on Enewetak Island and the other on Enjebi Island. After the invasion, both communities were moved to Aomon Island which was under the authority of the Chief of the Enewetak Island community (Chief Ioanej). Later, the Enjebi community moved (at their own request) to Bijire Island because the latter was under the authority of the Chief of the Enjebi community. Thus, the Enjebi people were moved twice prior to relocation to Ujelang (Enjebi to Aomon to Bijire) whereas the Enewetak people were moved once (Enewetak to Aomon) prior to relocation to Ujelang" (Kiste, 1973). In December, 1947, the people were transferred 124 miles to the southwest to then uninhabited Ujelang where they have remained. The Enewetak Atoll residents received compensation when they moved to Ujelang. They also have an annual income from a trust fund established as part of the compensation.

While on Ujelang, the people have been housed, supplied with a water system (including numerous rain catchments), a church, a Council Hall, a school, and a dispensary. Supply ships have brought in tools, clothing, and food to supplement the meager natural resources (Tobin, 1967).

3.3.4.3 Repatriation Plans. In April 1972, the United States announced its intention to transfer the administration of Enewetak Atoll to the Government of the Trust Territory of the Pacific Islands, subject to the retention of some residual rights, at the end of 1973. The Enewetak people have expressed a strong desire to return to the atoll. Plans are now being formulated with them for the proposed rehabilitation and resettlement process. These plans are discussed in greater detail in other sections of this statement.

3.4 ANTHROPOLOGY - ENEWETAK PEOPLE

Most anthropologists are of the opinion that the Marshalls and other islands of Micronesia were settled by peoples who migrated from the area of Indonesia and into the insular Pacific centuries ago. Reflecting the ancient migration patterns in Oceania, the Marshallese language belongs to the large Malayo-Polynesian language family which is spread from Madagascar, through the Indonesian area, and across Micronesia, Polynesia, and some regions of Melanesia. With regard to physical type, Marshallese are relatively short in stature and of stocky build. They have brown skin, brown eyes, broad flat noses, straight to curly black hair, and sparse body hair.

According to their own oral traditions, the people of Enewetak had always lived on Enewetak Atoll prior to their relocation to Ujelang. In their own words, "We were there from the beginning." Because of Enewetak Atoll's isolated location in the northwestern region of the western of the two island chains which comprise the Marshallese archipelago, the people had relatively little contact with others prior to the European era. As a consequence, the language and culture of the people of Enewetak became differentiated from those of other Marshall Islanders, and the people did not identify themselves with the others. Rather, they thought of themselves as a people who were separate and unique, "the people of Enewetak" as opposed to the islanders to the east and south.

The past and current accomplishments of the Enewetak people reflect intelligence and qualities of ingenuity, self-reliance, and hardiness, allowing them to meet the challenge of the atoll environment which is quite restrictive compared with that of the high volcanic islands of Oceania. Long before the advent of Europeans, they had developed a culture which represented a sophisticated adaptation to their ecological setting. They were skilled navigators, an art which has now been lost with the availability of travel on the vessels of foreigners. They remain expert builders of sailing canoes and are among the world's best fishermen. In response to traders, missionaries, and the successive colonial governments which have dominated the islands over the past century, they have been quick to learn and adjust to the different categories of outsiders. Today, they have achieved a good understanding of the behavior and values of Americans, and several have distinguished themselves in government and mission schools (Kiste, 1973).

3.5 ECONOMIC AND CULTURAL RESOURCES

Throughout the Marshall Islands, the traditional forms of settlement pattern and exploitation of the natural resources are characterized by several general features. First, the people of an atoll reside on one or more of its largest islands. Second, the people remain quite mobile within the atoll, as a nonintensive type of agriculture and various fishing and collecting activities are extended to embrace every niche of the environment. Regular expeditions are made to all islands in an atoll to make copra and collect coconuts, breadfruit, pandanus, arrowroot, and other vegetable foods in season. Clearing of brush and crop planting is done during these visits.

Marine resources are also exploited and a wide variety of marine animals are utilized. Special expeditions are made to catch fish, collect shellfish, and capture turtles and gather their eggs. Several species of birds are also captured as a food source. The Enewetak people may be expected to continue this way of life to some degree when they return to their home atoll, but will be influenced by their contacts with Western culture (Kiste, 1973).

3.5.1 Sociopolitical Pattern

Before their relocation to Ujelang, the people of Enewetak were divided into two separate and distinct communities. (Here community is defined as "the maximal group of persons who normally reside together in face-to-face association.") These communities were located on the two largest islands of the atoll, one on Enjebi Island on the northern rim, and the other on Enewetak Island across the lagoon and in the southeast quadrant of the atoll. The traditional settlement pattern of both communities was a dispersed one with residences located on separate land parcels and scattered along the length of the lagoon beach.

Members of the two communities intermarried and cooperated in certain economic activities. Each functioned, however, as a separate sociopolitical unit, and its members had their own identity. In contrast to the identity of "the people of Enewetak" by which they defined themselves in reference to all other populations, the people of the Enjebi community were identified as driEnjebi "the people of Enjebi Island" and those of the Enewetak community were driEnewetak "the people of Enewetak Island."

The sociopolitical structures of the two communities were identical. Each was headed by an hereditary iroij or chief, and succession to the office was patrilineal (Tobin, 1967). Chiefs directed the affairs of their respective communities, arbitrated disputes, and consulted one another with regard to concerns of the entire atoll and the total population's relations with outsiders. Each of the chiefs had authority over one of the two domains into which the atoll was divided. The domain of the Enewetak chief began with the islands of Kidrenen, Ribewon, Boken, Mut and Ikuren in the atoll's southwest quadrant, and extended counterclockwise around the atoll's south and eastern rims up to and including Runit Island. It also included Aomon on the northeast rim. With the exception of Aomon, the Enjebi chief's domain began north of Runit with Billae Island and extended counterclockwise around the atoll's northern and western rims down to and including Biken Island.

Relations between the two communities and the traditional dispersed pattern of residence were altered with the invasion of Enewetak Atoll. Because Enewetak and Enjebi Islands were devastated by the warfare, the United States Navy resettled all of the people in a compact village on small Aomon Island which, as indicated earlier, fell within the domain of the Enewetak Island chief. After several months, the Enjebi people moved to the adjacent Bijire Island which was within the domain of their own chief. With these relocations, the Enjebi and Enewetak peoples were no longer separated by the atoll's large lagoon, and while retaining their dual political structure, they in fact became a single community.

The consolidation of the population into one community and the new compact settlement pattern were perpetuated with the islanders resettlement on Ujelang Atoll. It has only one sizeable island, Ujelang Island, and the entire population was resettled there. Navy officials established a dividing line at the midpoint of the island and allotted the western half to the Enjebi people and the eastern half to the Enewetak people. A compact village was constructed in the middle of the island with the Enjebi and Enewetak peoples occupying houses on their respective sides of the dividing line. Later, each group divided the land on its portion of the island. At a still later date, other islands in the atoll were divided among members of the two groups.

During the initial years on Ujelang, the traditional political structure remained intact. The chiefs functioned in their accustomed roles, and they resisted American efforts to introduce democratic institutions. (Originally, according to American designs, each atoll population was to be governed by an elected council of elders headed by an elected magistrate.) By the early 1960's, however, some change was observable. Both chiefs were by then aged men; and being men who matured in a former era, some contemporary problems required that the decision-making process be opened to include younger men who had attended schools and/or had some other experiences with the American administration. Meetings of all males were occasionally held, and some decisions about community affairs were decided by a majority vote. The authority and status of the chiefs further declined in the latter 1960's when the old Enjebi chief died and was succeeded in office by his younger brother who was also an aged man and suffered the disadvantage of frequent poor health.

The combination of the above events precipitated a major transformation of the political structure. The chiefs yielded to younger men who desired and had been gaining a greater voice in community affairs. Then, in 1968, a magistrate and a council of 12 men were elected. Reflecting the traditional division of the population, the Enjebi people elected 6 councilmen from among their ranks and the Enewetak people elected 6. The magistrate became the head of the entire community, and the council became the legislative body governing the people's affairs. In a very recent election, however, the 12 councilmen were elected from the population at large and not from the two groups. Thus, the current council reflects the demise of the traditional system, indicating that the old division between Enjebi and Enewetak peoples has lost much of its meaning. The council is now a representative body drawn from the entire population and reflects a unified community with acknowledged common goals. The chiefs, however, remain important figures as advisors and men of influence (Kiste, 1973).

3.5.2 Church and Religion

The church is the focal point for many community social activities of the Enewetak people. The prevailing religious system is a conservative type of Protestantism in which church services, Bible classes, church group meetings, and hymn singing have replaced traditional intertribal wars, sports, games, and dancing.

The minister is the spiritual leader of the community and is supported and assisted by the chiefs of the clans. The church functions are time consuming and require a considerable effort from the membership. Sundays in particular are devoted almost entirely to church services and related activities. From this it is apparent that the church influences the life of the people of Enewetak to a great degree (Tobin, 1967).

3.5.3 Land

The atoll soil is poor, thus agriculture is limited. For centuries subsistence has been marginal and precarious for the island inhabitants despite hard work. Nevertheless, the residents have always maintained a deep emotional attachment to their home islands and ancestral land.

The land parcels, or wato, at Enewetak Atoll were like those found elsewhere in the Marshalls. Most commonly, each was a strip of land stretching across an island from lagoon beach to ocean reef and varying in size from about 1 to 5 acres in extent. The sources of all ecological zones were thus available to the individuals who held right to the land. Less commonly, a parcel was divided into two or more portions with transverse boundaries. This usually occurred when an island, Enjebi for example, was very wide. Boundaries were usually marked by slashes on the trunks of coconut trees, or less commonly, ornamental plants. Also, other features of the natural topography, e.g., large boulders on the ocean reef and the very configuration of an island were used to fix the position of landholdings. The latter type of markers have been employed by other Marshallese after all other markings had been obliterated.

One facet of Enewetak Atoll culture that differed from that of the rest of the Marshalls was the system of land tenure, and inheritance. In contrast to the rest of the Marshalls where matrilineal descent groups known as bwij (lineage) constitute landholding corporations, the land tenure system at Enewetak was in ideal and in practice, a bilateral one. In most cases, a married couple divided the land they had each inherited among their children, and a child usually received some land from both his father and mother. As younger islanders matured, they worked the land with their parents. As the parental generation died and as members of the next generation married and produced children, the process was repeated with parents allocating land among their offspring.

The islanders resided upon their landholdings on Enjebi and Enewetak Islands. Households were either extensive with many members or the basic family groupings. In most cases, households were headed by males and were situated upon land held by them. Ideally, residence was patriolocal, i.e., upon marriage, females moved to their husbands' households, although exceptions to the rule did occur.

Every individual possesses rights to some land on islands away from the settlements on Enewetak and Enjebi. All land in the atoll was held by someone with the exception of one parcel on Enewetak Island which was donated to the mission (Kiste, 1973).

3.5.4 Food

It is difficult to estimate the degree of utilization of local versus imported foods; however, it can be assumed that the Enewetak people will use imported foods to a much greater degree than they did before they were moved from the atoll. This is the general trend that was established throughout the Marshalls as the islands became more oriented toward a cash economy, based upon copra production and wage labor. The Enewetak people presently have a cash income from trust funds amounting to over $60,000 per year which is used to buy imported foods and other items. The proceeds from copra sales provide additional cash for purchases.

Rice, flour, sugar, coffee, tea, canned meats, canned milk, and other items are staples in the diet of the Enewetak people and have been for many years. They cannot be considered to be luxuries. Rice, for example, is eaten in large quantities, as often as three times a day.

It is possible that the abundance of fish and shellfish at Enewetak will mean a reduction in the purchase of canned fish, and even meat, when the people return there. The availability of pork and domestic fowl locally, as well as wildfowl and turtles, would also affect canned meat purchases. It should be noted that canned meats and fish are expensive in the Marshalls as they must be imported over vast distances. This is reflected in the cost to the consumer, especially on the outer atolls.

It is anticipated that a larger quantity of imported foods, such as rice and flour, will be consumed initially on Enewetak that has been on Ujelang. This will result from the fact that local vegetable foods will not be available on Enewetak for the near future. Coconuts, pandanus, arrowroot, and breadfruit are the main vegetable foods used. Bananas, squash, and papaya are used, but to less extent. Prior to the move to Ujelang, pandanus and arrowroot were especially important on Enewetak and grown in large quantities. Breadfruit, taro, and bananas were rare, but the people have developed these plants on Ujelang and probably will continue their cultivation on Enewetak.

It can be assumed that if local foods are available, as they will be eventually, the people will eat them as well as the imported foods. They enjoy both kinds of foods and none of them is wasted. The Enewetak people possess techniques for processing and preserving surplus breadfruit, pandanus, and arrowroot.

The agricultural resources on Enewetak Atoll today, in contrast to the marine resources, are practically nonexistent. There are a very few bearing coconut trees and no edible varieties of pandanus. There are no other food bearing trees or plants, including breadfruit, with the exception of a negligible amount of arrowroot.

Various kinds of plants are used in preparation of medicines. These are used both internally and externally. The Marshallese pharmacopoaia include the ubiquitous Tournfortia/Messerschmidia/Argentia, Scaevola frutescens, the leaves and shoots of coconut, pandanus, and banana, as well as other plants.

Of special interest to the marine biologist is the fact that practically all marine products are eaten by the Enewetak people, as well as by the other Marshallese. However, there are a few exceptions which include Sea Cucumbers (Holothuria) and Rays of all species found in the Marshalls. Puffer Fish (Wat) are recognized as deadly poison and are never eaten.

Ciguatera (fish poisoning) was found on Enewetak Atoll when the people lived there, according to reliable informants from that atoll. The fish affected included Ban (Red Snapper), Iol (Mullet), Mao (Blue Parrot Fish), Jawa (Bass), Likmouj (Pink Parrot Fish), Utot (?), and Drep (Moray Eel).

The poisonous fish on Enewetak Atoll were allegedly found in the Enjebi area and islands on the eastern (windward) side of the atoll. However, the leeward side, toward the south and west of the atoll was relatively free of fish poisoning. Poisonous fish (Lik karek) are said to live in both the ocean and lagoon reef areas.

(Identification (English names) are from Report of a Survey of the Fish Poisoning Problem in the Marshall Islands, US DPHEW PHS, Jan. 1959, Mimeo. - Tobin 1973).

The heads of fish are considered to be delicacies and the internal organs (heart, liver, and brain), are eaten. While the intestines of fish are not eaten, the intestines of turtles are consumed after cleaning and washing and either boiling or baking.

All kinds of shellfish are eaten and everything but the "black part" of clams is consumed. The best area for clams and other shellfish is reported to have been in the vicinity of many of the nuclear tests, i.e., the northwestern sector of Enewetak Atoll.

Sharks are eaten by the Enewetak people. They learned how to prepare them and eat them from Carolinians during the German protectorate. Porpoises also are eaten. They are a delicacy throughout the

Marshalls. They were caught in droves by using the surround method (jibuki). The porpoises would usually enter the lagoon through the Biken Island pass. When sighted, the men would go out in their large sailing canoes and herd the animals into the beach area. Some of the men would jump overboard to clap stones together under water. This would frighten the porpoises and cause them to beach themselves and become stranded. Then they could easily be captured. Whales became stranded occasionally on Enewetak. They were eaten when the people could get to them before the meat had spoiled.

It should be mentioned that the people of Enewetak, as well as the other Marshallese, prefer their food to be fresh rather than "high," or commencing to spoil. This is in contrast tothe Trukese, who have a taste for food that is high.

The Enewetak people, in common with other Micronesian groups, eat their fish raw as well as cooked. They also preserve marine products by sun drying, salting, and smoking.

The monitor lizards (Varanus indicus) which were imported by the Japanese to curb rodents were never eaten by the local people or by other Marshallese. Some of these reptiles have been reported on Japtan Island within recent years. The people dislike them and are afraid of them.

The Enewetak people eat the coconut crab (Birgus latro) which is considered a delicacy. Other species of crabs are used for fish bait only.

All species of birds are eaten by the Enewetak people. The brains, livers, and hearts are eaten, but the bird intestines are not a part of the local diet. Dogs are eaten by some. Apparently the appetite for this type of food was developed through contact with the Trukese and Ponapeans while attending school on Ponape. The intestines of pigs are eaten by the Enewetak people who clean and wash them before serving them either boiled or baked. This dietary habit also was acquired from the Trukese and Ponapeans who, in turn, were initiated by Filipinos living on their islands. The Enewetak people also have learned to eat the heads of pigs. Previously, they had discarded the heads with the intestines as inedible. The internal organs, e.g., brain, liver, kidneys, and heart are eaten by all of the Marshallese (Tobin 1973).

3.5.5 Water

The atoll had no fresh water other than rainwater stored in cisterns and barrels, and some brackish water collected from shallow wells dug on the larger islands. When drinking water was not available, fresh green coconuts were tapped for their liquid.

3.5.6 Housing

Traditionally, houses were constructed with frames made of breadfruit tree logs, other locally available woods, and driftwood; sidewalls and roofs were fashioned from pandanus thatch panels which were lashed to the frames with coconut fiber sennit.

Late in the Japanese period, some imported building materials such as sawed lumber, concrete, and metal roofing were available in limited quantities. The islanders quickly developed a preference for the imports because they are more durable than local materials and require less time and effort for the construction and repair of dwellings. The desire and preference for imported materials were reinforced by the islander's relocations within Enewetak Atoll and resettlement on Ujelang. The United States Navy provided scrap lumber, plywood, and metal roofing for the houses which were built on Aomon and Bijire in the post-invasion period. For the resettlement on Ujelang, new materials were provided for houses of single-wall construction with sheet metal or tar paper roofs. Today, the people only want dwellings made of imported materials, and they avoid the use of traditional materials insofar as possible (Kiste, 1973).

3.6 NATIONAL HISTORICAL PLACES - ARCHEOLOGICAL SITES

In accordance with the requirements of Section 106 of the National Historical Preservation Act of 1966 (16 U.S.C. 470 [f]), an exhaustive search has been conducted of the most recent listing of the National Register of Historic Places published in the Federal Register February 4, 1975, Vol. 40, No. 24, Part 2. Currently, it has been determined that no National Register property is located on Enewetak Atoll or would be affected by the proposed program. In addition, in accordance with Executive Order 11593 "Protection and Enhancement of the Cultural Environment" of May 13, 1971, a survey of the facilities on the atoll shows that no properties or facilities at Enewetak meet the National Register criteria. We have also contacted and consulted with the State Historic Preservation Office of the Trust Territories of the Pacific Islands.

3.7 THE UNITED STATES DEVELOPMENT OF THE ISLANDS FOR NUCLEAR TESTING

In 1945 and 1946, nuclear weapons tests were conducted in New Mexico (Operation Trinity) and at Bikini Atoll (Operation Crossroads). While Bikini satisfied the remote location requirement for a nuclear test site, its land area was small and not suitably oriented with the prevailing winds. This precluded the construction of a major airstrip which was necessary for the support of a lengthy nuclear test program (Hines, 1961).

Consequently, Captain J. S. Russell, USN, Deputy Director of the Division of Military Application and Dr. Darol K. Froman, of the Los Alamos Scientific Laboratory conducted a study of possible oceanic locations for a nuclear proving ground. Enewetak fulfilled the requirements, especially with regard to possible fallout. In this respect, the atoll was ideally situated with several hundred miles of open sea in the prevailing downwind direction. The study recommended that Enewetak be selected as a nuclear weapons test site and on December 2, 1947, approval was given by President Truman.

Between April, 1948, and July, 1958, Enewetak Atoll was the scene of 43 nuclear tests. On October 31, 1958, the moratorium on nuclear testing became effective, marking the end of all nuclear testing at Enewetak. Although the atoll suffered damage from the tests and the terrain was modified by building activities, the intervening years have permitted some natural restoration of the vegetative growth, as well as the time for a reduction in the residual radioactivity resulting from the tests. The geographical distribution of the 43 nuclear tests follows:

Number of Tests	Island Name: U. S. Code Name	Island Name: Enewetakese
18	Yvonne	Runit
10	Janet	Enjebi
4	Flora*	Eluklab
3	Sally	Aomon
2	Ruby	Eleleron
1	Alice	Bokoluo
1	Gene**	Dridrilbwij
1	Helen	Bokaidrikdrik
1	Pearl	Lujor
1	Henry	Mut
1	Irene	Boken

*This island no longer exists. It was removed by test Mike on November 1, 1952.

**This island no longer exists. It was removed by test Koa on May 23, 1958. The underwater craters from Mike and Koa overlap each other.

Further tests did occur in the Pacific, but they were in the vicinity of Johnston Island and Christmas Island (Glasstone, 1964; Edwards, 1966) so far to the east that there was no effect upon Enewetak Atoll. These tests followed the September 1, 1961 announcement by the USSR of its intention to resume nuclear testing. The USSR tests occurred within days of this announcement. Several months later, the United States started testing under a series called Operation Dominic, but, as stated above, not at Enewetak Atoll. This test series was completed by the end of 1962 and was followed by the Limited Test Ban Treaty, which was signed in September 1963. This Treaty prohibited all nuclear tests except those conducted underground. Although underground tests have been conducted in the Continental United States and at Amchitka, in Alaska, none have been conducted at Enewetak Atoll.

From 1963 to 1968, the atoll was an impact and scoring area for intercontinental ballistic missiles launched from the United States. In 1968 and 1970, tests were conducted on rocket motors. A misfire in 1968 resulted in local deposition of a small quantity of beryllium. A series of small non-nuclear high explosive detonations was begun in 1972 by the United States Air Force Weapons Laboratory under the PACE Program. The PACE Program has since been completed.

To establish Enewetak Atoll as a semipermanent proving ground for nuclear tests, it became necessary to accomplish a large construction program to support the test program. Enewetak and Medren Islands became the main support bases while the experiments, as well as the attendant instrumentation, were sited on other islands in the atoll including Runit, the Aomon-Bijire-Lojwa group, Enjebi, and Bokoluo. Japtan contained accommodations for arrivals and laboratories for animal test effects research and later the atoll radio receiving facilities were located there. As the nuclear testing program progressed, the support facilities were upgraded and enlarged.

The support islands of Enewetak and Medren were developed for a planned population in excess of 4,400, Enewetak for military personnel and Medren for AEC and scientific personnel. Facilities included housing, messing, laundry, recreational, freight handling and storage, and maintenance and repair. A complete air transport complex was maintained on Enewetak with a paved runway and parking areas. Smaller airstrips were maintained on Medren, Bokoluo, Enjebi, Bijire, and Runit islands and helicopter landing pads were laid on several of the smaller islands. Radio and hardwire communications were maintained and power generating plants and distribution systems erected. Fresh water was distilled from salt water and water storage and distribution systems were installed. An inter-island network of power-telephone-signal submarine cables was laid in the lagoon. Marine and land transportation was furnished along with the required maintenance and repair facilities. Camps of more temporary nature were erected on Lojwa, Runit, and Enjebi.

Most of the buildings constructed during the development of the atoll were of the metal frame, metal sheathed type, erected on concrete slabs.

3.8 RADIOLOGICAL AND PHYSICAL CONDITION OF THE ISLANDS

In late 1972 and early 1973, the AEC conducted a radiological survey of Enewetak to determine the current radiological status of the atoll. In 1972, an engineering survey was conducted which determined the current nonradiological status of the atoll. The results of the AEC radiological survey are reported in the publication NVO-140. The recommendations resulting from the survey are found in the Task Group Report reproduced in Tab B, Volume II of this EIS. The following description of the current status of Enewetak Atoll is based on these surveys.

3.8.1 Radiological Status

The residual radioactivity on Enewetak Atoll results entirely from nuclear detonations at the atoll from 1948 through 1958. To better understand the current radiological status of the atoll, a discussion will first be given concerning important factors of the Enewetak radiological problem. (See also, AEC Task Group Report, Tab B, Vol. II, of the EIS.) Then the current status will be summarized.

3.8.1.1 Radioactive Isotopes of Concern. The principal radioisotopes of concern existing on Enewetak Atoll are:

3.8.1.1.1 Cesium-137 (^{137}Cs). This 30-year half-life isotope is a fission product. When present in the top few centimeters of soil, its gamma rays result in external whole-body exposures for inhabitants. Of less importance is the fact that when present on the top surface of soil, its beta rays result in external skin exposures. Being chemically similar to potassium, Cesium-137 deposits in the muscles of the entire body upon entry via the food chain. Consequently, the principal health hazard is the risk of cancer being induced. Worthy of note here is the fact that this isotope tends to be concentrated in the Breadfruit and Pandanus fruit -- popular foods in the Marshalls.

3.8.1.1.2 Strontium-90 (^{90}Sr). Strontium-90 is a 29-year half-life isotope that is a fission product. Not being a gamma ray emitter, it provides only an external beta ray exposure to the skin when present as deposits on the top surface of the ground. Being chemically similar to calcium, it deposits in the bone upon entry to the human body via the food chain. The consequent health hazard is then principally the risk of inducing leukemia. This isotope also is concentrated by the Breadfruit and Pandanus fruit.

3.8.1.1.3 Plutonium-239 (^{239}Pu). This is a 24,000-year half-life isotope. It is present on the islands either as unconsumed remains from the Plutonium-239 compositon of the nuclear explosives, or as a result of formation by capture of a neutron into Uranium-238 (^{238}U) nuclei. Being principally an emitter of alpha particles, which penetrate very slightly, Plutonium-239 is of little importance as a contributor to external exposures. Available data indicates that the body's uptake and retention of Pu through the gastrointestinal tract is a small percentage of the Pu ingested. This pathway is therefore less significant than other potential means of ingress to the body. The principal danger from ^{239}Pu is through inhalation of Pu-bearing dust.

3.8.1.1.4 Cobalt-60 (^{60}Co). Cobalt-60 is an activation product with a half-life of 5.3 years. It emits both beta particles and gamma radiation. ^{60}Co is a bone seeker and contributes to the bone exposure much like ^{90}Sr.

3.8.1.1.5 Other Radioactive Isotopes. Table 3-5 lists other radionuclides which might be expected in Enewetak soil as a result of the various test series. These have been identified through the examination of test documents which had been stored in archives, as well as reports from the Lawrence Livermore Laboratory and Los Alamos Scientific Laboratory. These isotopes are of three types:

- Other fission product isotopes resulting from nuclear explosions.
- Activation products, i.e., isotopes resulting from neutron radiation of other materials produced during the explosion. For example, Iron-55 from neutron bombardment of iron and Carbon-14 from neutron bombardment of carbon found in the natural surroundings.
- Unburned weapon fuel that was unconsumed in the nuclear explosions, e.g., Uranium-235.

3.8.1.2 Natural Reduction of Radiation Levels. Radiation levels from residual fallout on the islands at Enewetak Atoll will not only decrease due to natural decay, but also from weathering effects. The effects of wind can cause dispersion and scattering of radioisotopes on surfaces. However, after 15 years of wind action on Enewetak Atoll, most of the dispersion of surface contaminants has already occurred, and any further significant redistribution due to wind action seems unlikely.

TABLE 3-5: ADDITIONAL RADIONUCLIDES EXPECTED IN ENEWETAK ATOLL SOIL
(After AEC 1973 Survey)
NVO-140

Radio-nuclide	Source	Radio-nuclide	Source
^{241}Am	Unburned weapon fuel	^{151}Sm	Fission product
^{240}Pu	Unburned weapon fuel	^{147}Pm	Fission product
^{238}Pu	Unburned weapon fuel	^{125}Sb	Fission product
^{238}U	Unburned weapon fuel	^{102}Rh	Activation product
^{235}U	Unburned weapon fuel	^{63}Ni	Activation product
^{207}Bi	Activation product	^{55}Fe	Activation product
^{155}Eu	Fission product	^{14}C	Activation product
^{154}Eu	Fission product	^{3}H	Activation product and fuel
^{152}Eu	Activation product		

The effects of rain can also reduce radiation levels by washing radionuclides into the soil and into the surrounding lagoon and ocean. The overlaying soil then tends to attenuate radiation passing through this "shielding material" and consequently surface radiation levels are reduced. The effectiveness of this form of weathering, known as leaching, depends upon the chemical and structural properties of the fallout particles as well as the soil type and climatic conditions (Crocker, et al, 1964). Typically, leaching alone would halve the radioactivity over a period of years (Glasstone, 1964, p. 458). However, leaching has been occurring for 16 years at Enewetak. In this time, most of the easily leached radionuclides have already been transported. The leaching mechanism thus cannot be counted on for further significant reduction of the radiation levels now existing. After 16 years of wind action on Enewetak Atoll, much of the dispersion of surface contamination has occurred also. Further significant redistribution due to wind action seems unlikely, although test related radioactivity is found in surface air at detectable levels. The dust raised by resident activities is expected to increase airborne concentrations with further redistribution of the radioactivity.

3.8.1.3 Existing Radiological Conditions - Debris. In addition to the radionuclides present in the soil, sediments, and waters of Enewetak Atoll, other radioactive materials are present on some of the islands in the form of contaminated debris. Some of this debris is on the surface and some is in burial sites on certain islands. In the course of the 1973 AEC survey, interviews with test personnel confirmed that burial and relocation of high level radioactive contaminated debris was attempted frequently in many places. Although verification by documentation was only partially successful, it is likely that radioactive debris is buried only on those islands which had surface ground zeros. Table 3-6 lists quantities of known contaminated metal and concrete debris on Enewetak Atoll. In addition to the debris indicated in Table 3-6, there are known to be three burial vaults containing Pu on Aomon and two on Enjebi.

3.8.1.4 Existing Radiological Conditions - Soil. Soil samples taken from islands in the northern part of the atoll were used to produce radiation profiles for those islands (NVO 140, Vols. II & III). Activities exhibited by these samples showed reasonable direct correlation with the amount of vegetation present in the area surrounding the sampling locations. This correlation with vegetative cover was also observed at Bikini Atoll. For a given island, densely vegetated areas showed the highest activities; sparsely vegetated areas showed intermediate activity levels; and beach areas exhibited the lowest activities. This pattern is sometimes perturbed in "hot spot" areas where ground-zero locations existed or where extensive earth moving activities have taken place. The correlation with vegetation might be expected since vegetation would serve to reduce the effects of the weathering processes.

TABLE 3-6: RADIOACTIVE SCRAP METAL AND CONCRETE
(After H&N Engineering Survey)
HN-1348.1

Island	Cu Yds
Bokoluo	10
Enjebi	568
Lujor	317
Eleleron	196
Aomon	2,106
Bijire	1
Runit	4,064
Total	7,262

Tables 3-7 and 3-8 give soil activity data for the northern and southern islands of Enewetak Atoll, respectively, for the top 15 cm of soil. The terms "dense" and "sparse" refer to the vegetative cover of the sampled areas. A comparison of Tables 3-7 and 3-8 show that the southern islands are much less contaminated than those in the northern portion of the atoll. This is as expected since the southern islands were the scene of only two tests, both of which were underwater tests off Mut Islet, downwind from most of the other southern islands.

3.8.1.5 Surface Radiation Levels. An aerial radiological survey of the islands of Enewetak Atoll was conducted by EG&G, Inc., in November 1972, for the AEC. The results of this survey identify zones of different levels of radioactivity on the islands. These zones are defined by iso-exposure (isopleths) contours giving exposure in $\mu R/hr$ at 3 feet above the soil surface. Contour maps showing the isopleths for each island were then prepared and are presented in Tab A, Vol. II, EIS. The exposure rate contour map key necessary for interpreting the isopleths is given in Tab A, Vol. II, EIS. Table 3-9 gives a summary of mean and average gamma exposure rates for the islands of Enewetak Atoll as determined by the AEC survey. The gamma radiation was primarily produced by ^{137}Cs and ^{60}Co. These gamma doses may be compared to the average total United States dose from all sources of 0.21 rem/yr or approximately 25 $\mu R/hr$.

3.8.1.6 Surface Air Contamination. Contamination levels were measured for surface air at various locations on Enewetak. Table 3-10 shows a summary of these results and comparison to Livermore, California, and Balboa, Panama. (fCi/m^3 is 10^{-15} curies per cubic meter.)

3.8.1.7 Lagoon Sediment Contamination. As part of the AEC Radiological Survey, extensive sampling was done of the lagoon floor by sediment and core sampling. Radionuclide concentrations are highest in the vicinity of Enjebi and decrease in all directions out from Enjebi. The levels decrease most rapidly to the south and north than to the center of the lagoon. Isolated pockets of relatively high concentration levels of some radionuclides (^{239}Pu, ^{60}Co, ^{241}Am, ^{155}Eu) are evident in otherwise lesser contaminated areas of the lagoon. There appears to be little difference in radionuclide concentrations of lagoon and ocean near-shore sediments. Table 3-11 gives mean radionuclide concentrations found in Enewetak Lagoon sediments. For comparison, Table 3-12 presents selected radionuclide data for aquatic sediments from other parts of the world.

3.8.1.8 Lagoon Water Contamination. Lagoon water samples were also taken during the AEC survey. Differences in radionuclide concentrations between lagoon and ocean samples clearly indicate the Atoll to be the source of radionuclides in the lagoon water. Table 3-13 shows the concentration of ^{137}Cs and ^{239}Pu in comparative surface samples and a comparison to other ocean areas.

TABLE 3-7: ENEWETAK SOIL DATA, NORTHERN ISLANDS (pCi/g in top 15 cm)
(After AEC 1973 Survey)
NVO-140

Island	Vegetation	^{90}Sr		^{137}Cs		^{239}Pu		^{60}Co	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
BOKOLUO		80	14-430	36	5.6-141	12	3.9-68	5.9	1.4-33
BOKOMBAKO	Dense	123	14-670	48	14-170	26	7.2-130	10	3.1-30
	Sparse	44	35-130	8.6	3.3-44	11	5.8-26	4.6	2.4-9.6
KIRUNU		65	13-310	26	5.6-110	22	3.5-88	6.4	0.91-20
LOUJ	Dense	190	100-380	11	3.4-33	41	22-98	11	6.4-26
	Sparse	32	16-120	3.8	0.86-90	15	3.8-33	0.85	0.37-7.4
BOKINWOTME		46	30-220	4.2	2.7-6.4	18	13-24	0.43	0.33-0.63
BOKEN		30	5.9-570	3.2	0.22-41	11	2.4-280	5.4	0.12-520
ENJEBI		44	1.6-630	16	0.57-180	8.5	0.08-170	1.9	0.02-33
MIJIKADREK	Dense	67	37-200	24	18-37	17	8.6-50	2.7	1.6-5.8
	Sparse	11	1.6-49	4.8	1.8-16	2.3	0.17-14	0.46	0.03-3.5
KIDRINEN		32	10-83	11	2.2-25	7.7	2.4-22	1.5	0.26-3.8
BOKENELAB		29	11-140	9.9	5.6-26	8.0	2.0-35	1.5	0.74-4.8
ELLE		36	16-110	12	6.0-28	9.1	2.3-28	1.6	0.56-5.3
TAIWEL		13	3.6-73	0.94	0.12-17	3.5	1.5-23	0.47	0.08-2.9

TABLE 3-7 (continued)

Island	Vegetation	^{90}Sr		^{137}Cs		^{239}Pu		^{60}Co	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
AEJ	Dense	22	4.6-70	8.5	3.5-28	7.7	2.2-30	1.5	0.65-4.1
	Spare	4.5	2.0-11	0.16	0.07-11	2.8	1.9-4.1	0.11	0.05-0.31
LUJOR	Hot Spot	62	35-140	19	7.4-55	51	15-530	12	3.6-70
	Remainder	17	3.2-61	7.6	1.2-34	11	0.85-100	4.1	0.49-49
ELELERON		12	7.1-63	1.4	0.71-7.2	7.3	3.0-24	0.93	0.29-16
AOMON		8.4	0.87-140	3.0	0.03-30	4.3	0.21-130	0.54	0.05-69
BIJIRE	Dense	27	17-54	8.4	3.5-20	7.6	1.4-17	1.2	0.61-1.9
	Sparse	8.7	2.2-47	1.0	0.04-5.3	2.5	1.1-34	0.37	0.21-1.7
LOJWA		6.8	2.0-19	1.7	0.13-7.8	1.3	0.26-7.3	0.31	0.05-1.7
ALEMBEL		6.3	1.1-68	2.0	0.03-12	2.5	0.60-25	0.30	0.02-2.2
BILLAE		3.3	0.26-13	1.3	0.31-72	1.1	0.1-5.3	0.12	0.01-0.51
Southern RUNIT[a]	None	1.7	0.09-20	0.40	0.02-3.6	3.2	0.02-50	0.64	0.01-20
Northern Beaches		6.4	1.2-30	0.30	0.03-9.0	2.7	0.34-18	0.13	0.03-1.6

[a]RUNIT - Because of the complex distribution of activities on northern RUNIT, no single mean value for an isotope can be used for the island as a whole without being misleading.

TABLE 3-8: ENEWETAK SOIL DATA, SOUTHERN ISLANDS (pCi/g in top 15 cm)
(After AEC 1973 Survey)
NVO-140

	^{90}Sr		^{137}Cs		^{239}Pu		^{60}Co	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Group A (JAPTAN, MEDREN, and ENEWETAK)	0.41	0.02-4.8	0.21	0.01-2.1	0.04	0.004-0.31	0.03	0.01-0.15
Group B (All others except BIKEN[a])	0.52	0.03-3.9	0.14	0.004-1.8	0.07	0.004-1.1	0.06	0.007-63
Group C (BIKEN)	11	1.6-34	3.2	0.5-10	0.63	0.02-2.0	0.58	0.04-5.0

[a] BOKO, MUNJOR, INEDRAL, VAN (no Enewetakese name), JINEDROL, ANANIJ, JINIMI, JEDROL. BOKANDRETOK, IKUREN, MUT, BOKEN, RIBEWON, AND KIDRENEN

TABLE 3-9: SUMMARY OF AVERAGE EXTERNAL EXPOSURE RATES FOR ISLANDS IN ENEWETAK ATOLL
(Average Exposure Rate in μR/hr at 1 m[a])
(After AEC 1973 Survey As Reported in NVO-140)

Island	^{137}Cs	^{60}Co	Total γ (0-3 MeV)	Range[b]
BOKOLUO	42	36	81	4-170
BOKOMBAKO	61	50	115	5-200
KIRUNU	20	19	42	5-100
LOUJ	6.8	14.4	21.3	5-140
BOKINWOTME	2.8	2.4	6	5-8
BOKEN	14	63	80	3-560
ENJEBI	25	13	40	2-150
MIJIKADREK	11	7	19	3-22
KIDRINEN	6	7	14	1-20
TAIWEL	2	2	5	2-11
BOKENELAB	5.5	4	10	2-12
ELLE	6	5	12	1-50
AEJ	6.5	4.5	11	1-15
LUJOR	12	45	70	1-400
ELELERON	2	12	14	1-42
AOMON	3.5	3	7	3-110
BIJIRE	4	2	6	2-11
LOJWA	3	1.8	5	1-7
ALEMBEL	2.8	2	5	1-6
BILLAE	1	1	2	1-3
RUNIT	5.6	22.4	33	1-750
BOKO	<0.3 (0.20)	<0.6 (0.11)	<0.9	0-1
MUNJOR	<0.3 (0.18)	<0.6 (0.13)	<0.9	0-1
INEDRAL	<0.3 (0.06)	<0.6 (0.43)	<0.9	0-1

TABLE 3-9 (continued)

Island	^{137}Cs	^{60}Co	Total γ (0-3 MeV)	Range[b]
Van (No Enewetakese Name)	<0.3 (0.08)	<0.6 (0.25)	<0.9	0-1
JINEDROL	N.D. (0.06)	<0.6 (0.25)	<0.9	0-1
ANANIJ	0.4 (0.22)	0.8 (0.34)	1.2	0-1
JINIMI	0.3 (0.04)	<0.6 (0.11)	<0.9	0-1
JAPTAN	N.D. (0.21)	N.D. (0.10)	<0.9	0-5
JEDROL	<0.3 (0.28)	<0.6 (0.25)	<0.9	0-1
MEDREN	N.D. (0.19)	N.D. (0.12)	<0.9	0-2
BOKANDRETOK	<0.3 (0.08)	<0.6 (0.10)	<0.9	0-1
ENEWETAK	N.D. (0.14)	N.D. (0.12)	<0.9	0-1
IKUREN	0.4 (0.33)	<0.6 (0.20)	<0.9	0-1
MUT	<0.3 (0.14)	<0.6 (0.20)	<0.9	0-1
BOKEN	<0.3 (0.08)	<0.6 (0.46)	<0.9	0-1
RIBEWON	<0.3 (0.05)	2.8	3.0	0-5
KIDRENEN	<0.3 (0.15)	0.6 (0.49)	<0.9	0-2
BIKEN	2.8	4.8	7.6	.3-8

[a] Average dose rates given are derived from aerial survey data. On islands where activity levels are at the lower limit of sensitivity of the aerial survey equipment, dose rates derived from the soil sample data are given in parentheses.

[b] As measured with the Baird-Atomic instrument.

N.D. = Nondetectable.

TABLE 3-10: COMPARISON OF RADIONUCLIDES IN SURFACE AIR ON ENEWETAK ATOLL, AT LIVERMORE, CALIFORNIA, AND BALBOA, PANAMA, fCi/m^3
(After AEC 1973 Survey)

Nuclide	RUNIT	Remainder of Enewetak Atoll	Livermore, California 1972	Balboa, Panama 9°N 79°W 1972-1973
^{7}Be	<49-193	<6-116	90-250	43-143[a]
^{54}Mn	<0.6-2.1	<0.14-4.0	-	-
^{95}Zr	<0.4-0.4[b]	0.03-0.3	0.005-0.4	<0.9-8.5
^{103}Ru	<5.5-5.5[b]	NDET[c]	0.29-3.4	-
^{125}Sb	<0.27-0.27[b]	NDET	0.04-0.23	-
^{106}Ru	<0.9-2.6	<0.2-1.6	0.14-2.9	-
^{137}Cs	0.49-0.82	<0.04-2.5	0.63-3.2	0.09-1.7
^{144}Ce	<2.5-3.7	<0.22-1.9	0.24-3.1	0.7-11.2
$^{239-240}$Pu	0.03-2.6	0.001-0.025	0.01-0.05	<0.001-0.030
^{238}Pu	0.04-0.13	0.0028-0.008	0.001-0.005	<0.001-0.003
^{241}Am	<0.3-0.30[b]	NDET	NDET	NDET

[a] Oct.-Dec. 1972 range
[b] Detected on only one sample.
[c] Not detected

TABLE 3-11: MEAN RADIONUCLIDE CONCENTRATIONS IN ENEWETAK LAGOON SEDIMENTS
(From AEC 1973 Survey)

Radionuclide	Activity/Unit Area (mCi/km^2)
^{90}Sr	586
$^{239,240}Pu$	463
^{155}Eu	369
^{241}Am	172
^{207}Bi	163
^{137}Cs	78
^{60}Co	73
^{125}Sb	22
^{102m}Rh	8.4
^{152}Eu	2.5
^{101}Rh	1.2

TABLE 3-12: SOME SELECTED RADIONUCLIDE DATA IN AQUATIC SEDIMENTS
(From AEC 1973 Survey)

Radionuclide	Collection Date	Location	mCi/km^2
$^{239,240}Pu$		Buzzards Bay, Mass.	2.3 ± 0.2
$^{239,240}Pu$	1971	Lake Ontario	0.6 ± 0.2
$^{239,240}Pu$	1968	Bylot Sound, Greenland	3.9
$^{239,240}Pu$	1968	Bylot Sound, Greenland	135
^{90}Sr	1970-71	Buzzards Bay, Mass.	0.6 ± 0.1
	1969	Lake Superior	4.4
	1966	Lake Michigan	3.7
	1966	Ligurian Sea	3.0
^{137}Cs	1970-71	Buzzards Bay, Mass.	7.6
	1973	Humboldt Bay, Calif.	21
	1969	Lake Superior	155
	1971	Lake Ontario	14
^{60}Co	1963	11 km off mouth of Columbia River, USA	64
	1973	Humboldt Bay, Calif.	3.5
^{155}Eu	1966	Ligurian Sea	18

TABLE 3-13: CONCENTRATION OF ^{137}Cs AND ^{239}Pu IN COMPARATIVE SURFACE WATER SAMPLES
(From AEC 1973 Survey)

Location	Concentration fCi/liter	
	^{137}Cs	^{239}Pu
Enewetak Lagoon		
SE quadrant	226	9.1
NE quadrant	334	42.6
NW quadrant	579	33.4
SW quadrant	332	21.6
Ocean, east of Enewetak Atoll	89	0.3
Lake Michigan (1971)	88	1.1
Humboldt Bay, Calif. (1973)	300	
14°N 180°W (1972)	143	0.44
12°N 170°E (1972)	170	0.35
Windscale (England) vicinity (1969)	105,000	
Mean Surface, Atlantic 0-31°N (1968)		0.7

To maintain the proper perspective, it should be noted that the average natural ^{40}K concentration in seawater is 2.95×10^5 fCi/liter, a concentration several orders of magnitude greater than that for any fission or activation product measured in any atoll water sample from the radiological survey.

3.8.1.9 Plant and Animal Contamination. The distribution of radionuclides in the terrestrial biota throughout the islands of Enewetak Atoll generally conforms to the results of the environmental radiation survey. On islands with elevated levels of radiation, the biota contained elevated concentrations of radionuclides. The most prominent radionuclides are ^{137}Cs, ^{90}Sr, ^{55}Fe, ^{60}Co, and $^{239,240}Pu$.

3.8.1.9.1 Plants. A wide range of plant species was sampled in order to obtain information on the transfer of radionuclides from soil to plants; while not eaten by man, several species were collected to provide a broad background on soil-plant relationships.

Messerschmidia argentea, a broad-leaved evergreen tree which was collected throughout the atoll. ^{137}Cs was found in *M. argentea* on every island. Highest concentrations were observed at the northern end of Runit, on Enjebi, and on Boken. Elevated concentrations of ^{137}Cs were found in *Messerschmidia* in islands from Bokoluo across the northern arc of islands and south along the eastern rim of the atoll to Runit.

Highest ^{137}Cs concentration occurred in the *Messerschmidia* collected at the northern end of Runit, and the highest ^{90}Sr, in *Messerschmidia* was on Boken. The southern chain of islands from Ikuren to Kidrenen have *Messerschmidia* trees (leaves) with concentrations of ^{137}Cs from 0.25 to 1.76 pCi/g. *Scaevola frutescens* leaf concentrations also fall in this range. For comparison, vegetation growing in the San Francisco Bay area (approximately 38°N latitude) in 1972 had a mean concentration of 0.25 pCi/g dry wt ^{137}Cs (Guidiksen, 1973), which is at the lower limit of concentrations observed in the southern arc of islands at Enewetak Atoll.

The levels of ^{137}Cs observed on the southern and eastern islands south of Ananij are higher than expected from world background for the southwest Pacific area. Elevated concentrations of ^{137}Cs in *Messerschmidia*, *Scaevola*, *Pisonia*, and *Pandanus* were found on Biken.

The radionuclide concentrations in *Scaevola frutescens* show patterns similar to those seen in *Messerschmidia*, but generally lower in value. Highest concentrations were again found on the northern end of Runit, where the maximum ^{137}Cs concentrations in both species occurred.

Maximum concentrations of ^{60}Co in both Messerschmidia and Scaevola were found on Boken adjacent to Seminole crater. Highest $^{239,240}Pu$ concentrations were observed on the north end of Runit in both Messerschmidia (0.766 pCi/g) and Scaevola (1.293 pCi/g). The highest ^{90}Sr value in Scaevola also occurred on Runit. There are eleven (11) islands on which Messerschmidia or Scaevola had over 25 pCi/g of either ^{137}Cs or ^{90}Sr. These are:

BOKOLUO	ELLE
KIRUNU	LUJOR
BOKEN	ELELERON
ENJEBI	BIJIRE
BOKENELAB	LOJWA
	RUNIT

The arc of islands bounded by Bokoluo on the west and Runit on the east embraces the portion of the atoll with the highest levels of environmental radioactivity. This is reflected by the radionuclide concentrations in the dominant vegetation of those sites. Within the sector of the atoll, the highest levels of environmental radioactivity in the biota were found on Enjebi and Runit.

The concentrations of radionuclides in Cocos nucifera, the coconut palm, on the islands of Enewetak Atoll are shown in Table 3-14.

The coconuts collected on Enjebi, Bokenelab and Elle, had the highest concentrations of ^{137}Cs. Almost every high concentration of ^{137}Cs in coconut milk was correlated with high ^{40}K. Two high concentrations of ^{55}Fe were found in coconuts from Boken and Bokenelab. The only $^{239,240}Pu$ detected in coconuts was found on Boken, in a radioactive area on the eastern side of the island.

The small tree, Morinda citrifolia, bears a soft, edible fruit. The leaves of this tree, and the fruit when available, were collected on 11 islands. High ^{137}Cs concentrations were found in Morinda on the northeastern arc of the islands from Mijikadrek to Alembel. The highest ^{137}Cs and ^{90}Sr values are observed on Bokenelab.

The Pandanus tree, Pandanus tectorius, was found on 11 islands at Enewetak Atoll (Table 3-15). Two trees bore fruit at the time of the survey, one on Bokombako in the northern part of the atoll and the other on Kidrenen in the southern islands. The fruit of this plant had 1.35 times the ^{137}Cs concentration that leaves from the same plant had. Pandanus on Biken had elevated ^{137}Cs levels which were seen in other trees on that island. A high uptake of ^{90}Sr is indicated by elevated levels of that radionuclide in Pandanus leaves on Medren and Kidrenen, where soil concentrations are low.

TABLE 3-14: RADIONUCLIDE CONCENTRATIONS IN COCOS NUCIFERA COLLECTED AT ENEWETAK ATOLL, 1972-1973

Island	Activity, pCi/g, dry wt.		
	^{40}K	^{137}Cs	^{90}Sr
Louj	5.65	7.17	0.195
Louj[a]	45.50	-----	1.405
Boken[a]	99.90	5.11	1.610
Boken	7.05	1.77	0.067
Enjebi	8.04	84.68	0.210
Enjebi[a]	60.05	210.70	1.570
Bokenelab	7.52	14.27	0.136
Bokenelab[a]	39.25	67.75	0.635
Bokenelab	3.75	5.59	14.140
Elle	6.54	18.83	0.167
Elle[a]	73.51	148.80	1.150
Alembel	5.64	9.30	0.134
Runit	6.39	1.99	-----
Runit	8.24	3.96	0.011
Ananij	5.93	0.58	-----
Japtan	6.44	2.59	0.014
Japtan	3.76	1.67	0.178
Japtan	4.69	0.40	0.026
Japtan[a]	30.93	23.32	-----
Medren	9.73	2.14	0.032
Medren	5.50	3.45	-----
Enewetak	6.39	2.39	0.029
Enewetak	5.59	0.53	0.367
Ikuren	7.53	1.65	0.326
Ikuren	6.12	0.86	0.020
Ikuren	8.28	1.30	-----
Mut	3.95	0.70	-----
Kidrenen	7.69	0.95	-----
Biken	4.12	3.54	0.189

[a]Coconut Milk.

TABLE 3-15: RADIONUCLIDE CONCENTRATIONS IN PANDANUS TECTORIUS COLLECTED AT ENEWETAK ATOLL, 1972-1973

Island	Activity, pCi/g, dry wt.			
	^{40}K	^{137}Cs	^{90}Sr	$^{239,240}Pu$
Bokombako (fruit)	14.38	923.00	206.30	----
Bokombako (leaves)	6.70	679.30	----	----
Enjebi (leaves)	8.12	0.62	4.41	----
Aomon (leaves)	14.02	14.98	1.97	0.015
Bijire (leaves)	13.29	152.20	15.50	0.0069
Alembel (leaves)	9.17	17.58	4.24	0.0076
Japtan (leaves)	9.74	15.0	3.56	----
Medren (leaves)	8.86	3.09	25.14	0.0020
Enewetak (leaves)	3.38	4.29	0.42	0.0077
Kidrenen (leaves)	12.70	0.86	13.11	----
Kidrenen (leaves)	8.18	0.57	-----	----
Biken (leaves)	7.99	9.14	1.69	0.0022
Biken (fruit)	30.2	26.2	16.26	----

Tacca leontopetaloides, or arrowroot, had low concentrations of radionuclides on Japtan, but no specimens were found on islands with higher levels of radioactivity. Hence, any tendency for accumulation of radionuclides in the underground storage organs could not be evaluated. This is a commonly used food plant which can be cultivated on islands with deep organic soils.

3.8.1.9.2 Animals

- Birds. Table 3-16 shows the mean of the radionuclide concentrations measured for muscle and liver in birds found on the atoll. The radioactivity of birds appeared to be related to the radioactivity levels of the lagoon adjacent to their nesting site. Table 3-17 is a summary of radionuclides in bird eggs.
- Coconut crabs. Coconut crabs were collectable only in the southern islands. Table 3-18 is a summary of the radionuclide concentrations measured for the coconut crabs that were collected. Coconut crabs were found only in the south because the environment of the northern islands does not conform with their ecological requirements, and no sampling could therefore be done.
- Fish. Extensive sampling of fish was done in the lagoon. Table 3-19 is a summary of the data obtained on the radionuclide concentrations found in lagoon fish. Table 3-20 is a brief comparison of some Enewetak data with data from other areas of the world.

3.8.2 Beryllium Contamination

Two static test firings of High Energy Upper Stage (HEUS) rocket motors were conducted on Enjebi in April 1968, and January 1970. These rocket motors contained beryllium as one of the propellant constituents. The 1968 test misfired and detonated resulting in localized beryllium contamination on the southwest tip of Enjebi. This exterior surface contamination was effectively removed by decontamination efforts (Professional Report No. 7IM-2, USAF, 1970). Subsequent erosion along the southern shore has substantially reduced the original area. However, some localized contamination remains on the interior southwest corner of the concrete bunker which was adjacent to the test stand. This contamination would be removed by scraping, chipping, or sandblasting and disposed of along with the radioactive debris.

All operations involving the removal of beryllium contamination and its transport and disposal will be conducted in accordance with Part 1910, Occupational Safety and Health Standards, Subpart G-Occupational Health and Environmental Control, para. 1910.93 - Air Contaminants and the values shown in Table G-2, dated July 1, 1973.

TABLE 3-16: RADIONUCLIDES IN MUSCLE AND LIVER OF BIRDS

Island	Sample Type	Concentration, pCi/g dry									
		^{55}Fe		^{60}Co		^{90}Sr		^{137}Cs		$^{239,240}Pu$	
		Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver	Muscle	Liver
Bokoluo	Common noddy	49.6	127	0.321	<0.165	0.0099	<0.0099	<0.072	<0.094		0.0622
Boken	Common noddy		49.6	0.247	0.324		0.509	<0.099	<0.057		0.0091
Enjebi	Common noddy	105	258	0.507	<0.165	0.0078	0.0667	<0.069	<0.097	0.0018	<0.033
Enjebi	Pooled terns	59.5	172	0.159	<0.514	0.0047	0.0050	0.0621	<0.406	0.0055	0.0015
Kidrinen	Common noddy	8.78	199	<0.216	<0.398	0.0046	0.187	0.192	<0.246	0.0228	<0.073
Bokenelab	Common noddy	14.2	251	0.316	0.568	0.482	<0.019	0.143	<0.093	0.0022	<0.012
Aej	Common noddy	92.8	232	<0.151	<0.195	0.0016	0.0362	<0.092	<0.107	0.0919	0.0105
Lujor	Pooled terns		317	0.659	0.647		<0.049	<0.142	<0.127		0.0041
Aomon	White-capped noddy	110		0.214	0.235	0.0135	0.0283	<0.087	<0.055	0.0196	0.0110
Aomon	Sooty tern	36.6	155	<0.114	<0.120	0.0064	0.0344	<0.081	<0.069	0.0054	<0.079
Runit	Common noddy	22.6	386	0.230	0.369	0.0073	<0.011	<0.086	<0.075	0.0201	0.0111
Van	Common noddy	99.6	279	0.283	0.195	0.0034	0.0403	<0.076	<0.060	0.0014	0.0025
Jinedrol	Pooled terns			<0.167	<0.187			0.128	<0.131		
Ananij	White-capped noddy	41.3	327	0.392	<0.253	<0.0080	0.0326	<0.079	<0.134	0.0069	0.0222
Jinimi	Sooty tern	20.4	146	<0.091	<0.549	0.0064	0.0149	<0.065	<0.054	<0.0015	0.0017
Japtan	Sooty tern	59.0	153	<0.108	<0.345		0.0545	<0.082	<0.230	0.119	0.0420
Jedrol	Common noddy	43.5	118	0.177	<0.161	0.0065	<0.0091	<0.076	<0.091	0.0056	0.0121
Boken	Common noddy	169	423	0.609	0.635	0.0085	0.233	0.306	<0.161	0.0434	0.0242
Kidrenen	Common noddy			0.452	0.689	<0.0041		<0.089	<0.129	0.0010	
Biken	White-capped noddy	64.4	811	2.07	2.83	<0.112	0.402	<0.134	<0.242	0.0033	0.0072

TABLE 3-17: RADIONUCLIDES IN BIRD EGGS

Island	Species	Concentration, pCi/g dry				
		^{55}Fe	^{60}Co	^{90}Sr	^{137}Cs	^{239,240}Pu
Boken	Common noddy	23.0	<0.075	0.095	<0.051	0.0015
Enjebi	Common noddy	57.2	<0.10	0.203	0.119	0.0148
Aomon	Sooty tern	37.6	<0.073	0.0043	<0.052	0.0154
Runit	Common noddy	<0.59	<0.10	1.06	<0.069	0.00045
	Common noddy	56.8	<0.11	<0.0020	<0.079	0.0232
	Common noddy	54.5	<0.087	0.073	0.079	0.00068
Van	Common noddy	63.5	<0.10	0.0022	0.136	0.00047
Jinimi	Sooty Tern		<0.82		<0.057	
Jedrol	Common noddy	51.4	<0.10	0.0066	<0.070	0.00077
Mut	Common noddy	54.1	0.048	0.0025	<0.015	0.00047
Boken	Common noddy	5.14	<0.12	<0.011	<0.083	0.00088

TABLE 3-18: RADIONUCLIDES IN EDIBLE PARTS OF COCONUT CRABS

Island	Tissue	Concentration, pCi/g dry				
		^{60}Co	^{90}Sr	^{137}Cs	^{152}Eu	^{239,240}Pu
Ananij	Muscle	0.198	0.185	1.98		0.0012
	Hepatopancreas	0.402	0.133	0.420		0.0023
Ikuren	Muscle	0.247		1.88		0.0013
	Hepatopancreas	0.276	0.269	0.545		<0.0066
Ribewon	Muscle	1.05	0.079	1.25		0.00076
	Hepatopancreas	1.56	0.0014	0.317		0.0019
Kidrenen	Muscle	0.420	1.19	1.92		0.0014
	Hepatopancreas	1.03	0.401	0.496	0.066	0.0098
Biken	Muscle	1.23	1.58	12.6		0.0031
	Hepatopancreas	1.46	2.58	3.29		0.0038

TABLE 3-19: RADIONUCLIDE CONCENTRATIONS IN FISH
(January 1972)

Nuclide	Sample	No. of Samples	Concentration, pCi/g dry weight		
			Average	High	Low
^{137}Cs	All fish[a]	128	0.39	6.8	0.026
^{60}Co	All fish[a]	128	2.0	38	0.041
^{90}Sr	All fish[a]	125	0.16	1.5	0.0010
^{90}Sr	Eviscerated whole fish	74	0.21	---	---
^{90}Sr	Fish muscle only	51	0.075	---	---

[a]All fish includes eviscerated whole fish and those fish where muscle was separated from bone and only the muscle was analyzed.

TABLE 3-20: COMPARATIVE CESIUM AND STRONTIUM DATA FOR MARINE FISH MUSCLE

Location		Concentration, mean pCi/g, dry wt.	
		^{137}Cs	^{90}Sr
Enewetak	1972	0.3	0.08
Amchitka	1971[a]	0.1	No data
Chicago	1971[b]	0.1	0.003
Chicago	1972[b]	0.2	0.003
Bikini	1968[c]	~1.0	0.7
Colorado mountain lakes	1972[d]	2.5	No data

[a] Amchitka Radiobiological Program Progress Report, NVO-269-17, 1972

[b] Radiation and Data Reports 1971, 1972;

Health and Safety Laboratory Quarterly Reports 1971, 1972, 1973.

[c] Radiological Report on Bikini Atoll, 1968.

[d] "Radioecology of Some Natural Organisms and Systems in Colorado, "Eleventh Annual Progress Report to Atomic Energy Commission, Department of Radiology and Radiation Biology, Colorado State University, Fort Collins, Colorado, Rept. COO-1156-63.

3.8.3 Physical Status of Each Island

Existing physical conditions as determined by the 1972 Holmes & Narver survey are summarized below. Further details are contained in the Engineering Studies HN-1348.1 and HN-1348.2. (For ease of reference, island code names are included with the native names.)

3.8.3.1 Bokoluo - (Alice). This island was used mainly for photo and other scientific purposes during several nuclear testing operations. Two stations presently remain from Ivy, both of which are of concrete construction. A quantity of steel scrap, as well as a derelict landing craft are in evidence. There are large amounts of stormborne materials in a few exposed areas, while the major portion of the island is covered with dense vegetation.

3.8.3.2 Bokombako - (Belle). A cased well and a grade beam from a signal terminal station used in operation Greenhouse are all that remain on the island. There is very little debris noted. The overall vegetation is dense, but thins out toward the northeast end of the island.

3.8.3.3 Kirunu - (Clara). A concrete bunker which contained electronically and radiation shielded instrumentation during operation Ivy still remains. A small amount of debris, along with a derelict crane in the lagoon off the southwest tip of the island, still remains. The island is densely covered with vegetation.

3.8.3.4 Louj - (Daisy). A small pipe used as a station in the Ivy operation as well as other miscellaneous pipes, are all that remain. Vegetation ranges from sparse on the lagoon side to dense on the ocean side.

3.8.3.5 Bokinwotme - (Edna). There is no debris on the island and vegetation is sparse.

3.8.3.6 Bokaidrikdrik/Boken - (Helen/Irene). Boken was used as a ground zero island during Redwing and contained instrumentation during other operations. Bokaidrikdrik cannot be considered a true island, as all that remains is a sand spit bordering the Seminole crater where the island used to be. With the exception of a few isolated locations, the beaches are generally free of debris. There is a clear corridor through Boken from the Seminole crater to the eastern tip. Vegetation varies from medium to dense and some of the debris is partially buried. Remains of scientific stations in the form of concrete bunkers and slabs are in evidence.

3.8.3.7 Enjebi- (Janet). This island contained the ground zeros for several events, as well as a number of instrumented scientific stations. One large concrete building and a reinforced concrete bunker are among those still standing. The remains of the camp area at the south end consist mostly of concrete slabs in various conditions of deterioration. The compacted coral surface airstrip is overgrown. This is also true for the greater part of the island. With the exceptions of Enewetak and Medren, Enjebi contains the largest amount of uncontaminated debris. While a large part of this is inland, some of it is located on both the ocean and lagoon beaches. Vegetation ranges from sparse, north of the airstrip, to moderately dense in the southern part of the island. The island contains two crypts holding small amounts of plutonium.

3.8.3.8 Mijikadrek - (Kate). This island was used extensively for photographic purposes and effects on test structures during Greenhouse. There is a considerable amount of metal debris and rubble on the island. The vegetation ranges from moderately dense in the south to dense in the central and extreme northern portions.

3.8.3.9 Kidrinen - (Lucy). This island was instrumented for biomedical and sampling purposes during Greenhouse. Most of the debris is in relatively small pieces. There is a dense cover of vegetation in all but the southeast portion where it is moderate.

3.8.3.10 Taiwel - (Percy). This island has a submarine cable terminal building which has been overturned. There is very little vegetation on the island.

3.8.3.11 Bokenelab - (Mary). The island was instrumented during Greenhouse, Ivy, and Hardtack. There are some concrete and wood-framed metal-clad structures remaining, mostly in poor condition. There is a nominal quantity of uncontaminated debris and the vegetation cover ranges from sparse to moderate.

3.8.3.12 Elle - (Nancy). The island is completely covered with dense vegetation. There is no debris.

3.8.3.13 Aej - (Olive). A concrete bunker, still in good condition, was used for recording purposes during Castle. It is the only station on the island. There is an estimated 1 cubic yard of uncontaminated debris on the shore at the eastern end of the island. The vegetation ranges from medium to dense cover.

3.8.3.14 Lujor - (Pearl). Most of the scientific stations which remain are in the southeast end of the island. Four concrete anchor blocks are on the northwest end. An uncontaminated aerial bomb of World War II vintage, but still intact, is on the lagoon shore near the southeastern end of the island. The island is densely covered with vegetation.

3.8.3.15 Eleleron/Aomon - (Ruby/Sally). This island complex was used for a ground zero in operation Greenhouse. It was also used for various types of instrumentation in other operations. This was one of the sites for the Pace Program as evidenced by the defoliated areas and small craters on Aomon. The Aomon-Bijire causeway is uncontaminated and in fair condition. Some of the bunkers and concrete structures are in fair condition. There is a nominal amount of uncontaminated debris. A number of crypts containing plutonium are also located in Aomon.

3.8.3.16 Bijire - (Tilda). Most of the concrete structures, including a photo bunker, are in fair condition. The airstrip is in fair condition and the remains of a derelict barge are on the lagoon shore. The island vegetation ranges from moderate to dense.

3.8.3.17 Lojwa - (Ursula). This island was used as the shot camp site for the Aomon-Bijire-Lojwa complex. Concrete tent slabs and one building remain in fair condition as does a metal building adjacent to the timber causeway to Bijire. The causeway itself is in good condition as are some of the concrete scientific stations. There is a comparatively small amount of uncontaminated debris. The personnel pier and boat ramp on the south tip of the island are in usable condition. Vegetation ranges from moderate in the camp area to heavy in the north and west sectors of the island.

3.8.3.18 Alembel - (Vera). A scientific station housed animals for medical research during the Greenhouse operation. It is a concrete structure in poor condition. Three of the interior walls are redwood lined. The island has a minimum of debris on it and is densely covered with vegetation.

3.8.3.19 Billae - (Wilma). There are remains of eight scientific stations on the island, two of which were photo towers. One of these towers at the south end of the island is intact. The asphalt surface of the helicopter pad is mostly disintegrated and heavily overgrown. Some structures, including a metal-clad wood framed building and an animal research structure, are still standing. The island has a dense cover of vegetation and a moderate amount of noncontaminated debris.

3.8.3.20 Runit - (Yvonne). This island was used as a shot island as well as for various types of instrumentation during several of the nuclear testing operations. The island also contained a camp, airstrip, and boat landing facilities. Cactus and Lacrosse craters are at the north end of the island.

Most of the concrete bunkers which served as scientific stations are considered to be in fair to good condition. The airstrip is in poor condition and the steel bulkheads at the ocean end have failed, resulting in erosion of the fill material. The personnel pier and boat landing ramp are usable. Of the concrete slabs remaining from the camp site, the majority are in poor condition and a few are in fair condition. The interior of the powerhouse bunker is in good condition. Vegetation is relatively sparse, leaving the greater portion of the island clear.

3.8.3.21 Boko - (Sam). This island was not used as a scientific site during the nuclear test operations. It is free of debris and the vegetation is sparse.

3.8.3.22 Munjor - (Tom). This island was not used for scientific purposes during the test program. The vegetation covers most of the land area in thick clumps and there is no debris.

3.8.3.23 Inedral - (Uriah). There is no record of the island being used as a scientific site. There are two structures existing, both in poor repair. One is the remains of a navigational beacon and the other is a submarine cable terminal vault. The vegetation is dense, except for a few small cleared areas.

3.8.3.24 Van. A large steel buoy in deteriorated condition is located at the southern tip of the island. Records show that the island was not used for scientific purposes during the test operation. Dense vegetation completely covers the island to the edge of the beaches.

3.8.3.25 Jinedrol - (Alvin). This is another small island in the southeast quadrant of the atoll which was not used as a scientific site. There is no debris and the vegetation is dense over most of the land area.

3.8.3.26 Ananij - (Bruce). There are remains of scientific installations on the island including a shielded and grounded structure used for electromagnetic measurements during the Redwing and Hardtack II operations. The major portion of a wooden tower is in a collapsed state and a submarine cable terminal vault is in poor condition. The shore line is clean except for some coaxial cable at the north end and a 50-foot pole at the south end.

The helicopter landing mat is deteriorated and overgrown with brush. There are five Mid-Pacific Marine Laboratory wells in a line across the central portion of the island and some coconut trees remain from what appears to have been a plantation. In general, the island is covered with dense vegetation.

3.8.3.27 Jinimi - (Clyde). This island was not used for scientific purposes during the testing operations. Vegetation is sparse and there is no debris visible.

3.8.3.28 Japtan - (David). It has been proposed that Japtan will be occupied on an interim basis by the Enewetak people during the proposed early return and atoll cleanup programs. It would also hold a small number of permanent residences for resettlement. The island was first used to house the animals used in test effects research. Later, during the Redwing operations, it became the radio receiver site for the atoll with a permanent 20-man camp. Following the termination of the nuclear testing program, when the atoll became a down range target area for the Navy's Pacific Missile Range (PMR) and the Air Force Western Test Range (AFWTR), a 3,000 square foot concrete building was constructed to house a Missile Impact Locating System (MILS).

The camp buildings, powerhouse, freshwater distillation building, radio receiver building, and the MILS building remain in fair to good condition. The small boat pier and boat ramp are usable, and most of the steel and wooden antenna poles are in salvageable condition. There is a considerable quantity of metal debris and concrete rubble on the island, including the bow of a derelict ship (Circa WWII) on the ocean reef.

Remains of the German coconut plantation are evident in the rows of trees; however, other vegetation has taken over, especially in the eastern half of the island where it is extremely dense.

3.8.3.29 Medren - (Elmer). This was the support island used by the AEC and the scientific groups during the nuclear testing program. At its peak, it contained facilities to house, feed, and generally support up to 3,000 people. Some of the facilities such as the power plant and the telephone exchange were moved to Enewetak Island during the missile testing phase. The Administration Building 1437 and mess hall/bakery 1201/1202 are still standing in fair condition. Several of the warehouses are usable, as are the two concrete boat landing ramps. Other marine facilities such as the barge slip and the deepwater cargo pier are in poor state of repair. The utility distribution systems, the POL farm and the 1,265-foot bituminous surfaced airstrip are deteriorated. Almost half of the noncontaminated metal debris and concrete rubble on the atoll is located on Medren.

This is one of the three islands which has been selected for permanent occupancy by the Enewetak people. The vegetation, though abundant, is still not as dense as on some of the other islands.

3.8.3.30 Bokandretok - (Walt). The island contained a navigational beacon, a generator, a radio transmitter, and short term accommodations for one or two persons during the nuclear testing program. There is some debris on the island including the remains of those facilities. Vegetation is dense, especially on the ocean side of the island.

3.8.3.31 Enewetak - (Fred). Scheduled as one of the "home" islands for the Enewetak people, Enewetak Island was also the support base for the military during the nuclear testing program. When the program was concluded, it became the support island for both PMR and AFWTR. The greater portion of the facilities and structures have received some degree of maintenance in the years following the close of the nuclear program.

The buildings occupied by the Coast Guard at the north end of the island are in good condition. The adjacent small boat pier and boat landing ramp are usable. Recreational facilities for softball, tennis, and golf are in fair condition, but the swimming pool is presently inoperable. The living quarters range from fair to good condition. The water storage tankage and the POL storage and pumping facilities are usable. Metal warehouse buildings in general are in a fair state of repair. The water distillation plant is in poor condition as is the main power plant. The infirmary and the mess hall complex are usable.

The utility distribution systems require repair as does the cargo pier. The airport terminal building and control tower are both in good condition. The saltwater pumping station and intake structure are in a fair state of repair.

There is a large amount of debris on the lagoon side of the island which ranges from derelict marine craft to concrete blocks. Also, the shoreline along the southwestern end of the island is littered with debris. Vegetation on Enewetak is sparse, appearing mostly on the ocean side and in the northern half of the island.

The 400-man base support camp for the cleanup personnel would be located on Enewetak. It is planned to utilize a minimum number of existing buildings and facilities during the operation.

3.8.3.32 Ikuren - (Glenn). The island was the site for a photo station and other scientific instrumentation during the nuclear testing program. It consists of two islets connected by a high ridge in the reef. There are some derelict marine craft on the lagoon side as well as a large quantity of miscellaneous uncontaminated debris scattered over the island. A steel mat helicopter landing pad located on the western end of the large island is badly deteriorated. Both of the land areas are densely overgrown with brush and other vegetation.

3.8.3.33 <u>Mut - (Henry)</u>. During the nuclear test program, the island was used as a rocket station for air blast measurements, as well as a camera station. Other scientific instrumentation also was located on or near the island. There is a moderate quantity of miscellaneous uncontaminated debris on the island as well as some derelict marine craft on the lagoon reef. The entire island is heavily overgrown with dense vegetation.

3.8.3.34 <u>Boken - (Irwin)</u>. Temperature, humidity, and changes in the water level were recorded on Boken during the Hardtack operation. A nominal amount of debris remains which consists of derelict marine craft and equipment. The dry land areas are covered with dense vegetation.

3.8.3.35 <u>Ribewon - (James)</u>. Wave, temperature, humidity, and water level recordings were made on this island during Operation Hardtack. There are the remains of three derelict marine craft beached on the ocean side of the island and a pile of debris is near the upper end of the lagoon side. The island is densely covered with vegetation. The survey team was unable to land due to the weather; the conditions are assumed from aerial photos, topographic maps, and conditions found on other islands.

3.8.3.36 <u>Kidrenen - (Keith)</u>. A temperature and humidity recording station was located here during the Hardtack operation. Remains of a small wooden observation tower are still standing. A derelict landing craft and a deteriorated steel pier are on the lagoon beach. There is a moderate quantity of miscellaneous uncontaminated debris on the island. The land area is covered by dense vegetation. Weather conditions precluded the survey party from landing. The existing conditions are based on the same assumptions used for Ribewon.

3.8.3.37 <u>Biken - (Leroy)</u>. Biken was used during three of the nuclear test operations for various scientific purposes including fallout collection. A radar reflector was erected for operation Ivy. With the exception of a derelict small boat and a concrete column, the beach is clear of debris. The helicopter landing mat is in a deteriorated condition, as is the radar reflector. The entire island is overgrown with brush, trees, and some coconut palms, especially on the ocean side. There are some clearings in the vegetation on the lagoon side.

3.8.3.38 Jedrol - (Rex). The island has been used as an explosives storage facility. A quantity of dynamite remains in the igloo at the northern end of the island. Some concrete rip-rap remains along the western shore of the island along with a quantity of scrap chain and cable. A timber structure at the north end and two steel containers located in the central portion of the island are in very poor condition. Most of the roads and stabilized areas are gone. Vegetation ranges from heavy in the central portion to moderate at either end of the island.

3.8.3.39 Drekatimon - (Oscar). The remains of a survey platform and a 20-foot high coral filled steel tank are all that is left on the coral head. The tank is topped off with a concrete slab about 7 feet above the waterline.

3.8.3.40 Unibor - (Mack). The 75-foot steel photo tower and generator platform originally erected on this coral head no longer remain.

4. PRESENT STATUS OF THE ENEWETAK PEOPLE ON UJELANG

4.1 HISTORICAL BACKGROUND

After the capture of Enewetak Atoll in 1944, the U. S. Forces moved the Enewetak people from Enjebi and Enewetak Islands and place them on Aomon. The Enjebi community was later moved, at its own request, to Bijire Island because this island was under the authority of the Chief of the Enjebi community. Prior to relocating them to Ujelang, the driEnjebi were moved twice, from Enjebi to Aomon to Bijire, whereas the driEnewetak were moved only once from Enewetak to Aomon. In 1946, when nuclear testing was first considered for Enewetak, the people of Enewetak Atoll were moved to Meik Island in Kwajalein Atoll. After a short stay, they were moved back to Aomon where they remained almost a year. Late in 1947, they were moved once again, this time to Ujelang Atoll, where they are presently located (Figure 4-1). Ownership of Ujelang was ceded to the Enewetak people by the Navy Administrator of the Trust Territory of that time.

4.2 COMPARISON OF UJELANG AND ENEWETAK

Ujelang lies 124 miles southwest of Enewetak. Prior to European influence, Ujelang was inhabited by a Marshallese population. In the 1890's, a typhoon decimated the atoll and killed all but a handful of people who were moved to the southern Marshalls. The atoll was then developed as a commercial copra plantation during the German and Japanese colonial eras. During the plantation period, a small group of islanders from the Eastern Carolines served as wage laborers on the atoll. It was abandoned, however, during World War II and was thus uninhabited and available for the relocation of the people of Enewetak (Kiste, 1973).

Ujelang is smaller than Enewetak, both in terms of lagoon and total dry land area size (Figure 4-2), as can be seen in the following:

	Lagoon	Dry Land
Ujelang Atoll	25.47 sq mi	0.67 sq mi
Enewetak Atoll	387.99 sq mi	2.75 sq mi

Details of the Ujelang Atoll are shown in Figure 4.2.

The comparison shows that the potential for good production from the reefs and lagoon is considerably less on Ujelang than it is on Enewetak. The limited potential for food growth on Ujelang has made

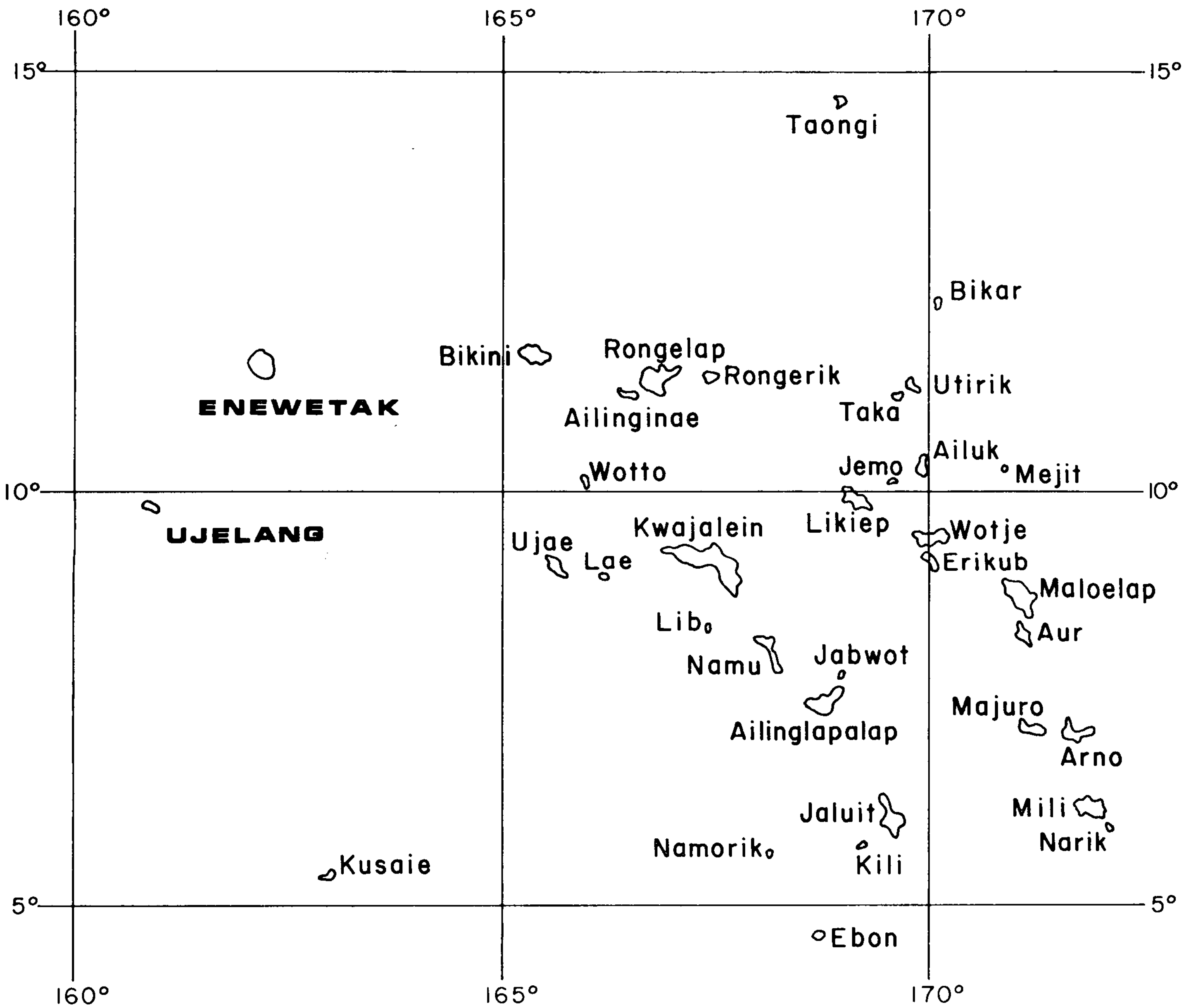


FIGURE 4-1: MARSHALL ISLANDS

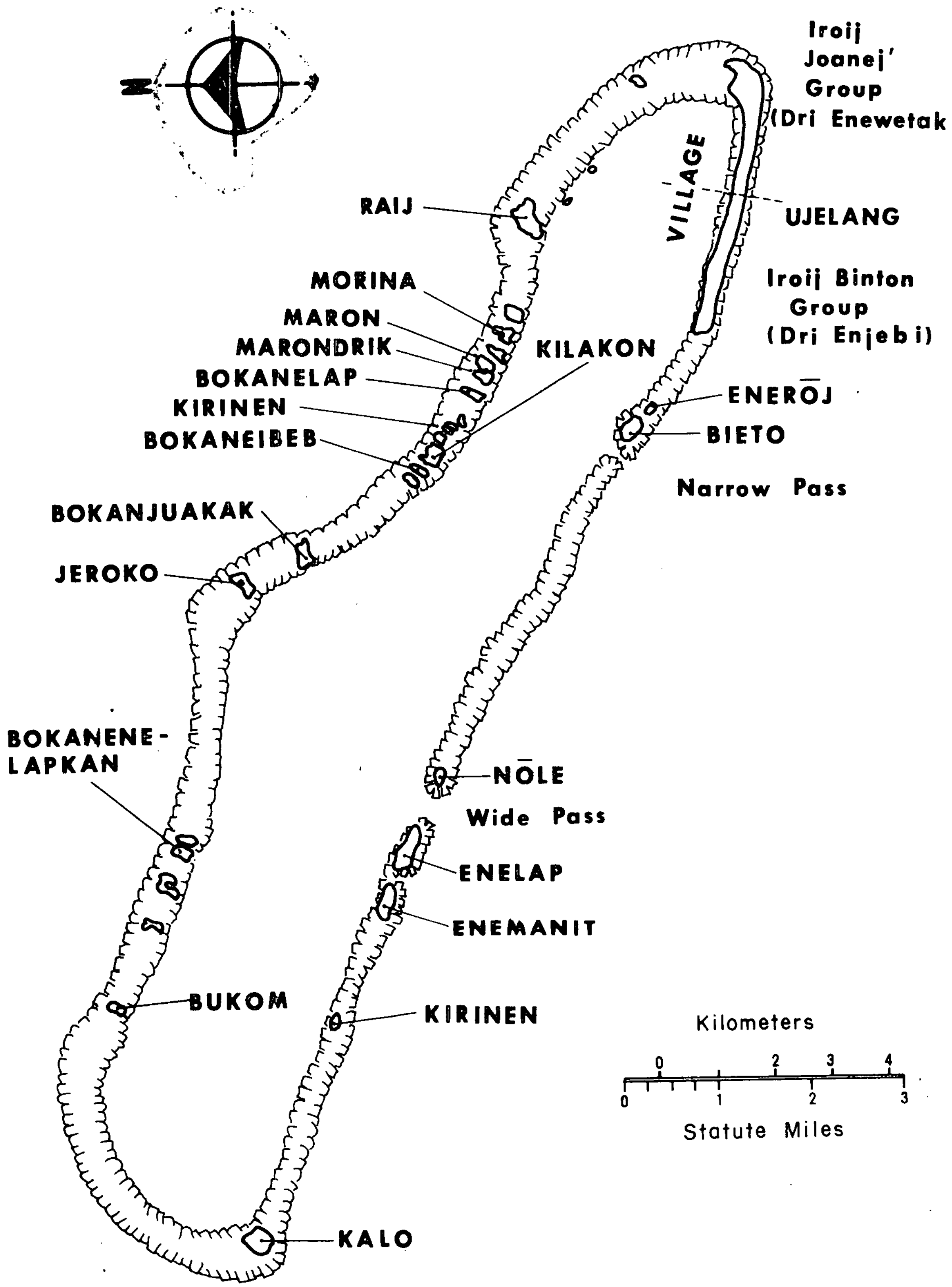


FIGURE 4-2: UJELANG ATOLL - POLITICAL DIVISIONS

it necessary to import more commodities than would be required on Enewetak (Tobin, 1967).

4.3 LIVING CONDITIONS ON UJELANG

The U. S. Navy had constructed a village on the main island of Ujelang for the displaced people of Enewetak and a brush clearing program was in progress when they arrived on the atoll. Coconut trees planted during both the German and Japanese administrations were still standing and bearing. Seedlings of breadfruit and pandanus were brought ashore and planted. After the Enewetak people had settled on the island, the Navy departed. No United States official remained on the atoll and radio communication with the outside world was nonexistent.

The former inhabitants of Enewetak adjusted to their new location, coping with difficult problems, the most serious being the great disparity in size between Ujelang and Enewetak (Tobin, 1973). As previously noted, the traditional Marshallese pattern of habitation is for family units to live on their land parcels (watōs), not in a village cluster. While it is common for community buildings, churches, schools, dispensaries, and warehouses to be centralized for convenience and access to all, dwellings were usually dispersed over the length of the lagoon beach of an island. This pattern is also desirable from the point of view of environmental sanitation and public health. The relocation of the Enewetak people disrupted this traditional pattern of life (Kiste, 1973).

4.3.1 Natural Resources

The people practice a nonintensive type of agriculture that takes maximum advantage of the atoll environment, using only the plants that best survive and produce. Coconut is converted to copra for cash sale to the visiting Trust Territory supply ship. Consumer goods are purchased from the ship with the proceeds of the copra sales. The interest payments from the trust funds provided by the TTPI administration also help buy needed commodities. Rice, flour, sugar, and canned meat, fish, and other goods, are staple items of the diet and have been for many years. If given the opportunity, the Enewetak people would consume up to 80 percent of their diet in imported foods. Their craving for Marshallese food is satisfied by a traditional meal of coconut, fish, and breadfruit at least once a week (Marsh, 1973). Fish, clams, lobster, turtles (flesh and eggs), seabirds (flesh and eggs), chickens, and pigs provide protein in the diet. The marine resources are extremely important in the diet of these people. The picture of diet that emerges then is that the outer island people want more unavailable imported foods and the population centers want more unavailable traditional foods. Improvement in inter-island transportation may help satisfy their nutritional desires (Marsh, 1973).

Coconuts, pandanus, breadfruit, and arrowroot are the main vegetable products used. Bananas, papayas, and squash are used to a lesser extent, probably due to the relative scarcity of the banana and papaya which do not seem to grow well on Ujelang.

The Enewetak population shares the upward trend of the rest of the Marshall Islands and Micronesia. Records show an increase from 104 in 1925 to 432 in 1972. This population expansion among the Enewetak people resulted in a greater drain on the meager resources of Ujelang. A census made in early November 1972, produced the data in Table 4-1.

4.4 ECONOMIC STATUS

The economic situation of the Enewetak people and their persistent desire to return to the atoll stimulated aggressive action on their part. They threatened to evacuate the atoll in 1967, and in 1968 their leaders petitioned the United Nations for assistance in returning to Enewetak. In 1968, they again threatened to evacuate the atoll and come to Majuro. Economic help was given them by the administration and relief shipments of food were sent to the community. An ex-gratia payment of $1,020,000 was made to them in 1969 and was placed in a trust fund, and benefits are realized from the interest payments. Funds were also allocated for a construction program to improve the housing on Ujelang and for the construction of badly needed public facilities on that atoll. The Ujelang community assumed the responsibility for performing the required labor (Tobin, 1973).

4.5 PREFERENCES OF THE ENEWETAK PEOPLE FOR THEIR FUTURE

The desire of the people to return to Enewetak Atoll did not lessen, however, and they continued to press for this goal. Discussions and meetings were held with Government officials. On April 18, 1972, the High Commissioner informed the District Administrator the Enewetak Atoll would be returned to the jurisdiction of the TTPI by the end of 1973. This, it was felt, might clear the way for a possible return of the entire population of 432 Enewetak people to the atoll. While it was not known whether those who have interests elsewhere would remain permanently, or leave after visiting relatives, it was assumed that they would all eventually retire on Enewetak.

TABLE 4-1: CENSUS OF PEOPLE OF ENEWETAK

Place of Residence	Population
Ujelang Atoll	340
Majuro Atoll (DUD)	31
Majuro Atoll (Rongron Island)	18
Maloelap Atoll, Marshall Islands	3
Kili Island, Marshall Islands	7
Ponape, Eastern Caroline Islands	5
Crew Members on Trust Territory Ships	4
Residing in the United States	3
Total Population	411
Non-Enewetak People Who Have Married Enewetak People and Who Live on Ujelang. (They are an integral part of the Enewetak Community.)	21
GRAND TOTAL	432

Notes:

Total Number of Males	226
Total Number of Females	204
Sex Not Reported	2
GRAND TOTAL (Tobin, 1973)	432

A Planning Council, elected from the Enewetak people has been formed. It has been empowered by the people to make decisions, within specified limits, on matters pertaining to both short term, intermediate, and long range planning. The Council has been and will continue to be augmented by technical advisors to assist them in translating the desires of the people into workable plans. The advisors will continue to work closely with the planning group and other parts of the community in their particular fields, e.g., architecture, short and long range economic development, and agriculture.

In December 1974, the Planning Council completed the locating of home sites on Enewetak Atoll for all families. This includes the relocated Enjebi residents and other families on Enewetak wishing to change sites to a prior relocation. (Enewetak - Ujelang Field Trip Report, Dec. 1974 Dennis P. McBreen, District Planner, Marshalls.)

4.5.1 Priorities in Planning

The Enewetak people have established priorities for their requirements. They are in two major categories, those of an immediate nature and those which can be deferred for a period of time. The actions requiring immediate attention are the ones which are designed to return the people to Enewetak, afford them the required housing and provide them with food through the establishment of a subsistence agricultural program. Section 7 discusses the proposed rehabilitation and resettlement plan in some detail. The Enewetak Atoll Master Plan for Island Rehabilitation and Resettlement, Volume 1, March 1975, is included in Volume II, Tab D, of the EIS.

5. CLEANUP AND HABITATION ALTERNATIVES

5.1 APPROACH

The Enewetak Atoll in its current condition contains a large number of adverse environmental impacts resulting from the nuclear testing program of the 1950's. The purpose of the operation being proposed here is to eliminate the effects of these impacts and return the atoll to a liveable and productive condition. Any task of this magnitude will encounter a number of conflicting demands. The proposed Enewetak project, as is true of most other operations of this type, is a problem in allocating finite resources in the manner that will obtain the optimum return.

The approach taken in this program has been to identify pertinent constraints and all reasonable courses of action, assess the advantages and disadvantages associated with each action, and present the assembled information for analysis. Reasonable alternatives have been identified and evaluated as openly and succinctly as possible, so that the safest and most effective solution may be chosen.

In following this approach to the problems requiring solution the following specific steps have been taken:

- Identification of the nonradiological and radiological hazards present on the atoll, their biological effects, and the protective guidelines proposed by the Energy Research and Development Administration (ERDA), formerly the Atomic Energy Commission (AEC).
- Listing of the various methods by which the hazards of radioactive and nonradioactive debris can be reduced to acceptable levels.
- Limitation of food sources and agricultural practices which must be observed in order to reduce the radioactivity ingested by the Enewetak people.
- Identification of the method of the distribution of the population around the atoll as a second means of reducing exposure to radioactivity.
- Analyses of the available procedures for cleanup and disposal of radioactive materials and other debris.

- Syntheses of a number of programs or "cases" for accomplishing the objectives.

- Comparative evaluation of all of the "cases" to select the optimum one for the situation existing on Enewetak Atoll.

As in many programs of this nature, a number of demands exist that are mutually contradictory. This leads, of course, to solutions which are less than perfect, but the most important consideration in choosing between alternatives has been the health and safety of the Enewetak people.

5.2 NONRADIOLOGICAL HAZARDS

The nonradiological hazards existing on the islands are of much lesser magnitude than the radioactive. As a result, the procedures for removing and disposing of nonradiological hazards are much simpler and can be covered in relatively short order.

5.2.1 Physical Removal of Nonradioactive Materials

There are large quantities of debris that could be removed including dilapidated buildings, towers, antennas, concrete slabs, derelict boats, scrap metal, and other assorted rubble. Some of these constitute definite physical hazards. For example, buildings on the verge of collapse, loose and swinging cables, loose or torn sheet metal, exposed broken pipe ends, etc., have been noted in surveys of the islands. Structures such as concrete pits and open manholes constitute what could be considered attractive nuisances and would pose hazards, primarily to small children. Other material, such as concrete slabs are not especially hazardous, but may be obstructive and interfere with the proposed use of the land, for agriculture or residence. Finally, some of the debris is neither hazardous nor obstructive but simply unsightly. An example is the rusting bow of a freighter on the reef at Japtan.

The degree of removal of nonradiological materials and structures from the islands provides several options. Different levels of nonradiological cleanup can be defined by differentiating among the structures and materials according to whether they provide physical hazard, obstruction to better land use, or detriment to environmental aesthetics. Three levels of activity are possible:

- Level 1. No removal of any nonradiological scrap.

- Level 2. Removal of physical hazards and obstructive structures and material.

- Level 3. Same as Level 2 plus removal of unsightly debris.

5.2.2 Disposal of Nonradioactive Materials

5.2.2.1 Salvage. The disposal of nonradioactive debris does not have the many problems connected with the disposal of radioactive materials. Salvageable material would be collected and stockpiled in designated areas as the cleanup progresses. This material would be used by the Enewetak people and/or sold as scrap and it would be carefully monitored to make certain that no radioactive substances are included.

5.2.2.2 Combustibles. Combustible nonradioactive debris would be hauled to a burn pit on each island where it would be burned to ashes. The ashes would be gathered and stockpiled for future use as a soil conditioner. The pit would then be backfilled with native material and the area regraded to its natural contours. Some of the nonradioactive vegetation removed during cleanup also would be shredded to a very small size to be used as additional organic matter in the soil.

5.2.2.3 Fish Reefs. Nonradioactive debris that remained after salvage material and combustibles had been segregated would be removed and dumped into the lagoon at selected spots to form artificial reefs to enhance the breeding of fish and other marine life. A study to determine the most beneficial locations will be conducted during the cleanup operation.

5.3 RADIOLOGICAL HAZARDS

Detrimental effects have been observed resulting from exposure of the body to radiation since radiation was first discovered. These effects range from a temporary reddening of the skin to an increased incidence of cancer. A recent review (BEIR, 1972) on the biological effects of ionizing radiation serves as the basis of risk analysis in the current document. Other studies reporting similar data are UNSCEAR, 1972 and ICRP-14, 1969.

5.3.1 Sources of Radiological Hazards

Radiological hazards arise from exposure to radiocontaminants which may be located both inside and outside the human body. The radiological dose estimates, based on anticipated dietary and living patterns of the people of Enewetak, are ranked (NVO-140, 1973) in order of decreasing importance: 1) the internal dose from radionuclides in ingested terrestrial foods, 2) the external dose from radionuclides in the soil, 3) the internal dose from radionuclides in ingested marine foods, and 4) the internal dose from radionuclides inhaled into the lungs. Externally, the important sources of radiation on Enewetak Atoll are ^{137}Cs, ^{60}Co, and ^{55}Fe radionuclides in the soil.

The lateral and vertical distributions of these vary considerably over the Atoll (NVO-140, 1973). Important internal sources of radiation are ^{137}Cs and ^{90}Sr, which concentrate in muscular and bony tissue respectively, and ^{239}Pu, when deposited in the lung.

5.3.2 Criteria for Evaluating Hazard Control

Guidelines for safe exposures to radioactivity on the atoll are given in terms of the maximum annual dose received by an individual and are also evaluated in terms of long-term health effects. The main objective of radiological cleanup is to reduce the radioactivity of the Atoll to levels at which the population can be expected to have annual exposures below the value of these guidelines.

5.3.2.1 Long-Term Health Effects. Quantitative evaluation of low levels of absorbed radiation on human health continues to be a subject of medical research. Present knowledge is based on the response to high levels of radiation of research animals, of persons undergoing medical treatment with radioactivity, and of a few victims of radioactivity accidents. Direct determination of the human health response to low levels of radiation, such as are discussed in this report, is complicated by a number of factors such as:

- the requirement to study radiation effects on a large population for statistically meaningful results,
- the long time delay between radiation exposure and appearance of such effects as neoplasms,
- difficulty in distinguishing between effects attributable to radiation and those not related to radiation,
- the fact that such factors as cancer susceptibility are widely varying functions of age, sex, genetic constitution, diet, personal habits, socioeconomic factors, and other variables.

Because of the above factors, present risk estimates are based predominantly on conservative extrapolations from data obtained at high doses.

The health effects of radiation on a population can be divided into two categories: somatic and genetic effects. Somatic effects relate to the body or its organs while genetic effects are widened only through those cells which differentiate to form the reproductive elements, i.e., sperm and ova. The risk-estimates stated in BEIR indicate that somatic effect predominates over other effects, for a given exposure condition. Somatic effects are, therefore, of primary concern when establishing protective criteria. Also, the BEIR, 1972, report states that of all bodily damage that could result from radiation effects, the induction of cancer is the only risk that needs to be considered. Consequently, the risk to the Enewetak people of cancer from radiation exposure has been the chief consideration in the study of radiation hazards.

The data upon which health risk estimates are based exhibit statistical variations so that, usually, the uncertainty in estimating a particular risk value is expressed by a range of values for the risk. In view of the many uncertainties related to this study, the risk models adopted result from very conservative assumptions.

For long term exposures to low levels of radiation, such as may apply to some aspects of residence on Enewetak Atoll, the model assumes a linear relationship between dose and effect, with no threshold. The assumption of "no threshold" implies that zero dose is the only dose that yields no adverse health effects. The less conservative assumption that a threshold dose exists, below which no health effects could be observed, has not been used.

The effects of the induced cancers, or even the cancers themselves, may appear immediately or several decades after exposure (BEIR, 1972, p. 91). Since effects are not expected to show up in the earlier years with the same frequency as in later years, and since the appropriate frequency distribution is not known, the number of effects expected to occur during the entire risk period are calculated instead of the number of effects expected to occur in any one year. The guideline values given in Table 5-1 are maximum and the number of incidents of induced cancer or fatalities may be as low as zero.

5.3.2.2 Annual Dose Limits. The primary sources of recommendations for radiation protection standards and guidance are the International Commission on Radiological Protection (ICRP), the National Council on Radiation Protection and Measurements (NCRP), and the Federal Radiation Council (FRC). The standard-setting responsibilities of the FRC were transferred to the Environmental Protection Agency (EPA) in 1969. The recommendations of these groups are all compatible with each other.

These groups have recommended maximum permissible doses for workers exposed to radiation, for individual members of the public, and for a suitable sample of an exposed population. In addition, they have recommended dose rate limits for exposure of various critical organs.

TABLE 5-1: OCCURRENCE OF RADIATION INDUCED SOMATIC CANCER EFFECTS ON HUMANS

Critical Organ	Radiation Induced Incidence of Cancer* Cases/Million Person-Rems
Whole Body	50 - 165
Bone	25
Lung	25

*Cancer Cases induced by a population dose of one million person-rems. A population dose of one million person-rems does not necessarily mean an equal dose to each individual in the exposed population, but is, rather, the sum of individual doses over the exposed population.

These recommended dose rate limits are presented with the understanding that radiation exposures should always be kept as low as can readily be achieved.

The recommendations are based on the conservative assumption of a nonthreshold linear relationship between radiological dose and the health effect. The assumption of no threshold means that any nonzero dose yields a nonzero effect detrimental to health. Evaluation of risks using this assumption probably results in overestimates of risks.

Values for annual dose limits in various situations are listed in Table 5-2. These limits represent the recommendations of the FRC. For application to the Enewetak Atoll, the United States Atomic Energy Commission Task Group Report recommends that the values needed to evaluate cleanup alternatives should be the FRC guides, reduced by 50 percent for annual doses to individuals, and by 20 percent for the 30-year gonadal doses, because of uncertainties in field measurements. These values are shown in Table 5-3. These reductions in the FRC Guides are made because of the uncertainty concerning dose estimates which depend greatly on the foods that the people will choose to eat and the way they will choose to live. The FRC Guides will be applied in the planned follow-on studies.

5.4 LIMITING AND CONTROLLING HAZARDS

The methods examined for limiting radiological hazards on Enewetak Atoll are: (1) the control of the diet of the Enewetak people and, by implication, their agricultural and food gathering practices; (2) the control of residence of the population throughout the islands of the atoll; and (3) the cleanup of radioactive materials.

5.4.1 Control of Food Sources

5.4.1.1 Internal Dose and Food Source. Radiocontaminants in foods come directly from the soil in which food plants are growing. Radiological surveys of Enewetak Atoll have found evidence of uptake of ^{137}Cs and ^{90}Sr, among other radionuclides, in both edible and inedible plants. Indigenous plants used for food that incorporate radionuclides from the soil include coconuts, pandanus, breadfruit, and arrowroot. Human internal radiation exposure is directly related to the amount of fruit of these plants ingested by the individual. The surveys also report radionuclides in the flesh and organs of indigenous fauna, such as terns, rats and land crabs. Internal doses will increase as a result of eating flesh from local birds and crabs, or from domestic animals such as poultry and swine, which have foraged on radioactive plants. Consequently, an

TABLE 5-2: FRC RADIATION PROTECTION GUIDES
(REM/YR)

Critical Organs	Individual in Population	Population Group
Whole Body	0.5	0.17
Bone	1.5	0.5
Bone, Alternate Guide (1)	0.003 μg of ^{226}Ra in adult skeleton	0.001 μg of ^{226}Ra in adult skeleton
Bone Marrow	0.5	0.17
Gonads	-	0.17(2)
Thyroid (3)	1.5	0.5

For the conditions and qualifications of this table, see Report Nos. 1 and 2 of the Federal Radiation Council (FRC). The responsibility for establishing generally applicable environmental standards was assigned to the Environmental Protection Agency in 1970, but the guides here are still generally known as FRC Radiation Protection Guides. The philosophy represented by these guides is that the dose given in the table should not be exceeded without careful consideration of the reasons for doing so, and that every effort should be made to encourage the maintenance of radiation doses as far below this guide as is practicable.

NOTES:

(1) The biological equivalents of the indicated amounts of ^{226}Ra may be substituted.

(2) Actually 5 rem per human generation period, assumed to be 30 years.

(3) Based upon a child's thyroid weighing 2g and other factors listed in Paragraphs 2.10 to 2.14 of FRC Report No. 2.

TABLE 5-3: DOSE GUIDELINES FOR ENEWETAK ATOLL (REM/YR)

Critical Organs	Individual in Population (AEC Task Group Report)
Whole Body	0.25
Bone	0.75
Bone Marrow	0.25
Gonads	4 rems in 30 years
Thyroid	0.75

These guides are Atomic Energy Commission Task Group Report recommendations applicable to the Enewetak Atoll situation. They are derived from the Federal Radiation Council (FRC) Radiation Protection Guides (RPG) by using 50 percent of the FRC RPG for individual exposure and 80% of the FRC RPG guide for gonadal exposure. These reduced values are recommended as a necessary precaution to allow for uncertainty in prediction of annual exposures to individuals in the alternative programs.

effective dose reduction procedure would be simply to restrict the islanders' use of these foods. Lacking such controls, the penalty would be the accumulation of large radioactive doses for the individual utilizing such food sources.

5.4.1.2 Possible Food Sources. The results of the radiological survey show high levels of contamination on the northern islands and low levels on the southern islands. Thus, one option would be to allow the people to eat food grown only on the southern islands. However, it is most likely that the people will eat largely imported foods for the next few years (Kiste, 1974; Tobin, 1973; Marsh, 1973) as it will require several years for trees to provide sufficient fruit for all. To furnish the Enewetak people the purchasing power for imported foods, one source of revenue could be coconut agriculture to produce copra (Enewetak Master Plan, Tab D Vol. II). It may be desirable to use the northern islands for coconut agriculture, although exercise of this option may require that coconut seedlings be planted in soil that is not contaminated with radionuclides. Consideration is also being given to the possibility of continued cultivation of land on Ujelang to alleviate problems of this nature. The Enewetak people own this land and will probably continue to farm it, at least until Enewetak Atoll is capable of supporting them. Later, the requirements of the population and the price of copra would be influential in continuing its use.

5.4.1.3 Subsistence and Commercial Agricultural Patterns. As noted earlier, the driEnjebi desire to live on the northern islands, particularly the island of Enjebi. If these people were to live on those islands, care would have to be taken to ensure that at least pandanus and breadfruit are grown under nonradioactive conditions. That is, a village site on Enjebi drawing on food resources grown in Enjebi soil, would require pandanus and breadfruit, which are either grown in nonradioactive soil on Enjebi or are imported to Enjebi. To provide the farm plots for pandanus and breadfruit, the existing soil will have to be removed and nonradioactive soil be put in place of it in sufficient volume to contain the roots of these plants. As will be discussed later, it does not appear possible to remove sufficient radioactive soil from Enjebi to permit people to live there or to grow food there for some time to come. Further, even if the soil removal was successful in reducing the plant uptake of radionuclides to acceptable levels, the possibility remains that radionuclides in the groundwater would provide a pathway. Based on this, the statement can be made that soil removal would not necessarily equate to a clean growing condition.

To summarize, the options for food source control that appear acceptable for further discussion include:

- No control over food sources.
- People living on Enjebi would use food grown anywhere on Enjebi, other than pandanus and breadfruit. Pandanus and breadfruit eaten by the residents of Enjebi would either be grown in farm plots or imported.
- Food for all the people would either be imported or grown only on the southern islands, except for coconut agriculture on the northern islands. Coconut culture includes growing both subsistence and commercial coconuts.
- All food, including coconuts, must either be imported or grown only on southern islands.

5.4.2 Population Distribution

Another means of controlling the dose accumulated by the Enewetak population would be to limit the time which its members spend in the vicinity of radiation sources, principally by postponing the use of some islands for residence. By limiting the islands available for residence, the population will receive less dose from external sources than they otherwise would. Also, the chance of ingesting food containing higher levels of radioactivity would be decreased.

5.4.2.1 Possible Distributions. The possible population distributions which have been considered are:

- All of the people of Enewetak would be free to choose their place of residence on any island of the atoll.
- The people would be limited to residence on the south islands, Jinedrol clockwise through Kidrenen, (Alvin through Keith).
- The people would be limited to the same group of islands as above, Jinedrol through Kidrenen (Alvin through Keith), plus Enjebi (Janet) in the north.

5.4.2.2 The Problem of Enjebi. Because the only difference between the second and third statements of the preceeding paragraph involves the island of Enjebi, the reason for making this distinction must be justified. Earlier in Section 3, it was explained that the people of Enewetak were historically divided into driEnewetak and driEnjebi, the first named occupying the largest island in the south, and the other the largest in the north. This traditional pattern was disrupted by activities in World War II and has never been fully restored. Restoration of the traditional pattern would require that the people of Enjebi reside on that island once again. However, since Enjebi was ground zero for, or within the fireball of, a number of nuclear explosions, the residual radioactivity of this soil is high enough to produce a sizeable external dose. In addition, all vegetation grown on the island would contain radioactive elements which would increase the internal dosage. These facts have had to be weighed against the strong desire of the driEnjebi to return to their ancestral island.

5.4.3 Cleanup and Disposal

The simplest method, in concept, of limiting radiological hazards is that of collecting and disposing of all radioactive materials. Further, a fundamental requirement in any cleanup and disposal is that radioactive materials are to be removed and disposed of in such fashion that they do not become further hazards in another time and place.

5.4.3.1 Physical Removal of Radioactive Materials. Control of both external and internal dose may be directly achieved by removing the radiation sources from areas to which the island inhabitants have direct access. Complete removal of radiation sources would require:

- Radioactive soil removal.
- Radioactive scrap removal.
- Plutonium removal.

5.4.3.1.1 Removal of Radioactive Soil. Removing soil containing radionuclides, especially ^{137}Cs and ^{90}Sr, has dubious value, since extensive land removal and replacement operations could result in serious ecological damage of unknown proportions. For example, the replacement soil could contain chemical, mineral or biological materials having characteristics which were inimical to the growth of the food plants. Such a result would be counterproductive at best, and possibly irrevocably destructive. Also there is no guarantee that sufficient soil could be removed/replaced to assure radiological safety to residents. Further, the possibility of uptake in radioactivity by plants through the groundwater system could nullify all apparent benefits of soil removal.

5.4.3.1.2 Removal of Radioactive Scrap. The optional levels of effort in the removal of radioactive scrap are minimal in number. Either none is removed or all of it is removed from all the islands. The differentiation that can be made in considering nonradioactive scrap (physical hazards, obstructive debris, and unsightly debris), does not extend to radioactive scrap. In general, no radioactive scrap should be left on the atoll and thus be available to the world scrap market where its presence could be the source of danger to people in other countries. Programs not involving radioactive scrap removal must be eliminated from consideration for this reason.

5.4.3.1.3 Removal of Plutonium. The removal of plutonium bearing soil options are determined by a number of factors including the difficulty in removing the plutonium, the potential use of the land, and the size of the tract involved. Decision making would depend largely on a team of experts to interpret field radiation and radioactivity measurements, to advise on cleanup actions, and to provide necessary health physics support. Of paramount importance would be any possible or potential hazard to the Enewetak people. The scraping and removal of plutonium bearing soil would be performed repetitively. After each scraping, the soil would be sampled and monitored for Pu concentration. Scraping and sampling would be repeated until the attendant scientific advisor had determined that the concentration was reduced to an acceptable level as described in the AEC Task Group Recommendations.

The Pu decontamination actions possible are listed below:

- < 40 pCi/gm of soil - corrective action not required.
- 40 to 400 pCi/gm of soil - corrective action determined on a case-by-case basis considering all radiological conditions.
- >400 pCi/gm of soil - corrective action required.

The islands on which Pu cleanup actions are required are shown in Table 5-4.

5.4.3.2 Disposal of Radioactive Materials. The quantity of radioactive debris on the islands of the atoll is estimated to be 7,262 cu yds. It is composed of scrap metal and concrete on the islands of Bokoluo, Enjebi, Lujor, Eleleron, Aomon, Bijire and Runit. There is, in addition, a considerable amount of soil that contains ^{239}Pu and is, therefore, radioactive. The amount to be removed has been subject to considerable study and it has been estimated that nearly 79,000 cu yds would have to be removed for disposal, as a minimum.

This had led to the important problem of how to dispose of the radioactive scrap and soil in such a manner that it could not cause harm to humans at some later date. There are several methods which have been suggested including ocean dumping, crater dumping, crater containment, and disposal in the continental U.S. (Conus). These are discussed in the following sections.

5.4.3.2.1 Ocean Dumping. The alternative of disposing of radioactive materials by dumping in the deep open ocean at 1000 fathoms (6000 ft) minimum depth has been given serious consideration. Possible alternatives, such as filling excess marine craft (liberty ships) with a soil cement made from the radioactive soil and sinking them or otherwise containerizing the soil, or even casting the soil into concrete blocks have been investigated. It is recognized that certain international agreements permit the dumping of low level long-term radioactive wastes in ocean waters and that permits for such disposal are attainable. However, since the proposed program at Enewetak would be under the sponsorship and cognizance of agencies of the U.S. Government, Federal law states that the program operations be conducted in compliance with the requirements of the Enivronmental

TABLE 5-4: ISLANDS REQUIRING PLUTONIUM CLEANUP PROCEDURES

Island		Remarks	Level of Pu Concentration*
Local Name	Code Name		
Boken	IRENE	Isopleth J (See Tab A, Volume II)	1, 2
Runit	YVONNE	Northern half, Pu burial grounds	1, 2
Lujor	PEARL	Hot spot	1, 2
Aomon	SALLY	Pu burial grounds	1
Bokuluo	ALICE		2
Bokombako	BELLE		2
Kirunu	CLARA		2
Louj	DAISY		2
Mijikadrek	KATE		2
Kidrinen	LUCY		2
Aej	OLIVE		2
Eleleron	RUBY		2

*Actions assumed for specific ranges of Pu concentration are tabulated as follows:

Level	Plutonium Concentration (pCi/g Soil)	Action
1	>400	Soil removal by repetitive scraping
2	40≤C≤400	Individual case consideration

All other islands have Pu concentrations <40 pCi/g and do not require cleanup action.

Protection Agency Regulations on Transportation for Dumping, and Dumping of Material into Ocean Waters (40 CFR 220-226; 38 FR 28610; October 15, 1973). In order to comply with these criteria, a comprehensive study of the oceanic community in the vicinity of the proposed dump site would have to be conducted. The study would include characteristics of all ocean currents from the surface down to the bottom. Bottom conditions would have to be known and both local and transient marine life would have to be cataloged. In addition, the containerized wastes (^{239}Pu) would be approved for dumping only if they radiodecay to environmentally innocuous materials considering the life expectancy of the containers and/or their inert matrix; if only short-term localized adverse effects would occur should the containers rupture at any time; and that the containers are disposed of at depths and locations where they would cause no threat to navigation or fishing.

Under these, or any other, conditions it would be impossible to guarantee the integrity of containers through one half-life of ^{239}Pu (24,000 years), let alone the five half-lives which is considered by some to be a necessary requirement. Likewise, no assurances could be given that, if the radiocontaminated solids were cast into concrete blocks they would maintain their integrity for that length of time.

Even without requiring assurances of container integrity, the magnitude of the environmental study and its probable high cost could severely restrict the implementation of the proposed cleanup, rehabilitation and resettlement program. In fact, if projected program costs were substantially increased due to this requirement, the result could be the abandonment of the entire program. These are the major factors upon which the rejection of the ocean dumping alternative was based. The estimated cost of ocean dumping these materials in containers is about 50 percent higher than that for crater containment.

5.4.3.2.2 Crater Dumping. In this method, the radioactive debris and solid would simply be dumped into the Cactus and Lacrosse craters on Runit with no preparatory or closing operations. This procedure would have the disadvantage that the crater area would have to be quarantined for an indefinite period.

Although the cost of crater dumping is approximately only 5% of the crater entombment procedure described later, it has been rejected from further consideration as the contaminated material would remain a potential threat to the safety of the Enewetak people. The debris-laden craters would require continuous surveillance and policing to enforce a quarantine on the area which would be necessary for the safety of the atoll population. In addition, the craters would be neither lined nor capped in this option and there would be nothing to prevent the migration of the radionuclides into ocean and lagoon waters through cracks and fissures in the crater walls, or to prevent redistribution on land as a result of wave action or storms.

5.4.3.2.3 Crater Entombment. This method of disposal also utilized the Runit craters, but includes additional measures which prevent human contact with the radioactive material and minimize the entry of the material into the human food chain. It is estimated that Lacrosse Crater would have sufficient volume to contain the radioactive material to be disposal of using Case 3 criteria. A study to confirm the feasibility of this method of disposal has been performed (Tab F, Vol II, EIS).

Without attempting to pump out the crater, the plutonium contaminated soil would be mixed with cement and water to form a soil cement slurry which would be placed in the crater by the tremie method. Radioactive debris would be dumped into the crater along with the slurry. This would be done in such a manner that erosive water velocities would be held to the lowest practicable level to reduce the transport potential of the plutonium in the mixture. Protection from tidal currents and wind generated waves would be provided by constructing temporary dikes during the disposal operation. This method of entombing, or containing, the contaminated material also has these advantages:

- Reducing the availability of contaminated particles and scrap by binding them in a cementatious mix.

- Providing a coating for the particles to shield and reduce the hazards of alpha emissions.

- Placing the material in a location where it would be least available to man, but where it could be observed and retrieved if necessary or desirable.

It should be noted that this method of containment is not required nor intended to be leakproof. An 18-inch thick concrete cap would be placed over the entire mass for erosion resistance and as a shield from alpha radiation. It is expected that some migration of plutonium particles to the surrounding environment could occur. However, any such migration into the lagoon or ocean waters is expected to be of little significance in view of the relatively high concentrations found in the lagoon sediments near the north end of Runit.

It is acknowledged that this alternative would require periodic monitoring and inspection to ensure the integrity of containment. However, it must be emphasized that this method would permit retrieval of the material, simply by breaking the cap and digging the material out. Thus, if the state of the art were to make removal for processing or disposal elsewhere feasible at some future time, the contaminated material would be available in approximately the same state as when it was interred.

5.4.3.2.4 Conus Disposal. This term designates the procedure of disposing of radioactive materials in the continental United States. These materials, including soils, would be sealed in containers and shipped from the atoll to one of the low-grade disposal areas in the western part of the United States. There are two radioactive waste burial areas which have been identified in the western United States, both near Richland, Washington, One is operated by the ERDA for waste from the ERDA's Richland operations, but which does not accept offsite-generated waste. The other is operated by a private firm licensed by the State of Washington. Under proposed regulations, this latter burial ground may not be permitted to accept plutonium-contaminated waste.

If either of these sites were available to receive the plutonium bearing soil and radioactive debris from Enewetak, they could be reached by a combination of ocean, Columbia River, railroad, and truck transports. This method would move the contaminated material away from the atoll, however, it has serious disadvantages. The procedural or legal difficulties could be considerable and the cost would be approximately three times that of crater containment (Table 5-15). If Conus disposal were the only open option and the west coast sites prove to be unavailable, east coast sites, such as Savannah River, might have to be considered, or other arrangements might have to be made.

Transport of this material by vessel would be required to comply with current regulations (46 CFR 146.19).

5.5 PROGRAM SYNTHESIS

Many possible combinations of residence, agriculture and cleanup levels were examined. Some combinations were found to be incompatible and others were rejected for basic deficiencies. Of those remaining, a matrix was constructed to show a reasonable range of alternatives (Table 5-5), and five representative combinations chosen for detailed analysis of dose reduction, health effects, cost and general acceptability. These five, identified as "cases" are indicated in Table 5-5 and discussed in detail in the following sections.

The matrix arrangement is such that the following trends are apparent:

- The level of cleanup effort increases from top to bottom.
- Restrictions on living conditions and agricultural practices increase from left to right.
- The level of population dose decreases from top to bottom.

TABLE 5-5: RECOMMENDED CORRECTIVE ACTION PROGRAMS

Habitation Plans / Cleanup Actions	A No restrictions on island or food usage	B Live on southern islands and Enjebi; visit northern islands; food from southern islands or Enjebi plus coconut from 12 N. E. islands and pandanus and breadfruit from Enjebi farm plots or imported	C Live on southern island; visit northern islands; food from southern islands plus coconut from 12 N. E. islands	D Live on southern islands; visit on southern islands; use food grown on only southern islands
I. No cleanup.	Case 1 AEC Option I[a]			Case 2[b] AEC Option II
II. Removal of all scrap and Pu concentrations greater than 40 pCi/g from residence and agriculture islands[c]. concentrations from four islands.		Case 4 AEC Option IV	Case 3 Conforms with Task Group Recommendations	
III. Total cleanup of residence and agriculture islands[d].	Case 5 Approximately AEC Option V			

[a] "Report by the AEC Task Group on Recommendations for Cleanup and Rehabilitation of Enewetak," June 19, 1974.

[b] Case 2 differs from other programs in Row 1 by removal of physical hazard and obstructive debris categories of nonradioactive scrap on southern islands.

[c] Plutonium concentrations refer to burial grounds and soil dispersions of concentration in excess of 40 pCi/g. Areas of soil concentration in excess of 400 pCi/g should be removed without question; areas of soil concentration between 40 and 400 pCi/g should be considered on an individual basis.

[d] Removal of all scrap from all residence islands specified in each column and removal of specific amounts of soil in specific areas to achieve external and internal doses no greater than would be absorbed from naturally occurring sources.

5.5.1 Case 1 - No Restrictions on Island Residence or Food Usage. No Cleanup

In this case no cleanup action would be taken. All nonradioactive scrap and radioactive materials would remain in place. Two mutually exclusive possibilities would result, i.e., (1) not to return to the atoll or (2) to return.

5.5.1.1 Discussion. If the islanders were to return to Enewetak Atoll, they would be exposed to the possibility of injury to themselves and their children as a result of hazardous debris and exposure to residual radiation, none of which would be cleaned up. The possibility of injury from radiation exposure would be predominant as Case 1 imposes no restriction on sources of food, whether terrestrial or marine, and no limitations on traveling or location of habitation (Figure 5-1). Under these conditions it can be expected that the radiological dose to the people would exceed the recommended ERDA guidelines.

5.5.1.2 Conclusions. In view of the existing hazards to which the Enewetak people would be exposed should they return to the atoll under Case 1 conditions, it is recommended that they do not return.

5.5.2 Case 2 - Living, Terrestrial Food Sources, Travel, and Cleanup Restricted to Southern Islands

Case 2 would establish the requirement for a long term quarantine of certain islands in the atoll. With a quarantine in effect, the radiological dose to the islanders would be well below the ERDA guidelines, but if access to certain islands, especially Runit, were uncontrolled a potential for radiological exposures exceeding the guidelines would exist.

5.5.2.1 Habitation Plan

- Residences restricted to southern islands, Jinedrol through Kidrenen, and the same limitation imposed on interisland visiting.
- All terrestrial foods including birds and bird eggs would be grown on or collected from the southern islands only.
- Coconuts for subsistence or for copra would be grown only on the southern islands. Any use of coconuts from the northern sector, Bokoluo through Runit, would be specifically prohibited.
- Domestic animals and fowl for consumption would be reared only on the southern islands.

- Coconut crabs would be taken for consumption from the southern islands only.

- Wells intended for providing groundwater for human consumption or agricultural use would be drilled only in the southern islands, Jinedrol through Kidrenen. Prior to being approved for use, water from each well would be checked for salinity, bacteria count, and radioactivity.

- Lagoon fishing would be unrestricted.

5.5.2.2 Cleanup Actions. Under the conditions presented in Case 2, there would be no cleanup of any radioactive materials on the atoll as cleanup is restricted to the southern islands where no radioactive contamination occurred. In Table 5-5, Case 2 provides an exception to the cleanup actions generally meant by Row 1. The level of cleanup of nonradioactive materials would be limited to the southern islands, Jinedrol through Kidrenen (Figure 5-2), and would include:

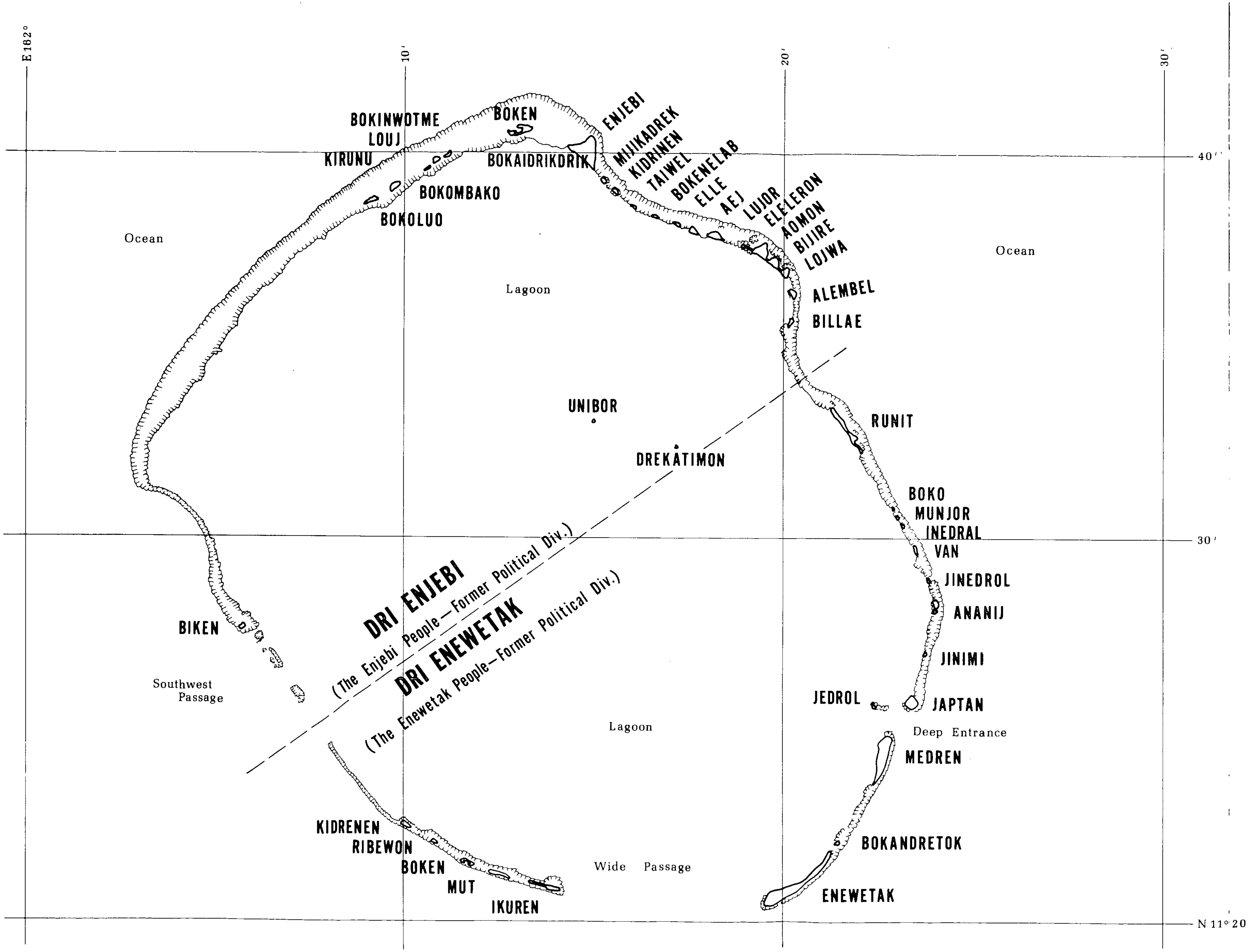
- Removal of all physical hazards.

- Removal of all debris which would obstruct the development of villages and agricultural areas.

- Disposal of unsalvable noncombustible debris by dumping in the lagoon.

5.5.2.3 Conclusions. Case 2 limits all foods sources to the southern islands which action is difficult to justify as some of the northern islands are only lightly contaminated. Also, it is difficult to justify limiting travel to the southern islands since ambient gamma levels on the northern islands do not represent a significant external exposure potential for occasional visitation. Case 2 does leave the problems of contaminated scrap on many islands of the atoll, and the Pu in the soil on Runit, Boken, Lujor, and in the burial sites on Aomon, unresolved. It also leaves the generally contaminated areas on Bokoluo, Bokombako, Kirunu, and Lujor as they presently exist. There is also a question as to the ability of such a limited land area to support 400 people, with a continuous upward population growth rate.

A selection of Case 2 would necessitate the establishment of off-limits areas in perpetuity, at least for Runit, since the metallic Pu can be expected to be on the surface of the island indefinitely. Under present conditions, there is a potential for exceeding established standards through inhalation, and the possibility of spreading contamination if access to the island is not controlled as it is at the present time.



Notes:

1. No Cleanup At All
2. No Living Restrictions
3. No Agriculture Restrictions
4. No Food Gathering Or Fishing Restrictions

ENEWETAK ATOLL

CASE 1

FIGURE 5-1

Since Case 2 offers no solution to these problems, it is not recommended as a course of action.

5.5.3 Case 3 - Living on Southern Islands, Food from Southern Islands plus Coconuts from 12 Northern Islands. Travel Unrestricted. Material and Some Plutonium Cleanup

Case 3 permits partial use of areas of the atoll having low radioactive levels, greatly reduces radioactive hazards for the indefinite future, and permits living patterns which, with high confidence, are expected to result in population doses well below the ERDA guidelines. This case does restrict habitation to the southern islands, Jinedrol through Kidrenen, and does not recommend specific action against radioactivity in the soils of Bokoluo, Bokombako, and Kirunu (Figure 5-3).

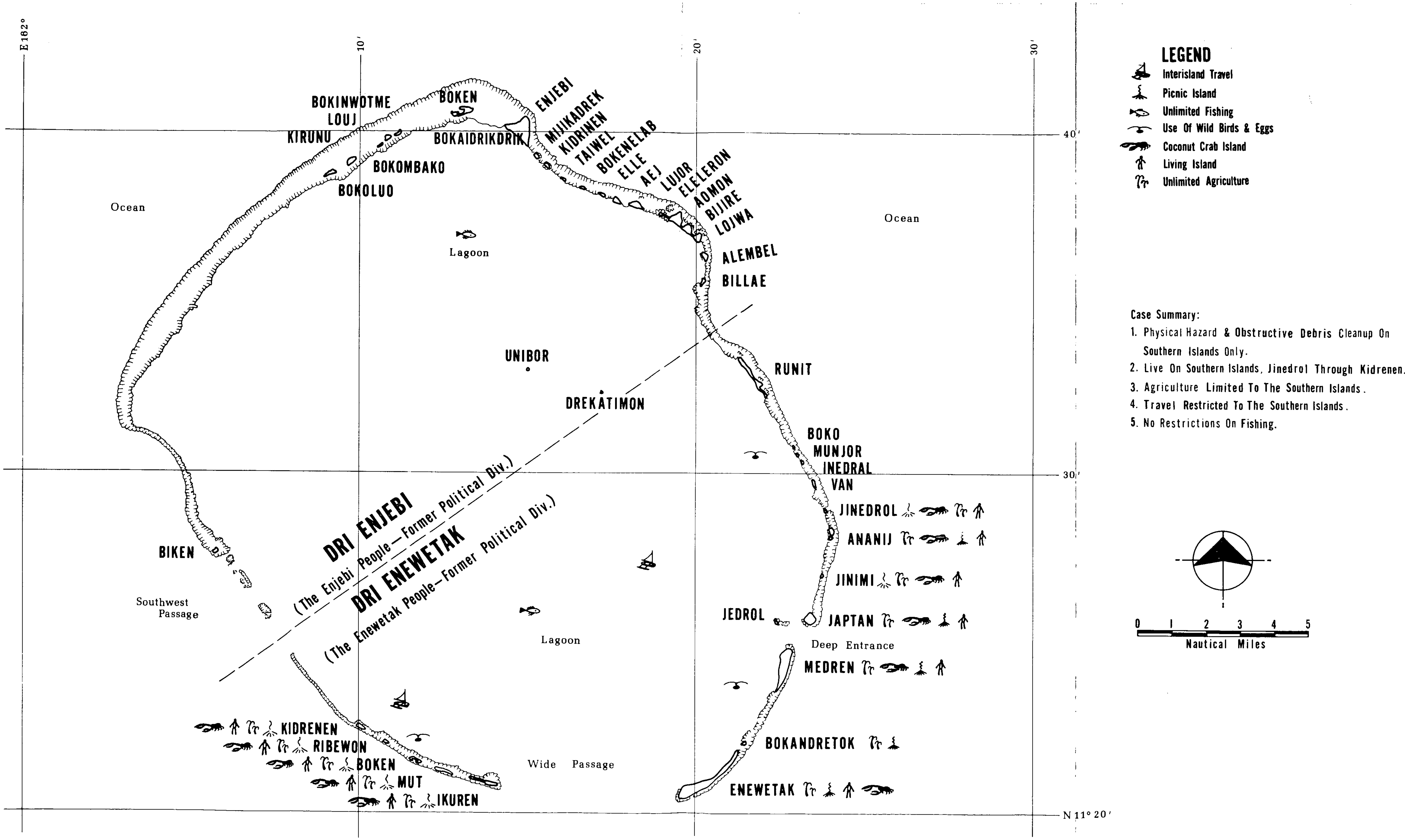
5.5.3.1 Habitation Plan. In Case 3, the Enewetak people would live and obtain food as follows:

- Residence would be restricted to the southern islands, Jinedrol through Kidrenen.
- Runit would be quarantined until Pu cleanup is effected and crater containment has been completed. Other travel would be unrestricted.
- Pandanus, breadfruit, arrowroot and other subsistence food would be cultivated on the southern islands only.
- Coconuts would be grown on the southern islands and in the northern islands of Mijikadrek through Billae only. No cultivation would be permitted on the northwest islands of Bokoluo through Enjebi and on Runit.
- Domestic meat would be raised on the southern islands only (Jinedrol-Kidrenen).
- Coconut crabs would be taken from the southern islands only.
- Lagoon fishing and wild bird and bird egg gathering would be unrestricted (except on Runit).

5.5.3.2 Cleanup Actions. The following actions would be taken to clean up the atoll:

- Physical hazards would be removed from all islands.
- Obstructions to development of habitations and agriculture would be removed.
- Radioactive scrap would be removed from all islands in the atoll.
- Boken, Lujor, and Runit plutonium concentrations greater than 400 pCi/g would be excised and all other concentrations between 400 and 40 pCi/g would be dealt with on an individual basis as described in AEC Task Group Report. Concentrations of less than 40 pCi/g would not be disturbed. Cleanup of Pu is expected to be performed iteratively until a sufficiently low concentration level well below 40 pCi/g is attained. Some 79,000 cu yds of soil are estimated to be in this removal.
- Plutonium would be removed from the three burial crypts on Aomon.
- Unsalvable nonradioactive and noncombustible material would be disposed of by dumping in the lagoon at selected locations for forming artificial reefs.
- Radioactive materials would be disposed of as discussed in Section 5.4.3.2.3, namely by containment in Lacrosse and, if necessary Cactus craters on Runit.

5.5.3.3 Conclusions. Case 3 reasonably insures a safe habitation plan for the proposed return of the islanders and provides a means of eventual improvement of the environment for the benefit of all of the Enewetak people. By virtue of the fact that it requires removal of only the most seriously contaminated materials, it is less expensive than succeeding Cases 4 and 5. Although this case recommends that Enjebi not be utilized for habitation, it does impose far less stringent limitations on interisland visitations and the growing of commercial crops. With respect to the latter, it provides for the clearance of obstructions which would deny use of some of the land. Case 3 also provides for the removal of contaminated scrap to negate the possibility of any radioactive material reaching the world's markets. Although Case 3 is composed of all actions described in Case 2, it also provides for further actions in establishing and maintaining radiological safeguards, such as the quarantine of Runit.



ENEWETAK ATOLL

CASE 2

FIGURE 5-2

In addition to this quarantine, (Paragraph 5.5.3.1), Case 3 recommends that studies be conducted as follows:

- A test planting program on Enjebi to determine when exposure would be within acceptable criteria without the removal of soil. This program has been initiated.
- A program to determine radioactivity levels in coconut and other food crops produced on Lujor, Kirunu, Bokoluo, Bokombako, and Runit (after plutonium cleanup).
- As an alternate to the preceding program, soil removal on Enjebi, followed by a test planting series to determine whether exposure for Enjebi residents would be within acceptable criteria.
- The assembly of a team of experts to make and interpret field radiation and activity measurements, advise on cleanup actions involving plutonium and other radionuclides, and advise on necessary health physics support for protection of workers, decontamination of workers and equipment, and handling of collected contaminated materials.
- A comprehensive underground water lens sampling and analysis program for a minimum period of 1 year. Bacterial content, salinity, and radionuclide content would be measured every twelve months. However, the primary emphasis would be on the development of understanding those processes which are operating or can be made to operate to reduce the ecological half-life of ^{90}Sr and ^{137}Cs below the radioactive half-life on the northern islands. This program has been initiated.
- An air sampling program, conducted during cleanup, which would obtain samples representative of those that might be expected from the activities of the returned population.

Further, the controlling criteria for radiation exposure developed by the AEC Task Group can be best met by this particular alternative. This is most likely to provide the lowest possible exposure in accordance with accepted guidelines.

5.5.4 Case 4 - Living on Southern Islands and Enjebi; Subsistence and Commerical Crops on Southern Islands and, Under Controlled Conditions, on Enjebi; Material, Soil and Some Plutonium Cleanup

Assuming the effectiveness of the corrective measures to be suggested, Case 4 would still result in annual and 30-year gonadal doses (Task Group Report, 1974) at or above the ERDA guidelines for those who would live on Enjebi, and would be well above those predicted for Case 3. The success of this case would depend upon the following factors (Figure 5-4):

- Importation of food for the Enjebi inhabitants. While this is the most dependable method, it would be a long-term burden on the driEnjebi which would eventually become objectionable to them.

- Removal of soil and replacement with imported soil. This method is not as certain a safeguard against internal exposure as the importation of food, but in theory it is possible that it would reduce the dose from pandanus and breadfruit to levels comparable to those found on the southern islands. All this depends upon providing sufficient imported soil to encompass the entire root system of the mature trees, and that factors do not exist which would lead to recontamination. In any event, there is reasonable doubt that safe levels could be attained by soil replacement alone.

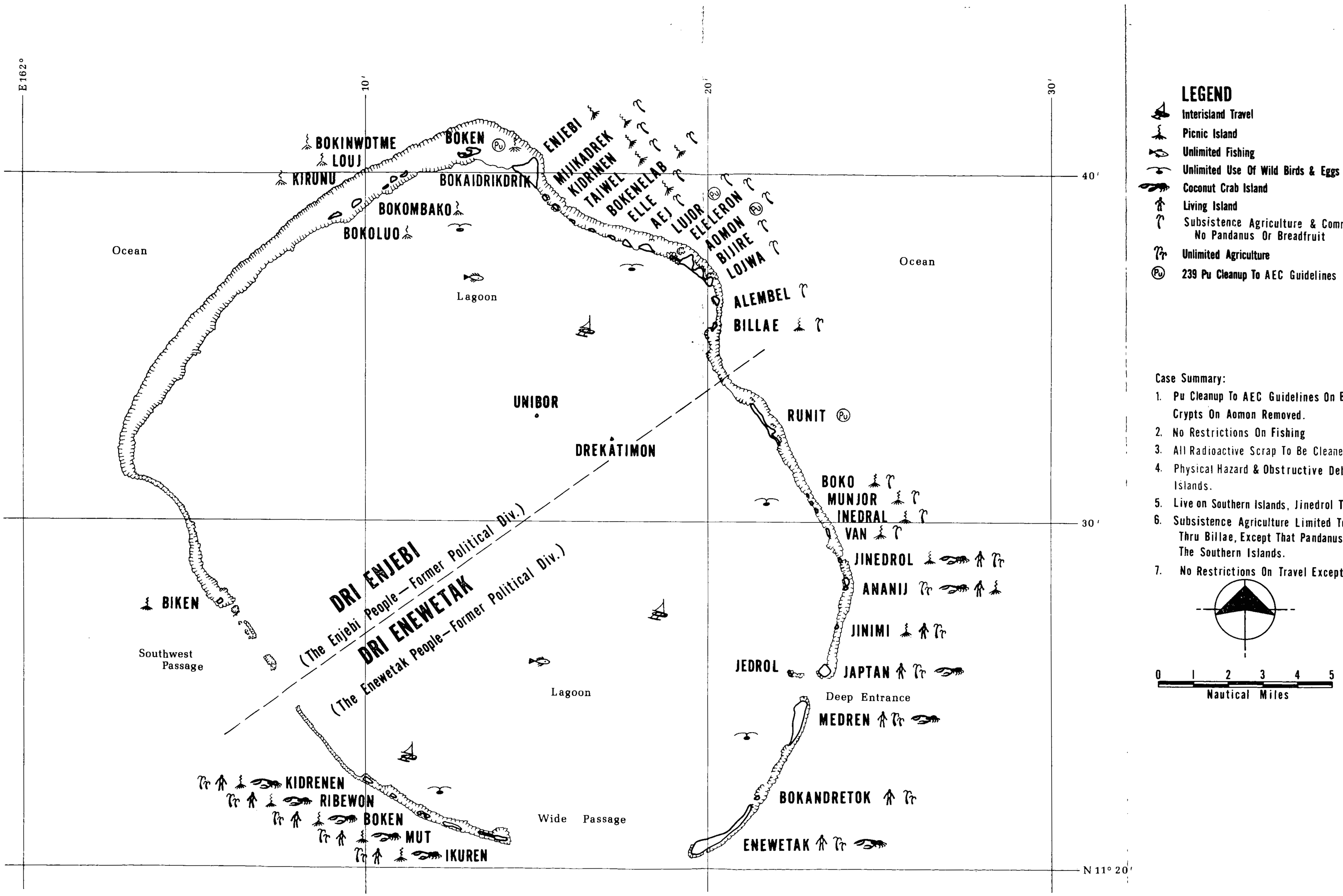
- The water supply for these crops must not have radioactivity levels higher than those in the southern islands.

5.5.4.1 Habitation Plan. If the cleanup actions to be described in Paragraph 5.5.4.2 should prove to be as effective as predicted, the Enjebi people could be permitted to return to their island with the following conditions applying:

- Residence would be restricted to the southern islands, Jinedrol through Kidrenen and Enjebi.

- Pandanus and breadfruit would be cultivated in the south and in imported soil on Enjebi (Paragraph 5.5.4.2).

- Other subsistence crops, e.g., arrowroot, papaya, etc., would be grown only in the south and on Enjebi.



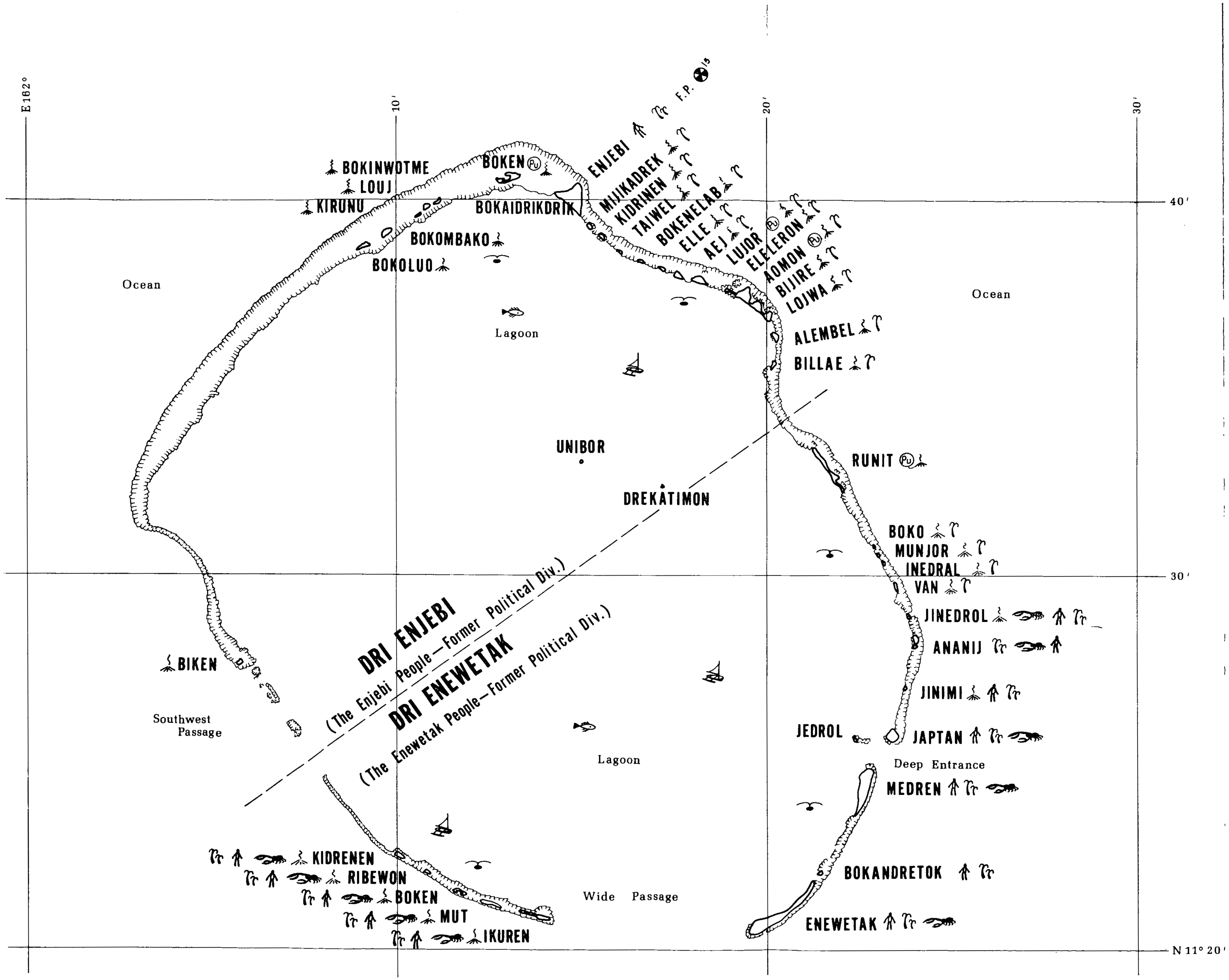
Case Summary:

1. Pu Cleanup To AEC Guidelines On Boken, Lujor & Runit. Crypts On Aomon Removed.
2. No Restrictions On Fishing
3. All Radioactive Scrap To Be Cleaned Up From All Islands.
4. Physical Hazard & Obstructive Debris Cleanup On All Islands.
5. Live on Southern Islands, Jinedrol Through Kidrenen.
6. Subsistence Agriculture Limited To Southern Islands, Plus Mijikadrek Thru Billae, Except That Pandanus & Breadfruit Are Limited To The Southern Islands.
7. No Restrictions On Travel Except Runit, Pending Cleanup.

ENEWETAK ATOLL

CASE 3

FIGURE 5-3



LEGEND

- Unlimited Interisland Travel
- Picnic Island
- Unlimited Fishing
- Unlimited Use Of Wild Birds & Eggs
- Coconut Crab Island
- Living Island
- Subsistence Agriculture Except For Pandanus & Breadfruit
- Unlimited Agriculture
- F.P. Farming Plot-Remove 30cm Depth of Soil & Plant in Sufficient Imported Clean Soil To Encompass The Root System of Mature Trees
- (Pu) 239 Pu Cleanup To AEC Guidelines
- 15 Remove 15cm of Soil in Subsistence & Commercial Agriculture Areas & Replace With Clean Soil

Case Summary:

1. Pu Cleanup To AEC Guidelines On Boken, Lujor & Runit. and The Aomon Burial Sites.
2. Remove 15cm of Soil From The Subsistence & Commercial Agriculture Areas On Enjebi, & Replace With Clean Soil.
3. Farming Plots on Engebi For Pandanus & Breadfruit.
4. All Radioactive Scrap To Be Cleaned Up From All Islands.
5. Physical Hazard & Obstructive Debris Cleanup On All Islands.
6. Living Restricted To Southern Islands & Enjebi.
7. Subsistence Agriculture Restricted To Southern Islands & Enjebi.
8. No Restrictions On Travel Except Runit, Pending Cleanup.
9. No Restrictions On Fishing.

0 1 2 3 4 5
Nautical Miles

ENEWETAK ATOLL

CASE 4

FIGURE 5-4

- Coconuts could be grown on the northern islands of Enjebi through Billae and on the southern islands. They are specifically prohibited on the northwest islands (Bokoluo-Boken).
- Domestic meat would be raised on the southern islands and on Enjebi.
- Coconut crabs would be taken only from the southern islands.
- Interisland travel would be unrestricted except to Runit.
- Wild bird and bird egg gathering would be unrestricted.
- Lagoon fishing would be unrestricted.

5.5.4.2 Cleanup Actions. Actions are categorized as follows (removal of approximately 318,000 cu yds of soil is required):

- Removal of physical hazards from all islands.
- Removal of debris and structures obstructive to the use of the land by the people.
- Removal of plutonium contaminated soil from Boken, Lujor, and Runit and removal of plutonium crypts on Aomon.
- Scraping and removal of soil in pandanus and breadfruit growing areas (along the lagoon shore and on the northwest shore) of Enjebi to a minimum depth of 30 cm.
- Scraping and removal of soil in commercial coconut grove areas on Enjebi to a depth of 15 cm.
- Scraping and removal of soil in other subsistence agricultural areas on Enjebi to a depth of 15 cm.
- Replacing soil from scraped areas with at least equal depths of imported soil.

5.5.4.3 Conclusions. In Case 4 predicted doses would equal or exceed the upper limit of the ERDA guidelines (Task Group Report, 1974). The uncertainity of achieving even this dose reduction, the fact that no record of successful cultivation by farm plot exists, as well as the undesirable effects which groundwater could have, make it very difficult to justify the return of the driEnjebi to their home island. Case 4 is not recommended as a course of action.

5.5.5 Case 5 - Unrestricted Living, Food Sources and Travel, Total Cleanup of Residence and Agricultural Islands

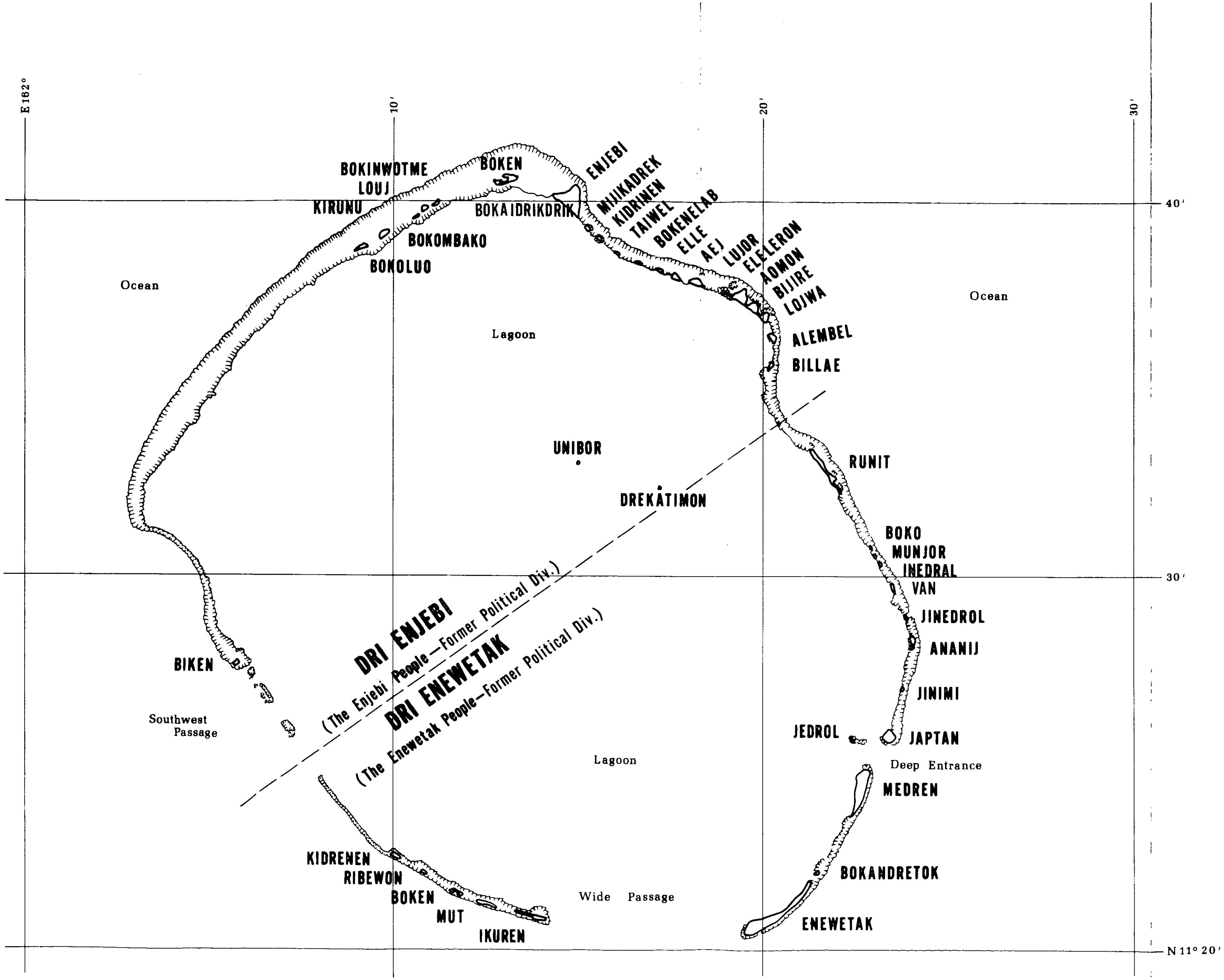
In addition to the removal and replacement of soil on Enjebi as in Case 4, Case 5 provides for the removal of soil to specific depths on Lujor, Bokoluo, Bokombako, and Kirunu. The islands designated for agricultural development in the Master Plan (Tab D, Appendix) would also be treated to a soil removal and replacement operation similar to that described for Enjebi. There would be no restriction on living patterns or food sources in Case 5 (Figure 5-5).

5.5.5.1 Habitation Plan. If the actions to be described in Paragraph 5.5.5.2 would achieve a level of exposure reduction as large as the calculated result, the entire atoll could be used as originally planned with unrestricted living patterns. Agriculturally, this would mean that pandanus and breadfruit would be permitted to grow only in soil having a ^{90}Sr content of less than 4.6 pCi/g. Assuming that these conditions would be met, the following would apply:

- The people would be able to live on any island in the atoll.
- Coconut, pandanus, and breadfruit could be cultivated on those islands designated in Table 4-1 (Tab D, Vol. II).
- Domestic meat could be raised on any island.
- Coconut crabs could be collected on any island.
- Wild birds and bird eggs could be gathered on any island.
- Interisland travel would be unrestricted.
- Lagoon fishing would be unrestricted.

5.5.5.2 Cleanup Actions. The following cleanup actions would be undertaken (removal and replacement of about 779,000 cu yds of soil is involved in these cleanup actions):

- Removal of physical hazards from all islands.
- Removal of debris and structures obstructive to the use of the land by the people.
- Removal of unsightly debris.
- Removal of plutonium contaminated soil from Boken, Lujor, and Runit and the removal of plutonium crypts on Aomon.
- Scraping and removal of 10 cm of soil from Lujor and Kirunu, 14 cm of soil from Bokombako, and 47 cm from Bokoluo.

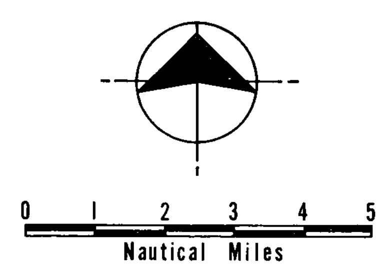


Case Summary:

1. Pu Cleanup To Less Than 40pCi/gm On Boken, Lujor, Aomon & Runit Burial Sites.
2. Remove 15cm Of Soil From The Subsistence Commercial Agri-culture Areas On Enjebi And Replace With Clean Soil.
3. Farming Plots On Enjebi, Runit, Alembel, Lojwa, Aomon, Bijire, Lujor, And Aej For Pandanus & Breadfruit Require Removal Of 30cm. Of Soil And Replacement With Clean Soil.
4. All Radioactive Scrap To Be Cleaned Up From All Islands.
5. Remove The Indicated Depth Of Soil And Replace With Clean Soil On The Following Islands:

Bokoluo	47cm	Kirunu	10cm
Bokombako	14cm	Lujor	10cm

6. Physical Hazard, Obstructive And Unsightly Debris Cleaned Up On All Islands.
7. Enjebi, Medren, Enewetak And Japtan Are Living Islands.
8. All Islands Available For Use In Accordance With The Master Plan.
9. No Restrictions On Travel.
10. No Restrictions On Fishing.



ENEWETAK ATOLL

CASE 5

FIGURE 5-5

- Scraping and removal of 30 cm of soil from areas where pandanus and breadfruit would be grown on Enjebi, Alembel, Aomon, Bijire, Lojwa, Lujor, Aej, Ananij and Runit.
- Scraping and removal of 15 cm of soil where commerical coconut crops will be grown on the same islands.
- Scraping and removal of 15 cm of soil in other subsistence agricultural areas on Enjebi.
- Replacing soil from scraped areas with at least equal depths of imported soil.

5.5.5.3 Conclusions. Case 5 is clearly more difficult and more expensive than the other cases as it requires removal and replacement of much more soil in the cleared areas (Case 3: 79,000 cu yds; Case 4: 318,000 cu yds; Case 5: 779,000 cu yds). Consideration of the actions in Case 5 as a viable alternative is clouded by uncertainties regarding the exposure reduction that can be achieved through partial soil removal and selective soil replacement. At the present time there appears to be no record of this method of attempting to reduce radionuclide concentrations in the soil being successful. In addition, the quantity of soil which is estimated to be involved (779,000 cu yds) limits the method of disposal to ocean dumping or to transportation to Conus. Additionally, the removal of this large volume of soil would appear to be ecologically infeasible - an ecological insult so severe that the character of the atoll would be grossly and adversely affected. This adverse effect alone would be sufficient to warrant rejection of this method. Neither of these methods appears to be a satisfactory solution to the problem for the foreseeable future. In view of these considerations and the additional high cost of the operation, Case 5 is not recommended as a course of action.

5.6 EVALUATION OF ALTERNATIVE PROGRAMS

Several considerations are treated quantitatively here to assist in selecting a suitable course of action in cleanup and rehabilitation of the atoll and in resettlement of the Enewetak people on the atoll. These considerations include estimated dose and the associated radiological risk, and the financial costs of alternative programs. The effectiveness of each alternative program in reducing the estimated potential population radiological dose is evaluated by calculating whole body, bone, and lung dose for each program (see Paragraph 5.6.1). These doses are estimated on two time bases: a 30-year dose and a maximum annual dose. Relative values of radiological risks for each alternative program is estimated in Paragraph 5.6.2. Estimates of the financial costs of selected alternative programs and associated disposal methods are discussed in Paragraph 5.6.3.

5.6.1 Dose Estimates

Estimates of doses that individuals in the Enewetak Atoll population may incur after they have resettled on the atoll are presented for various alternative programs in Tables 5-6 and 5-7. In both tables, the dose estimates are given for the whole body, the bone (mineral) and the lungs. These estimates are based on information contained in the AEC Radiological Survey of Enewetak Atoll, NVO-140, 1973 and in the AEC Task Group Report, June 19, 1974.

Particular considerations in calculating these dose estimates are:

- No contribution to dose is assumed from groundwater since it will be monitored and will not be used unless it meets established guidelines for radioactive and nonradioactive impurities.

- Bone marrow dose estimates are not given because the ratio of bone marrow dose to the AEC guidelines of 0.25 rem/yr is essentially the same as the ratio of mineral bone dose estimates to the AEC guideline of 0.75 rem/yr. The basis for this conclusion derives from observing that when ^{90}Sr deposition is the principal source of bone and bone marrow exposure, as on Enewetak, it is traditionally accepted that the marrow dose is one-third the bone dose. AEC data show that contributions due to sources other than ^{90}Sr do not add significantly to bone or bone marrow dose estimates. Consequently, it makes no significant difference whether bone or bone marrow is the organ used for radiological hazard analysis since the bone dose is essentially three times the bone marrow dose and the bone dose guideline is three times the bone marrow dose guideline.

- Separate dose estimates are not provided for the traditionally more sensitive members of the population (fetus and newborn). The AEC Task Group Report (Tab B, Vol. 2 of the EIS) and NVO-140, page 505, show that calculations based on the most sensitive individual do not result in significant differences in dose estimates.

- The dose estimates are maximums expected in the population for an individual free to move about and eat foods obtained within the restrictions of each habitation plan/cleanup action combination. These estimates are developed to provide a means for estimating radiological health effects and risks for each combination of interest. Dose estimates for individuals subjected to more restrictive and adverse combinations of habitation and

TABLE 5-6: ESTIMATED 30-YEAR INTEGRATED DOSES TO INDIVIDUALS[a] (REM)

Habitation Plans / Cleanup Actions	A	B	C	D
	No restrictions on island or food usage	Live on southern islands and Enjebi; visit northern islands; food from southern islands or Enjebi plus coconut from 12 N.E. islands and pandanus and breadfruit from Enjebi farm plots or imported[b]	Live on southern islands; visit northern islands; food from southern islands plus coconut from 12 N.E. islands[c]	Live on southern islands; visit on southern islands; use food grown on only southern islands
I. No cleanup.	Case 1 WB = 6 B = 60 L = 0.1	WB = 3 (6 on Enjebi) B = 10 (20 on Enjebi) L = 0.06 (0.1 on Enjebi)	WB = 1 B = 5 L = 0.04	Case 2 WB = Background[d] B = Background L = Background
II. Removal of all scrap and Pu concentrations greater than 40 pCi/g from residence and agriculture islands.	WB = 6 B = 60 L = Background	Case 4 WB = 3 (6 on Enjebi) B = 10 (20 on Enjebi) L = Background	Case 3 WB = 1 B = 5 L = Background	Same as Case 2
III. Total cleanup of residence and agriculture islands.	Case 5 WB = Background B = Background L = Background	Habitation restriction not required. See Case 5	Habitation restrictions not required. See Case 5	Habitation restrictions not required. See Case 5

LEGEND

WB = Whole Body Dose
B = Bone Dose
L = Lung Dose

[a] Doses calculated to one significant figure based on data from NVO-140 and AEC Task Group Report.

[b] Doses calculated from an assumed population distribution of 44 percent of the Atoll population on Enjebi and the balance of the population on the southern islands.

[c] Doses calculated from island area weighted distribution of coconuts: 40 percent from Mijikadrek to Billae and Biken, and 60 percent from the southern islands.

[d] Background means that the dose is estimated to be no greater than would be absorbed from naturally occurring sources, either externally or internally. Estimates for background 30-year doses are: WB = 1 rem, B = 4 rem, and L = 0.0009 rem.

TABLE 5-7: ESTIMATED MAXIMUM ANNUAL DOSES TO INDIVIDUALS[a] (REM)

Habitation Plans / Cleanup Actions	A No restrictions on island or food usage	B Live on southern islands and Enjebi; visit northern islands; food from southern islands or Enjebi plus coconut from 12 N.E. islands and pandanus and breadfruit from Enjebi farm plots or imported	C Live on southern islands; visit northern islands; food from southern islands plus coconut from 12 N.E. islands	D Live on southern islands; visit on southern islands; use food grown on only southern islands
I. No cleanup.	Case 1 WB = 0.3 B = 2 L = 0.004	WB = 0.1 (0.3 on Enjebi) B = 0.5 (1 on Enjebi) L = 0.002 (0.004 on Enjebi)	WB = 0.05 B = 0.2 L = 0.001	Case 2 WB = Background[b] B = Background L = Background
II. Removal of all scrap and Pu concentrations greater than 40 pCi/g from residence and agriculture islands.	WB = 0.3 B = 2 L = Background	Case 4 WB = 0.1 (0.3 on Enjebi) B = 0.5 (1 on Enjebi) L = Background	Case 3 WB = 0.05 B = 0.2 L = Background	Same as Case 2
III. Total cleanup of residence and agriculture islands.	Case 5 WB = Background B = Background L = Background	Habitation restrictions not required. See Case 5	Habitation restrictions not required. See Case 5	Habitation restrictions not required. See Case 5

LEGEND

WB = Whole Body Dose
B = Bone Dose
L = Lung Dose

[a] Doses calculated to one significant figure based on data from NVO-140 and AEC Task Group Report. AEC guidelines for maximum annual dose are: WB = 0.25, B = 0.75. See Table 5-6 for assumptions used in dose calculations for columns B and C.

[b] Background means that the dose is estimated to be no greater than would be absorbed from naturally occurring sources, either externally or internally. Estimates for annual background dose are: WB = 0.04 rem, B = 0.1 rem, and L = 3×10^{-5} rem.

cleanup are provided in the AEC Task Group Report but are not considered in the alternative programs in this EIS. These more adverse Task Group Report combinations are extremely unlikely when considering historic living patterns on the atoll and the stated preferences of the Enewetak Atoll people for use of the various islands. Furthermore, it has been determined that consideration of these other combinations would increase already unacceptable doses but would not change the acceptability of recommended alternative programs.

Table 5-6 lists estimates of doses absorbed over a period of 30 years. These estimates can be considered the highest that any generation would receive. The maximum annual doses listed in Table 5-7, include recognition that the maximum for each component of radionuclide contribution to total dose occurs at different times during the 30-year period. Data and methods used to obtain the estimates in Table 5-6 and 5-7 are discussed in Paragraphs 5.6.1.1 through 5.6.1.3.

Comparison of these results with the dose guidelines recommended by the AEC Task Group Report, 1974 (see Table 5-3) is shown in Table 5-8. This comparison is given as the ratio of estimated individual dose to the appropriate dose guideline. For habitation plan A with cleanup actions I or II, the maximum annual whole body dose for an average individual on the atoll is about 20 percent higher than the AEC guideline. For habitation plan B, the maximum annual whole body dose for an average individual is well below the AEC guideline; but for an individual residing on Enjebi, the whole body dose under these conditions is estimated to be 20 percent higher than the AEC guideline. For other combinations of cleanup actions and habitation plans, the maximum annual doses are well within the guidelines recommended by the AEC.

Regarding bone doses, estimates for habitation plan A exceed the AEC guideline of 0.75 rem/yr, except for cleanup action III, even when the distribution of population is taken into account. For habitation plan B, the bone dose appears to be satisfactory in comparison to the guideline except for an individual residing on Enjebi. Other combinations result in maximum annual doses well within AEC guidelines.

5.6.1.1 Internal 30-Year Doses. Data for internal doses to whole body and bone are presented in Table 5-9. These data were used in developing the estimates in Table 5-6. In addition, data from Tables 1 and 2 of the AEC Task Group Report were used in deriving these estimates. In particular, living patterns A and D in Tables 1 and 2 of the Task Group Report were used for estimating whole body and bone doses in Column B of Table 5-6. These patterns correspond to life styles likely to be adopted

TABLE 5-8: RATIOS OF ESTIMATED MAXIMUM ANNUAL DOSES TO RECOMMENDED ANNUAL DOSE GUIDELINES FOR INDIVIDUALS[a]

Habitation Plans / Cleanup Actions	A No restrictions on island or food usage	B Live on southern islands and Enjebi; visit northern islands; food from southern islands or Enjebi plus coconut from 12 N.E. islands and pandanus and breadfruit from Enjebi farm plots or imported[b]	C Live on southern islands; visit northern islands; food from southern islands plus coconut from 12 N.E. islands[c]	D Live on southern islands; visit on southern islands; use food grown on only southern islands
I. No cleanup.	Case 1 RWB = 1.2 RB = 2.7	RWB = 0.4 (1.2 on Enjebi) RB = 0.7 (1.3 on Enjebi)	RWB = 0.2 RB = 0.3	Case 2 b
II. Removal of all scrap and Pu concentrations greater than 40 pCi/g from residence and agriculture islands.	RWB = 1.2 RB = 2.7	Case 4 RWB = 0.4 (1.2 on Enjebi) RB = 0.7 (1.3 on Enjebi)	Case 3 RWB = 0.2 RB = 0.3	b
III. Total cleanup of residence and agriculture islands.	Case 5 b	b	b	b

LEGEND

RWB = Ratio of Maximum Annual Dose to Recommended Limit for Whole Body Dose (0.25 rem/yr).
RB = Ratio of Maximum Annual Dose to Recommended Limit for Bone Dose (0.75 rem/yr).

[a] Applicable to average individual on entire atoll, except where noted. People should not return if the ratios are greater than unity.

[b] The ratios are effectively less than or equal to the ratio of background dose to recommended guideline where RWB ≤ 0.16 and RB ≤ 0.13.

TABLE 5-9: INTERNAL DOSES DERIVED FROM INGESTION OF FOODS GROWN ON GIVEN ISLANDS

Island Group	Area (Acres)	Remarks	Foods	30-Year Doses[a] (Rem) Whole Body (^{137}Cs)	Bone (^{90}Sr)
Bokoluo to Boken	104.87	Northern islands showing greatest radioactivities of Enewetak Atoll survey	Coconuts Pandanus and Breadfruit Other	0.95 6.15 2.45	8.6 93.4 24.0
		Sum		9.55	126.0
Bokombako	30.50	Same as above	Coconuts Pandanus and Breadfruit Other	2.18 13.80 5.42	14.9 156.5 40.6
		Sum		21.40	212.0
Enjebi	290.58	Same as above	Coconuts Pandanus and Breadfruit Other	0.71 4.60 1.80	5.2 55.5 14.7
		Sum		7.10	75.4
Mijikaidrek to Van plus Biken	524.31	Northeastern (Biken is south-western) islands with intermediate levels of radioactivity	Coconuts Pandanus and Breadfruit Other	0.27 1.71 0.03	2.2 24.0 6.5
		Sum		2.67	32.7
Jinedrol to Kidrenen	804.58	Southern islands with very low levels of radioactivity	Coconuts Pandanus and Breadfruit Other	0.04 0.06 0.04	0.28 0.48 1.34
		Sum		0.14	2.10
Enewetak Lagoon	--	Marine Source	Seafood	0.05[b]	0.84[b]

[a] "Enewetak Radiological Survey," NVO-140 (1973), Table 202, p. 604, except where noted.

[b] Ibid., Table 162, p. 540. The values taken correspond to whole body and bone doses from all nuclides, not just ^{137}Cs and ^{90}Sr.

by people living and growing food on the southern islands and by people living and growing food on Enjebi, respectively. An appropriate combination of these patterns reflecting the spatial distribution of the population is used for the final evaluations in Tables 5-6 and 5-7.

The contributions of radionuclides in coconuts, pandanus and breadfruit, and other components of the Enewetak diet are given for each of several island groups in Table 5-9. The islands are grouped in decreasing order of contamination as follows:

- Bokoluo to Boken plus Bokombako
- Enjebi
- Mijikaidrek to Van plus Biken
- Jinedrol to Kidrenen

These data were used in the construction of area weighted food and island contributions to the internal dose estimates in Column C of Table 5-6.

Variation in the time of exposure among foodstuffs influences the cumulative internal dose. As a period of about 7 to 10 years is required for the maturation of seedling pandanus, breadfruit, and coconut trees, and few fruit bearing plants are now available on Enewetak Atoll, these foods can not contribute to the internal dose until the maturation period has passed. For simplicity, the maturation period is assumed to be 8 years in the calculation of doses for Tables 5-6 and 5-7.

Values for the lung dose contributions are comprised of two components, dose from inhalation of plutonium and whole body dose. In every case of Table 5-6, the magnitude of the inhalation dose is insignificant compared to the whole body dose. Estimates of inhalation dose to the lungs were based on the data in Table 204 of NVO-140, 1973, using living patterns I and III. These estimates are noted in Table 5-6. Due to the small magnitude found for the plutonium contribution to the lung dose, the time dependent character of the inhalation dose is not significant to the calculation of maximum annual dose.

5.6.1.2 <u>External 30-Year Doses.</u> External dose contributions from gross gamma radiation fields of different isopleths on different island groups are listed in Table 5-10. Area weighted averages of the exposure rates of isopleths and of the external dose estimates by island group areas were used in determining the external dose contributions to the estimates given in Table 5-6.

The sources of external exposure are assumed to disappear by their nuclear decay alone. No credit is assumed in the estimation of integral doses for any removal from the local environment by weathering or other natural processes.

TABLE 5-10: CALCULATIONS OF EXTERNAL DOSES TO INDIVIDUAL RESIDING ON GIVEN ISLANDS

Island Group	Land Area (Acres)	Cleanup Action[a] (Code)	Isopleths Code	Isopleths Area (Acres)	Isopleths Exposure Rate[b] (μR/hr)	Remarks	Thirty Year External Dose (rem)
Bokoluo to Boken plus Bokombako, Lujor and Runit	281.06	Row I	K	2.09	390	Dose calculated by isopleth area weighted and normalized (to Enjebi) exposure rates; Enjebi external dose taken from AEC pattern III[c]; all locations assumed equally accessible	6.4
			J	7.15	195		
			I	63.62	98		
			H	54.22	50		
			G	54.63	24		
			F	54.87	12		
			≤E	44.48	6		
		Row II				Radiological cleanup does not appreciably reduce external dose in Row I	6.4
		Row III				Removal of at least isopleths F through K	Background[d]
Enjebi	290.58	Row I	I	5.98	98	Enjebi external dose taken from AEC pattern III[c]	
			H	138.15	50		
			G	28.51	24		
			F	34.09	12		
			≤E	23.85	6		4.0
		Row II				Same remark as for Row II cleanup of Bokoluo to Boken plus Bokombako, Lujor and Runit	4.0
		Row III				Removal of at least isopleths F through I	Background[d]
Mijikaidrek to Billae and Biken	378.92	Row I	G	17.49	24	Same remark as for Row I cleanup of Bokoluo to Boken plus Bokombako, Lujor and Runit	
			F	77.03	12		
			≤E	285.40	6		1.1
		Row II				Same remark as for Row II cleanup of Bokoluo to Boken plus Bokombako, Lujor and Runit	1.1
		Row III				Removal of at least isopleths F and G	Background[d]
Jinedrol to Kidrenen	804.58	Row I	≤E	804.58	6	External dose of southern islands taken from pattern I;[c] estimated to be approximately that of background	0.8
		Row II				Same remark as for Row II cleanup of Bokoluo to Boken plus Bokombako, Lujor and Runit	0.8
		Row III				Little radiological cleanup required	Background[d]

[a]Cleanup actions referenced as follows:

Code	Cleanup Action
Row I	No radiological cleanup
Row II	Cleanup of all radioactive scrap
	Removal of plutonium burial sites
	Removal of plutonium bearing soil with concentration in excess of 400 pCi/g
	Removal of plutonium bearing soil with concentration between 40 and 400 pCi/g considered on case by case basis
Row III	Complete radiological cleanup such that the expected dose is not greater than would be absorbed from naturally occurring sources

[b]Exposure rate is related to individual annual dose by

Exposure rate (μR/hr) = 8.4×10^{-3} rem/yr (1 person · 1 yr)

[c]"Enewetak Radiological Survey," NVO-140 (1973, Table 204, p. 613. Living pattern I corresponds to people living, growing food, and visiting on only the southern islands Jinedrol to Kidrenen. Living pattern III corresponds to people living and growing food on only Enjebi, and visiting northern islands.

[d]Background means that the dose is estimated to be no greater than would be absorbed from naturally occurring sources.

5.6.1.3 Maximum Annual Dose. The dose rate is not constant during the 30-year period for which "generation" doses are calculated. Consequently the maximum annual dose during this period is calculated for comparison with the annual exposure guidelines recommended by the AEC.

The internal dose rate is dependent on the particular radionuclide as well as its retention characteristics within the body. Consequently, the time dependence and the point in time of the maximum dose rate is different for each combination of radionuclide, environmental pathway, and target organ for which the dose is being calculated. Because of uncertainties inherent in some of these time constants, the internal contribution to the maximum annual dose rate is the sum of the individual maxima disregarding their separation in time. This results in a slightly conservative estimate of the maximum annual dose. The times of these maxima are shown in Table 5-11. As discussed in Paragraph 5.6.1.1, the maturation time for pandanus, breadfruit, and coconut trees is taken to be 8 years for simplicity. The maxima for these exposure pathways are then adjusted accordingly.

The external dose contribution is simply corrected for its radiological decay with no credit being assumed for any weathering, erosion, or other natural process that might increase its rate of disappearance. The sum of the internal and external contributions represents the total of the maximum annual dose. The results are presented in Table 5-7. Referring to Case 1 in Table 5-7, higher maximum annual doses could be estimated as shown in Table 3 of the AEC Task Group Report. However, these higher doses represent highly unlikely living patterns and, even if included, would only have increased the unacceptability of this case.

5.6.2 Comparison of Risks for Alternative Programs

Each alternative program considered for cleanup and habitation can be associated with a level of radiological risk for the people of Enewetak Atoll. A semi-quantitative measure of this risk is provided by estimating the number of health effects* expected from the radiological exposure in each alternative. The risk criteria given in Table 5-1 are used as the basis for making these estimates, assuming a total atoll population of 1,000 receiving the 30-year integrated doses given in Table 5-6 for each alternative. Table 5-12 lists the estimated health effects.

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*As indicated in NCRP Report No. 43, Review of the Current State of Radiation Protection Philosophy, January 15, 1975, it is very unreasonable to interpret these upper limit estimates as actual risk. Because of the extreme conservatism in these estimates, they should be used only as general guidelines in any risk analysis.

TABLE 5-11: INFORMATION FOR CALCULATING MAXIMUM INTERNAL ANNUAL DOSES

Radionuclide	Critical Organ	T_{max}[a] (yrs)	T_{max} + 8 yr[b] (yrs)	Dose Period T[c] (yrs)	Dose Conversion Factor[d]	
					K	1/K
^{90}Sr	Bone	4.82	-	30	23.10	0.0433
			-	22	18.22	0.0549
		-	13	30	25.65	0.0390
^{137}Cs	Whole Body	1.83	-	30	21.11	0.0474
			-	22	17.75	0.0563
		-	10	30	25.17	0.0397
Pu	Lung	19.00	-	30	28.01	0.0357

[a] The time at which the internal exposure rate becomes maximum for a particular radionuclide and target organ is denoted by T_{max}, and is calculated from the formula

$$T_{max} = \frac{\ln(\lambda_m/\lambda_r)}{\lambda_m - \lambda_r},$$

where λ_m is the biological decay constant for man, and λ_r is the radioactive decay constant for the radionuclide.

[b] Assumed 8-year maturation periods for pandanus, breadfruit, and coconut seedling trees.

[c] The period of time over which the dose rate is integrated is denoted by T.

[d] An empirical factor used to relate the maximum annual dose to an integrated dose for a longer period is denoted by K. The relation is given by

$$D_{T_{max}} = \frac{D_T}{K}.$$

The factor K is determined from equations given in NVO-140, pp. 537-38.

TABLE 5-12: ESTIMATED NUMBER OF HEALTH EFFECTS[a] FROM 30-YEAR DOSES TO POPULATION OF 1,000

Habitation Plans / Cleanup Actions	A No restrictions on island or food usage	B Live on southern islands and Enjebi; visit northern islands; food from southern islands or Enjebi plus coconut from 12 N.E. islands and pandanus and breadfruit from Enjebi farm plots or imported	C Live on southern islands; visit northern islands; food from southern islands plus coconut from 12 N.E. islands	D Live on southern islands; visit on southern islands; use food grown on only southern islands
I. No cleanup.	H(WB) $\le$0.3 to 1 H(B) $\le$2 H(L) $\le$0.003 H(Total) $\le$3	H(WB) $\le$0.2 to 0.5 H(B) $\le$0.3 H(L) $\le$0.002 H(Total) $\le$0.8	H(WB) $\le$0.05 to 0.2 H(B) $\le$0.1 H(L) $\le$0.001 H(Total) $\le$0.3	Case 2 Background[b]
II. Removal of all scrap and Pu concentrations greater than 40 pCi/g from residence and agriculture islands.	H(WB) $\le$0.3 to 1 H(B) $\le$2 H(L) $\le$Background[b] H(Total) $\le$3	Case 4 H(WB) $\le$0.2 to 0.5 H(B) $\le$0.3 H(L) $\le$Background[b] H(Total) $\le$0.8	Case 3 H(WB) $\le$0.05 to 0.2 H(B) $\le$0.1 H(L) $\le$Background H(Total) $\le$0.3	Same as Case 2
III. Total cleanup of residence and agriculture islands.	Case 5 Background[b]	Same as Case 5	Same as Case 5	Same as Case 5

LEGEND

H(WB) = Maximum Expected Whole Body Health Effects
H(B) = Maximum Expected Bone Health Effects
H(L) = Maximum Expected Lung Health Effects
H(Total) = Maximum Expected Total Health Effects

[a]Health effects mean somatic cancer inductions that result in fatality, calculated to one significant figure. The number of fatal and nonfatal cases is estimated to be twice the number of fatal cases. See Table 5-1 for dose response rates used to estimate health effects. These effects would be in addition to those from background radiation.

[b]Health effects for 30-year background doses of WB = 1 rem, B = 4 rem and L = 0.0009 rem are: H(WB)$\le$0.05 to 0.2
H(B)$\le$0.1
H(L)$\le$0.00002
H(Total)$\le$0.3

As indicated in Table 5-12, the total number of health effects per 1,000 people is the sum of health effects estimated for whole body, bone and lung doses. This total is the maximum estimated health effect or risk. The actual risk may actually be zero or negligible when compared to effects resulting from natural or background exposure.

Reviewing Table 5-12, it can be seen that several alternative programs result in health effects which are estimated to be no greater than those induced by naturally occurring background radiation. These programs, yielding the greatest reduction in radiological risk, also are either the most restrictive in terms of habitation plans or the most costly in terms of cleanup. For example, Case 2 restricts the Enewetak Atoll people to the southern islands with no agriculture or visitation on the northern islands and Case 5 places no restriction on residence, agriculture or visitation of the people but imposes enormous costs as is shown in later discussion.

Short of reducing radiological risk to background levels, it can be seen that Cases 3 and 4 offer compromises which increase the extent of Enewetak Atoll people's agricultural, residence and visitation activities without causing significant increases in risk. For Case 3 the total number of health effects (Case 3 plus background) is estimated to be no more than twice the background condition. Quite probably it would be impossible to discern any increase in health effects over those attributable to background radiation. For Case 4 the total number of health effects (Case 4 plus background) is estimated to be no more than about 4 times the background case. Again it should be noted that actual number of added health effects may be no greater than the background effects; however, as suggested by the Case 4 risk estimates, the Enewetak people will be exposed to a slightly increased radiological risk because of the Enjebi agricultural activities.

As shown in Table 5-12, the cleanup actions introduced when going from Row I to Row II do not significantly reduce the overall estimate of radiological risk for any given habitation plan. These added cleanup actions consist of radioactive scrap removal and removal of plutonium concentrations in accordance with Pu cleanup guidelines. Such cleanup results in negligible dose reduction since these actions mitigate the external and inhalation pathway doses which contribute only small fractions to the total dose. This result does not mean that cleanup actions defined by Row II should be omitted. They are desirable from the standpoint of eliminating the possibility of undue individual exposure and the accessibility to radioactivity.

In summary, the radiological risks displayed in Table 5-12 suggest that further consideration of alternative programs can be restricted to Cases 1 through 5. Case 1 represents the risk, clearly unacceptable, associated with unrestricted use of the atoll and no cleanup action and Case 5 represents the case of essentially complete removal of risk to allow unrestricted use. Cases 2, 3 and 4 represent compromises on use, cleanup and risk between Cases 1 and 5. These factors are summarized in Table 5-13 along with cost data to provide a basis for overall consideration of each case. The cost data are developed in Section 5.6.3. Reviewing Table 5-13, THE BEST COMBINATION OF FEATURES IS FOUND IN CASE 3. IN THIS CASE CLEANUP IS PRACTICALLY COMPLETE; THE PROBLEMS OF CONTAMINATED PANDANUS AND BREADFRUIT ARE MINIMIZED; RESTRICTION ON POPULATION MOVEMENT IS MINIMAL, EXCEPT FOR THE RESTRICTION OF NO RESIDENCES OR AGRICULTURE ON ENJEBI; THE 30-YEAR DOSES ARE LOW; THE MAXIMUM ANNUAL DOSES FALL WITHIN AEC GUIDELINES; AND THE INCREASED RADIOLOGICAL RISK, EXPRESSED AS HEALTH EFFECTS, IS NO MORE THAN EQUAL TO THE RISK FROM BACKGROUND RADIATION.

5.6.3 Estimated Costs

The estimated costs for cleanup operations involved in Cases 2 through 5 are summarized in Table 5-14. These estimates were based on the assumption that work would begin in late 1975 using estimated values of services and products applicable to 1976. These values were determined from contracts and recent historical purchasing data.

Base camp rehabilitation includes the cost of renovating the existing structures on Enewetak and any new construction connected with the establishment of the camp. Cleanup costs are those associated with the actual radiological and physical cleanup work on the individual islands. They include estimated travel times from the base camp to the work sites, as well as a contingency for time lost due to weather conditions. The technical support costs are those which are associated with planning, engineering, and estimating activities pertinent to the cleanup program. The costs included in logistical support are for air transportation, helicopter operation, barging and shipping, interisland marine operations, packing and crating of equipment and supplies, general services for Government agencies, operation of off-site offices in Oakland and Honolulu, and the hiring and processing of personnel. Maintenance and operations costs included all base camp operations associated with the program as well as procurement and maintenance of equipment.

TABLE 5-13: SUMMARY OF CASE STUDIES

Item	Case 1	Case 2	Case 3	Case 4	Case 5
Residence Islands	No Restrictions	South Only	South Only	South plus Enjebi	No Restrictions
Interisland Visitation	No Restrictions	South Only	No Restrictions*	No Restrictions*	No Restrictions*
Sources of Pandanus and Breadfruit	No Restrictions	South Only	South Only	South and Farm plots on Enjebi	No Restrictions
Sources of Coconuts	No Restrictions	South Only	South and agriculture islands in northeast	South and Enjebi through Billae	No Restrictions
Physical Cleanup	None	Hazardous and obstructive non-radioactive scrap	Hazardous and obstructive non-radioactive scrap. All radioactive scrap	Hazardous and obstructive non-radioactive scrap. All radioactive scrap	Hazardous, obstructive, and unsightly nonradioactive scrap. All radioactive scrap
Plutonium Cleanup	None	None	All concentrations ≥ 400 pCi/g and concentrations between 40 and 400 pCi/g as considerations warrant	All concentrations ≥ 400 pCi/g and concentrations between 40 and 400 pCi/g as considerations warrant	All concentrations ≥ 400 pCi/g and concentrations between 40 and 400 pCi/g as considerations warrant
B & Y Cleanup	None	Radioactive scrap	Radioactive scrap	Radioactive scrap, soil removal and replacement	Radioactive scrap, soil removal and replacement
Thirty Year Dose to Average Individual (rem)					
Whole Body	6	Background	1	3 (6 on Enjebi)	Background
Bone	60	Background	5	10 (20 on Enjebi)	Background
Lung	0.1	Background	Background	Background	Background
Number of Fatalities from Thirty Year Dose to Population of 1000	≤ 3	Background	≤ 0.3	≤ 0.8	Background
Maximum Annual Dose to Average Individual (rem)					
Whole Body	0.3	Background	0.05	0.1 (0.3 on Enjebi)	Background
Bone	2	Background	0.2	0.5 (1 on Enjebi)	Background
Lung	0.004	Background	Background	Background	Background
Ratio of Maximum Annual Dose to AEC Criteria					
Whole Body	1.2	≤ Background	0.2	0.4 (1.2 on Enjebi)	≤ Background
Bone	2.7	≤ Background	0.3	0.7 (1.3 on Enjebi)	≤ Background
Cleanup Cost (Millions of Dollars)	0	20.3	33.6	49.4	79.6
Disposal Cost (Millions of Dollars)	0	0	6.3	23.9	83.0

*Runit temporarily quarantined

TABLE 5-14: SUMMARY OF ESTIMATED COSTS ($000)

Program Activity	Case 2	Case 3	Case 4	Case 5
Field Construction				
Base Camp Rehabilitation	3,771	3,800	3,800	3,800
Radiological Cleanup	0	3,420	7,802	14,170
*Physical Cleanup	2,852	3,396	3,396	6,357
Technical Support	97	97	97	97
Logistical Support	8,719	14,710	19,587	31,571
Maintenance and Operations Including Equipment	4,883	8,225	14,733	23,609
Total Program	20,322	33,648	49,415	79,604

NOTES:

1. Cost estimates are based on use of third country nationals and other considerations.

2. Estimates assume commencement of operations in late 1975.

3. Disposal costs are shown separately in Table 5-15 and are additive to the above totals.

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*Agreed cleanup level for Cases 2, 3, and 4, level 3 for Case 5.

Estimates for the costs of disposal operations for contaminated materials are summarized in Table 5-15. These estimates were based on considerations of material quantities, methods of preparation, and transportation distances. Assuming the work will be started in late 1975, these estimates reflect 1976 prices.

Major factors influencing the costs in the ocean dumping and Conus disposal options are material preparation and transportation distance. In the crater disposal option, the contaminated materials are left on Runit. Transportation requirements are minimal for this option and no particular preparation of materials is required. Material preparation is a major factor in the crater entombment option, although transportation requirements are minimal.

Material quantities vary strongly among the different cases for soil that is removed, but is constant among cases for radioactive scrap. Measured estimates of these quantities are tabulated as follows (Engineering Study, 1973):

Case	Contaminated Soil (cu yds)	Contaminated Scrap (cu yds)	Uncontaminated Scrap (cu yds)
1	-	-	-
2	-	-	58,000
3	79,000	7,262	73,000
4	318,000	7,262	80,000
5	779,000	7,262	126,000

A summary of the physical details and costs for cleanup of each island is given in Table 5-16. The physical details include the acreage, the radioactivity levels, the plutonium concentrations, the Volumes of radioactive, nonradioactive, and cosmetic debris. Estimated costs are shown for debrushing, scraping, replacing soil, and removing radioactive and nonradioactive debris. Costs for disposal are not included; these are tabulated in Table 5-15.

To obtain a broader view of overall costs for the total proposed program, the three major elements of cost should be added together. These include the estimated cost for Case 3 as shown in Table 5-14, the estimated cost for crater entombment of radioactive materials contained in Table 5-15,

TABLE 5-15: DISPOSAL COSTS($000) -- RADIOACTIVE SOIL AND CONTAMINATED DEBRIS

Method	Case			
	2	3	4	5
Material Volume, 10^3 Cubic Yards	0	87.3	327.3	787.3
Material Disposal Cost, $1000				
Crater Dumping	0	288.0	17,483.0*	68,087.0*
Ocean Dumping	0	8,990.0*	38,953.0*	99,324.0*
Conus Disposal	0	17,019.0*	71,069.0*	177,608.0*
Crater Entombment	0	6,292.0	23,902.0	83,019.0

*Includes additional support costs due to schedule extension required for completion of operation.

and the estimated cost for rehabilitation and resettlement which is based on the tentative budget allocated by the Trust Territory of the Pacific Islands for this purpose. It should be noted that this latter estimate does not include provision for administrative or agricultural maintenance costs beyond the first two years of operation.

In summary, the estimated cost of the entire program, as proposed, is:

Cleanup to Case 3 criteria	-	$33,648,000
Crater entombment of radioactive materials	-	6,292,000
Rehabilitation and resettlement of the atoll	-	12,000,000
Total Estimated Cost	-	$51,940,000

TABLE 5-16: CLEANUP REQUIREMENTS BY CASE AND ISLAND

Present Condition		Cleanup Actions	Case 2		Case 3		Case 4		Case 5	
			Qty.	Cost ($000)	Qty.	Cost ($000)	Qty.	Cost ($000)	Qty.	Cost ($000)
Bokoluo/22 Acres		Debrush							21.99 A	170.2
B+Y	130 µR/hr (1)	Scrape							54,706 cy	323.9
Pu	68 pCi/g (2)	Replace Soil							54,706 cy	610.8
Debris, Radioactive	10 cy	Debris-Radioactive				2.5		2.5		2.5
Total Debris N.C.	426 cy	Debris-Physical				13.9		13.9		20.5
Debris-Cosmetic	147 cy	Total				16.4		16.4		1,127.9
Bokombako/30 Acres		Debrush							33.15 A	191.0
B+Y	260 µR/hr	Scrape							24,495 cy	142.1
Pu	130 pCi/g	Replace Soil							24,495 cy	277.9
Debris, Radioactive	0	Debris-Radioactive								
Total Debris N.C.	6 cy	Debris-Physical				4.1		4.1		5.4
Debris-Cosmetic	3 cy	Total				4.1		4.1		616.4
Kirunu/7 Acres		Debrush							5.73 A	141.9
B+Y	66 µR/hr	Scrape							3,051 cy	19.1
Pu	88 pCi/g	Replace Soil							3,051 cy	38.4
Debris, Radioactive	0	Debris-Radioactive								
Total Debris N.C.	112 cy	Debris-Physical				5.3		5.3		10.8
Debris-Cosmetic	100 cy	Total				5.3		5.3		210.2
Louj/21 Acres		Debrush								
B+Y	66 µR/hr	Scrape								
Pu	98 pCi/g	Replace Soil								
Debris, Radioactive	0	Debris-Radioactive								
Total Debris N.C.	0	Debris-Physical								
Debris-Cosmetic	0	Total								
Bokinwotme/10 Acres		Debrush								
B+Y	16 µR/hr	Scrape								
Pu	24 pCi/g	Replace Soil								
Debris, Radioactive	0	Debris-Radioactive								
Total Debris N.C.	0	Debris-Physical								
Debris-Cosmetic	0	Total								
Boken/Bokaidrikdrik/ 45 Acres		Debrush			1.21 A	68.2	1.21 A	68.2	1.21 A	68.2
B+Y	260 µR/hr	Scrape			6403 cy	39.9	6403 cy	39.9	6403 cy	39.9
Pu	280 pCi/G	Replace Soil			6403 cy	73.8	6403 cy	73.8	6403 cy	73.8
Debris, Radioactive	0	Debris-Radioactive				3.2		3.2		3.2
Total Debris N.C.	1,312 cy	Debris-Physical				50.3		50.3		50.3
Debris-Cosmetic	717 cy	Total				235.4		235.4		235.4
Enjebi/291 Acres		Debrush					250 A	548.4	250 A	548.4
B+Y	130 µR/hr	Scrape					239,112 cy	991.3	239,112 cy	991.3
Pu	170 pCi/g	Replace Soil					239,112 cy	2,825.2	239,112 cy	2,825.2
Debris, Radioactive	568 cy	Debris-Radioactive				76.1		93.6		95.0
Total Debris N.C.	9,884 cy	Debris-Physical				338.6		338.6		338.6
Debris-Cosmetic	2,821 cy	Total				414.7		4797.1		4797.1

(1) Gross count exposure rate, typical all islands (EG&G Aerial Survey, 1972.

(2) pCi/g in top 15 cm of soil, except Runit where high concentration is at a greater depth (Enewetak Radiological Survey, NVO-140, October 1973).

TABLE 5-16 (Continued)

Present Condition		Cleanup Actions	Case 2 Qty.	Case 2 Cost ($000)	Case 3 Qty.	Case 3 Cost ($000)	Case 4 Qty.	Case 4 Cost ($000)	Case 5 Qty.	Case 5 Cost ($000)
Mijikadrek/16 Acres		Debrush								
B+Y	33 μR/hr	Scrape								
Pu	50 pCi/g	Replace Soil								
Debris, Radioactive	0	Debris-Radioactive								
Total Debris N.C.	1,049 cy	Debris-Physical				35.0		35.0		42.9
Debris-Cosmetic	691 cy	Total				35.0		35.0		42.9
Kidrinen/20 Acres		Debrush								
B+Y	33 μR/hr	Scrape								
Pu	22 pCi/g	Replace Soil								
Debris, Radioactive	0	Debris-Radioactive								
Total Debris N.C.	61 cy	Debris-Physical				4.3		4.3		4.9
Debris-Cosmetic	57 cy	Total				4.3		4.3		4.9
Bokenelab/12 Acres		Debrush								
B+Y	16 μR/hr	Scrape								
Pu	35 pCi/g	Replace Soil								
Debris, Radioactive	0	Debris-Radioactive								
Total Debris N.C.	272 cy	Debris-Physical				16.2		16.2		24.3
Debris-Cosmetic		Total				16.2		16.2		24.3
Elle/11 Acres		Debrush								
B+Y	16 μR/hr	Scrape								
Pu	28 pCi/g	Replace Soil								
Debris, Radioactive	0	Debris-Radioactive								
Total Debris N.C.	0	Debris-Physical								
Debris-Cosmetic	0	Total								
Aej/41 Acres		Debrush							28 A	128.5
B+Y	33 μR/hr	Scrape							26,621 cy	158.1
Pu	30 pCi/g	Replace Soil							26,621 cy	303.3
Debris, Radioactive	0	Debris-Radioactive								
Total Debris N.C.	1 cy	Debris-Physical								1.9
Debris-Cosmetic	1 cy	Total								591.8
Lujor/54 Acres		Debrush			1.1 A	3.2	1.1 A	3.2	50.75 A	91.6
B+Y	260 μR/hr	Scrape			600 cy	6.7	600 cy	6.7	41,135 cy	244.2
Pu	530 pCi/g	Replace Soil			600 cy	12.4	600 cy	12.4	41,135 cy	464.6
Debris, Radioactive	317 cy	Debris-Radioactive				20.8		20.8		20.8
Total Debris N.C.	29 cy	Debris-Physical				1.8		1.8		3.5
Debris-Cosmetic	27 cy	Total				44.9		44.9		824.7
Eleleron/4 Acres		Debrush								
B+Y	33 μR/hr	Scrape								
Pu	24 pCi/g	Replace Soil								
Debris, Radioactive	196 cy	Debris-Radioactive				12.1		12.1		33.1
Total Debris N.C.	0	Debris-Physical				0.2		0.2		.4
Debris-Cosmetic	0	Total				12.3		12.3		33.5

TABLE 5-16 (Continued)

Present Condition		Cleanup Actions	Case 2 Qty.	Case 2 Cost ($000)	Case 3 Qty.	Case 3 Cost ($000)	Case 4 Qty.	Case 4 Cost ($000)	Case 5 Qty.	Case 5 Cost ($000)
Aomon/99 Acres		Debrush			2.8 A	5.7	2.8A	5.7	20 A	35.9
B+Y	33 μR/hr	Scrape			6800 cy	45.3	6800 cy	45.3	72,140 cy	435.5
Pu	130 pCi/g	Replace Soil*			140,200 cy	1,617.4	140,200 cy*	1,617.4	204,140 cy	2,316.0
Debris, Radioactive	2106 cy	Debris-Radioactive				95.2		95.2		95.2
Total Debris N.C.	1054 cy	Debris-Physical				13.7		13.7		40.4
Debris-Cosmetic	954 cy	Total				1,777.3		1,777.3		2,923.0
Bijire/52 Acres		Debrush							34 A	61.4
B+Y	16 μR/hr	Scrape							31,461 cy	187.4
Pu	34 pCi/g	Replace Soil							31,461 cy	355.2
Debris, Radioactive	0	Debris-Radioactive								
Total Debris N.C.	200 cy	Debris-Physical				20.0		20.0		29.9
Debris-Cosmetic	196 cy	Total				20.0		20.0		633.9
Lojwa/40 Acres		Debrush							25 A	45.3
B+Y	8 μR/hr	Scrape							24,201 cy	144.1
Pu	7.3 pCi/g	Replace Soil							24,201 cy	275.4
Debris, Radioactive	0	Debris-Radioactive								
Total Debris N.C.	170 cy	Debris-Physical				14.0		14.0		21.2
Debris-Cosmetic	154 cy	Total				14.0		14.0		486.0
Alembel/38 Acres		Debrush							23 A	41.5
B+Y	8 μR/hr	Scrape							22,587 cy	135.2
Pu	25 pCi/g	Replace Soil							22,587 cy	256.0
Debris, Radioactive	0	Debris-Radioactive								
Total Debris N.C.	25 cy	Debris-Physical				0.8		0.8		5.4
Debris-Cosmetic	18 cy	Total				0.8		0.8		438.1
Runit/94 Acres		Debrush			57 A	95.6	57 A	95.6	61 A	102.1
B+Y	520 μR/hr	Scrape			63,725 cy	40.3	63,725 cy	40.3	100,832cy	60.3
Pu	840 pCi/g	Replace Soil			63,725 cy	714.0	63,725 cy	714.0	100,832cy	1,130.3
Debris, Radioactive	4,064 cy	Debris-Radioactive				487.6		487.6		487.6
Total Debris N.C.	6,155 cy	Debris-Physical				14.4		14.4		965.4
Debris-Cosmetic	3,748 cy	Total				1,351.9		1,351.9		2,745.7

TABLE 5-16 (Continued)

Present Condition		Cleanup Actions	Case 2		Case 3		Case 4		Case 5	
			Qty.	Cost ($000)	Qty.	Cost ($000)	Qty.	Cost ($000)	Qty.	Cost ($000)
Taiwel/5 Acres B+Y	8 μR/hr	Debris-Physical								1.3
Pu	23 pCi/g	Total								1.3
Billae/16 Acres B+Y	4 μR/hr	Debris-Physical				10.2		10.2		18.3
Pu	5.3 pCi/g	Total				10.2		10.2		18.3
Inedral/4 Acres B+Y	1.5 μR/hr	Debris-Physical				0.8		0.8		1.3
Pu	1.1 pCi/g	Total				0.8		0.8		1.3
Van/7 Acres B+Y	1.5 μR/hr	Debris-Physical								1.3
Pu	1.1 pCi/g	Total								1.3
Ananij/25 Acres B+Y	2 μR/hr	Debris-Physical		15.1		15.1		15.1		17.7
Pu	1.1 pCi/g	Total		15.1		15.1		15.1		17.7
Japtan/79 Acres B+Y	1.5 μR/hr	Debris-Physical		290.9		290.9		290.9		1,266.6
Pu	.31 pCi/g	Total		290.9		290.9		290.9		1,266.6
Jedrol/5 Acres B+Y	1.5 μR/hr	Debris-Physical		13.4		13.4		13.4		13.4
Pu	1.1 pCi/g	Total		13.4		13.4		13.4		13.4
Medren/220 Acres B+Y	8 μR/hr	Debris-Physical		1,741.0		1,741.0		1,741.0		2,169.2
Pu	.31 pCi/g	Total		1,741.0		1,741.0		1,741.0		2,169.2
Bokandretok/2 Acres B+Y	1 μR/hr	Debris-Physical								3.8
Pu	1.1 pCi/g	Total								3.8
Enewetak/322 Acres B+Y	4 μR/hr	Debris-Physical		559.7		559.7		559.7		1,015.3
Pu	.31 pCi/g	Total		559.7		559.7		559.7		1,015.3
Ikuren/41 Acres B+Y	2 μR/hr	Debris-Physical		124.9		124.9		124.9		139.0
Pu	1.1 pCi/g	Total		124.9		124.9		124.9		139.0
Mut/40 Acres B+Y	2 μR/hr	Debris-Physical		18.3		18.3		18.3		28.6
Pu	1.1 pCi/g	Total		18.3		18.3		18.3		28.6
Boken/29 Acres B+Y	1.5 μR/hr	Debris-Physical		17.9		17.9		17.9		28.6
Pu	1.1 pCi/g	Total		17.9		17.9		17.9		28.6
Ribewon/19 Acres B+Y	2 μR/hr	Debris-Physical		29.0		29.0		29.0		43.0
Pu	1.1 pCi/g	Total		29.0		29.0		29.0		43.0
Kidrenen/19 Acres B+Y	2 μR/hr	Debris-Physical		19.6		19.6		19.6		19.6
Pu	1.1 pCi/g	Total		19.6		19.6		19.6		19.6
Biken/14 Acres B+Y	8 μR/hr	Debris-Physical		22.6		22.6		22.6		22.6
Pu	2 pCi/g	Total		22.6		22.6		22.6		22.6
Western Reef		Debris-Physical								1.6
		Total								1.6
		Total		2,852.4		6,816.0		11,198.4		20,527.0

5.7 SUMMARY OF AEC TASK GROUP RECOMMENDATIONS

This summary was prepared by the AEC staff for presentation to the Commissioners and is presented verbatum except for insertion of Marshallese place names. A more detailed report is contained in Tab B, Vol. II.

INTRODUCTION

The Atomic Energy Commission agreed to provide radiological criteria for cleanup and rehabilitation of Enewetak Atoll to the Department of Defense (DOD) and to the Department of the Interior (DOI). A comprehensive survey of the radiological environment of Enewetak was made to serve as a basis for judgement and recommendations. The survey data show that the northern islands have the greater amount of radioactive contamination and there are plutonium problems.

The Director, Division of Operational Safety, appointed a Task Group and through it staff liaison representatives of DNA, DOI and EPA were kept informed of progress toward completion of recommendations. Current radiation protection guidance containing numerical standards and radiation protection philosophy of national and international standards bodies was used to develop recommended criteria:

- Population dose to the Enewetak people should be as low as practicable.
- The Federal Radiation Council (FRC) Radiation Protection Guides (RPG) for individual and gonadal exposures will be used to evaluate exposure options. The values should be reduced by 50 percent for individual exposure and 20 percent for gonadal exposure to allow for uncertainties in dose predictions. The guides for cleanup planning become:

	Exposure
Whole body and bone marrow	0.25 Rem/yr
Thyroid	0.75 Rem/yr
Bone	0.75 Rem/yr
Gonads	4 Rem in 30 yr

Cleanup of soil containing Pu can be handled on a case-by-case basis using the following:

a. <40 pCi/gm of soil - corrective action not required.

b. 40 to 400 pCi/gm of soil - corrective action determined on a case-by-case basis considering all radiological conditions.

c. >400 pCi/gm of soil - corrective action required.

DOSE ASSESSMENT AND CORRECTIVE ACTION ALTERNATIVES

For comparison with population dose guidelines, evaluations were made for the following conditions:

- Dose without cleanup.
- Dose reductions obtained by diet modification.
- Dose reductions achieved by removal of contaminated soil.

In addition, estimates were made for representative living patterns plus corrective actions:

- Plow the village island, and gravel the village area for radiation shielding.
- Import pandanus and breadfruit from the southern islands Jinedrol-Kidrenen (Alvin-Keith) for inhabitants of the northern islands to control ingestion of radionuclides.
- Import pandanus, breadfruit, coconut and tacca from the southern islands.
- Import pandanus, breadfruit, coconut, tacca, and domestic meat from the southern islands.

DISPOSAL OF CONTAMINATED MATERIAL

Contaminated material is composed of soil, debris and scrap. At some places there is Pu including pieces of Pu metal. Contamination is distributed on and below the surface; some is in rad waste burial sites.

Fission products and induced radioactivity found on such scrap and debris, particularly scrap metal, should be made unavailable to the returning people. Possible approaches are:

1. Disposal in water-filled and underwater craters.

2. Land burial where the radiation level of the scrap is not significantly above that on land.

3. Disposal in deep water.

Pu excepted, the Task Group has not made recommendations for removal of contaminated soil. For any disposal there should be no pathway to people; periodic followup surveys are necessary. Disposal of Pu in any form is a greater problem, and disposal must protect against exposure for the future.

OBSERVATIONS AND CONCLUSIONS

The consensus of the Task group reflects consideration of a range of options and the benefits of reviews and comments.

Choice of the method which will optimize reduction of exposures is a matter of judgement. Action such as use of imported foods could be effective but is not recommended. Although engineering actions, e.g., soil removal and replacements may appear to be preferable to restricting use of land for living and agriculture, these actions can otherwise adversely affect the environment and for some the effectiveness is uncertain. The extent of compliance by the people with restrictions has been considered, and an acceptable level of cooperation is expected so that they may use land where the radiation environment is or can be made acceptable.

Return of people to live on the southern islands, Jinedrol (Alvin) through Kidrenen (Keith), is expected to result in radiation doses within the recommended criteria. Enjebi (Janet), which the people desire for a residence island is a special case of the category of islands having radiation and radioactivity levels which preclude living and agriculture. Steps to make this island completely or partially available in the near term are important from the social as well as scientific viewpoint. Predicted radiation doses associated with the Task Groups recommendation are given in the following table. The Bikini Atoll estimates and natural background estimates of typical levels in the U. S. are given for comparison.

RECOMMENDATIONS

The Task Group reached the following conclusions:

1. Observing precautions, the people may safely return after certain actions are taken. Exposures will be somewhat above current levels in the U. S., but the small risk seems permissible in relation to the desire of the people to return.

2. To assure exposures that will be as low as practicable:

   a. Villages and residences to be located on Medren(Elmer), Enewetak (Fred), Japtan (David), or other southern islands, Jinedrol-Kidrenen (Alvin-Keith).

   b. Travel and visits may be unrestricted to all islands except Runit (Yvonne). When Pu contamination on Runit (Yvonne) is removed, the restriction of travel to that island may be lifted.

   c. Coconut excepted, growth of animal and vegetable subsistence crops to be limited to southern islands Jinedrol-Kidrenen (Alvin-Keith).

   d. Subsistence and commercial coconut may be grown without remedial measures except on Bokoluo, Bokombako, Kirunu, Louj, Boken, Enjebi and Runit (Alice, Belle, Clara, Daisy, Irene, Janet, and Yvonne).

   e. Fishing permitted anywhere.

   f. Wild birds and eggs may be collected anywhere.

   g. Coconut crabs may be collected only on the southern islands Jinedrol-Kidrenen (Alvin-Keith).

   h. Wells to provide lens water for human consumption or for agricultural use to be drilled only on the southern islands Jinedrol-Kidrenen (Alvin-Keith). Water from any well to be assayed for bacterial, salinity, and radioactivity content before approved for use.

3. Enjebi (Janet) is a special case, and the people have a strong desire to live there. Three ground zeroes were on Enjebi and high yield events were fired nearby, with the result that this

was the most heavily contaminated of the larger islands. The Task Group has been unable to determine a reliable, feasible way to bring exposures within the acceptable criteria and permit resettlement of Enjebi on the same schedule as southern islands. The island can be resettled sometime in the future when radionuclide ingestion is no longer a problem. To develop the facts, test plantings with and without soil removal may be made. Construction and agriculture would be deferred until produce from test plantings showed acceptably low levels of radioactivity. Test plantings without soil removal would have least adverse impact on the island environment.

4. Concurrent with the Enjebi work, radioactivity levels should be measured in coconut and other food crops grown on Lujor (Pearl), Kirunu (Clara), Bokoluo (Alice) and Bokombako (Belle). Produce from Runit (Yvonne) should be included after removal of plutonium contamination.

5. All radioactive scrap metal and contaminated debris now or later identified should be removed. This includes three locations on Aomon (Sally) and one on Medren (Elmer) where buried contaminated debris should be exhumed and removed.

6. Runit (Yvonne), quarantined by the USAF in 1972, should remain quarantined until plutonium contamination on that island has been cleaned up. An authority responsible for enforcement of the quarantine should be identified and in residence in the atoll if people return to the atoll before cleanup is completed.

7. Only general recommendations for cleanup of Pu on Runit (Yvonne) can be presented at this time. An accurate picture of this contamination should develop as the decontamination proceeds. The area observed to have small pieces of plutonium and the highest soil concentrations is about 30% of the island. A background for plans for the recovery of Pu will require:

   a. Assembly of a team of experts to interpret field radiation and radioactivity measurements, advise on cleanup actions and provide necessary health physics support. A Public Health Service group, now part of EPA, provided radiological assistance for cleanup of Bikini Atoll. Similar support should be sought from EPA for Enewetak.

   b. Decontamination of Runit (Yvonne) is seen as an iterative process. This amounts to a search for and removal of the higher plutonium levels in soil.

c. The objectives of the cleanup are two:

(1) Recovery of the pieces of plutonium that have been observed on or near the island surface.

(2) Recovery of plutonium contaminated soil.

d. Recovery of plutonium in soil at concentrations greater than 400 pCi/g $^{239,240}Pu$ at any depth these levels are found. Also, recovery of contaminated soil sufficient to reduce surface levels to a value well below 40 pCi/g $^{239,240}Pu$. After soil removal, all areas should be resurveyed to ensure no pieces or hot spots of plutonium remain.

8. Plutonium contaminated soil on Boken (Irene) should be handled as on Runit (Yvonne). Pieces of Pu metal are not expected to be found.

9. Test plantings of food crops may be conducted on each of the "no crops" islands as designated by the Enewetak people. As edible parts of these plants become available, concentrations of significant radionuclides should be measured and compared with the radiological survey predictions. These studies will indicate times at which planting of subsistence and commercial crops can be safely resumed.

10. Lens water sampling and analysis should be conducted, samples to be taken over a period of at least 12 calendar months. Bacterial content, salinity, and radionuclide content should be measured. Radioactivity information will contribute to an understanding of processes operating - or which can be made to operate - to reduce the ecological half-life of ^{90}Sr and ^{137}Cs below the radioactive half-life on the northern islands, especially Enjebi (Janet).

11. A comprehensive air sampling program should be conducted over a period of 12 consecutive months under conditions closely approximating human habitation and expected soil disturbance to provide information on radioactivity levels in air. This program could be conducted coincident with and support cleanup.

12. Base-line surveys of body burdens and urine content of ^{137}Cs and ^{90}Sr should be made for the Enewetak people prior to return to Enewetak Atoll, and periodically thereafter. Resurveys

of the environmental radiation and radioactivity should be made in the first year of return and repeated, for example, every other year.

13. Methods of disposal of plutonium contaminated soil and scrap will have to be decided. Pending a decision, it is recommended that cleanup should accomplish the recovery of plutonium contaminated soil and scrap with storage on Runit (Yvonne). If disposal is deferred for further study, such study should be initiated promptly.

14. The cleanup, with particular attention to removal and disposal of contaminated scrap, debris, and soil, should be documented in detail in a final report by those responsible in the field.

15. Advantage would be taken of experience gained during cleanup of Bikini Atoll. No objection should be made to employment of Enewetak people during cleanup.

5.8 PLUTONIUM AND THE HOT PARTICLE THEORY

The presence of plutonium on several islands of the atoll and the effort required for its removal has been the subject of previous discussions in this document. A controversial issue exists on the degree of risk associated with any quantity of plutonium which is permitted to remain in the soil, particularly in the top layers which might be available for human ingestion in the form of suspended particles in the air. This controversy suggests that the plutonium and other radioactive contaminates in the soil should be reduced to levels achievable only by removing all of the radionuclides in the soil.

After the publication of the Draft Environmental Impact Statement (DEIS) of the cleanup, rehabilitation and resettlement of Enewetak Atoll, a letter was received from the National Resource Defense Council, Inc. (NRDC) which stated in part:

> "Furthermore, the proposed (preferred) cleanup operation is totally inadequate to protect the health of the Enewetak people from exposure to hot particles of plutonium which carry a high risk of producing lung cancer. The basis for these conclusions is presented in the report, 'Radiation Standards for Hot Particles', intended to be an integral part of these comments." (Dated 4 September 1974.)

Later, a second letter was received (dated 14 November 1974) from the NRDC, enclosing a copy of a second report on this subject entitled, "The Hot Particle Issue: A Critique of WASH-1320 as it Relates to the Hot Particle Hypothesis", written by the same authors. Copies of these documents are included in Volume IV of the EIS.

Letters and publications referenced in or responding to these articles have been reviewed and pertinent sections abstracted and included in the following discussion to provide other viewpoints on the hot particle issue. Since the Tamplin/Cochran publications appear in Volume IV in their entirety, sections of these documents have not been abstracted.

The following information has been abstracted from WASH-1320:

"There has been no recorded incidence of cancer in man resulting from the internal deposition of any plutonium isotope in the more than three decades that plutonium has been used. This excellent record has resulted from extremely effective control methods. The absence of tumors is also significant evidence concerning the tumorigenic potential of plutonium in the lung because a number of wartime accidental exposures occurred three decades ago -- a time comparable with probable tumor induction times. Data from occupationally exposed Pu workers, limited as it is, constitutes human experience of the most relevant kind for establishing value judgments where experimental data are not always conclusive for formulating risk evaluations."

To illustrate this point, WASH-1320 reviews several incidents of Pu exposure. One which has a particularly long history follows:

"During late 1944 and 1945, at what is now the Los Alamos Scientific Laboratory, 29 men associated with the Manhattan Project as plutonium workers were identified on the basis of nose swipes or urine radioassay as having received plutonium exposures (Hempelmann et al., 1973b). Of these, 3 were latter dropped from the series when assays indicated lower plutonium burdens, and 1 died of coronary heart disease. These individuals were all young men involved in four basic operations related to the development of the first nuclear weapons: plutonium purification (wet chemistry); fluorination (dry chemistry); reduction to metal; and recovery."

WASH-1320 then provides a comparison of estimated effects in the remaining group of 25 using the hot particle theory vs. actually observed effects as follows:

"One can then calculate that each person in the group of 25 men might have retained about 4 x 10^5 particles above 0.6 μm diameter (0.07 pCi or more per particles) from the original 10 μCi. If the cancer risk for such 'hot particles' were 5 x 10^{-4} per particle, as postulated by the Natural Resources Defense Council report (Tamplin and Cochran, 1974), the 4 x 10^5 particles should yield about 200 cancers per man or about 5000 for the group. Even the residual plutonium (average of 6 nCi per man) measured in 14 of the original Manhattan Project plutonium workers should yield 3 cancers per person. One could also argue that the number of cancers predicted from such a risk estimate might be 10 times larger as the product of 10^8 particles (10 μCi ÷ 0.07 pCi), each 0.6 μm real diameter, and the risk estimate of 5 x 10^{-4} per particle yields 5 x 10^4 tumors for the group. The observed lung cancer incidence after almost 30 years since exposure is zero."

The report, LA-5810-MS, issued by the Los Alamos Scientific Laboratory of ERDA, sets forth additional evidence regarding human exposure and the hot particle theory:

"In a subsequent paper, Lushbaugh et al., describe the result of the study of 8 such lesions resulting from plutonium in wounds in which the plutonium had resided for periods of time ranging from 0.5 to 8 years.[27] They indicate, 'The lesions were found to vary morphologically in an orderly manner related roughly to the length of time the plutonium had been present. All were confined to the dermis. The size of the nodule depended on the dispersion of the particles present rather than the duration of the lesion. The largest nodule was about 2 mm in greatest dimension.' They conclude in the discussion, 'Although this study is based on too few small lesions to evoke much confidence in these retrospective interpretations, the conclusions may be warranted that metallic plutonium implanted in the skin in minute amounts elicits a foreign-body reaction of granulomatous type, which after subsiding in cellular activity become fibromatous.' No reference is made in this paper to cancerous or similarity to pre-cancerous lesions.

"These lesions are the most severe changes which have been reported in humans as a result of plutonium and, as such, require the question of wound contamination to be taken seriously in radiation protection programs. However, to extrapolate these to cancers, in view of the uncertainty on outcome expressed by pathologist, and especially to extrapolate to lung cancer seems to be an unjustifiable step.

Dr. G. N. Dolphin, in Radiological Protection Bulletin #8, Harwell England, has commented on the Tamplin and Cochran report as follows:

> "It should be noted that no human cancers have been positively associated with exposure to insoluble particles or soluble compounds of plutonium. Hence the conclusions in the Report are based on implication or extrapoloation from animal experiments.
>
> "The authors have no new biological evidence. The Report is based on data published during the last 15 years by other scientists.
>
> "Tamplin and Cochran refer to the only well-documented human case of biological changes in cells surrounding a particle of plutonium embedded in the palm of a man's hand. This was reported by Lushbaugh and Langham in 1962. .... Lushbaugh, a pathologist, carefully described the cell changes as having 'a similarity to known precancerous epidermal cytologic changes'. Tamplin and Cochran acknowledge this wording in the first reference to it in their Report. .... From this alleged 'cancer' in the palm of the hand, they go to the conclusion that the risk of cancer from a hot particle is 1 in 1,000 for they assume that there are 1,000 men with plutonium embedded in tissues as a result of wound accidents who have not developed cancers at the wound site. Clearly this is an absurd conclusion from the available human data."

Dr. Dolphin also identifies two recent findings related to actual occurrences of transuranic material in lung tissue and concludes that clinical evidence does not support the hot particle theory. His specific comments are:

> "Blair (1974) reports the finding in dogs studied for periods up to 4068 days after deposition in lungs of 10 million to 100 million plutonium oxide particles (0.2μCi to 3.3μCi). 1 dog out of 21 living for more than 1600 days has not developed a lung cancer. Tamplin and Cochran note this finding but dismiss it and make no estimate of the risk of cancer per particle in the lung. If they had made an estimate, it would be that the cancer risk in this dog that survived was in the range of 1 in 500,000 to 1 in 5 million per particle.
>
> "Lafuma (1974) has reported greater toxic effects including cancer in rats following deposition of curium-242 in lungs compared with equal amounts of plutonium-239 activity. This he attributes to the

diffuse nature of the curium deposit and the particulate nature of the plutonium, as shown by autoradiographs. This is in direct contradiction to the Tamplin and Cochran hot particle hypothesis.

"It is noted that the basis of ICRP recommendations is the average radiation dose to an organ and not the number of radioactive particles in the organ. This dosimetric basis of radiological protection has been established for many years by observation of humans and experimental work with animals. A better evaluation than that offered by Tamplin and Cochran would be needed for this system to be set aside in favour of the hot particle concept. Their estimate that there is a risk of cancer being generated in cells surrounding a hot particle of 1 in 2,000 cannot be substantiated by our present knowledge."

The British Medical Research Council in the report, "The Toxicity of Plutonium", 1975, discussed the "hot particle" hypothesis of Tamplin and Cochran as follows:

"Recently a petition by Tamplin and Cochran (1974) to the United States Atomic Energy Commission from an organization called the Environmental Defense Research Council concerned with problems of pollution in general, concluded that the currently recommended MPC for air, and as a consequence the MPAI, for respirable insoluble plutonium is 115,000 times too large for particles containing 0.07 pCi or more of plutonium-239 (or any other long-lived alpha emitter). This conclusion was based on the 'Geesaman hypothesis' and the document quoted extensively from Geesaman (1968 a and b) without adding any additional information in support of his suggestions. Tamplin and Cochran changed his value of 2,000 rad for the critical dose for carcinogenesis (see above) to 1,000 rem per year because of 'a precipitous change in the dose-response curve (for tumour induction in the experiments of Albert et al.) as the dosage exceeds 1,000 rem. This suggests that a particular level of tissue damage must occur before this carcinogenic response occurs.' They went on to say: 'It therefore seems appropriate, but not necessarily conservative, to accept as guidance that this enhanced cancer risk occurs when particles irradiate the surrounding lung tissue at a dose rate of 1,000 rem/year or more'. Thereafter all their discussion refers to particles which cause this level of exposure to some of the closely adjacent lung tissue. According to calculations of tissue dose by Langham (1968), applied to an idealized model of lung architecture by Geesaman

(1968a), and an unstated assumption that a particle deposited in the deep lung does not move even a few microns over the course of a year, such particles contain 0.07 pCi (or more) of any long-lived and insoluble alpha emitter."

The British report then discusses the likelihood of cancer induction by these particles:

"On the unlikely assumption of uniform distribution of particles and sensitive cells, if 1,000 rem in a year to 64 μg of lung tissue resulted in a mean lung cancer incidence of 1/2,000, the cancer risk for irradiation of 130 mg would be 100 per cent, and after uniform irradiation of the whole lung of mass 1,000 rem some 8,000 separately induced lung cancers would be expected on average in each individual. There is no evidence that this happens. Parts of the lung are frequently irradiated to doses of this order in the course of radiotherapy. In some cases, the whole lung or a great part of it is treated, as in children with Wilm's tumour, and there is no report known of lung cancer induction following radiotherapy in these cases even though a certain number of patients survive for more than a decade."

The final conclusion of the report is expressed as follows:

"In summary, therefore, there is at present no evidence to suggest that irradiation of the lung by particles of plutonium is likely to be markedly more carcinogenic than when the same activity is uniformly distributed."

No attempt has been made to draw conclusions regarding the validity or the lack of validity of the proposed "Radiation Standards for Hot Particles" of Drs. Tamplin and Cochran or its application at Enewetak. The guidelines for conducting the cleanup of Enewetak Atoll were developed by the Atomic Energy Commission (now ERDA) after consultation with the Environmental Protection Agency based on standards established by the Federal Radiation Council. Since these guidelines are based on established standards set by competent authority, it is planned that the proposed cleanup be conducted on the basis of the recommended AEC guidelines.

6. PROPOSED (PREFERRED) CLEANUP OPERATION.

6.1 SELECTION OF CLEANUP CASE 3

The present radiological and physical conditions on Enewetak Atoll are presented in Section 3.8 of this volume. The factors involving physical cleanup, radioactivity, agriculture, animal husbandry, fishing, hunting, disposal of contaminated and noncontaminated debris, and living areas are categorized in Section 5. Five cases, also appearing in Section 5, were derived from combinations of the factors.

The selection of Case 3, as presented in Section 5, as the preferred case is based on the premise that the safeguarding of the Enewetak people from harmful radioactivity is of prime importance. Acceptance of the AEC exposure criteria together with the above premise leaves no viable choices other than the AEC recommendations which are described as Case 3. These recommendations are designed to keep the population radiation dose safely within the guidelines set by the AEC. Deviations from the AEC recommendations regarding radiological standards are not considered to be acceptable.

Case 1 was eliminated as it would expose the people to all of the existing radiological and physical hazards now present on Enewetak Atoll and it exceeds limits recommended by the AEC. Case 2 was dropped from consideration because it does not provide a plan of action that would eventually result in the people being able to use the northern islands. The other cases, 4 and 5, assume that the people would be able to live on Enjebi after soil is removed to the extent required to reduce radioactivity to a safe level. Cases 4 and 5 were no longer considered because the uncertainity in the effectiveness of the corrective actions proposed to bring the exposures within the AEC guidelines is so great that the gamble is not justified. Based on the findings of the AEC Task Group Report (Tab B. Volume II, EIS), these cases were dropped from consideration. In particular, the report recommends that the resettlement of Enjebi be deferred until test plantings show acceptable low levels of radioactivity for internal exposures.

The major drawback to Case 3 is that it would not permit scheduling of the planting of crops, the construction of family and community housing, and the resettlement of the people on Enjebi Island. It also quarantines the island of Runit for an indefinite period. The quarantine would be enforced by the TTPL. However, it would provide for the eventual return of the people to Enjebi when the test plantings and environmental monitoring program indicate that it is safe to do so.

Other than Cases 1 and 2, Case 3 is the least expensive in terms of cleanup costs. This is offset to an undetermined extent by the costs of test plantings and monitoring of radioactivity over an indefinite period of years. However, it is likely that test planting, health and environmental monitoring would occur over a long time period regardless of whether Case 3 or more drastic methods are used in cleanup operations.

6.2 DETAILED CLEANUP PLAN

A discussion of the salient features of Case 3 follows. Island code names are included in this section for ease in referring to the Engineering Study for a Cleanup Plan, HN-1348.1 and the associated drawings in HN-1348.2.

6.2.1 Operation and Logistics

Work on the Atoll would be performed by a civilian construction work force with necessary military support, or, alternatively, by an all military force augmented with civilian skills as necessary. The driEnewetak would be added to the work force when their skills may be utilized feasibly and safely. Military sources may supply the boats, barges, amphibious vehicles and helicopters which would be operated by the civilian work force personnel. All transport of personnel, supplies, and equipment to and from the Atoll would be by military air and sea carriers. Exceptions to this would be confined to instances where Government furnished equipment and services would not be available or could not be furnished economically due to circumstances and priorities.

6.2.2 Enewetak (Site Fred) Base Camp Rehabilitation

The facilities on Enewetak Island which would be required to establish a 400-man base camp for the cleanup operation would be repaired and rehabilitated to a 2-year use level and left as-is at the completion of cleanup. Capacities and capabilities of these facilities are summarized below. A detailed description of the rehabilitation task is contained in Holmes & Narver Document HN-1348.1.

• POL Storage	52,610 barrels
• Warehousing	61,700 square feet
• Living Quarters	40,500 square feet
• Freshwater Distillation	43,200 gallons/24 hours
• Freshwater Storage	305,000 gallons
• Saltwater Pumping	1,000 gallons/minute
• Power Generation	4,000 kva

In addition, the sewage systems would be renovated to accommodate the sanitary requirements of the camp. Athletic facilities, movies, and hobby clubs would fulfill the camp recreational requirements.

Construction and camp equipment would be obtained through Government sources to the greatest extent possible. Items that are not available would be purchased or leased through commercial sources.

6.2.3 Material Disposition

Radioactive scrap metal and contaminated debris would be removed from the islands. Brush would be cleared, when necessary, to expedite the work and monitors would accompany each cleanup crew to insure that radioactive contaminated material has been located and removed.

The noncontaminated debris resulting from the construction and operation activities by Government agencies over a long period is described in Paragraph 3.8.3. The cleanup would include the disposition of all of the debris described as hazardous and obstructive. All noncontaminated materials that can be used by the Enewetak people would be salvaged and stockpiled; the unuseable material would be dumped in the lagoon at selected locations.

The plutonium contamination on Runit (Yvonne), Boken (Irene) and Lujor (Pearl) and in the burial sites on Aomon (Sally) would be removed and collected on Runit with the radioactive scrap for entombment in Lacrosse crater. Temporary dikes would be built around the crater area to protect the work area from wave action. A batch plant would be set up on Runit to mix the contaminated material and soil, and the concrete cap or lid. After the protective dikes were built, a soil cement slurry would be prepared consisting of contaminated soil, coral aggregate if needed for strengthening, and cement. This mixture would be placed in the crater by underwater placement methods. The contaminated scrap collected from other islands would be placed in the mixture. After this material had hardened, an 18-inch thick concrete cap or lid would be placed on top of the mass. Lacrosse crater has an estimated volume of 105,225 cu yds. The total volume of the materials to be placed in the crater have been estimated to be approximately 101,800 cu yds as follows:

Debris and Scrap	7,300 cu yds
Soil Cement	87,800 cu yds
Concrete Cap	6,700 cu yds

6.2.4 Prevention of Contamination

Steps to prevent contamination of noncontaminated areas during the cleanup operation would include:

- Watering. The frequent use of water trucks during contaminated soil removal operations to prevent airborne contamination of surrounding areas.

- Handling. To avoid spillage of contaminated soil and debris during transfer to the disposal site or to Runit (Yvonne), extreme care would be taken in loading and transporting the contaminated material. Samples of radioactive materials transported by vessel away from the atoll would be accomplished in accordance with current regulations, 46 CFR 146.19. However, in intra-atoll transport these regulations would be observed also as far as is practicable. Protective clothing would be worn by those engaged in these operations and all activities would be monitored by radiation safety personnel.

- Equipment Decontamination. The decontamination of equipment used in the contaminated soil and debris removal-transport-disposal operation would be performed at the completion of the operation. All equipment utilized in the cleanup operation would be decontaminated at Runit (Yvonne).

The ERDA/AEC has proposed that a team of radiological scientists and technicians monitor the proposed cleanup program under the auspices of DNA. They would monitor the operation to insure that the workers are protected from radioactivity and that adequate decontamination procedures are enforced. They would resurvey the plutonium contaminated areas as the removal of soil proceeds and advise when it has been reduced to a safe level.

At the conclusion of the cleanup program ERDA would continue to furnish advice to the Enewetak people concerning the radiological safety of land areas, water sources, and marine and terrestrial food sources. They would conduct future periodic followup radiological surveys as necessary, and maintain periodic monitoring of the health status of the resettled people and of the radioacivity in the environment subsequent to rehabilitation.

All actions during the cleanup phase would be carefully documented in a comprehensive final report by those conducting the cleanup operation. (See Section 5.7, Summary of AEC Task Group Report).

6.3 SUMMARY OF ISLAND CLEANUP OPERATIONS

The cleanup task groups would be based on Enewetak (Fred) but temporary camps may be established on other islands in the atoll as cleanup conditions require. They would use marine craft for travel to nearby islands and helicopters when the travel distance is sufficient to justify it. The marine craft would include landing craft, amphibious vehicles, tugs, and barges. The helicopters would be both freight and personnel types. The material handling equipment would consist of tractors, dump trucks, front-end loaders, cutting torches, and hand tools.

The size of the work force would be dictated by a number of factors. One of the chief considerations is the time allowed for the entire operation from the beginning of contract (Notice to Proceed) to the completion of the contract and certification by the cognizant health physics authority. Other items are the housing and feeding capacity of the camp or camps and the availability of military support such as helicopters, landing craft, barges, and tugs.

The practical capacity of the Enewetak (Fred) camp after renovating existing dormitory space and the mess hall is about 400 people. Accommodations for a larger number would require a considerable amount of new construction which would not be practicable considering the added cost involved and the short time the facilities would be needed. If the work force were augmented beyond the estimated 400 people, a tent camp could be established to accommodate the excess.

The peak population of 400 is compatible with the cleanup schedule of about two and a half years. Approximately six months of this time would be used in initial mobilization activities including purchasing, marshalling, and transporting supplies and equipment from the continental United States to Enewetak (Fred).

The next six month period would be utilized in rehabilitating the Enewetak (Fred) camp facilities. As quarters become available, workers would be brought in to commence cleanup work on Enewetak (Fred) and Japtan (David). Over a 60-day period the remainder of the work force would arrive on the Atoll. A maintenance, housing, and feeding force would operate the camp; three task groups will work concurrently on cleanup.

The first task group would clean up Enewetak (Fred), Japtan (David), Medren (Elmer), and Jedrol (Rex). The travel time is short in this group, but the amount of noncontaminated debris is over 70 percent of the total on the Atoll. The only known contaminated debris in this group is buried on Medren (Elmer) and would be exhumed and removed. There are a large number of structures on these islands that are either hazardous or obstructive. Many of them must be disassembled and the materials stockpiled for later use by the Enewetak people.

The second task group would work on the islands starting at Bokoluo (Alice) and clean up clockwise around the Atoll through Mijikadrek (Kate), then proceed to Aomon (Sally), Bijire (Tilda) and Lojwa (Ursula). Besides large amounts of noncontaminated debris on several of these islands, there is also contaminated debris on Bokoluo (Alice) and Enjebi (Janet), plutonium contamination in the soil at Boken (Irene), and plutonium contaminated burial sites on Aomon (Sally). The areas on Aomon that were disturbed by recent nonnuclear testing would be regraded as closely as possible to the natural contours. Fill material would be imported as needed.

The third task group would clean up the southwest sector of Ikuren (Glenn) through Biken (Leroy), then Alembel (Vera) clockwise through Jinimi (Clyde), and Kidrinen (Lucy) clockwise through Lujor (Pearl). With the exception of Runit (Yvonne), these islands have small amounts of debris to be removed. Most of them present landing difficulties; but, since the amount of debris on them is small, amphibious vehicles can do the job efficiently.

Runit (Yvonne) is by far the most difficult island to clean up. In addition to the sizeable amounts of both contaminated and noncontaminated scrap to be removed, there is an indeterminate amount of soil contaminated with plutonium. This must be removed, then, together with the plutonium contaminated material brought in from Boken (Irene), Lujor (Pearl), and Aomon (Sally), encapsulated in concrete in one or both of the craters on Runit.

The recovery, handling, and disposal of plutonium contaminated material would be difficult as the workers must be protected by special clothing and must be carefully monitored each time they leave Runit (Yvonne). Equipment must also be free of contamination before leaving the island.

As each task group would complete its cleanup assignment, its members would be discharged and sent back to the point of hire. The maintenance, housing, and feeding staff operating the camp on Enewetak (Fred) would be reduced as the number of cleanup personnel decreased. Equipment that would not be required in operations subsequent to the initial phase would be transported back to its source as shipping became available or, if not economical to retroship, would be disposed of in place.

6.4 REHABILITATION AND RESETTLEMENT

These operations would be under the auspices of the TTPI and would follow the island-by-island completion of cleanup. On an island designated for agricultural development by the Enewetak people, the rehabilitation crews would first remove any unwanted obstructions and then commence preparations for planting. The actual planting of seedlings would closely follow these preparations.

On the islands of Enewetak, Medren, and Japtan, which have been designated as residential sites by the Enewetak people, construction personnel would also commence operations. The new housing would be built as the areas were cleaned of obstructions. Community centers on Enewetak and Medren would be established, as well as the commercial facilities, such as piers and copra warehouses.

The Enewetak people could be expected to move into their new homes as rapidly as they are completed.

7. PROPOSED REHABILITATION AND RESETTLEMENT PLAN

This plan is concerned with returning the people of Enewetak to the atoll, providing them with suitable housing, establishing functional communities on the islands, and developing Enewetak's natural resources for the economic benefit of its inhabitants. The "Enewetak Atoll Master Plan," published by Holmes & Narver, Inc., March 1975, describes the elements of this plan in detail. The Enewetak Planning Council (see Section 4.5), with the assistance of their planning advisors, has been a major contributor to the development of this plan. Much of the data in this section is based on the Master Plan which was first issued in November 1973. The plan was revised and updated in March 1975 to conform to the recommendations of the AEC Task Group Report, June 1974 (Tab B, Volume II), summarized in Section 5.7. The report recommends against the use of Enjebi as a community site due to the possible internal exposure to radionuclides which would result from ingestion of foods raised on the island. The southern sector of the atoll is recommended in the report as being radiologically safe for community sites and for growing local foods. The report also recommends that Runit be quarantined pending a satisfactory solution to the plutonium disposal problem.

A first step toward the resolution of the Enjebi problem was the initiation of a test planting program on that island under the sponsorship of ERDA. While the immediate objective of the program is to meet present high-priority needs for the effective rehabilitation of Enewetak Atoll, indications of results sufficient for evaluation are not expected for five years.

The Enewetak people were first apprised of the Enjebi problem in a meeting on Enewetak in September 1974. Subsequently they agreed amoung themselves to share the islands of Enewetak, Medren and Japtan as community sites and presented their individual residential preferences to the TTPI in December 1974. In addition, they were made aware of the necessity for a quarantine of Runit until the plutonium problem has been solved, and of the necessity of diet restrictions for their own safety.

7.1 IMMEDIATE AND GENERAL REQUIREMENTS

7.1.1 Return of the Enewetak People

The Enewetak people's return to their atoll is planned for three phases:

Phase I	Early Return -- An "advance party" of 62 people maximum would set up a temporary community on Japtan Island.
Phase II	Cleanup and Rehabilitation -- The "advance party" would support the cleanup and rehabilitation programs for the atoll.
Phase III	Resettlement -- Occupation of permanent housing by the Enewetak people.

The planned phases are defined as follows:

7.1.1.1 Phase I - Early Return. Acknowledging the Enewetak people's wish to occupy the island of Japtan as soon as possible, an "advance party" would be permitted to settle on Japtan Island during the first half of 1975. The "advance party" would be comprised of the following:

1. Ten heads of household with their family groups -- 50 people maximum.

2. The District Administrator's Representative and his family -- up to 12 people.

The "advance party", which may include a Health Aid and members of the Municipal Council and Planning Council, would initially set up a temporary community using the Earl Return Operational Plan (Tab E, Volume II) as a guideline. In addition to the temporary community construction, some planting, fish drying and seafood collection activities may be initiated. In consideration for their health and safety, all members of the advance party will be subject to close control of their movements throughout the atoll (Tab J, Vol II).

7.1.1.2 Phase II - Cleanup and Rehabilitation. Upon the completion of the Phase I work required to set up the temporary community, some members of the "advance party" would be hired and trained to assist in the cleanup and rehabilitation programs for Japtan, Medren, Enewetak and other adjacent islands. Work activities would include debris cleanup, construction of permanent housing and facilities, and planting programs. Those members of the Planning Council in the "advance party" would provide assistance in the detailed planning activities for the rehabilitation and resettlement (Phase III) program.

Throughout Phase I and II the "advanced party" would be limited to 62 people.

7.1.1.3 Phase III - Resettlement. Upon the completion of cleanup and construction of housing for permanent occupancy, the resettlement of the Enewetak people would take place in accordance with the Master Plan (Tab D, Vol. II).

It is expected that the TTPI would provide agricultural advisory services including the supervision of planting and maintenance of nurseries and groves. The TTPI would also supervise medical, communication and educational facilities, and provide any required assistance in economic, administrative or government affairs. This would include assistance for the educational program on radiation hazards and the ERDA continuing health monitoring program.

7.1.2 Residential Housing

The Enewetak people have decided to depart from their traditional separate-buildings-for-each-function (i.e., cooking, sleeping, washing, etc.) life style to integrated modules for all activities, except toilet facilities.

Three types of residential construction have been investigated. These were masonry block, reinforced concrete cast in place, and a modular reinforced-concrete construction called the W-panel System. The latter has been recommended because it most closely satisfies all design criteria. The panel itself is a welded steel wire 3-dimensional space frame 4 feet by 8 feet by 2 inches thick. The center of the modular space frame is filled with plastic foam leaving the face frame wire revealed approximately one-half inch from the face of its foam core on either side. These panels weigh only 25 pounds each, permitting easy handling at the construction site.

The erection procedure is relatively simple and consists of setting the panels in place and hand wiring them together, then sealing the vertical joint between the plastic foam edges with a bead of mastic. When complete, the resulting structure is then coated with a 1-inch thick layer of Portland cement plaster on both sides, using a plaster spray gun or hand plastering methods. This coating completes the structural composite of wire reinforcing, foam insulation, and cement plaster.

Roofs as well as walls can be constructed using this method resulting in the building becoming a true monolithic structure. Ceilings are not required since the plastic foam core in the roof panels contains adequate insulation. The advantages of this type of construction are:

- Elimination of formwork.
- Long-range structural life of reinforced cement construction.
- High insulation factor due to plastic foam core.
- Fire resistance.
- Low maintenance requirement for cement plaster.
- Waterproof.
- Impervious to termite, fungus, dry rot.
- Durability and adaptability to use of esthetically desirable finishes and textures or cement plaster.
- Excellent resistance to typhoons.
- Anticipated lower construction cost.

There are six different house types, including two 2-story, two 1-story single unit, and two 1-story split unit designs. All designs are based on a 12-foot building module and contain about the same amount of usable space. These various models were presented to the people for their approval and selection.

The number of residents per house to be constructed on Enewetak Atoll averages only four, a relatively low number for a typical Marshallese household. Since the population has tripled since 1945, it can be expected that population growth will continue to be rapid and the number of occupants per house could double in the next ten to twenty years. Therefore, provisions for altering room sizes and uses and future expansion of enclosed space have been considered. To maintain flexibility in multiuse of spaces, dividing walls between rooms are Shoji-type sliding panels 3 to 4 feet wide permitting these rooms to be enclosed or enlarged to suit the desired purpose.

Typical space allocations are as follows:

- Parents' sleeping room - 144 square feet (12' x 12').
- Boys' sleeping room - 144 square feet (12' x 12').
- Girls' sleeping room - 144 square feet (12' x 12').
- Utility core - cooking - food storage - 144 square feet (12' x 12').
- Living - 144 square feet (12' x 12').
- Eating - 144 square feet (12' x 12').
- General purpose porch - 288 square feet (12' x 24').
- Cistern - 72 square feet (6' x 12').
- Stair - 72 square feet (6' x 12').
- Washing porch - 144 square feet (12' x 12' on two stories) or 72 square feet (6' x 12').

The total square footage for a one-story house ranges from 1138 to 1463 square feet and for a two-story house it is 1626 square feet. In the one-story house, there are 976 square feet of enclosed area, while porches, cistern, and stairs (in the two-story models) occupy the rest of the roofed area, while the two-story models have 974 and 1139 square feet enclosed. The cooking area will include a counter top and sink for washing and a storage shelf underneath. A screened 4-foot by 4-foot pantry also would be provided for food storage. A separate 144-square-foot work shed would be provided with each house.

No electricity would be provided for the residences in the initial stage. Kerosene would be used for lamps and stoves. Rainwater from the individual roofs would drain into a 3,780-gallon cistern. A supplemental 3,200-gallon cistern would be provided with each house to guarantee an adequate water supply. A system for rationing water during dry spells would consist of faucets located at three different levels on the cistern. As water level decreases, the user is made aware of the situation when the highest faucet goes dry. In this way, water consumption can be regulated and supplemented with well water when required. A common well would serve each cluster and while the water may be too brackish for drinking, it would be adequate for washing clothes and dishes and for bathing (see paragraph 7.2.5). Plumbing fixtures in the house would be limited to a kitchen sink, shower room lavatory and shower head, and a utility sink on the washing porch. The shower floor would be depressed one foot below the finished floor permitting the installation of a shower head fed from the top of the cistern.

Sanitary facilities, in the form of privies (benjos), would be provided for each house and would be located not more than 200 feet to the rear of the house. Each privy would contain a water seal toilet and a 100 gallon tank for flushing and cleaning purposes. The tank would be fed from roof runoff. The water closets would discharge into septic tanks with as many as three closets interconnected to discharge into one tank. The septic tank leach fields would be located beyond the tanks and as close to the lagoon shore as would be feasible (see Tab G, Volume II for sanitary waste disposal study).

In the community centers on Medren and Enewetak Islands, a privy-septic tank system is planned only for the schools.

7.1.3 Land Use

Since the determination of the Ujelang Council in March 1974 to utilize Enewetak and Enjebi Islands as the major residential sites, the AEC Task Group Report on July 1974 has recommended against settling Enjebi. In the period between September 1974 (when this and other recommendations were made known to them in the presentation of the Draft Environmental Impact Statement), and December 1974 (during the Ujelang-Enewetak Field Trip), the Enewetak people and their councils agreed to settle on the three southern islands of Enewetak, Medren and Japtan. The driEnjebi and the driEnewetak would not be separated geographically as had been originally planned.

The Master Plan divides the islands of the atoll into three categories reflecting the primary functional use of each island, and also reflecting the recommendations of the AEC Task Group Report as defined in Case 3 of the EIS. The islands are designated as (1) inhabited, (2) agricultural and food gathering, and (3) picnic sites.

The first group of islands, those designated as centers of habitation, include Medren, Japtan, and Enewetak. Enewetak and Medren are to serve as permanent residential sites, while Japtan will be used for temporary quarters during the early return program and the atoll cleanup and rehabilitation. It will also serve as permanent residence for four families who have expressed a desire to live there.

As a consequence of the Ujelang meeting in December 1974, it was decided that Medren and Enewetak would be the two major residential islands with the four previously mentioned families in residence on Japtan. Extensive agricultural planting would complement the community development on these islands. The Ujelang meeting also established the following important points.

- The community center on Enewetak Island would be on the Mwillimor Wāto.
- The community center on Medren will be on the Lowit Wāto.
- No community facilities would be requested or built on Japtan to support the four proposed houses.

According to the Master Plan, only two of the eight islands selected for agricultural usage, Runit and Ananij, are in the southern sector of the Atoll. However, Runit has been quarantined until such time as the residual plutonium concentrations have been cleaned up and the island has been certified safe. The enforcement of this quarantine is the direct responsibility of the TTPI. Others in the northern sector include Alembel, Aomon, Bijire, Lojwa, Lujor, and Aej. The apparent imbalance between the larger number of agricultural islands in the north and the two in the south is offset to a degree by the relatively larger areas on Japtan, Medren, and Enewetak which will be under cultivation. Enjebi will not be cultivated until it has been declared safe for growing crops. This will depend upon the results of the current test planting program.

The people of Enewetak anticipate using the remaining 27 islands in the atoll for food gathering and fishing, as well as for recreational purposes. No permanent habitations are planned for these islands.

Agriculture on the inhabited islands in the first group would consist of both subsistence and cash crops, while the agricultural islands in the second group would be devoted almost entirely to cash crops.

The AEC Task Group Report makes the following recommendations relative to use of the islands in the atoll:

- The first villages would be established on any of the southern islands, Jinedrol through Kidrenen.
- Subsistence and commercial coconut may be grown anywhere except on Bokoluo, Bokombako, Kirunu, Louj, Boken, Enjebi, and Runit.
- Growth of all other subsistence crops and terrestrial foodstuffs except coconuts would be limited to Jinedrol through Kidrenen.
- Coconut crabs may be collected only on southern islands, Jinedrol through Kidrenen.

- Fishing and collection of birds and bird eggs would be unrestricted.

- Travel would be unrestricted except to Runit (until plutonium contamination is removed).

- Wells to provide water for human consumption or agricultural use would be drilled only in the southern islands, Jinedrol to Kidrenen. All water wells would be checked by the proper authority before being approved for use.

It is acknowledged that some of these recommendations are in conflict with the desires of the Enewetak people as expressed in the original Master Plan. However, it must be remembered that the prime purpose of the entire proposed operation would be the safe return of the people to the atoll.

7.2 INTERMEDIATE REQUIREMENTS

7.2.1 Island Communities

As indicated in Paragraph 7.1.3, Medren and Enewetak Islands would be the sites of the two permanent communities with four families living permanently on Japtan. Since preparation of the original Master Plan, it has been shown that it is impractical to establish homes or otherwise to develop Enjebi until such time as it can be shown to be radiologically safe.

Tentative plans have been prepared which delineate the wāto (land parcel) boundaries on Medren and Enewetak, which were determined by the people of Enewetak on Ujelang in December 1974. Field confirmation of the wātos by on-site surveys would be required prior to construction.

There is no wāto plan for Japtan although it is understood to be of multiple ownership as are all of the smaller islands. On Japtan, existing metal buildings augmented by additional structures as required would be modified to accommodate the early returnees and workers' families. The four families who would permanently settle on the island would be accommodated in the same type of housing as is proposed for Enewetak and Medren.

7.2.2 Cultural Considerations

The island residences would be arranged in clusters with the house of the extended family on each wāto group around a common courtyard. This courtyard acts as a focal point for social intercourse among the family groups for it is here that the younger children play, Kiemem(s) (1st year birthday party) and other celebrations are given, and daily gossip exchanged. The number of houses in any one cluster grouping varies, but in cases where there are eleven or twelve families living on one wāto, three clusters of four or five houses each would be provided.

The clusters would be situated along the lagoon side of the islands and near the road which runs parallel to the shoreline about 350 feet inland except for Enewetak Island where the road is between the lagoon and the housing clusters. Subsistence agricultural foods would be planted in and around the immediate area of the housing clusters, in the strip of land between the road and the lagoon. Privies (benjos), gardens, and animal pens would be located around the periphery of the clusters.

The housing density for the community location on Enewetak Island indicates the need for a residential cluster complex only on the Kabnene Wāto and Lokiob Wāto, at the southwest end of the island. All other housing would be grouped in single clusters.

The housing density on Medren indicates the requirements for multiple clusters on the Ininmedren Jiteonmwenelap Wāto and on the Wotto Lokanal Wāto. All other wātos would contain single housing clusters. Since accommodations for only four families are planned for Japtan, a single housing cluster would suffice for that island.

7.2.3 Environmental Considerations

Although the yearly climate and temperature around Enewetak remains relatively constant, extreme seasonal conditions with high wind, rain, and solar radiation do occur. Even though Enewetak is out of the typhoon belt, it is still susceptible to them and buildings would be designed accordingly. The people with first-hand knowledge of these conditions have requested the houses be made of materials with greater resistance to typhoons with a minimum design load of 35 psf on walls and roofs. To avoid water damage during such storms, the ground floors would be raised approximately two feet off grade using a perimeter wall footing with slab on fill.

Window openings are designed for maximum flexibility of ventilation, with a full floor to ceiling height and 6-foot width. The window unit itself consists of wood louvered shutters set above a 2-foot 6-inch balustrade. Sliding vertical slats under the balustrade provide ventilation at floor level and also prevent entry of animals. No glass is recommended in the window areas and louvers, slats, and hardware must be of sturdy construction for minimum maintenance. Individual requirements and siting conditions may alter window placement and frequency from unit to unit, but window type and dimensions would remain constant.

Bolted-on sun shades over windows project a minimum of 3 feet from the outside walls. The bolted-on sun shades are preferable during storm conditions since their loss does not affect the basic roof structure.

7.2.4 Community Center Development

Community centers have been planned for Medren and Enewetak Islands. In most instances, existing metal buildings would be used to house the community functions, some in place and others relocated to suit the arrangements. However, churches and houses for ministers and teachers would be of new construction. Community center facilities would include a four-classroom school, a two-bed dispensary and health aid quarters, an open-sided recreation building, a play field, a cooperative store, a council house containing the magistrate's office, radio transceiver equipment, weather office, and meeting hall, an open nursery and storage sheds, and a berm enclosed POL yard. Rain-water storage and water wells would be located in these areas for community use.

Each community would be provided with a four-classroom school building totaling about 3,600 square feet.

Small dispensaries would be located on Enewetak and Medren. Relocated metal buildings would be used in each instance to provide a two-room two-bed facility with health aid quarters. The total area required for each facility is approximately 1,200 square feet. The TTPI intends to man a dispensary with a health aid or nurse as is the case with other outer islands. A medical officer and dentist generally will accompany a field trip vessel which will call approximately once a month. Radiation related health problems may require evacuation to a properly equipped facility in Hawaii or on the mainland.

The typical council house would contain a meeting room, magistrate's office, radio and weather equipment, as well as the necessary power-generating equipment.

New churches would be built on Medren and Enewetak, functionally designed and built to resist extreme weather. They would be located in the community centers and would be large enough to accommodate both the present and expanded congregations.

The community centers would provide both indoor and outdoor recreational facilities. The outdoor facility would consist of a play field large enough for softball. Buildings would also be provided for indoor games and sports. Burial facilities would be in family plots on the respective wātos.

7.2.5 Utilities

The inhabitants of the atoll would have two sources of water for their daily requirements. Rainwater drained from roof catchment systems into cisterns for storage is considered the primary source. Brackish water wells located in the communities are expected to augment these supplies, provided their water does not contain dangerous amounts of radioactivity. Present planning provides for all cisterns to be filled with water from the camp distillation plant prior to its shutdown. This would insure an adequate initial water supply for the Enewetak people.

Each residence would be equipped with a primary cistern of approximately 3,800 gallons storage capacity. During dry periods, the types of rainwater usage would be curtailed commensurate with the receding water level, i.e., when the level reaches the lower third of the cistern, rainwater would be used only for drinking and cooking. Based on an initial daily requirement of 20 gallons per person, decreasing to 3 gallons per person as the supply diminished, a residential cistern would supply water to a family of 4 for 168 days without being replenished. Both the primary cistern and the additional 3,200-gallon capacity cistern to be provided for each house would be positioned to collect runoff from the entire roof area more efficiently and would double the available supply of water. Locations of the cisterns would be determined in the final design phase.

Rainwater from community building roof catchments will be stored in larger cisterns ($\simeq$10,000-gallon capacity). These would provide water to irrigate the plants in the community nursery and would also serve as a reserve water supply for the village.

Brackish water wells are planned to provide a supplementary source of water to the rainwater catchment systems. The wells would be located adjacent to the residential housing clusters and the community facilities, and normally would provide water for sanitary purposes. However, when rainwater supplies are low, well water can be used for washing and bathing and for drinking and cooking. The community wells would supply additional water for agricultural use as required. Skimming wells such as are being tested on Enewetak Island could provide a solution to this requirement. However, the success of these wells would be largely dependent upon the conditions of the fresh water lens. The feasibility of windmill-driven mechanical pumps to pump water for agricultural irrigation and other pumping applications, such as conventional power-driven pumps, wave pumps, and wind-powered pumps would be studied.

Each residence would have its own privy separately located to the rear of the house and would be equipped with a water seal toilet, for which a bucket of brackish water or a hand pump drawing from a brackish water source can be used to maintain the water seal in the fixture. The water closets would discharge into septic tanks behind the privies with as many as three closets interconnected to discharge into one tank. The septic tank leaching fields would be located beyond the tanks. A privy and septic tank is also planned for the school facilities for operation in the same manner as those in residential areas.

Other organic waste, such as garbage, would be disposed of by burial pits located near the housing clusters and close to the lagoon shore. These pits can become a source of compost for agricultural use.

Nonbiodegradable waste, including glass, plastic, and metal cans would be collected periodically and dumped into a predesignated deepwater location or buried in pits. If the burial method is used, one pit would be required for each residential cluster and could be located near the housing area. A central disposal area is also planned for both Enjebi and Enewetak. The meager amount of land available precludes extensive continuous use of burial pits.

Electrical power requirements for the communities on Enewetak and Medren Islands would be limited to operating a radio transceiver and a low level of lighting in the school, recreational building, and cooperative store. The dispensary and the council house containing the radio equipment would require more lighting than the other buildings. The total power and lighting load for each island can be supplied with a 2-kw generator unit, powered with either a diesel or gasoline engine. Due to the distances between the generator location and the furthest community building, 600 feet on Medren, a 110-volt system should be planned. To conserve on repair parts and maintenance, a 110-volt system should be planned for installation on Enewetak as well.

While present planning considers only the electrical requirements of community facilities, future plans may include residential requirements. If wind-generator units are found to be feasible as the main community power source, similar units might be used to provide lighting for houses.

At the conclusion of the atoll cleanup program, all existing utilities systems on Enewetak Island, including salt and fresh water, power generation, and distribution and sanitary sewer, would be disposed of in accordance with existing regulations and statutes.

7.2.5.1 Mid-Pacific Marine Laboratory (MPML). The MPML (formerly the EMBL) is expected to continue with its research programs under the sponsorship of ERDA. A new facility has been proposed to house the research activities and would be located at the northern end of Enewetak

Island near the Coast Guard Enclave (Master Plan, Tab D, Vol. II). It is understood that any support requirements for the MPML would have to be negotiated directly with the Enewetak people.

7.2.6 Transportation

Road systems linking residential clusters with community centers and other areas would be provided on Enewetak, Medren and Japtan. There would be approximately 9 miles of roads for light traffic on these three islands.

On Medren, some existing roads in the vicinity of the community center would be used, but the major portion of the planned 3.0 miles of roads would be new. The main access road runs parallel to the lagoon shore line and separates the residential and commercial facility areas from the commercial agricultural areas. Two loop roads parallel the ocean shore and join together at the community center.

The plan for Enewetak provides for using the existing 4.7-mile road network. The majority of these roads are paved and are easy to maintain. The road network could be expanded as required.

The existing road network on Japtan would be used during the period of the island's occupancy by the participants in the early return program and by the work force. This network contains 1.6 miles of roads and would be upgraded as required.

Paths for pedestrian traffic would be established by the inhabitants of all islands during the course of their daily routines, linking the residential clusters with both the community centers and the agricultural areas.

Copra exported from Enewetak Atoll would be carried on Trust Territory supply ships (field trip vessels). These ships make scheduled stops at the atolls through the Marshalls, carrying staples to trade for copra, as well as passengers. The inhabitants are dependent on the visits of the field trip ships for both subsistence items and luxury goods. This dependency on outside transportation would decrease if the Enewetak people obtain a vessel of their own. Tentative plans are centered around a 65-foot diesel-powered boat, rigged for an auxiliary set of sails. The vessel would be capable of making trips to Ujelang, Ponape, and other nearby atolls carrying copra directly to market, and also has accommodations for a few passengers.

There are no atoll docking facilities capable of accommodating field trip vessels at present. Existing pier locations on Enewetak and Medren Islands, where water depths are sufficient for shallow draft vessels or landing craft, are insufficient for vessels of deeper draft (field trip ships).

To accommodate Trust Territory vessels such as the Militobe and Truk Islander with a draft of 9 feet or the Yap Islander with a draft of 10 feet, it would be necessary to rebuild and/or extend existing piers on all three islands. A depth of 15 feet at low tide should be planned since it is known that some ships in field trip service draw as much as 12 feet of water.

The cargo pier at Medren is partially damaged by erosion from wave action and requires rebuilding. A 200-foot extension is required to reach the depth of 15 feet of water at low tide. The existing cargo pier at Enewetak will be used for berthing field trip ships. For this, a 75-foot extension would be required to reach a depth of 15 feet of water at low tide. These are estimates and final determination of the docking accommodations can only be made after comprehensive hydrographic surveys have been conducted.

Most of the intra-atoll (or interisland) marine traffic would consist of small boats generally about 20 feet in length. The majority of these would be privately-owned outboard motorboats used mainly for fishing and visiting other islands around the atoll. In addition to these craft, the two island communities will probably obtain small cargo boats for hauling copra. These are furnished to communities or island cooperatives through a Trust Territory Economic Development Loan Program. The boats are about 22 feet long and powered by small inboard diesel engines.

Marinas are planned for docking the small boats on Enewetak and Medren Islands. A small rip-rap breakwater would be constructed extending leeward from each cargo pier, running parallel to the shore line, thus forming a sheltered enclosure. The marinas would also serve as unloading points for the small copra boats whose cargo could be discharged directly onto the piers adjacent to the copra warehouse facilities. The establishment of a sheltered small boat harbor at the northern end of Enewetak Island has been proposed for the accommodation of the MPML research craft.

Air traffic at Enewetak would be light since the majority of the flights would be to support the United States Coast Guard or the Mid-Pacific Marine Laboratory and probably will not exceed a biweekly flight schedule. If some limited commercial activities would be established at Enewetak, additional flights could be scheduled as required.

7.3 LONG-RANGE COMMERCIAL/AGRICULTURAL PLANNING

7.3.1 Economic Development

Several possibilities for developing the economy of the atoll aside from the standard copra cash crop exist, including limited tourism, marine products processing, handicrafts, mariculture, and sport fishing. The economic advisor and the Planning Council would continue to discuss the best course to take.

The people of Enewetak have traditionally depended upon marine and plant life in and around the atoll for their subsistence. In recent years this diet has been supplemented by imported foods such as rice, flour, and canned commodities. Making copra and trading it for their staples is the traditional means of obtaining these imports.

At the present time, most of the coconut palms still remaining on the atoll are quite old and past their age of maximum productivity. Coconut seedlings would be planted and the islands involved and the density of the planting would be recommended by the agricultural advisor.

An estimate of yield, 5-7 years after planting seedlings, is that with a density of 61 trees per acre, the yield would be 0.4 tons of copra per acre. Current copra prices are about $250 per ton. At this figure the copra crop from each acre would be worth about $100 per year.

Whether the Enewetak people ultimately adopt or reject tourism as an adjunct to their economic development remains to be seen. The atoll is certainly not ready for large scale tourism; however, it is possible that some limited form of tourism could be established on Enewetak in the near future, providing the people with foreign exchange. Many of the basic facilities required to support such an enterprise are presently available on the atoll, on Enewetak in particular.

The airport on Enewetak is currently handling jet traffic and is an extremely valuable asset. The three-story dormitory facing the ocean on Enewetak could be converted easily into comfortable guest accommodations. The saltwater swimming pool on the north end of the island would be a natural focal point for tourists. An island store, stocked with necessities as well as local handicraft products, could be established in one of the existing buildings. An island taxi service could be established serving the airport, hotel, swimming pool, and boat loading. A bicycle rental service could augment the taxi operation and also serve as a means of recreation. Some tourists would be interested in the sport fishing in the atoll's ocean waters, which include sport fish such as wahoo, yellowfin tuna, mahi-mahi (dolphin), and marlin in abundant quantities. Other activities could include scuba diving in the lagoon and island tours; these tours might include visits to points of interest such as the island villages and Cactus and Lacrosse craters on Runit, after the island had been made radiologically safe. Tours of the lagoon in glass-bottomed boats or in minisubmarines might attract some tourists.

Copra exports and tourism presently rank one and two in the income producing industries of the Trust Territory. Fish exports are third, accounting for about 18 percent of the total in 1970, and appear to be steadily on the increase.

If it is economically feasible to establish a commercial fishery on Enewetak, it might also be profitable to include a seafood processing plant for future planning. Canning, or fast freezing processes require investigation. The lagoon and ocean waters at Enewetak contain an abundance of sharks. Shark fins are in constant demand throughout the Orient and commanded prices as high as $4.00 per pound in 1974. They are easily prepared for market, requiring only washing and sun drying for about 2 weeks. There is also a market for tanned shark hides.

Because the lagoon in sheltered and near the nutrient rich, deep ocean waters, it is a plausible location for mariculture. Time is needed, however, to identify and define the physical and chemical properties of the local aquatic environment, and experiments need to be conducted to determine the marine organisms best suited for mariculture at Enewetak.

7.3.2 Agricultural Development Plan

The purpose of agricultural rehabilitation is to provide subsistence and cash crops for the Enewetak people returning from Ujelang. Coconut, breadfruit, and pandanus, the principal crops, all require from five to seven years to come into bearing after being planted. This time estimate can be significantly delayed by adverse weather conditions, inadequate care of the developing orchards, or poor selection of seed sources. The initial agricultural development, including land preparation and planting, is estimated to take from 16 months to 24 months for completion. In the interim, the population would have to subsist on existing crop plants which can be rehabilitated, suitable short term crops planted following their return, and on imported foods. Dependence on imported foods may be lessened and additional copra production encouraged if the Enewetak people were provided with suitable ocean transportation and were encouraged to return periodically to Ujelang to forage and harvest copra and other food crops.

Future land use within Enewetak Atoll would be conditioned on the initial success with which the main inhabited islands can be rehabilitated and planted. Later the secondary or agricultural islands could be planted, thus providing additional sources of foods and copra for export. Also to be considered are factors such as real population growth (compared to current gross estimates) and the pressures this growth would place on available resources. In real terms, as additional population pressures are exerted on the limited resources, more and more of the resources would be consumed directly in support of the population and less would be available to generate income from outside the atoll. A number of the people have been exposed to education away from Enewetak and have developed strong tastes for imported foods and other luxuries. Additional internal pressures may develop to turn the future economy from a cash/ subsistence crop economy towards a total cash crop pattern, with the basic food requirements of the population being provided essentially by imported foodstuffs, as is the present case at Ujelang.

Agricultural rehabilitation and development of the atoll must fulfill two basic requirements: first, the basic subsistence requirements of the people returning to the atoll; and second, production of some type of cash crop which would generate income for the local economy. One crop, the coconut, satisfies both these requirements. Two other crops, breadfruit and pandanus, are essential in the subsistence diet, while other plant foods such as the banana, sweet potato, arrowroot, squash, vegetables, papaya, and lime are eaten when available.

The coconut is the staff of life of many Pacific peoples, and certainly of the people of Enewetak. This palm not only provides one of the most important foods directly consumed in the economy, but also is utilized for timber, cordage, thatching, firewood, matting, fiber, handicrafts, and medicine; there is hardly an area of life not touched by the coconut. The dwarf coconut palm, locally called Ni Karu, has also gained prominence in Marshallese communities. Because it is short, and the nuts are easily harvested, it is grown essentially for drinking and cooking and also for making a coconut toddy called "jakaru." Ni Karu is also a good landscaping material and is recommended for this purpose rather than as a plantation material.

Breadfruit, of which there are numerous varieties within the Pacific Islands, is used in the Marshall Islands as a major source of carbohydrate. Most varieties are cooked prior to eating, and one or two of the varieties are preserved as "bwiro."

The pandanus is grown for its edible fruit. It provides sugars and starches in the diet and is a good source of vitamin C. A number of varieties are used, and a suitable selection should be made of planting material for variety. Pandanus leaves are also used for thatching materials, weaving sleeping mats, and other articles. Nonbearing varieties can be used in plantation windbreaks.

The arrowroot is a major source of starch on many atolls. It requires some effort to prepare for eating. It is often used during food shortages resulting from storm damage and drought. Since it is a staple in the modern diet of the Enewetak people, it should be planted widely as a regular as well as emergency source of food because it spreads rapidly and requires very little care.

In addition to being the subsistence base of the people, the commercial or cash crop of choice and of necessity is the coconut. The commercial product is the dried meat of the mature coconut, known in the trade as copra. Copra, the major source of coconut oil, is one of the important world sources of edible oils. It is also a source of oil for soap manufacture. World production of commercial copra exceeds a million tons per year. Local consumption in the form of edible oils and other products probably equals this production. The Trust Territory of the Pacific Islands, where copra is a major export, have approximately 76,000 acres devoted to copra production. Production from Enewetak Atoll would be handled through the normal Marshall Island commercial channels.

Copra, or coconut production, is difficult to predict because of variables such as the anticipated yield of coconuts per palm at full bearing, which depends on soil fertility, weather conditions, and the genetic quality of the seed sources, all of which affect both the quantity of nuts produced per tree and the number of coconuts required to produce a ton of copra. Another variable is the quantity of coconuts required to meet the dietary needs of the local atoll inhabitants.

The Enewetak people want a number of exotic or introduced plant species as part of their diet. These include papaya, banana, citrus (lime), squash, and other vegetables. These foods enhance and add balance to the normal diet. Soils and climate are likely to be marginal for production of these plants without irrigation and intensive horticultural care. Inputs of labor and limited water resources may not justify planting these crops unless individuals or families wish to do so independently.

Other plants considered to be of aesthetic value and cultural significance should not be left out of the planting program. Some of these plants are used as local medicines and some are maintained for their landscaping and social values.

Structures considered dangerous to the returning people, and hazardous debris and rubble would be removed from all islands within the atoll during the major cleanup operation and would contribute to make a fuller use of available land. Land clearing in preparation for agricultural development would consist primarily of removing existing concrete slabs and buildings remaining after cleanup operations, trees, brush and shrubs, and ground cover. Much of this work would be carried out with medium bulldozers equipped with rake blades rather than straight blades. Every effort would be made to minimize damage to the soil profile and all organic material would be conserved for incorporation in the soil. The land to be planted would be selectively cleared with care taken to retain valuable trees and food plants and to retain existing windbreak areas.

Land leveling or grading would be required only in those areas where initial clearing operations have left the land in a rough condition. Old sand and gravel stockpiles would be leveled and old borrow pits would be filled. Some minor leveling could be carried out during the brush removal phases.

Agricultural rehabilitation of the islands, and particularly those islands where heavy construction and movement of heavy vehicles has destroyed or disturbed the normal soil profile, would require replenishment of the organic (humic) content of the soil. The soils in many low atolls are essentially coral sands and coraline soils. Inherent soil fertility is low at best and is held almost entirely within the organic fraction of the top few inches of the soil which is subject to very rapid breakdown when exposed.

Organic replenishment of the soils could be carried out through natural means, e.g., by allowing a slow accumulation of material through the natural growth and spread of trees and shrubs. However, this process is extremely slow, and any crop yields during this period would be marginal at best.

Trees, branches, shrubs, and all available plant material can be shredded, chopped, or disintegrated by rakes and shredders, and stockpiled for incorporation into the planting holes. This process is advocated for the three residential/agricultural islands, and also for those islands intended for intensive agricultural use. However, it is doubtful that sufficient plant cover presently exists on all islands (or even on all areas of each island) to adequately replenish the needed organic material for all potential agricultural areas. Therefore, it is suggested that serious consideration be given to incorporation from other areas, possibly the Pacific Northwest, of large quantities of organic matter (bark, wood chips, sawdust, etc.) for incorporation into deficient soil areas.

With Enjebi presently excluded from agricultural development, the major seed requirement would be approximately 76,700 selected seed coconuts. This estimate is based on the anticipation that failure or slow germination and culling of seeds in the plant nurseries would eliminate up to 40 percent of the total seed nuts obtained. Other plant material requirements would include approximately 1,100 rooted breadfruit plants and 1,550 pandanus cuttings. Other materials such as lime plants, banana suckers, papaya seeds, and similar materials would also be required but in lesser quantities. Utmost care should be taken in selecting the sources of these seed requirements since poor seeds would produce plants of inherently poor yields.

Plant nurseries would be established on Japtan, Medren, and Enewetak, which are intended for residential/agricultural utilization. Seeds and developing plants could be given good care on these islands where supplemental irrigation is good. These nurseries would accommodate coconuts, breadfruit, and pandanus; and would also maintain sources of banana, citrus, papaya, and other introduced plants for use by individuals as may be desired. Ornamentals may also be maintained in the nurseries to meet the desires of the people.

The planting of coconuts involves the placing of the seedlings in the prepared holes and burying them with sand to about the base of the growing portion of the plants. Where wind is prevalent, a wooden stake is required to secure the young seedlings. However, to minimize exposure to the tradewinds, alternate rows of native vegetation will be left in place to serve as windbreaks for the young plants. The planting of breadfruit requires overhead shades to protect the growing plants from direct sunlight. The whole box should be planted along with the breadfruit plant as transplanting (from box to hole) would damage delicate root hairs necessary for growth. A wooden stake is also required for securing the breadfruit plant against heavy winds. Pandanus plants are hardier than breadfruit and should be planted in the same manner as coconut seedlings. The use of a wooden stake is normally not required.

The proper maintenance of the growing plants is considered the most important aspect of the planting program. Although initial planting starts during the wet season (mid-May to December), irrigation of the growing plants would be required at least for the first year after initial planting, and especially during the dry season. The spot or direct irrigation method is recommended as opposed to an overhead sprinkler system.

Rainwater would be the major source of irrigation water. Construction of rainwater catchment systems and reservoirs with a minimum capacity of 50,000 gallons is suggested in plant areas. The reservoirs would have to sustain the crops through the seven month dry period (December to June) when the rainfall is only 34 percent of the annual 57 inches (Table 3-2). If this supply is inadequate, groundwater wells would be required as a supplementary source of irrigation water.

Commercial fertilizers would be required and their selection should be made only after the fertilization needs of the soils have been determined. It is possible that some of the results obtained from experiments and fertilization studies on coconut seedlings and palms conducted by the Philippine Coconut Research Center may be applied to the planting on Enewetak. The addition of trace elements in the chelate form, especially magnesium and iron chelates, is also suggested.

Adequate maintenance of the coconut, breadfruit, and pandanus plantings would be mandatory to avoid competition of weeds with the growing plants. At least a monthly cutting down of weeds and other unwanted vegetation in the coconut groves is recommended.

The use of herbicide or weedicide for weed control is also suggested but with limitations. An effective rat control program should be initiated and continued throughout the development and mature phase of the agricultural plan.

In view of the limited resources available within the Atoll, it is essential that maximum use be made of the land for the production of subsistence and cash crops. However, there is also a need to provide for the psychological and cultural requirements of the people. This must modify the purely agricultural or economic solutions to the major problem.

Agricultural development must be carried on in close relationship with village and community plans, with the residential clusters of the wāto as the focus of the plan. The residential cluster would be placed inland from the lagoon beach, and would be protected from exposure by plantings of pandanus, breadfruit, and coconuts, which would provide windbreaks, storm shelter, shade, food, and firewood. Bananas, lime, vegetable gardens, and ornamental plants such as spider lily, hibiscus, and plumeria may also be planted, depending on individual desire and inclination. In effect, the village areas would be wholly or partially surrounded with subsistence crops. The commercial plantings of coconuts would be placed to the interior of the island and toward the ocean. There should be no clear-cut and permanent boundary delineating the residential clusters, village centers, subsistence crops, and commercial crops. Instead, these areas would blend almost imperceptibly from one area of emphasis to another.

The remaining uninhabited islands in the atoll would be used primarily for family picnics, fishing, and gathering birds and eggs, turtles and eggs, coconut crabs, pandanus, iu, copra, and firewood.

7.3.3 Possible Modifications to Proposed Rehabilitation and Resettlement Plan

The recommendations contained in the AEC Task Group Report (Tab B, Volume II) have made it necessary to consider possible alternatives to the originally planned rehabilitation and resettlement of Enewetak Atoll. These are contained in the Master Plan (Tab D, Volume II). For example, these recommendations include using the islands of Japtan, Medren and Enewetak, or other islands from Jinedrol through Kidrenen for locating villages and residences. This recommendation was made to assure that exposures to residual radiation would be "as low as practicable". Some thought must therefore be given by the Enewetak people to adjusting their plans in keeping with the principles of radiation safety.

7.3.3.1 Remaining on Ujelang Atoll. This alternative, although contrary to the expressed desires of the Enewetak people would maintain them in a controlled environment with no exposure to radiological hazards. Inasmuch as Ujelang Atoll lacks sufficient natural resources to completely support the present 340 residents (Tobin, 1973), it is highly probable that large subsidies would be required to support the people should they elect to remain. The subsidies would have to be enlarged to keep pace with the projected population growth which is expected to reach 800 in 1984 (Master Plan, Tab D, Volume II).

7.3.3.2 Relocation to an Atoll Other Than Enewetak. This option would not provide the Enewetak people with any better living conditions than those under which they are at present. Most of the atolls in the Pacific are occupied, and it is doubtful that any of the few uninhabited atolls would support the Enewetak population. In addition, moving the Enewetak people to a foreign atoll would undoubtedly precipitate a radical change in their life style. In the end, this alternative would probably create more social and economic problems than if the people remained on Ujelang. This would be especially the case if the people of Enewetak were moved to an atoll that was already occupied by others. This would be expected to result in over-crowding, the eventual creation of a slum area and a gradual loss of identify as a people.

7.3.3.3 Compensation in Lieu of Return to Enewetak. The alternative of offering money to the Enewetak people for their land in lieu of their return to the atoll is contrary to their expressed desires. This would amount to purchasing the land and then designating it as a permanently unsafe area.

Such compensation might better their present economic condition, but it would still deny them the use of their land.

7.3.3.4 Return to Enewetak in Accordance with the AEC Task Group Recommendations. This alternative, while not completely fulfilling the plans of the Enewetak people for their return to the atoll, would be more compatible with their desires than the alternatives previously discussed. The Task Group Report (Tab B, Volume II) concurs on the return of the Enewetak people to the atoll, but recommends that the Enjebi community locate on the southern islands, possibly Medren and Japtan, for an indeterminate period. The duration of their stay in the south would depend on the time required for the reduction of the present levels of radiation on Enjebi to acceptable levels compatible with AEC guidelines for dose rates. In keeping with this philosophy, consideration would be given to the revision of agricultural plans for the northern islands. A test planting program has been initiated to determine when exposures would be within acceptable criteria. This program necessitates the deferring of planting subsistence and commercial crops on Enjebi and other northern islands until research with the test plantings showed acceptable levels of radioactivity. The current program will be conducted on Enjebi and it is expected to take 5 years before results are sufficient for analysis. Runit will be quarantined for an indefinite period, until such time as the plutonium has been successfully removed.

A possible alternate option for the driEnjebi would have been to settle on Bijire and Lojwa. While the combined land areas of the two islands is about one-third of that of Enjebi (92 acres vs 291 acres), the lagoon shore frontage is only slightly less than that of Enjebi (~3425 ft vs ~3700 ft). Also Bijire and Lojwa are the property of the driEnjebi.

It should be pointed out that the return of the Enjebi community to their home island could be deferred for as long as 50 years, or more, which would make their residence on other islands of a permanent nature. Housing and community facilities on these islands should be the same as were planned for Enjebi.

The expected curtailment of land use in the atoll would result in a setback to the economic planning of the Enewetak people. More than 300 acres on five islands, originally planned for copra and subsistence crops, would be unavailable for agricultural purposes for an indefinite period.

Another possible alternative which should be considered is the use of Ujelang Atoll as a plantation for growing subsistence and commercial crops as a supplement to those which may be planted on Enewetak Atoll. This could provide them with a source of food and a cash crop while the

Enewetak Plantings are maturing. In years to come productive plantations on Ujelang might be a necessity to support the growing Enewetak population. In keeping with this, on December 7, 1974, the people of Enewetak, through their council, submitted a resolution to the Department of Interior (DOI) requesting conveyance of title and ownership of Ujelang Atoll from the DOI to the Enewetak people.

7.4 EDUCATIONAL PROGRAM

The quarantine of Runit will be enforced by the people of Enewetak and the TTPI through their law enforcement agency. An educational program, presently in preparation, would be initiated to indoctrinate the people in the dangers of radiation. The program will emphasize basic rules which, if followed by the people, would permit them to live on the atoll with little danger from exposure to the residual low level radiation. Graphic illustrations of these rules as they apply to food sources, visits to the northern islands, fishing and food gathering would be included in the program.

As a further step, officials of the Trust Territory and the Marshalls District, as well as the peoples' legal representatives and others who would be involved in Enewetak Atoll activities would also be included in this program. They would be apprised of the seriousness of the problems which could arise from nonobservance of the restrictions. They also would be instructed in the necessary steps to be taken, should an emergency arise from negligence in enforcement of the restrictions.

It is possible that the educational program could be implemented as an adjunct to both the pre-return and follow on ERDA health monitoring programs which should detect any undue exposure to the residual low level ionizing radiation, and also would serve as a guide as to the effectiveness of the quarantine measures. Federal agency assistance for initiation or implementation of the educational program would be available upon request.

8. ENVIRONMENTAL IMPACTS OF THE PROPOSED CLEANUP OPERATION AND REHABILITATION/RESETTLEMENT PLAN

In this section, the impacts to the environment that would result from the levels of cleanup and associated activities related to the preferred case defined in Section 6 are identified and discussed in detail. It should be noted that the activities are divided into three categories:

- Base Camp.
- Cleanup.
- Rehabilitation and Resettlement.

These cover the base camp rehabilitation and operation, the actual cleanup activities, and the rehabilitation and resettlement program. All of these actions would have some degree of impact on the environment.

8.1 IMPACT OF BASE CAMP CONSTRUCTION ACTIVITIES

8.1.1 Human Health

The impact of the establishment of the base camp for the cleanup personnel is beneficial. The base camp would provide proper living quarters, and sleeping, dining, and working facilities, as well as the means to maintain a high standard of cleanliness in these areas. Janitorial personnel would clean each facility on a daily basis. The camp laundry would provide fresh bed and table linens, as well as clean clothing for the personnel as scheduled. Insect control measures would be established throughout the camp area and continued on a scheduled basis. The medical facilities would provide for the daily health care of all personnel, and the medical staff would be responsible for maintaining high hygienic standards in the kitchen and mess hall as well as in other facilities.

All equipment used in base camp construction will be operated in accordance with the provisions contained in the appropriate subparts and sections of Part 1926, Safety and Health Regulations for Construction, dated July 1, 1973.

8.1.2 Air Quality

Exhausts and fumes from motorized construction equipment and cooking facilities would have a very minor adverse impact on air quality. Prevailing trade winds and dispersion into the atmosphere will minimize this impact. Table 3-2 (Section 3) shows the percent of frequency of winds greater than 17 kts for each month of the year, observed over a 10-year period. The yearly average is about 32 percent. Since temperature inversions are unknown in that part of the Pacific, there appears to be little chance of a smog buildup. Also the equipment causing the exhaust fumes will be operating in widely separated locations when working concurrently (see Section 6), and the total number will be less than that found on a highway construction project in the United States. (See Paragraph 8.3.2 and Table 8-1).

8.1.3 Land Use

The stockpiling of usable materials for future use by the Enewetak people will occupy about 10 acres of land area which might be used for other purposes, e.g., agriculture. However, since the use of land for stockpiling would be temporary, this acreage would be released for agricultural development without permanently impairing its potential.

8.1.4 Terrestrial Flora

The movement of personnel and equipment during base camp construction will destroy some local vegetation. This impact would be minimal since little vegetation exists on Enewetak (Site Fred) because of the large surface areas covered by asphalt and concrete.

8.1.5 Terrestrial Fauna

The movement of personnel and equipment could possibly disturb birds utilizing the island. However, the only colonial nesters that utilize the atoll in large numbers are four species of terns (Woodbury, 1962) and they are not reported nesting on Enewetak Island. Therefore, base camp construction activities are not expected to have a significant impact on bird populations of the atoll area.

8.2 IMPACT OF BASE CAMP NOISE

8.2.1 Human Health

Personnel engaged in base camp construction activities, as well as others, who may be exposed to noise levels in excess of permissible noise exposures (Table D-2, Section 1926.52, Subparagraph D, Part 1926 - Safety and Health Regulations for Construction, dated July 1, 1973), will be provided with personal protection equipment in accordance with the provisions of Section 1926.101, Subpart E, Part 1926, SHRC.

8.2.2 Terrestrial Fauna

Noise associated with base camp construction activities could disturb birds that might be using the island for nesting. However, as mentioned above, no significant numbers of nesting birds are known to occur on Enewetak; so little impact, if any, is expected.

8.3 IMPACT OF BASE CAMP POWER GENERATION AND DISTRIBUTION

8.3.1 Human Health

Power generation and distribution will have a beneficial impact on human health in that it provides the energy necessary to distill drinking water, run sewage system pumps, provide lighting and power for refrigeration, etc.

8.3.2 Air Quality

In evaluating the effect on air quality of exhaust effluents of the diesel engines in the power plant, the worst case has been assumed, i.e., four 750 HP engines operating at peak load conditions for a 24-hour period. In addition, the engines are assumed to be the direct fuel injection type. Emissions of oxides of nitrogen, hydrocarbons, and carbon monoxide are calculated from basic data in grams per brake horsepower for that period of time.

Table 8-1 shows the estimated densities of those gases (lbs/cu ft) at the exhaust stack, 500 feet downwind, and 5,000 feet downwind. Density calculations are based on Pasquill Class D weather stability conditions, and a 12 kt wind was assumed (See Table 3-2 for frequencies of wind velocities.)

Since the volumes of these exhaust effluents are small in comparison to the vast area of open ocean, they would disperse. Any adverse impact to the air quality is considered to be minor.

It should be noted that other diesel powered equipment would be in operation in various locations in the atoll during the cleanup and rehabilitation program. However, they would be more dispersed, rather than concentrated in a single location. Their engines would be smaller and their usage would be intermittent in contrast to the continuous nature of the power plant operation. The emission of gases into the atmosphere from this equipment would be less than those shown in Table 8-1.

TABLE 8-1: DIESEL EXHAUST GASES DOWNWIND OF SOURCE

Gas	Downwind Distance		
	0 Ft	500 Ft	5,000 Ft
Oxides of Nitrogen	0.10203	0.00031	0.000001
Hydrocarbons	0.10176	0.00031	0.000001
Carbon Monoxide	0.10214	0.00031	0.000001

Notes:

Estimated Densities (lbs/cu ft) of Exhaust Gases from Four Diesel Engines Downwind from Source over 24-Hour Period.

Pasquill Class D Weather Stability Conditions from Figure 1, Appendix B, WASH-1238.

(Quantities of oxides of nitrogen, hydrocarbons, and carbon monoxides emitted are based on data furnished by Shepherd Machinery Co., Los Angeles Caterpillar Representative.)

8.3.3 Land Use

The power plant and associated transmission lines presently occupy some land area that might be used for other purposes. However, the total area occupied by these structures is less than an acre. No significant impact on land use is foreseen.

8.3.4 Terrestrial Flora

The power plant and transmission systems presently displace some native vegetation. However, due to the small total area involved, this impact is minimal.

8.3.5 Terrestrial Fauna

A few birds might fly into the overhead transmission lines and become injured Seabirds have been observed using the lines for resting and possibly watching for food in the lagoon. Minimal impact is foreseen on the bird populations of the atoll due to the presence of overhead transmission lines on Enewetak. Since these lines in most cases have been in existence for many years with no significant effect, it is anticipated that no problem would exist.

8.4 IMPACT OF BASE CAMP COMMUNICATIONS

8.4.1 Land Use

A very minor impact on land use would result from communications facilities since only a small amount of land area will be occupied.

8.5 IMPACT OF BASE CAMP TRASH AND GARBAGE DISPOSAL

8.5.1 Human Health

If improperly handled, trash and garbage can pose a threat to human health. During previous operations, mess hall garbage was dumped off the garbage pier located on the southwest tip of Enewetak. Prevailing ocean and tidal currents at this site tend to carry those materials which are immediately consumed by fish, out to sea. Trash will be burned near the pier and suitable ashes stockpiled for soil conditioning in agricultural areas. Unburnable residues are periodically pushed into ocean waters as the land available for burial is very limited. These disposal practices have been successful in the past and no adverse impact on human health is foreseen.

During nuclear test operations the population averaged about 3,000 persons. Trash disposal averaged approximately 100 cu yds of unburned residue and about 60 cu yds of garbage daily. The proposed 400-man base camp operation is not expected to produce more than 15 to 20 percent of those amounts.

8.5.2 Air Quality

If improperly handled, trash and garbage could contribute undesirable odors to the atmosphere. When disposed of as discussed above, no significant impact on air quality would occur.

8.5.3 Land Use

Trash and garbage will be disposed of as discussed in Paragraph 8.5.1 of this section. No impact on land use is foreseen. It is necessary to keep trash and garbage burial at a minimum because of the limited amount of available land.

8.5.4 Lagoon Use

By dumping garbage and burned trash residues off of the Enewetak garbage pier, prevailing currents carry the materials out to sea in a relatively short time period. No impact on lagoon use is foreseen.

8.5.5 Ocean/Lagoon Water Quality

No significant impact on ocean/lagoon waters would occur from burned trash residues and garbage disposed of as discussed above.

8.5.6 Groundwater Quality

With trash and garbage disposed of as discussed in Paragraph 8.5.1, no impact to groundwater quality would occur.

8.5.7 Terrestrial Flora

Trash and garbage disposal as discussed in Paragraph 8.5.1 would have no impact on terrestrial flora. However, it is possible that the ashes remaining from burning the combustible trash could be stockpiled and used as a soil conditioner in the preparation of the island for planting new vegetation. This would have a beneficial impact on the land as well as on existing and newly planted terrestrial flora.

8.5.8 Terrestrial Fauna

No impact to the terrestrial fauna is foreseen from trash and garbage disposal as discussed in Paragraph 8.5.1.

8.5.9 Marine Flora

Marine vegetation in the immediate vicinity of the garbage pier might benefit because of increased nutrient availability due to the dumping of burned trash residues and garbage. However, due to the prevailing currents, most nutrients will be quickly swept out to sea so the impact will be minimal.

8.5.10 Marine Fauna

The marine fauna, particularly fish, in the immediate vicinity of the garbage pier will benefit from the increased food supply. Therefore, the dumping of garbage and trash residues will have a slight beneficial impact on the local marine fauna.

8.6 IMPACT OF BASE CAMP SEWAGE DISPOSAL

8.6.1 Human Health

It is estimated that base camp support for the cleanup program will use about 100 GPCD. Of this 70 GPCD would be fresh water used in cooking, bathing and laundry activities while 30 GPCD would be saltwater used for sanitary flushing. The chlorides from the saltwater, which is 30 percent of the total, are estimated at 5,400 ppm. Total average peak flow of saltwater effluents from sanitary usage is estimated at 210 gpm. (Tab G, Volume II, EIS.) The present sewage disposal system on Enewetak consists of eight sewage outfalls. Seven of these dump into the lagoon; and one, which serves the air terminal building, dumps into the ocean. Due to the constancy of the northeast trade winds, surface ocean currents are generated which flow from northeast to southwest. These currents tend to flow into the lagoon over the submerged reefs on the northeast section of the atoll and through the east channel. Currents tend to flow out of the lagoon through the southwest passage and the south channel which borders Enewetak Island. The possibility of installing a sewage treatment plant was studied and the reasons for not doing so are detailed in Tab G, Volume II.

It is estimated that the action of the lagoon currents, and the exchange between lagoon water and sea water would result in a rate of exchange of one lagoon volume in about 40 days. This is based upon the assumption that conditions in the Enewetak lagoon parallel those in the Bikini Lagoon. Von Arx (Circulation Systems of Bikini and Rongelap Lagoons, 1954) states that 3.8 percent of a lagoon's volume is transported into and out of a lagoon with each tidal cycle. At that rate a complete exchange of volume would take place every 13 days. However, this rate of exchange should be reduced to an amount proportional to the ratio of the rate of exchange through reef passes to that of the "rectified flow" over the reefs. This would require a correction factor of about 3.0, resulting in a 39-40 day exchange of lagoon volume.

The materials which could survive the marine fauna would be carried out to sea through either the south channel or the southwest passage. There are no known reports of humans on the atoll suffering from the practice of raw sewage disposal in the lagoon. This includes the nuclear testing program when the atoll population numbered several thousand. The cleanup camp population is expected to be approximately 400 and the duration of the operation 24 months. On this basis and in view of prior experience, no significant impact on human health is anticipated. However, it has been reported that outbreaks of viral hepatitis have occurred in the United States and Sweden among persons consuming raw shellfish which were taken from fecally infected waters (Woodbury, 1962). Contamination of shellfish by sewage is essentially a problem involving bivalve mollusks. Waters in the tropical Pacific are generally low in phytoplankton upon which these animals feed, and thus bivalve mollusks are generally uncommon in tropical waters, including around Enewetak. A notable exception is the giant clam (Tridacna) which has evolved an additional nutritional mechanism. Tridacna clams are, however, rare along the lagoon shore of Enewetak Island (possibly because of heavy predation by human shell collectors over the past twenty years). Posted signs, information sheets, and briefings of personnel of this potential hazard will be conducted as a precautionary measure. Shellfish will cleanse themselves of pathogenic organisms in a relatively short time when the source of these organisms is removed (Helfrich 1973). Therefore, the possible contamination of shellfish in the area of the sewer outfall would be relatively short-lived if the sewage outfalls are no longer used after the cleanup personnel depart.

8.6.2 Air Quality

If not handled as described above in Paragraph 8.6.1, sewage effluents could release noxious odors into the surrounding atmosphere. Proper maintenance of the sewage disposal systems would minimize this probability.

8.6.3 Land Use

Since sewage would be disposed of through lagoon and ocean outfalls and since the sewage system facilities occupy such a small land area, no significant impact on land use is foreseen.

8.6.4 Lagoon Use

As discussed in Paragraph 8.5.1 of this section, shellfish found in the immediate area of the base camp sewage outfalls would not be eaten. To this extent the use of the base camp would restrict the use of the lagoon.

8.6.5 Ocean/Lagoon Water Quality

Since prevailing lagoon and ocean currents appear to transport sewage effluents from Enewetak Island out to sea within a 30-day period of time, minimal impact on the ocean/lagoon water quality is expected as a result of base camp sewage disposal.

8.6.6 Groundwater Quality

Sewage effluents disposed of by lagoon and ocean outfalls would have no impact on the quality of groundwater.

8.6.7 Terrestrial Flora

No impact to the terrestrial flora is foreseen from sewage disposal by lagoon and ocean outfalls.

8.6.8 Terrestrial Fauna

Base camp sewage disposal as discussed in Paragraph 8.5.1 would have no significant impact on the terrestrial fauna.

8.6.9 Marine Flora

Aquatic flora in the immediate vicinity of the sewage outfalls will probably show increased growth and abundance due to the increase in available nutrients.

8.6.10 Marine Fauna

With the exception of possible contamination of shellfish in the immediate vicinity of the sewage outfalls at Enewetak, no significant impact on the marine fauna is expected as a result of base camp sewage disposal.

8.7 IMPACT OF BASE CAMP FRESHWATER DISTILLATION AND DISTRIBUTION

8.7.1 Human Health

This impact is beneficial in that fresh water will be provided for drinking, cooking, and bathing.

8.7.2 Air Quality

Exhausts from the oil fired boilers of the distillation plant would affect the local air quality. However, due to the prevailing trade winds and dispersion into the atmosphere, no significant impact on the local air quality is foreseen (see Paragraph 8.3.2).

8.7.3 Land Use

The impact on land use is limited to the land area already occupied by the distillation plant and water distribution systems. These facilities already exist and only occupy about one acre of the total land area of Enewetak.

8.8 IMPACT OF BASE CAMP SALTWATER DISTRIBUTION

8.8.1 Human Health

Salt water will be used at the base camp for the sewage disposal system and the fire protection system. It also would be distilled to provide fresh water. The impact of this usage on human health is beneficial.

8.8.2 Land Use

The saltwater distribution system occupies less than one acre of land area that might be used for other purposes. However, such a small area of land is occupied that it provides no significant impact on land use.

8.9 IMPACT OF BASE CAMP AIR OPERATIONS

8.9.1 Air Quality

Exhausts from aircraft engines will temporarily degrade the local air quality. However, due to the prevailing trade winds and dispersion into the atmosphere, no significant impact is foreseen (see Paragraph 8.3.2).

8.10 IMPACT OF BASE CAMP MARINE OPERATIONS

8.10.1 Air Quality

Exhausts from marine craft engines would contribute pollutants to the atmosphere. Again, due to prevailing trade winds and diffusion into the atmosphere, no significant impact to the local air quality is foreseen.

8.10.2 Land Use

Small areas of shore line would be required for loading and off-loading marine craft during the establishment and operation of the base camp. Since only small areas would be temporarily involved and no other use of the shore line is contemplated, the impact on land use would be minimal.

8.10.3 Lagoon Use

As the marine operations progress, it is possible that a vessel might accidentally sink and create a hazard to future marine craft using the area. The possibility of this happening is slight, and no significant impact to lagoon use is foreseen.

8.10.4 Ocean/Lagoon Water Quality

During the course of marine operations, small quantities of petroleum products, e.g., fuel, oil, grease, etc., would undoubtedly be introduced into the marine environment. Due to the small quantity of these products expected to be released from a small number of marine craft and the larger volume of water involved, together with the continued exchange of ocean/lagoon waters by prevailing ocean currents, no significant impact to the local ocean/lagoon water quality is expected.

8.10.5 Marine Flora

The movement of marine craft would have no significant impact on the local marine flora. As discussed in the preceding paragraph, petroleum products accidentally introduced into the marine environment are not expected to be of sufficient quantity to produce any significant effects. Due to the prevailing ocean currents, accumulation of the small quantities released would not be possible. No significant impact to the marine flora is foreseen resulting from marine operations.

8.10.6 Marine Fauna

The preceding paragraph also applies to the marine fauna. No significant impact is foreseen.

8.11 IMPACT OF PESTICIDES IN BASE CAMP

8.11.1 Human Health

Pesticides have been used in past operations at Enewetak and would be required during base camp establishment and operations. Pesticides are required primarily for roach and fly control. Roaches are not known to be a specific vector of disease, but they contaminate food, have an unpleasant odor, and are serious pests (Borror and DeLong, 1963). Several species of flies including house flies, blow flies, and flesh flies occur on Enewetak (Woodbury, 1962). These flies are known to be vectors of typhoid fever, dysentery, cholera, yaws, anthrax, and some forms of conjunctivitis (Borror and DeLong, 1963); therefore, control of these insects is essential.

Pesticides used properly, i.e., applied only in quantities necessary for the required level of control in latrines, occasional treatment of living quarters and mess facilities during the temporary operation of the base camp, and not applied indiscriminately, would have an indirect beneficial impact on human health. Chlorinated hydrocarbons would not be used due to their persistence, and the fact that they have been shown to interfere with calcium metabolism in some species of birds causing weak egg shells and low hatching success. Nonpersistent organic phosphate pesticides would be used only in the quantities required to maintain the necessary level of control. All pest control operations will be conducted in accordance with OSHA Standards, Part 1910, Subpart G, Section 1910.93, Table G-1 and Section 1926.55.

8.11.2 Air Quality

Pesticides, improperly applied, e.g., spraying large quantities upwind of occupied facilities, would temporarily degrade the local air quality. However, if properly applied, as discussed in the preceding paragraph, no significant impact to the local air quality would occur.

8.11.3 Land Use

The application of nonpersistent organic phosphate pesticides in the small quantities required for control would not have any significant impact on land use.

8.11.4 Lagoon Use

As above, the use of nonpersistent pesticides in small quantities would have no significant impact on lagoon use.

8.11.5 Ocean/Lagoon Water Quality

No significant impact on the local ocean/lagoon water quality would result from the use of small quantities of nonpersistent pesticides for terrestrial insect control.

8.11.6 Groundwater Quality

The small quantities of nonpersistent pesticides required for insect control would not have a significant impact on the groundwater quality of the islands.

8.11.7 Terrestrial Flora

When properly applied, the small quantities of nonpersistent pesticides required for insect control would have minimal impact on the local vegetation. A slight beneficial impact to the local vegetation may result if populations of plant eating insects are temporarily reduced.

8.11.8 Terrestrial Fauna

The use of nonpersistent pesticides in small quantities would have a temporary impact on insect population in those areas treated, e.g., base camp. No significant impact to the other forms of local terrestrial fauna is foreseen.

8.11.9 Marine Flora

Nonpersistent pesticides applied in the small quantities required for terrestrial insect control in localized areas would not have a significant impact on the marine flora.

8.11.10 Marine Fauna

Little impact, if any, on the atoll marine fauna would result from the use of the small quantities of nonpersistent pesticides required for localized insect control.

8.12 IMPACT OF DEBRUSHING DURING CLEANUP

8.12.1 Air Quality

The exhaust emissions and fumes from motorized equipment and brush burn pits would temporarily degrade the local air quality. However, due to the prevailing trade winds and atmospheric diffusion, this impact would be temporary and minimal (see Paragraph 8.3.2).

8.12.2 Land Use

This impact is beneficial in that areas debrushed would allow scraping and the removal of contaminated soil and debris. Immediately after replacement of scraped soil with new soil, desirable vegetation types would be planted. All bare areas between plants would be sown with a hardy grass already present on the atoll such as Cynodon dactylon (Bermuda grass) to prevent soil erosion.

8.12.3 Terrestrial Flora

Debrushing to allow access to contaminated debris and soils would affect approximately 83 acres. The major impact on existing vegetation is adverse in that vegetation would be removed; however, soil enrichment would result due to mulching. Also, desirable vegetation would be planted immediately following cleanup actions in the affected areas so that the net result would be favorable.

8.12.4 Terrestrial Fauna

Debrushing will remove vegetation which provides nesting sites for some species of birds. Colonial nesting birds that utilize vegetated areas, such as the common noddy and the fairy tern, may be temporarily displaced if nesting sites happen to occur in areas to be debrushed. Amerson, 1969, records the breeding season for these colonial nesting birds as February through May. If debrushing activities are conducted before February, these birds can be expected to relocate to undisturbed areas. Activities after May should have little impact since these species would not be nesting; and upon their arrival the following year, they would likely relocate to undisturbed areas. Activities conducted during the nesting period might result in the abandonment of eggs of fledglings and in low hatching success.

8.13 IMPACT OF DEMOLITION OF STRUCTURES DURING CLEANUP

8.13.1 Land Use

This impact would be beneficial in that it removes debris and makes about 28 acres available for other purposes such as agriculture.

8.13.2 Terrestrial Flora

As above, the removal of debris will increase the available land area, allowing more land for growing desirable vegetation.

8.13.3 Terrestrial Fauna

Noise associated with the demolition of structures might disturb birds nesting in the vicinity. However, due to the temporary nature of these activities, no significant impact on bird populations is expected. A beneficial impact may be realized in that the demolition and removal of unsafe structures will eliminate some rat habitats and possibly result in a slight decrease in their numbers.

8.14 IMPACT OF SCRAPING SOIL DURING CLEANUP

8.14.1 Human Health

This impact would be beneficial in that soils on four islands containing high levels (>400 pCi/g) of plutonium would be removed for disposal. The risk of inhalation of plutonium (and subsequent internal disposition) to which visitors to these islands would be exposed would be greatly reduced by this action.

8.14.2 Air Quality

Equipment used for soil scraping and removal will contribute exhaust fumes to the atmosphere and temporarily degrade the local air quality. However, the prevailing trade winds and atmospheric diffusion will minimize this impact.

Radiologically contaminated soils will be kept moist by spraying with water from tank trucks during scraping and removal operations to prevent the formation of airborne contamination. Therefore, no significant impact on air quality from airborne contaminants is foreseen.

8.14.3 Land Use

The scraping and removal of plutonium contaminated soils would be beneficial to the returning people in that exposure levels would be reduced, and contaminated soils would be removed. Area and depth of scraping would be governed by ERDA guidelines and procedures, thereby creating more land area for eventual use. Areas to be scraped would be fogged with salt water to lay the dust. Since a mist spray would be used, it is anticipated that no adverse effects on the land due to use of salt water would occur, as might be the case if the soil were saturated. Deleterious side effects such as reduction of moisture content of the soil and loss of nutrients could occur as a result of this type operation. Fortunately the areas of concern are relatively small, about 5 acres total on Boken, Lujor, Aomon. On Runit the complete northern half of the island would be devegetated. It could be expected that many years would be required through natural weathering processes to achieve satisfactory conditions for agriculture. Importation of sterilized clean topsoil could be attempted to restore nutrients but no such operation has been known to be successful. Importation of soil was worked fairly successfully on Japtan during the German period; however, this was done in small quantities over a long period of time. This soil was really added to the existing soil, and no large scale removal of existing topsoil was involved.

8.14.4 Groundwater Quality

No significant impact on groundwater quality resulting from soil scraping is foreseen. On vegetated islands, groundwater is withdrawn by plants and transpired to the atmosphere. It is estimated that less than half, and perhaps only about a quarter of the groundwater recharge resulting from rainfall, remains after the evapotranspiration losses are deducted (Wiens, 1962). Increased evaporation rates from the soil due to devegetation and scraping are not expected to equal the normal transpiration losses by plants. Therefore, no depletion of the freshwater lens system or other adverse effects are foreseen. Scraping is beneficial to the extent that radionuclides which might continue to leach into the groundwater system are removed.

8.14.5 Terrestrial Flora

Areas requiring scraping and soil removal would be debrushed prior to this activity. The impact of debrushing is discussed in Paragraph 8.12.3. No additional impact to the vegetation would occur due to scraping.

8.14.6 Terrestrial Fauna

Scraping and soil removal would have little impact, if any, on the terrestrial fauna since these areas will be debrushed prior to this activity. The impact of debrushing on the terrestrial fauna is discussed in Paragraph 8.12.4.

8.15 IMPACT OF REMOVING SLABS DURING CLEANUP

8.15.1 Air Quality

Exhaust fumes from motorized equipment used for removing slabs would be released into the atmosphere. This impact on air quality would be minor due to the prevailing trade winds and atmospheric diffusion.

8.15.2 Land Use

The impact of slab removal on land use would be beneficial in that the area occupied by concrete slabs would be made available for other purposes, e.g., agriculture or housing. This is estimated at approximately 22 acres.

8.15.3 Terrestrial Flora

The removal of slabs would have a beneficial impact on the terrestrial flora in that a greater area of land would be available for planting new vegetation.

8.15.4 Terrestrial Fauna

The removal of slabs would provide additional areas capable of supporting vegetation. An increase in vegetated areas would provide new habitats for terrestrial animals. Therefore, this impact is considered to be beneficial to the terrestrial fauna.

8.16 IMPACT OF BLASTING DURING CLEANUP

8.16.1 Human Health

Marine craft would be required to transport cleanup equipment and debris removed during the cleanup operation. It would be necessary to clear access channels for the marine craft through coral in the immediate vicinity of some northern islands of the Atoll. Channel dimensions necessary for the safe operation of marine craft to be used are 150 feet wide and 6 feet in depth below the low-tide mark. Access channels would be required for Bokoluo, Bokombako, Kirunu, Louj, and Bokaidrikdrik. All channels would provide island access from the lagoon side only. No channels would be cut through the reef to the ocean side.

Other methods of obtaining access for equipment to the northern islands have been considered. Past attempts to "walk" heavy tracked vehicles ahore have resulted in the loss of one or more in deep water holes. The use of "flying crane" type heliocopters has been explored, but their capacity and range limits them to only the smaller types of equipment. In addition, there is some question as to whether their availability would be compatible with the projected schedule. The marine craft access channels would penetrate shoreward only that distance necessary to insure safe landing of personnel and equipment and also insure the capability of loading the collected debris onto the designated marine craft.

Gelodyn #1, produced by Atlas Powder Company, is proposed to be used as the explosive for clearing access channels for two reasons. First, it is environmentally desirable in that undesirable detonation products common to many other types of explosives have been eliminated in Gelodyn. The major species and quantities of Gelodyn detonation products are listed as follows (Atlas Powder Company, 1973)

Detonation Product	Moles/100g
H_2O	2.1902
H_2	0.0000 to 0.0013 (Trace)
N_2	0.9514 to 0.9517
CO	0.0000 to 0.0012 (Trace)
CO_2	0.5898
Na_2CO_3	0.0163
SiO_2	0.0181

Secondly, during the nuclear testing program at Enewetak, Gelodyn was proven to be more effective than explosives previously used for clearing marine craft access channels. Due to the superior coral shattering qualities of Gelodyn, considerably smaller quantities were required to accomplish an equivalent amount of channel clearing.

A field survey of coral conditions at each northern island requiring marine craft access would be necessary to allow an accurate determination of the quantities of explosives required. Most of the channel clearing would involve only the removal of coral heads and will require small quantities of explosives. However, some blasting of the coral reef would be required. Until accurate quantity requirements are determined by a field survey, it is proposed to proceed with a worst case assumption, i.e., that access channels must be cleared through solid coral for a length of 1,000 feet, a width of 150 feet, and to a depth of 6 feet below low-tide sea level. Channel clearing would be accomplished by positioning a total of 48 cases of explosives on 30-foot centers and blasting 200-foot long channel segments at a time. One segment would be blasted per day. The quantities of detonation products released into the lagoon each day during blasting operations are listed as follows:

Detonation Product	Wt in Lbs/Day
H_2O	945.6
H_2	0 to 0.00156
N_2	638.4
CO	0 to 0.806
CO_2	622.8
Na_2CO_3	41.4
SiO_2	26.04

The continual exchange of lagoon waters by ocean waters at Enewetak would dilute and carry these detonation products away in a relatively short time period. Standard blasting safety procedures would be followed, and only qualified blasting personnel would be in the area during channel clearing operations. Since the detonation products are not significantly hazardous substances and due to dilution and the exchange of lagoon/ocean waters within 30 days, no adverse impact to human health as a direct result of blasting is foreseen.

An indirect threat to human health is the potential ciguatera problem. Ciguatera is a Spanish term originating in Cuba for a condition where normally wholesome food fishes become toxic to man and other animals (Brock, et al., 1965). The exact biogenesis of ciguatera is unknown. Halstead, 1967, lists 26 theories on the origin of ciguatoxin, the poison of ciguatera. Recent findings indicate that the toxin is a complex of poisons (Helfrich, 1973). Most field investigators agree (according to Halstead) that the toxin has its origin in the algae food chain. Randall, 1958, postulated that the toxin responsible for ciguatera was possibly produced by a blue-green algae which occurred early in the pattern of succession of a newly denuted substrate. Such a substrate might be produced by blasting. The toxin is believed (Brock, 1965) to be passed along the food chain by herbivorous fish eating the toxin-produced algae. These herbivorous fish then become toxic, and carnivorous species feeding on them become toxic. These predators, upon death, recycle the toxin to fishes feeding on their remains. The exhaustion of the algae which produces the toxin is marked first by the absence of young toxic herbivores. Man can be affected by consuming toxic fish at any stage of the cycle. Tobin, 1973, relates oral historical accounts of poison fish at Enewetak. Limited samples of fish have been collected at Enewetak and tested for toxicity and no toxic fish were found (Banner and Helfrich, 1964). The algae (Schiszothrix calcicola identified by Banner, 1967, as a possible source of ciguatera has not been identified in the waters in or around Enewetak Atoll (Welander, 1966). However, one can only conclude that there has been inadequate sampling to make a scientific evaluation as to the toxicity or nontoxicity of fish at Enewetak. Likewise, it is not known if ciguatera occurred during or following the nuclear testing program since the normal indicator of fish poisoning on populated islands was not operational because the consumption of fish by the local population was prohibited during that time and for some time afterward. If the oral historical accounts of poison fish at Enewetak as related by Tobin, 1973, are accurate, there is no reason to assume that ciguatera would not reappear in the future. There is simply not enough known about ciguatera at this time to allow an accurate determination of whether the disturbance of the coral reefs by blasting five marine craft access channels would trigger an outbreak of ciguatera. In the event that ciguatera should develop at Enewetak, a temporary restriction of fish from the diet of the construction workmen would be imposed until the problem has passed. The Enewetak people are not expected to be present on the atoll in an unsupported role until a considerable period after the blasting occurs.

8.16.2 Lagoon Use

The clearance of access channels to the northern islands by blasting would have a beneficial impact on lagoon use. This would provide channels of safe entry to these islands and enhance the harvesting and transportation of agricultural crops such as copra.

8.16.3 Ocean/Lagoon Water Quality

The detonation products of Gelodyn #1 listed in Section 8.17.1 would be released into the lagoon waters. This impact to the lagoon water quality would be insignificant since the detonation products are not particularly hazardous and would undergo dilution and be transported out of the lagoon due to the continual exchange of lagoon water by ocean water.

8.16.4 Terrestrial Fauna

Noise associated with blasting could distrub birds that might be nesting on the lagoon side of islands requiring channel clearance. Woodbury, 1962, reported large numbers of Wedgetailed Shearwaters (15,000) in the vicinity of Bokoluo during a period from February 24 to May 24, 1962. However, these birds were in the lagoon and not nesting and would be expected to relocate to other areas during the placement of the explosives. If necessary, boats would be used to clear the blast area of birds prior to detonation. The maximum numbers of terns reported during daily observations of the same time period was 150 white terns on Bokoluo, Bokombako, and Bokaidrikdrik/Boken. These are not large numbers for terns which commonly nest in areas by the thousands. Amerson, 1969, lists the breeding period for the terns at Enewetak as occurring between February and May. Blasting during this period would disturb relatively few terns; if blasting is conducted after May, no significant distrubance is expected since the birds would not be nesting. The blasting of marine craft access channels is not foreseen to have any significant impact on the local terrestrial fauna.

8.16.5 Marine Flora

Some marine flora would be destroyed during the clearing of access channels. These species are expected to rapidly reoccupy areas of denuded substrate. The detonation products produced by the explosive Gelodyn #1 are not particularly hazardous substances and would be rapidly diluted and then carried away by the prevailing currents. The impact to marine flora as a result of clearing marine craft access channels would be minimal.

8.16.6 Marine Fauna

Some fish and other marine organisms in the immediate vicinity of the blast areas would be killed by concussion associated with detonations. Blasting would be carried out in shallow waters never greater than 6 feet in depth. By blasting at low tide, some areas would be very shallow or in some instances above sea level. Since the blasting would be conducted in shallow waters, much of the detonation shock wave would pass into the atmosphere and would produce much less underwater concussion than an equivalent detonation in deep water. Therefore, the effects of concussion are expected to be localized and no significant decrease in fish populations of the atoll is foreseen. However, blasting coral heads will create minute particles of coral which, due to the shallowness and insufficient quantity of water in the blast areas, would not wash away. Those coral particles would interfere with filter feeders in the lagoon and cause some kill in those species. A rapid repopulation is expected in the reef areas where blasting has occurred. The University of Hawaii has conducted studies to determine the repopulation of a reef after complete fish removal by poisoning. These studies have shown that several species moved into the area only a few days after depopulation. After 241 days, the species diversity of the study reef was approaching complete equilibrium and was about the same as the other control reefs (Wass, 1967).

Blasting of channels in shallow water in areas that do not have a great deal of natural cover can produce advantageous situations for marine organisms by creating additional habitats. Blasting may result in the creation of an ecotone which often produces an increased density and variety of organisms called an "edge effect." The ecotone concept in ecology relates to the transition zone between two diverse communities. Often the abundance of animals is greater in the transition zone between the two communities (deep and shallow water) than it is in either the deep water of the channel or the shallow water of the reef. This is known as the "edge effect." Evidence that this conditions follows the creation of a channel on a reef is indicated in research done at Johnston Island and on Kauai and Hawaii, Brock, Van Heukelem and Helfrich (1966), and Helfrich and Kohn (1955).

The quantities of detonation products that would be released into lagoon waters are not expected to have any significant impact on the local marine fauna.

It has been suggested that the disturbance of a coral reef, such as by dredging or blasting, would create an environment favorable to a significant population increase of the coral-eating starfish Acanthaster planci. This hypothesis is as yet unproven, although outbreaks have occurred in areas of relatively little disturbance (Reese, 1972). A review of reef damage by Acanthaster planci reports the findings of a team of divers from the U. S. Geological Survey and the Smithsonian Institution which spent nearly 2 weeks exploring the lagoon and reef of Enewetak Atoll (Ladd, 1971). Even though the reefs at Enewetak were dredged, blasted, and otherwise disturbed during World War II and the nuclear testing program, the divers found no actual specimens outside the lagoon and only three Acanthaster planci inside the lagoon. No evidence was found that indicated great concentrations of the starfish in the past. Since past reef disturbances apparently did not result in population increases of Acanthaster planci at Enewetak, it appears unlikely that the clearing of five marine craft access channels during cleanup operations will do so.

8.17 IMPACT OF STOCKPILING MATERIALS DURING CLEANUP

8.17.1 Land Use

The stockpiling of usable materials for future use would occupy about 10 acres of the land area which could be used for other purposes, e.g., agriculture. This impact is considered to be minimal as there is not a great amount of salvageable material to accumulate. (Engineering Survey, HN-1348.1) Usable materials will be collected and stockpiled in a central location, probably on Enewetak Island.

8.17.2 Terrestrial Flora

The temporary stockpiling of materials will occur on the various islands where demolition is in progress. There will be some destruction of local flora in those areas; but since the actions will be of a temporary nature, the impact also will be temporary. This situation will be ameliorated when the materials are removed, either for disposal or for accumulation in a central storage area on Enewetak. This storage area will be one of the existing hardstands which previously has been used for that purpose.

8.17.3 Terrestrial Fauna

Material stockpiling activities near the demolition sites will possibly disturb birds in the vicinity of those loacations. The movement of men and equipment during this operation could also destroy some land crabs. However, due to the temporary nature of this operation and the large numbers of land crabs at Enewetak, this impact is expected to be minor.

8.18 IMPACT OF DUMPING NONCONTAMINATED MATERIALS IN THE LAGOON DURING CLEANUP

8.18.1 Marine Fauna

It is proposed that steel and concrete debris be dumped at selected sites in the lagoon, in waters about 200 feet deep. During operations, a study would be performed to determine their exact locations. Currents acting on the materials as they sink to the bottom will tend to disperse them over a wide area. If fine-grained sediments are present on the bottom, most of the materials will probably become buried upon impact and some of the materials may provide habitats and refuge for some species of organisms. It is possible that this debris could be dumped in predesignated locations in the lagoon which would be determined to be most beneficial to the marine fauna. However, due to the vastness of the marine environment and low species diversity and abundance as compared to surface waters, the introduction of 115,000 cu yds of noncontaminated materials are expected to have minimal, if any, impact on the marine fauna.

8.19 IMPACT OF CRATER ENTOMBMENT OF RADIOACTIVE MATERIAL DURING CLEANUP

8.19.1 Human Health

It is expected that this would result in a beneficial impact in that the radioactive materials entombed in this manner would be fixed for a significant period of time in a relatively impermeable mass. This removes most of the respiratory hazard from the surface of the land and places the material in a known location which can be avoided but can still be observed. The durability of concrete over plutonium is an unknown factor, probably about 50 years. Some small leakage is expected; however, this could be controlled through monitoring. Thus, maintenance of the crypt would be a continuing problem.

8.19.2 Land Use

Containment of the radioactive materials in the Lacrosse Crater is expected to have a beneficial impact on the amount of land available on the atoll in that much of the land which is contaminated will then be available for other purposes. It would, however, leave a contamination legacy on Runit, and it would require periodic monitoring and maintenance.

8.19.3 Terrestrial Flora

Crater entombment would have a beneficial impact on the vegetation of the atoll. The semipermanent containment of radioactive materials by this method would prevent recontamination of the environment and consequent uptake of radionuclides by plants.

8.19.4 Terrestrial Fauna

The impact of containing radioactive materials in a crater on terrestrial fauna is similar to the impact in Paragraph 8.19.3. This would prevent the recontamination of the environment and subsequent uptake and internal deposition of radionuclides in terrestrial animals.

8.19.5 Marine Flora

Due to the expected minor leakage from the crater into the lagoon, some impact on the marine flora can be anticipated.

8.19.6 Marine Fauna

This impact would be similar to that in Paragraph 8.19.5.

8.20 IMPACT OF BURNING DURING CLEANUP

8.20.1 Air Quality

Burn pits would be established on islands in conjunction with debrushing and other cleanup operations for the purpose of vegetation and combustible debris disposal. Fumes and some airborne ash from these burn pits would enter the atmosphere. This impact to the local air quality would be short term and slight due to atmospheric diffusion and the prevailing trade winds (see 8.5.1). The amount of vegetation to be disposed of by burning would be proportional to the size of the areas to be debrushed. In Case 3, approximately 60 acres will be debrushed in the cleanup operation. However, it should be noted that only small amounts of vegetation removed by debrushing would be burned, as most would be chopped into pieces and plowed back into the soil as a mulch.

8.20.2 Land Use

No significant impact to land use is foreseen from the utilization of burn pits on those islands requiring debrushing. Burn pit areas would be covered with soil and leveled after use. Vegetation may show greater growth in these locations due to an increased availability of nutrients.

8.20.3 Groundwater Quality

If burn pits were centrally located on the islands, some leaching or residues into the freshwater (brackish) lens would eventually occur. However, burn pits would be marginally located on the islands. This places them on the lagoon side of the freshwater/saltwater transition zone thereby preventing the leaching of residues into the freshwater table.

8.20.4 Terrestrial Flora

The short term use of burn pits during debrushing and other cleanup activities is not expected to have any significant impact on the local terrestrial flora. An increased nutrient supply will be available to plants which become established over buried burn pits as well as from ashes collected after burning and distributed over the soil as a conditioner. Plants growing in the immediate vicinity of a burn pit may be killed by heat or fumes. Due to the prevailing trade winds and the small areas involved, this adverse impact would be minor.

8.20.5 Terrestrial Fauna

The construction of burn pits may affect habitats used by terrestrial fauna such as land crabs, birds, and rats. However, due to the small areas involved, this impact would be very minor. Heat and fumes produced from the burn pits are not expected to produce any significant impact on the local terrestrial fauna.

8.21 IMPACT OF NOISE DURING CLEANUP

8.21.1 Human Health

See Section 8.2.1.

8.21.2 Terrestrial Fauna

Noise associated with cleanup operations could have an adverse impact on nesting birds. Woodbury, 1962, reports that of nine species of terns found on Enewetak, four are found only in small numbers; one is common, but has not been found breeding; and four are common colonial nesters. A population approximating 45 to 50 thousand of the breeding terns forages in the lagoon and surrounding areas. Amerson, 1969, records the breeding season for these four species of colonial nesting birds found at Enewetak as February through May. Therefore, if cleanup activities commence after May, noise associated with cleanup activities, e.g., limited blasting and heavy equipment engine noise would have the least adverse impact as these species would not be nesting at this time. When the birds return to the atoll and commence with breeding activities the following February, much of the cleanup operation would be completed. It is anticipated that the birds would relocate nesting colonies to those areas where cleanup disturbance is minimal. Because of the widespread occurrence and abundance of the four species of colonial nesting terns known to utilize Enewetak Atoll, the impact of noise associated with cleanup activities would have no significant impact on the total number of these species.

8.22 IMPACT OF TOXIC MATERIALS ENCOUNTERED DURING CLEANUP

8.22.1 Human Health

The purpose of the cleanup program is to reduce the existing quantities of toxic materials on Enewetak Atoll to levels which would allow safe habitation of the atoll by the Enewetak people. Two categories of toxic materials presently exist, i.e., radioactive materials and slight beryllium contamination on a concrete building located on the southwest tip of Enjebi.

During the cleanup operation standard radiological safety procedures would be practiced. Radiological safety teams would monitor and maintain control of all areas determined to be radiologically hazardous and also control personnel and cleanup activities being conducted in these areas. Standard decontamination techniques would be employed if required during and upon completion of cleanup activities. Beryllium-contaminated materials would be disposed of along with the radioactive materials. No significant adverse impact to human health resulting from exposure to toxic materials during the cleanup is foreseen.

All operations involving the removal of beryllium contamination and its transport and disposal will be conducted in accordance with Part 1910, Occupational Safety and Health Standards, Subpart G - Occupational Health and Enviornmental Control, paragraph 1910.95 - Air Contaminants, and the values shown in Table G-2, dated July 1, 1973.

8.22.2 Land Use

The two categories of toxic materials discussed above presently limit the land use of the atoll. The cleanup program is designed to reduce these materials to levels determined to be safe for human habitation. The cleanup of these materials would release previously contaminated areas for more beneficial usage. Since extreme care would be exercised in their handling, no adverse impacts are foreseen.

8.22.3 Terrestrial Flora

Of the two categories of toxic materials present on the atoll, beryllium has no significant impact on the local flora because of its localization to a concrete structure on the beach at Enjebi and the existing low levels of contamination. However, present levels of radiological contamination provide an adverse impact on the local terrestrial flora. Some radionuclides are presently being incorporated into plants growing in contaminated areas. This uptake and internal deposition of radionuclides in plants causes some somatic and germinal cell damage due to the increased levels of radiation exposure. The cleanup operation which reduces the quantities of available radionuclides also would reduce exposure rates and the consequent biological effects on the local vegetation.

8.22.4 Terrestrial Fauna

As in the case of terrestrial flora, the localized, low-level beryllium contamination on Enjebi has no significant adverse impact on the terrestrial fauna. However, radionuclides in the local environment are being incorporated into the local food chains. Animals such as birds, crabs, and rats receive internal depositions of radionuclides by ingesting contaminated vegetation, preening and grooming contaminated materials from their bodies, by eating other contaminated animals, and possibly by respiration when appropriate conditions exist.

8.23 IMPACT OF TRANSPORT AND HANDLING OF HAZARDOUS SUBSTANCES DURING CLEANUP

8.23.1 Human Health

Standard radiological safety procedures would be practiced during the cleanup operation. These procedures include the use of radiological monitoring teams to identify hazardous areas and materials and to specify appropriate radiological protective clothing, equipment, and decontamination requirements. Contaminated soil would be moistened by spraying a salt-water mist prior to handling and transport to a disposal site. This would prevent the formation of airborne contamination and its consequent spread to noncontaminated areas. Appropriate safeguards would be employed to insure against contaminating personnel or areas along the transport route. No adverse impact to human health is foreseen resulting from the transport and handling of hazardous substances during the cleanup operation.

8.23.2 Air Quality

Engine exhausts from equipment used to handle and transport hazardous substances would enter the atmosphere. This impact to the local air quality would be minor due to the prevailing trade winds and atmospheric diffusion (see Paragraph 8.3.2).

8.23.3 Land Use

Necessary measures would be employed to prevent the spread of contamination during land transport and handling operations. No significant impact on land use is foreseen.

8.23.4 Lagoon Use

If a barge transporting contaminated materials across a portion of the lagoon were to accidentally sink, it would not seriously affect future lagoon use due to the existing radioactivity of the lagoon sediments and its minor effects on lagoon conditions. Although it is highly unlikely that such an accident would occur during normal operating conditions, the possibility must be considered. In Cleanup Case 3, plutonium contaminated soils would be removed from three islands and transported to Runit for preparation for disposal. Care must be exercised in navigation, and weather conditions must be considered to minimize the risk of accident during barging operations. All transport of radioactive materials by vessel away from the atoll will be accomplished in compliance with current regulations, 46 CFR 146.19. However, in intra-atoll transport, these regulations would be observed as far as practicable.

8.23.5 Ocean/Lagoon Water Quality

The preceding discussion also applies to this section.

8.23.6 Groundwater Quality

Care would be taken to prevent the spillage and contamination of clean areas along inland routes used for transporting and handling hazardous substances. If quantities of contaminated soil were spilled over a freshwater (brackish) lens system and allowed to remain, it is possible that radioactive contamination would eventually leach into the groundwater system and adversely affect water quality. The extent of radioactivity in existing groundwater lens is unknown at this time and is presently being investigated by the ERDA. If any accidental spills of contaminated soils occur, these spills would be cleaned up. No significant impact to groundwater quality is foreseen resulting from the transport and handling of hazardous substances in clean areas.

8.23.7 Terrestrial Flora

Some terrestrial vegetation will be destroyed by the movement of equipment used to transport radioactive materials during the cleanup operation. This impact to the vegetation resulting from the transport of hazardous substances would be ameliorated by planting desirable types of vegetation immediately following the cleanup operation.

8.23.8 Terrestrial Fauna

Little, if any, adverse impact to the terrestrial fauna would occur from the transport and handling of hazardous substances. A few hermit crabs might be run over by equipment used for the transport and handling of radioactive materials. However, hermit crabs are very abundant along beach areas of the atoll, and no significant decrease in their population is expected.

8.23.9 Marine Flora

The accidental introduction of radioactive materials into the lagoon, e.g., the sinking of a loaded barge, could have a minor adverse impact on the local marine vegetation. This impact would result from the uptake and retention of radioactive elements by marine plants. The probability of this happening is slight. No other significant impact to the marine flora is foreseen resulting from the transport and handling of hazardous substances during a cleanup operation.

8.23.10 Marine Fauna

The above discussion relative to marine flora also applies to marine fauna.

8.24 IMPACT OF REPLANTING VEGETATION DURING REHABILITATION AND RESETTLEMENT

8.24.1 Human Health

This impact is beneficial in that it represents the establishment of food sources which are of prime importance in the diet of the inhabitants. However, it is known that radionuclides will be present in locally grown pandanus, breadfruit, and coconut trees, e.g., ^{90}Sr and ^{137}Cs if planted in the northern islands of the atoll. These plants grown in the southern areas of the atoll will not be affected due to the very low levels of radiation present. Even after test plantings have been determined to be safe, discrimination should be exercised locating planting areas for these species to minimize the possibility of dietary intake of these radionuclides by the population. This potential problem is addressed in detail in Section 5 of this report.

8.24.2 Land Use

The degree of impact on land use in Case 3 is severe. Enjebi and the northern islands would be denied as usable land areas. Confining the atoll agriculture to the southern islands, Jinedrol through Kidrenen, may eventually result in insufficient production of food to support the growing population. Also, the adverse effect of maintaining both the Enjebi and Enewetak communities in the south would increase as the population grew. Other possibilities dealing with this problem are discussed in Section 7.

8.24.3 Terrestrial Flora

This impacts the existing flora to the extent that some species which have grown without restraint over the past 15 years will be cleared away to make room for other species more beneficial to man, e.g., pandanus, arrowroot, coconut, and breadfruit. Selected clearing methods would be used wherever possible to minimize this impact. All noncontaminated flora to be removed would not be wasted but shredded and added to the soil to increase the organic content.

8.24.4 Terrestrial Fauna

The clearing of undesirable vegetation from some of the islands to provide space for planting species more beneficial to the inhabitants could disturb birds utilizing the islands. These include four species of terns, some of which have been reported to be nesting on Enjebi and Runit at various times. (Woodbury, 1962, and Jackson, 1972). These impacts can be considered to be of a temporary nature as it appears that the terns vary their nesting habits from time to time. Overall, this impact will prove more beneficial to the birds because of the new trees being planted which will increase their nesting choices.

8.25 IMPACT OF BUILDING CONSTRUCTION DURING REHABILITATION AND RESETTLEMENT

8.25.1 Human Health

The impact of this activity on the health of the inhabitants may eventually be beneficial, inasmuch as the purpose of this construction is to provide new dwellings and facilities for community activities in accordance with the desires of the people and as indicated in the master plan. The construction itself, if conducted in a safe manner, would not adversely affect the participants. The houses and related facilities would provide a more sanitary and therefore a more healthy environment.

8.25.2 Air Quality

These effects are similar to those described in Paragraph 8.3.2.

8.25.3 Land Use

The building construction effort would be the culmination of the master planning for the atoll which embodies the desires of the Enewetak people regarding the use of the land area. Thus, building construction would have a beneficial effect on the use of the land.

8.25.4 Terrestrial Flora

This impact would be beneficial in that the existing flora would be replaced by houses for the Enewetak people. New plantings of coconut, pandanus, and breadfruit would also replace the existing flora to be removed. Effects are also similar to that described in Paragraph 8.24.3.

8.25.5 Terrestrial Fauna

The effects are the same as those discussed in Paragraph 8.24.4.

8.26 IMPACT OF NOISE DURING REHABILITATION AND RESETTLEMENT

8.26.1 Human Health

See Paragraph 8.2.1.

8.26.2 Terrestrial Fauna

Rehabilitation and resettlement activities which are noise producers, e.g., replanting, building construction, power generation, trash and garbage collection, and freshwater distillation will disturb those birds using the islands upon which these activities will occur. However, the noise impact would be temporary, lasting only for the duration of each activity.

8.27 IMPACT OF POWER GENERATION AND DISTRIBUTION DURING REHABILITATION AND RESETTLEMENT

8.27.1 Human Health

The effects of this activity during rehabilitation are the same as those discussed in Paragraph 8.3.1. Since resettlement power requirements can be met with a 2kW generator, there is no need for large capacity generators.

8.27.2 Air Quality

The impact is similar to that described in Paragraph 8.3.2.

8.27.3 Land Use

See Paragraph 8.3.3.

8.27.4 Terrestrial Flora

See Paragraph 8.3.4.

8.27.5 Terrestrial Fauna

See Paragraph 8.3.5.

8.28 IMPACT OF COMMUNICATIONS DURING REHABILITATION AND RESETTLEMENT

8.28.1 Land Use

See Paragraph 8.4.1.

8.29 IMPACT OF TRASH AND GARBAGE DISPOSAL DURING REHABILITATION AND RESETTLEMENT

8.29.1 Human Health

See Paragraph 8.5.1.

8.29.2 Air Quality

See Paragraph 8.5.2.

8.29.3 Land Use

See Paragraph 8.5.3.

8.29.4 Lagoon Use

Trash and garbage dumped from the garbage pier on Enewetak Island would have no impact on lagoon use (Paragraph 8.5.4). Garbage and trash dumped into the lagoon from other islands would probably benefit the local fish population and have no other effects on the use of the lagoon.

8.29.5 Ocean/Lagoon Water Quality

See Paragraph 8.5.5.

8.29.6 Groundwater Quality

Garbage burial pits would be located as close as feasible to the lagoon shore. This would prevent contact between the garbage and the central part of a freshwater lens. In addition, as the lens water migrates toward the lagoon from the ocean, any liquid effluents would be filtered through the coral formations into the lagoon. Solids, when decomposed would provide valuable mulching material for the agricultural effort.

8.29.7 Terrestrial Flora

See Paragraph 8.5.7.

8.29.8 Terrestrial Fauna

See Paragraph 8.5.8.

8.29.9 Marine Flora

See Paragraph 8.5.9.

8.29.10 Marine Fauna

See Paragraph 8.5.10.

8.30 IMPACT OF SEWAGE DISPOSAL DURING REHABILITATION AND RESETTLEMENT

8.30.1 Human Health

The use of septic tanks and leach fields for the permanent residents of Enewetak Atoll would represent an upgrading of the present methods of sanitary waste disposal in the Trust Territory. The effluent from these systems would be filtered through a minimum of 4 feet of coral before discharging into the lagoon and being liquid would mix readily with the lagoon water. The lagoon shore locations of the tanks and leach fields would minimize chances of contact with the central water tables, as the groundwater flow is from the ocean toward the lagoon (Section 8.30.6). See Tab G, Volume II.

8.30.2 Air Quality

See Paragraph 8.6.2.

8.30.3 Land Use

See Paragraph 8.6.3.

8.30.4 Lagoon Use

See Paragraph 8.6.4.

8.30.5 Ocean/Lagoon Water Quality

See Paragraph 8.6.5.

8.30.6 Groundwater Quality

Sewage disposal for resettlement will be upgraded to septic tank systems. Effluents will be collected from residential privies and discharged into septic tanks. The liquid effluents from the septic tanks will be discharged into leach lines. The tanks and leach lines will be located at shallow depths near the lagoon shore. This should provide a minimum separation of four feet between the invert of the leach lines and the lagoon edge of a water lens. A recent survey by Lawrence Livermore Laboratory indicates that subterranean lens water tends to migrate from the ocean side of an island toward the lagoon. In addition, the hydraulic gradient between the center of the island and the shore would aid in the flow of effluent toward the lagoon. On this basis, the effluents from the leach lines would enter the lagoon without contacting the central portion of the water lens, (Tab G, Volume II, EIS).

8.30.7 Terrestrial Flora

There would be no impact on terrestrial flora if present sewage disposal methods are continued. However, if new construction is implemented involving rerouting of sewers and/or the installation of new sewage facilities, the destruction of some flora can be foreseen. This can be expected to be confined to the immediate areas of the work thus limiting the impact on the terrestrial flora.

8.30.8 Terrestrial Fauna

There would be no foreseeable impact on the terrestrial fauna resulting from the current method of sewage disposal. Some disturbance to birds in the immediate areas of construction can be anticipated if new sewage facilities are installed.

8.30.9 Marine Flora

See Paragraph 8.6.9.

8.30.10 Marine Fauna

See Paragraph 8.6.10.

8.31 IMPACT OF FRESHWATER DISTILLATION AND DISTRIBUTION DURING REHABILITATION AND RESETTLEMENT

8.31.1 Human Health

See Paragraph 8.7.1.

8.31.2 Air Quality

See Paragraph 8.7.2.

8.31.3 Land Use

See Paragraph 8.7.3.

8.32 IMPACT OF SALTWATER SYSTEMS DURING REHABILITATION AND RESETTLEMENT

8.32.1 Human Health

See Paragraph 8.8.1.

8.32.2 Land Use

See Paragraph 8.8.2.

8.33 IMPACT OF RADIATION AFTER RESETTLEMENT

8.33.1 Human Health

The degree of impact on human health will be negligible as long as the safeguards and habitation plan stated in Case 3 are maintained (Paragraph 5.3.3). However, the potential of radiation related physical effects, although small, is present. The cause can be either from external exposure through residual radiological concentration or from internal exposure to radionuclides which have entered the food chain. Use of water obtained from wells would be limited to those islands where the radiological content of the water is deemed to be safe. Wells with water containing unsafe levels of radioactivity would be capped and would not be utilized by the people. The somatic risk resulting from Case 3 will be as a maximum, a doubling of the number of health effects from background alone. This can be seen in Table 5-12 where, for Case 3, the Maximum Expected Total Health Effects $[H(\text{Total})] \leq 0.3$. As this represents the difference in H(Total) between Case 3 and Background, and since Background $H(\text{Total}) = 0.3$, the maximum somatic risk is doubled. The possible minimum risk, it should be emphasized, is zero.

8.33.2 Land Use

The degree of impact on land use would be severe as only 12 islands, about 475 usable acres out of 950, would be available for living and agriculture. The direct impact would be denial of use of land for both living and agriculture. However, it is expected that Enjebi will be certified as safe for agricultural development at a future date. This would result in over 200 acres becoming available for planting.

8.33.3 Terrestrial Flora

There would be no impact on the indigenous flora. New plantings such as coconuts would be affected by uptake of radionuclides through the root system. A test planting program which will provide greater understanding of the movement of radionuclides in the ecosystem has been initiated. Information gained from this will be valuable to the ongoing agricultural development of Enewetak. Present indications are that preliminary results of the program may be available in five years.

8.33.4 Terrestrial Fauna

There would be no impact on the indigenous fauna. Fauna such as pigs, chickens, etc., brought in by the returning people can be affected by ingestion of food containing residual radionuclides present in food originating in the area.

8.34 IMPACT OF IMPORTATION OF SOIL DURING REHABILITATION AND RESETTLEMENT

8.34.1 Human Health

The effect of overlaying imported material on denuded areas determined to be safe for agriculture will be beneficial to the health of the islanders. Soil imported from sources outside the Atoll would be sterilized, thus negating the possibility of transporting foreign plant seeds and other forms of life to the atoll. Use of imported soil after adding the proper nutrients will result in crops relatively free of radionuclides.

8.34.2 Land Use

Land left in the raw state as the result of scraping (in some cases down to rock) to reduce the radionuclide concentrations to acceptable levels would be difficult to develop agriculturally. The addition of an imported soil overlay (with the proper nutrients mixed in) would make more land available for agriculture and enhance its productivity potential.

8.34.3 Groundwater Quality

The effect on groundwater quality of laying imported soil over scraped areas would be beneficial as it would replace the contaminated soil from which radionuclides have been leaching into the subsurface water lens.

8.34.4 Terrestrial Flora

It is not expected that any specimens of terrestrial flora would remain in those areas which have been scraped. However, it is possible that some seeds from existing plants could survive the cleanup operation. These would benefit from the imported soil overlay since it would provide improved conditions for plant growth.

8.35 SOCIOECONOMIC IMPACTS OF RESETTLEMENT

8.35.1 Life Style of the Enewetak People

It is expected that some stresses will be evidenced by the Enewetak people due to their relocation from Ujelang to Enewetak. There also may be stresses due to the reallocation of land which is the direct result of the loss of Enjebi as a community island for a number of years. In addition, stresses could appear in the every day conduct of the people which could be attributed to an uncertain economic outlook over the near future. However, the officials of the Trust Territory Government are experienced in dealing with displaced populations and have a depth of knowledge of the problems which could beset the people of Enewetak in their resettlement. It has been stated that the TTPI will accept the responsibility for solving these problems and will endeavor to make the transitional phase, as well as the following years as trouble-free for the people as is possible.

The impacts of resettlement which would be experienced by the Enewetak people can be both beneficial and detrimental. The positive or beneficial impacts are as follows:

- Fullfillment of the people's desire to return to their homeland.
- Establishment of traditional separate communities and their attendant social benefits.
- Construction of new housing which would provide lasting protection from the elements and more modern benefits including sanitary facilities.
- Use of existing facilities for possible future commercial development.
- Training of the people in operation and maintenance of equipment which would remain for their use.
- Salvaged materials stockpiled for the people's use or sale for economic gain.
- Training in new agricultural methods resulting in increased yields of both subsistence and commercial crops.
- Improved diet resulting from increased use of imported foods for a period starting with cleanup through maturity of crops.
- Availability of a larger and more prolific atoll providing for more potential economic growth.
- Greater exposure to modern western civilization which could enable the people to adjust their culture to modern methods.

The negative or adverse impacts might be as follows:

- Cultivation of agricultural products such as coconuts that might have limited international marketability due to the possible stigma attached to the point of origin which would be a slightly radioactive atoll, resulting in reduced income to the people. Although this is possible, copra from other atolls in the Pacific also is known to contain detectable quantities of radionuclides from atmospheric tests of nuclear explosives. At the present time it is extremely difficult to determine what level of radioactivity in copra would be acceptable without question.

- Growing dependence on outside sources of food which could result in neglect of local sources.

- Increased dependence on mechanized equipment with limited sources of fuel and repair parts.

- Increased exposure to western civilization which could initiate social stresses unknown at present.

- Problems concerning land tenure which can only be solved internally by the Enewetak people.

- Long term denial of land for use designated by the Enewetak people due to high levels of residual radioactivity which cannot be reduced to safe levels in a short time span.

- The probable relocation of the Enjebi community to one or more islands in the southern part of the atoll for an indefinite period of time, instead of being permitted to resettle on their home island, could result in extremely crowded conditions in the villages and low morale in both communities.

- Long term denial of land planned for agriculture would extend the length of time required for governmental, financial, technical, and administrative assistance to support the people until the atoll economy can be established.

- The physical and emotional stresses to which the Enewetak people could be subjected as a result of their relocation from Ujelang to Enewetak. Also the emotional stresses caused by living on land which is not their own. For the large number of the Enewetak people who are too young to have lived on Enewetak prior to the move to Ujelang, the adaptation to strange surroundings could cause problems which might require a long time to resolve. Even those who had resided on Enewetak before the move to Ujelang would probably have difficulty in reconciling their memories of the atoll with its present condition. The driEnjebi, who would not be returning to their traditional island (see above) would be required to adjust to living on the southern islands with no immediate hope of going back to Enjebi. In addition, the fact that the entire atoll population would be required to live in the southern sector of the atoll would create difficulties. The latest housing census (December 1974) shows that nearly all the people had compromised in their choice of residential location. These selections were determined by the people themselves without external interference. These factors, coupled with the people's uncertainties as to the future, could prove to be major problems for the TTPI to consider. It is understood that the TTPI and the Marshalls District Administration have personnel on their staffs, or others who are available for consultation, who are experienced and are competent in handling problems arising from population relocations. It is also recognized that, even with expert assistance, considerable time would elapse, before these difficulties could be resolved.

8.36 IMPACT OF RESETTLEMENT ON THE QUALITY OF THE ENVIRONMENT

8.36.1 Present State of the Atoll

Most of the natural resources of Enewetak Atoll are greater than those on Ujelang to which the Enewetak people have become accustomed. An abundance of fish and other marine life in the Enewetak lagoon and the nearby ocean waters has been reported. Seabirds are known to nest on some islands in great numbers. However, the atoll's vegetation leaves much to be desired with few trees, other than coconut, which would be useful to the people. Much of the land area is occupied by man-made structures and scrap, some of which is radioactive. Some of this would be hazardous to a returning people in a physical as well as a radiological sense. The soil on some islands is also radiologically contaminated. The atoll in its present state presents only a limited area for habitation.

8.36.2 The People and the Environment

The Enewetak people have lived on their atoll for centuries before their displacement. They have lived with the environment for so long that they have become a part of it. In the past they utilized the natural resources of the islands, the lagoon, and ocean waters to eke out an existence. They would return in greater numbers than when they left. It is doubtful that the existing natural resources could support them, even for a short time.

Marine resources form a large part of the daily diet of the Enewetak people. Coconuts are also a major item. Wild birds and birds eggs contribute to their daily fare. It can be categorically stated that the present resources of the atoll are insufficient to support the more than 400 people who would return.

8.36.3 Changes to the Environment

The proposed cleanup and rehabilitation of the atoll would result in definite changes in the environment. New housing and community facilities would take over land area which is presently occupied by deteriorating structures, piles of scrap, or wild vegetation. Other areas would be cleared for agriculture, i.e., coconuts, pandanus, and breadfruit.

The pollution caused by rehabitation would be present, although atempts would be made to minimize it. Sanitary facilities would be constructed which include septic tanks and disposal fields. The extent to which they would be used depends upon the inclination of the people. As in any community, there would be refuse and scrap as a result of daily living. It is intended that these be kept to a minimum through periodic collection and disposal. There would be atmospheric pollution from cooking fires, vehicle exhausts, and marine craft. However, it is not expected that there would be many internal combustion engines in use, and the effluents of combustion would be dispersed in the atmosphere over a wide area of open ocean (Paragraph 8.3.2).

8.36.4 Economic Outlook

It is a foregone conclusion that for at least the next decade the Enewetak people would not be self-supporting. The Trust Territory Government is encouraging the cultivation of coconuts for copra throughout the Marshalls. The selling price is relatively high at this time and there is no reason to expect a falloff in the world requirement for copra. For the majority of the atolls, copra is the basis of their economy. In the northern atolls, rainfall is a problem due to the annual dry season. Enewetak is no exception to this; therefore, a practical method of water storage and irrigation for agriculture would have to be developed before a copra economy can be realized. Present planning includes the construction of rainwater reservoirs on agriculture islands. Technical assistance in irrigation would continue to be forthcoming from the experts provided by the TTPI. Other means of economic development, such as the preserving of marine products, have been discussed. These would determine the success of any economical ventures.

It is known that over 400 people would return to the atoll, but it is not known how many of these would stay to work and develop the economy. The number of people under thirty is geater than those over thirty. It is possible that a large number of the young people would not want to stay to work on the plantations, but would rather enjoy the amenities of westernized civilization elsewhere. Under these circumstances, it is doubtful that the remaining older people would be able to handle future copra crops or would be inclined to do so. These factors coupled with a probable increase in population indicate that the Enewetak people would require outside assistance in economic development for some time to come.

9. ADVERSE ENVIRONMENTAL IMPACTS WHICH CANNOT BE AVOIDED

Potential impacts to the Enewetak environment resulting from the proposed cleanup operation were discussed in detail in Section 8. These impacts were identified by assuming the "worst case" in each instance. By conducting the cleanup operation in a preplanned, intelligent manner, the likelihood of these impacts occurring would be made negligibly small.

Operational surveillance would be maintained at all times to prevent unnecessary impact on the environment. For example, nonpersistent pesticides would be used, and these only in small quantities, in camp areas for temporary insect control; care would be taken to avoid spillage of hazardous materials during transport; lagoon transport would be conducted only when weather and lagoon conditions are ideal and in accordance with current regulations 46CFR146.19; materials would be permanently stockpiled only on predesignated surfaced areas; and sewage disposal systems would be maintained with outfalls placed at predesignated locations to cause the minimum impact on the marine environment. These measures would preclude occurrence of most undesirable secondary impacts. Adverse impacts which cannot be avoided are described below.

9.1 AIR QUALITY

Exhaust effluents from construction equipment, the diesel engines of the power plant, and fumes from burn pits would enter the atmosphere. These effluents are not voluminous and moreover would be dispersed rapidly by the prevailing trade winds (Section 8.3.2, Table 8-1). Thus, no significant deterioration of the air quality would result from the proposed operation.

9.2 LAND USE

Salvageable materials temporarily stockpiled for future use by the Enewetak people would occupy some land area which might be used for other purposes, e.g., agriculture. Material stockpile yards for permanent storage would be predesignated to minimize this impact.

9.3 OCEAN/LAGOON WATER QUALITY

Some impact to the ocean/lagoon water quality would result from trash, garbage and sewage disposal, blasting products, and small quantities of petroleum products, i.e., grease, oil, and diesel fuel associated with marine craft operation. Due to the continuous exchange of water between lagoon and ocean, most of these materials would be dispersed within a short period of time and carried out to sea (Section

8.6.1). No significant accumulation of these materials is expected, and therefore, this impact would be minor and temporary.

9.4 TERRESTRIAL FLORA

Some existing vegetation would be destroyed by debrushing activities and the movement of construction equipment used in the cleanup operation. Those areas debrushed would be planted with desirable vegetation types to ameliorate this impact.

9.5 TERRESTRIAL FAUNA

Some habitats used by certain species of birds, land hermit crabs, lizards, and rats would be destroyed during the course of cleanup activities. Additionally, some of the slower moving animals, e.g., land hermit crabs, would be destroyed by the movement of construction equipment. However, due to the abundance and distribution of these animals throughout the islets of the Atoll, no significant decrease in their population is foreseen.

Large colonies of nesting terns could be encountered and disturbed by cleanup operations. Work schedules would be developed, based on available data, to avoid disturbances of known nesting areas during the seasonal nesting period. In addition, construction personnel would be restricted from nesting areas throughout the nesting period. During the remainder of the year, it is expected that birds would relocate to other areas when disturbed and would not be significantly affected by the cleanup operation. During and after resettlement it is expected that the bird population may decrease since birds and birds eggs are a part of the diet of the Enewetak people.

9.6 MARINE FAUNA

Fish and other marine organisms would be destroyed in the immediate vicinity of blast areas during marine craft access channel clearing operations. Blasting would be conducted in shallow water that is never greater than 6 feet in depth. By blasting at low tide, some areas would be very shallow, or, in some instances, above sea level. Therefore, much of the shock wave will pass into the atmosphere, and concussion effects may be localized to a much smaller area than would be encountered by an equivalent blast in deep water. Although some fish would be destroyed, no significant decrease in the fish populations of the Atoll is foreseen. As fish are an important part of the Enewetak people's diet some of the species may become less abundant during and after resettlement.

9.7 SOCIOECONOMIC IMPACTS OF RESETTLEMENT

The expected increase in use of imported foods and modern equipment may result in the people becoming more dependent on outside sources for every day necessities. This dependence could also result in eventual neglect of the Atoll's resources and could require added sources of income to maintain a higher standard of living than had been experienced heretofore.

Social stresses which have not been apparent may become evident due to the move from Ujelang to Enewetak and the new community arrangements on Japtan, Medren and Enewetak islands. Also the increased exposure of the Enewetak people to modern western civilization could cause additional stresses.

Denial of use of Enjebi as a community site for an extended period of time could not only adversely affect the people's morale, but also create a situation where the agricultural effort in the south might eventually become insufficient to fulfill the needs of the growing population (See Tab F, Volume II, EIS).

9.7.1 Effects of Residual Low Level Ionizing Radiation

The effects of low level ionizing radiation as socioeconomic impacts will include the following:

- The use of Enjebi as a residential island will be delayed for an unknown number of years.
- The island of Runit will be quarantined against use until the radioactivity of its surface has been reduced to a safe level.
- The use of a number of potential agricultural islands will be lost for an unknown period of time.
- The production of copra, and the related monetary income to the atoll, will be reduced through the inability to utilize some islands.
- Through loss of Enjebi as a residential island, the solidarity of the driEnjebi will continue to decline and the old political divisions may ultimately disappear. It does not seem possible to place any value judgements on this occurring or not occurring.

10. RELATIONSHIP BETWEEN SHORT TERM OPERATIONS AND LONG TERM PRODUCTIVITY

The effects of the proposed operations are clearly beneficial to the long term productivity of Enewetak Atoll. This section summarizes the relationship between the short-term actions and effects of the operation and the long-term productivity.

The actions of debrushing, scraping, and cleaning debris from an island to reduce the risk of exposure to radiological and other hazards would produce a series of immediate, short-term adverse effects on the local environment. For one thing, areas on some islands would be denuded of vegetation. In addition, some wildlife and their habitats would be disturbed or destroyed during the course of the operations. However, once an island area is cleared, it can be prepared for development as provided for in the Master Plan. The long-term results are beneficial in that concentrations of plutonium are removed by scraping, then the area is covered with a shielding layer of topsoil. Desirable species of vegetation would be planted, such as coconut palms. The land also could eventually become available for village development.

Construction activities on the islands and the preparatory actions involved with the disposal of contaminated soil and debris in the area in general would adversely affect the local environment on a short-term basis. Vegetation and wildlife in the vicinity of these preparations for disposal would be disturbed and some wildlife habitats may be destroyed. These effects would be created by the movement of personnel and equipment engaged in the operations. Inasmuch as the construction activities would be conducted in accordance with master planning, the damage is considered insignificant when compared to the advantages gained by the inhabitants in adequate housing, community development, and economic advancement. These advantages are significant in comparison to existing living conditions of the people on Ujelang Atoll. Similarly, the long-range benefits which would be derived from the disposal of contaminated materials are significant, since these materials would be contained in a sealed crater.

The blasting of marine craft access channels in portions of the lagoon reef at five northern islands will destroy some marine fauna in the immediate vicinity. However, this effect will be localized and temporary. The diversity of species and abundance of fish are expected to be reestablished in these areas in about 200 days by fish relocating from adjacent areas (Wass, 1967). In addition, the long-term effect of blasting would probably show advantage by creating new habitats for fish.

This possibility is due to the ecotone and edge effect described in Section 8.16.6.

In summary, the short-term effects are minor and are more than offset by the tremendous gain in the long-term productivity of Enewetak Atoll which would result from the proposed cleanup operation.

11. IRREVERSIBLE OR IRRETRIEVABLE COMMITMENTS OF RESOURCES

The proposed cleanup, rehabilitation, and resettlement program would require the irretrievable or irreversible commitment of some resources. These consist of:

- Pu contaminated surface soils would be removed from five islands and contained in sealed craters on the island of Runit.

- Construction materials, such as lumber, structural steel, and concrete ingredients would be consumed.

- Petroleum products, i.e., fuels and lubricants, would be essential for the operation and maintenance of the construction and support equipment and would be consumed.

- Money and effort would be expended.

In return for these commitments, the Atoll environment would be tremendously improved. Land areas currently unusable due to the presence of radioactive and obstructive debris would once again be available for growing cash crops and for otherwise supporting the Enewetak people. Master planning would maximize the effective and efficient use of the resources of Enewetak Atoll. Hydrological investigation would determine the island areas capable of supporting low salt tolerant subsistence crops and such areas would be devoted entirely to agriculture. The adjacent, less productive areas would be used for housing, community functions, and planting of high salt tolerant crops such as coconut palms. The lagoon and ocean waters would again be harvested to provide for additional subsistence food requirements. This resource could play a large role in establishing the economic independence of the Enewetak people. The ultimate benefit from these commitments would be, of course, to the Enewetak people, thereby enabling them to resume life on Enewetak Atoll.

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