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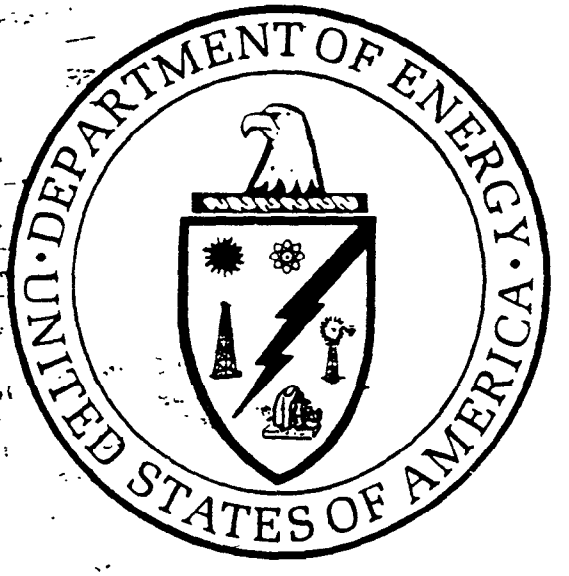
ENEWETAK RADIOLOGICAL SUPPORT PROJECT

FINAL REPORT



SEPTEMBER 1982

UNITED STATES DEPARTMENT OF ENERGY
NEVADA OPERATIONS OFFICE
LAS VEGAS, NEVADA

FOREWORD

This final report thoroughly documents the technical and logistic accomplishments of the Enewetak Radiological Support Project. The reader will readily recognize the magnitude and significance of the effort. This document duly recognizes all aspects of the project except one, possibly the most important though not so obvious to the casual reader. This was truly a cohesive scientific "expedition" because of the achievements, both personal and collective, of all the participants from a variety of governmental and private agencies. Particularly impressive to visitors at Enewetak was the ability of this group of scientists, technicians and support personnel to work in an environment relatively hostile to the required sophisticated technology. Despite adverse conditions, this team collected samples of soil, performed radiochemical analyses on the samples, applied statistical analysis to the data, interpreted the results and provided guidance to the Joint Task Group virtually overnight so that the daily activities for removal of contaminated soil could continue. This concerted effort under the leadership of the Nevada Operations Office is remarkable; its absence would have severely hampered the accomplishments detailed in this report.

William J. Bair
Manager, Environment, Health
and Safety Research
Battelle - Pacific Northwest Laboratory

July, 1982

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PREFACE

The work reported here may be said with some precision to have had its inception in September, 1975 with an agreement between the Energy Research and Development Administration (ERDA) and the Defense Nuclear Agency (DNA), committing ERDA to provide technical support to DNA in the cleanup of Enewetak. But in truth the effort had become an inevitable moral obligation of the United States many years earlier, in 1947, when the People of Enewetak were persuaded to leave their homeland to make way for our nation's atmospheric nuclear test activities. It might be said to have begun in April 1972 when Ambassador Franklin Haydn Williams and High Commissioner Edward E. Johnston promised the return of Enewetak to the administration of the Trust Territory. Or it might be said to have begun at Enewetak on May 20th, 1972, on the occasion of the first visit of the Enewetak leadership to their home atoll after 26 years away. On that latter occasion, Enewetak Magistrate Smith Gideon closed a four-day conference by saying to the United States officials, "We know that your people are going to help in cleaning up the place and preparing for our return to our home islands."

It was five years later that the mobilization for the cleanup occurred, and work began in earnest to prepare for the return. The intervening time had been used in surveying, establishing criteria, obtaining Congressional authorization and funding, planning, acquiring resources and developing equipment and techniques.

Radiological support to the cleanup was assigned as a mission to the ERDA Nevada Operations Office, which formed a project team known as the Enewetak Radiological Support Project (ERSP). For the most part, this is the report of that Project from its first authorization on February 23, 1977, to the completion of the cleanup. At this writing the ERSP remains in being on at least an informal basis, and will until this report goes to press.

A few brief words about the role of the ERSP are in order. The key word in the Project name is support. The Project Manager and his several Deputies did not direct the atoll cleanup action. They recommended, advised and assisted Department of Defense officials in carrying out the Congress' mandate for the cleanup. The Project takes full responsibility for its advice and recommendations, but often the decisions of the Director, DNA, the Commander, Field Command or the Commander of the Joint Task Group necessarily took into account overriding considerations of a non-technical nature. In these cases it was the responsibility of the ERSP Manager to define and articulate alternatives and their likely consequences and then to fully support the decisions and actions of the DOD. Another function which the ERSP did not perform was the establishment of criteria and standards. These were given to us in guidance received from AEC, ERDA, and later, DOE Headquarters. The ERSP management team interpreted these criteria and standards in terms suitable for direction of the field effort.

A special note of acknowledgement is due Bert Friesen, who served as Editor and a major contributor to this volume. The other members of the ERSP team are acknowledged and credited as appropriate elsewhere in this report. I feel confident that I speak for all of them in observing that it has been a rare privilege and a stimulating challenge to be a part of so unique a project of such high importance to so deserving a group of people. We wish the People of Enewetak health, prosperity, happiness and peace in their ancestral home.

Roger Ray, Project Manager
Enewetak Radiological Support Project
Nevada Operations Office

ACKNOWLEDGMENTS

Jobs are done by people; difficult jobs require special people with interest and dedication a cut above the normal work-a-day world. Planning, execution, and wrap-up of the Enewetak Radiological Support Project involved two categories of special people: those who put in a tour of duty on Enewetak Atoll, and those who performed their duties without the opportunity to participate first hand in this unique experience.

Duty rosters maintained during cleanup on Atoll list all of the following individuals as participants in the Enewetak Radiological Support Project. To these special people, and the organizations they represented, we express deepest thanks for a difficult job done well.

We wish also to acknowledge, with a special "thank you," the many people who did what they were paid to do as a part of their job, and are not named below, without whom the task would have been vastly more difficult.

For simplicity, individuals within each organization are listed in alphabetical order. Because organizations change names and people move to new jobs, we show the organization/employee relationship in effect during execution of the project. The exception to this rule is that all DOE employees are shown as DOE even though they worked for ERDA during the first few months of the project.

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ORNL

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C. Begley
C. Bell
K. Burnham
A. Doles
D. Ebenhack
M. Ennis
W. Frain
P. Griego
K. Gustafson
J. Hayden
N. Johnson
E. Lang
R. Martinez
W. O'Neal
M. Ortiz
W. Parker
R. Powell
A. Reust
B. Sanchez
E. Sanchez
G. Smith
P. Smith
D. Taylor
A. Whitehouse
D. Williams
P. Wilson
F. Zaman

EG&G

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R. Conner
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D. Beach
J. Chambers
L. Edwards
H. Erdman
D. Fettis
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E. Henry
G. Howell
B. Lemon
M. Montgomery
C. Okerstrom
R. Osborne
C. Passini
D. Price
D. Reed
J. Rice
D. Riedlinger
D. Robbins
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H. Strong
R. Swanson
D. Tucker
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U.S. NAVY

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G. Bartholomeo
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S. Bell
B. Bittle
D. Brock
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D. Fells
S. Fowler
G. Hritz
K. Hutchison
B. James
L. Johnson
D. Kaplan
D. Labbe
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P. Mann
P. Rivera
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K. Taylor
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ABSTRACT

From 1972 through 1980, the Department of Energy acted in an advisory role to the Defense Nuclear Agency during planning for and execution of the cleanup of Enewetak Atoll. The Nevada Operations Office of the Department of Energy was responsible for the radiological characterization of the atoll and for certification of radiological condition of each island upon completion of the project.

In-situ measurements of gamma rays emitted by americium–241 were utilized along with wet chemistry separation of plutonium from soil samples to identify and delineate surface areas requiring removal of soil. Military forces removed over 100,000 cubic yards of soil from the surface of five islands and deposited this material in a crater remaining from the nuclear testing period. Subsurface soil was excavated and removed from several locations where measurements indicated the presence of radionuclides above predetermined criteria.

The methodologies of data acquisition, analysis and interpretation are described and detailed results are provided in text, figures and microfiche. The final radiological condition of each of 43 islets is reported.

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ABBREVIATIONS AND ACRONYMS

ADC	Analogue Digital Converter.
AEC	Atomic Energy Commission. AEC was abolished on 19 January 1975 and many functions transferred to the newly created ERDA (cf).
Am	Americium. Specifically, the isotope ^{241}Am when the mass number is omitted.
AS	Amersham-Searle.
AFRRI	Armed Forces Radiobiology Research Institute.
BAF	Brush Attenuation Factor. More accurately BCF (cf).
BCF	Brush Correction Factor. Factor applied to the in situ gamma measurement to adjust for the presence of vegetation in the detector field of view.
BX	Base Exchange.
C	Commander; cf CJTG.
CDC	Control Data Corporation.
CEQ	Council on Environmental Quality.
CHEM	Chemistry. Usually refers to the wet chemistry component of the Enewetak Radiation Laboratory complex.
Ci	Curie. The quantity of any radioactive species undergoing 3.7×10^{10} nuclear disintegrations per second (dis/sec). Millicurie = 0.001 curie = 3.7×10^{7} dis/sec. Microcurie = 0.000001 curie = 3.7×10^{4} dis/sec.
CJTG	Commander, Joint Task Group.
cm	Centimeter.
Co	Cobalt. Specifically the isotope ^{60}Co.
CONEX	Container Express. Metal shipping container with approximate dimensions 4' x 6' x 8'.
CONPLAN	Concept Plan. An information technique used within DOD to provide general guidance for justifying a proposed major project. See OPLAN.
cpm	Counts per minute.
cps	Counts per second.
CR	Congressional Record.
CRT	Cathode Ray Tube.
Cs	Cesium. Specifically the isotope ^{137}Cs.
DEIS	Draft Environmental Impact Statement.

DF	Disposition Form. A memorandum form in common use by the military.
DIRDNA	Director, Defense Nuclear Agency.
DNA	Defense Nuclear Agency of the Department of Defense.
DOA	U.S. Department of Agriculture.
DOD	U.S. Department of Defense.
DOE	U.S. Department of Energy (established on 1 October 1977; absorbed ERDA).
DOI	U.S. Department of the Interior.
dpm	Disintegrations per minute.
DRI	Desert Research Institute. One component of the University of Nevada system.
EA	Enewetak Atoll.
EC	Enewetak Council.
EG&G	DOE technical support contractor for ERSP field measurements, Las Vegas, NV.
EIC	Eberline Instrument Corporation, Santa Fe, NM. Radiological support contractor for ERSP radiation instrument maintenance and calibration and for soil sample collection and analysis.
EIS	Environmental Impact Statement.
EOD	Explosive Ordnance Disposal.
EPA	U.S. Environmental Protection Agency.
ERDA	Energy Research and Development Administration; established 19 January 1975. Initial organization of ERDA included the AEC. Formation of the DOE included ERDA. ERDA was abolished on 1 October 1977 when the DOE was established.
ERSP	Enewetak Radiological Support Project (of the U.S. Department of Energy).
Eu	Europium. Specifically, the isotopes ^{152}Eu and ^{155}Eu.
FC	Field Command (element of DNA located at Kirtland AFB, NM).
fCi	Femto curies, 10^{-15} curies.
FCDNA	Field Command, Defense Nuclear Agency.
FIDLER	Field Instrument for Detection of Low Energy Radiation.
FPDB	Fission Product Data Base.
FRC	Federal Radiation Council.
FRST	Field Radiation Support Team. A military element (Air Force) of the Enewetak Joint Task Group.

FWHM	Full width at half maximum.
g	Gram
GAR	Gated Analogue Router.
GM	Geiger-Muller
GZ	Ground Zero. Land surface directly beneath or at the site of a nuclear test. SGZ and AGZ occasionally used to distinguish between tests at the surface and in the air.
h	hour, as in R/h.
H&N	Holmes & Narver, Inc., Orange, CA. Logistics and base support contractor for DNA and DOE.
HEPA	High Efficiency Particulate Air (type of filter).
Hg	Mercury.
HP	Hewlett-Packard. Electronics manufacturer, including desktop computers and laboratory equipment.
HPGe	High Purity Germanium - crystal for detection of gamma rays (also referred to as IG)
HQ	Headquarters.
HV	High voltage.
IAEA	International Atomic Energy Agency.
ICRP	International Commission on Radiological Protection.
IG	Intrinsic Germanium (detector). Also referred to as high purity germanium (HPGe) detector.
IMF	Instrument Maintenance Facility.
IMP	Not an acronym, but a trademark owned by the DeLorean Manufacturing Company. Although actually the manufacturer's name for the tracked vehicle used to house the in situ measurement equipment, this term was often used to refer to the entire system.
JCS	Joint Chiefs of Staff, DOD.
JTG	Joint Task Group.
KAFB	Kirtland Air Force Base.
keV	Kilo electron volt.
KT	Kilotons (nuclear tests are rated in thousands of tons of TNT).
LAB	Laboratory. See RADLAB.
LASL	Los Alamos Scientific Laboratory, Los Alamos, NM.
LARC	Landing Amphibious Recovery Craft.

LCM	Landing Craft, Mechanized.
LCU	Landing Craft, Utility.
LLD	Lower Limit of Detection.
LLL	Lawrence Livermore Laboratory, Livermore, CA (became LLNL in 1980).
LLNL	Lawrence Livermore National Laboratory.
LN	Liquid Nitrogen.
m	Meter.
MAC	Military Airlift Command.
MARS	Military Affiliate Radio System.
mCi	Millicurie.
MDA	Minimum Detectable Activity.
MFR	Memorandum For Record.
ml	Milliliter.
MILCON	Military Construction.
MILVAN	Military van. Military-owned container for transport of equipment and supplies.
MLSC	Micronesian Legal Services Corporation.
mm	Millimeter.
MPC	Maximum Permissible Concentration.
MPRL	Mid-Pacific Research Laboratory. (Formerly the Mid-Pacific Marine Laboratory, MPML.) Located at Enewetak, operated by the Univ. of Hawaii for the DOE.
mR	milli Roentgen.
mrad	millirad.
mrem	millirem.
MUX	Multiplex.
NBS	National Bureau of Standards.
ND	Nuclear Data (Corporation).
NIM	Nuclear Instrument Module.
NRC	U.S. Nuclear Regulatory Commission.
NTS	Nevada Test Site (of the DOE).
NV	Nevada Operations Office of the DOE (also NVO).

OMB	Office of Management and Budget.
OPLAN	Operations Plan. An operations plan is standard within DOD to provide specific guidance for conducting an approved major project. See CONPLAN.
ORNL	Oak Ridge National Laboratory, Oak Ridge, TN.
PACE	Pacific Cratering Experiments. Project included removal of soil down to coral rock in an area of 19 acres on the island of Sally.
PASO	Pacific Area Support Office (of DOE/NV), Honolulu, Hawaii.
pCi	Picocurie. 1×10^{-12} Curies.
pCi/g	Picocuries per gram.
PHA	Pulse Height Analyzer.
PGT	Princeton Gamma Tech, manufacturer of HPGe gamma ray detectors.
PIMM	Portable Instrument Maintenance Manual.
PLOWX	Plowing Experiment (site on Janet).
PM	Photomultiplier (tube).
PMEL	Precision Measurement Equipment Laboratory (electronics technician).
PNL	Battelle - Pacific Northwest Laboratory.
Pu	Plutonium. Specifically, the isotopes ^{238}Pu, ^{239}Pu, and ^{240}Pu. Context may imply the sum of these Pu isotopes.
QA	Quality Assurance.
QC	Quality Control.
R	Roentgen. A unit of exposure to ionizing radiation. It is that amount of gamma or X rays required to produce ions carrying 1 electrostatic unit of electrical charge in one cubic centimeter of dry air under standard conditions.
rad	Radiation absorbed dose. The basic unit of absorbed dose of ionizing radiation. One rad is equal to the absorption of 100 ergs of radiation energy per gram of matter.
RADCON	Radiation Control.
RADLAB	Radiation Laboratory. (Complex of trailers in which a radiation laboratory was established and used by DOE and ERSP contractors at EA.)
RCC	Radiation Control Committee (of the JTG).
REECO	Reynolds Electrical and Engineering Company, Inc., operating contractor for the DOE at NTS.
rem	A special unit of dose equivalent. The dose equivalent in rems is numerically equal to the absorbed dose in rads multiplied by the quality factor, the distribution factor, and any other necessary modifying factors.

ROM	Read-only memory.
RSAIT	Radiation Safety Audit and Inspection Team.
SAC	Scintillation Alpha Counter.
SATCOM	Satellite Communication.
SitRep	Situation Report.
SN	Serial Number.
SOP	Standard (or Standing) Operating Procedure.
Sr	Strontium. Specifically, the isotopes ^{85}Sr and ^{90}Sr.
TG	Task Group.
Tl	Thallium.
TRU	The transuranic elements. Specifically, ^{238}Pu, ^{239}Pu, ^{240}Pu, and ^{241}Am.
TWX	Teletype message.
TTPI	Trust Territory of the Pacific Islands.
U	Uranium. Specifically the isotopes ^{234}U, ^{235}U and ^{238}U.
UPS	Uninterruptible Power Supply.
USAF	United States Air Force.
Y	Yttrium. Specifically the isotope ^{90}Y.
μ	mu - Greek alphabet letter used to denote attenuation; also micro (10^{-6})
ρ	rho - Greek alphabet letter used to denote density.

CHRONOLOGY OF SIGNIFICANT EVENTS

*Double zero (00) in day (D) column means the day of the month is unknown, or that a span of time was involved such that a fixed day has no meaning.

**Events listed without a page number are not discussed in this report.

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**Events listed without a page number are not discussed in this report.

CHAPTER ONE: BACKGROUND

by Bert Friesen
Holmes & Narver, Inc.

1.1 INTRODUCTION

> "The light - it was many times brighter than the sun. The mountains back of us showed as clear as in daylight. We were stationed ten miles away from the explosion. At the five-mile station, two men were knocked over by the blast. The immense ball of flame rapidly going up into the sky was followed by a cloud of dark dust. The hundred-foot steel tower on which the bomb was placed was completely evaporated. The surface sand around it for a thousand feet was melted into glass." (Compton, 1956.)

Thus was the birth of the Atomic Age witnessed in secrecy on 16 July 1945, with the first test of a nuclear bomb, code named Trinity, at Alamogordo, New Mexico. Three weeks later, on 6 August 1945 (local time), the second nuclear bomb was detonated over Hiroshima, Japan, followed by the third bomb over Nagasaki, Japan, on 9 August 1945 (local time). The successful detonation in combat of these powerfully destructive weapons brought a quick end to World War II. The devices had worked as planned but very little was known of either the immediate or the long-range aftereffects.

Although the war had ended and no further military use was anticipated in connection with WW II, military officials were anxious to learn much more about the newest weapon in their arsenal. Theoreticians could predict enough of the effects from a nuclear explosion to realize that additional testing would have to be conducted in an area far from any population centers to minimize the dangers of exposure to hazardous radiation. The fourth nuclear device, Test Able, was detonated about 500 feet above a fleet of surplus naval craft at anchor in Bikini lagoon on 30 June 1946. Test Baker followed on 24 July 1946. The Baker device was suspended beneath a small landing craft, LSM 60, with the burst point at 90 feet below water surface.

> "The air burst (of Test Able), despite the damage it had inflicted, scarcely had prepared observers for the wrath of sound, light, and volcanic shock that erupted within the lagoon. At the moment of explosion, a giant bubble, brilliantly lighted within by incandescent materials, burst from the surface of the water to be followed by an 'opaque cloud' which quickly covered about half of the ships of the target fleet. Within seconds, the cloud had vanished and a hollow column, 2,200 feet in diameter and containing some 10 million tons of water, rose from the surface of the lagoon to a height of more than a mile. The 26,000-ton battleship, Arkansas, broadside to the LSM 60 but more than 500 feet away, was lifted and upended in the column before she was plunged to the bottom. At the base of the column was a tumult of foam several hundred feet high, and the descent of the water back into the lagoon set up a base surge from which rolled waves eighty to one-hundred feet high. The waves subsided rapidly as they proceeded outward, and the highest wave recorded at Bikini Island, three miles away, was seven feet, not sufficiently high to pass over the island or to cause damage there." (Hines, 1962.)

The brief chronology and quotations presented above set the stage for the rest of this document. Enewetak Atoll became a critical component of the very large and complex program of nuclear testing conducted by the United States from 1946 to 1958. Detonation of 43 nuclear devices at Enewetak Atoll created radiological conditions deemed too hazardous for unrestricted use of the atoll by future residents. The U.S. Department of Energy (DOE), acting in advisory and support roles to the Defense Nuclear Agency (DNA), participated in the radiological cleanup of Enewetak Atoll, undertaken to prepare the islands for their return to the people of Enewetak. Most of this report is devoted to a detailed description of the conduct by the DOE and its contractors of what became known as the Enewetak Radiological Support Project.

Readers are directed to other sources for additional background on nuclear testing in the Pacific or details on related topics. Hines presents an interesting account of the problems and successes of conducting radiobiological studies in the Pacific Proving Ground concurrent with nuclear testing. Compton and Groueff provide excellent views of how the atomic age was conceived and carried full-term to Alamogordo and Japan. The problems of dislocation experienced by the people of Bikini