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Nevada Test Site
Radionuclide Inventory and Distribution--
Project Operations Plan

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ABSTRACT

This document is the operational plan for conducting the Radionuclide Inventory and Distribution Program (RIDP) at the Nevada Test Site (NTS). The basic objective of this program is to inventory the significant radionuclides of NTS origin in NTS surface soil. The expected duration of the program is five years. This plan includes the program objectives, methods, organization, and schedules.

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I. INTRODUCTION

A. BACKGROUND

The Nevada Test Site (NTS) has been used to test nuclear weapons since 1951. Until the Test Moratorium in late 1958, most of these tests were conducted in the atmosphere with devices dropped from aircraft, suspended from balloons, placed on towers, or occasionally placed on the surface. The yield was typically low to intermediate--larger tests were fired in the Pacific Islands. In 1961, testing was resumed at NTS but the tests were conducted underground. This was mostly successful in containing radioactivity underground, although there have been several containment failures. From 1962 to 1968, several Plowshare experiments were also conducted in an attempt to develop nuclear explosives as a viable means of producing craters or trenches.

Several other activities have also been carried out at the NTS that are related to nuclear explosives. Many hydrodynamic experiments were done to examine the behavior of nuclear materials under high pressure and temperature, and several tests of nuclear engines and ramjets were conducted.

These activities have been conducted throughout much of the NTS and have caused extensive surface radionuclide contamination. These radionuclides consist of fission products (e.g., ^{90}Sr and ^{137}Cs), residual nuclear materials (e.g., ^{3}H, ^{235}U, and ^{239}Pu), device activation products (e.g., ^{59}Fe and ^{60}Co), soil activation products (e.g., ^{152}Eu and ^{154}Eu), and activation of radiochemical tracers (e.g., ^{174}Lu). The greatest activity was initially associated with short-lived fission and activation products such as ^{131}I, ^{187}W, and ^{239}Np; these short-lived radionuclides have all decayed. The radionuclides of current interest are all long lived such as ^{60}Co, ^{90}Sr, ^{137}Cs, ^{152}Eu, ^{239}Pu, and ^{241}Am.

In recent times there has been a strong interest in determining the inventory and distribution of these radionuclides in and near the surface. These materials are accessible to the present work force and to future populations; in some areas the levels are such that occupational safety problems could exist if the areas were to be uncontrolled. Such areas are candidates for remedial action. In addition, the NTS as a whole constitutes a large area source of resuspendible activity. While this is not believed to be a significant problem, a credible evaluation depends on an adequate knowledge of the inventory and distribution.

Several partial studies have already been conducted. There was a Distribution and Inventory Element (Church et al., 1974) of the initial Nevada Applied Ecology Group (NAEG). These studies were concerned primarily with $^{239,240}Pu$, and work was conducted both on- and off-site. Early on-site measurements consisted of surveys with the FIDLER instrument, which responds to the 60-keV gamma emitted by ^{241}Am. The activity of $^{239,240}Pu$ was then inferred by selective measurements of ^{241}Am and $^{239,240}Pu$ in soil samples and correlations with FIDLER-determined count rates. Many additional soil samples were collected and analyzed by radiochemical techniques, gamma spectroscopy, or both.

Distribution and inventory results for $^{239,240}Pu$ in ten areas (Project 57 site in Area 13; GMX site in Area 5; A, B, C, and D sites in Plutonium Valley of Area 11; and the four Roller Coaster sites in the Tonopah Test Range) were reported by Gilbert et al. (1975) and revised by Gilbert (1977). The area covered is 11.4 km^2.

In addition to these samples collected at safety-shot sites, an Overview Sampling Phase was conducted to identify areas of contamination. At least 73 event areas were identified as contaminated (Brady and Church, 1975), and priorities for more intensive soil sampling were established. Through 1975, over 6000 soil samples were collected in Areas 1, 4, and 5 of the NTS (Markwell and Church, 1977). Radiochemical methods were used to analyze $^{239,240}Pu$ in about 10% of these samples; all samples were counted on a Ge(Li) detector for 100 min. The plan was to infer $^{239,240}Pu$ concentrations from the ^{241}Am measurement (60-keV gamma) and to measure other gamma emitters. Many samples from Area 5 contained ^{137}Cs, ^{60}Co, and ^{152}Eu. These results were never reported in significant detail; the reason given is that all the data are open to question because of analytical problems that started at an unknown time (Dunaway and Markwell, 1980).

During the early years of the NAEG program, the capability of performing in-situ gamma spectrometry with a portable Ge(Li) detector was established at Lawrence Livermore National Laboratory, LLNL (Anspaugh et al., 1972), and a demonstration study was conducted at the NTS (Anspaugh et al., 1973). These early detector systems, however, were not as sensitive as desired at 60 keV. A more sensitive detector system was developed by Kirby et al. (1976). This consisted of four thin (2.5-mm), planar, high-purity Ge detectors having special electronic circuitry to combine the outputs of the four detectors. The success of this system led to a Nevada Operations Office (NVO) funded study at the Hamilton site in Area 5 that used both in-situ detector systems (Kirby et al., 1977a). Results were reported for 10 gamma-emitting radionuclides: ^{40}K (natural), ^{232}Th (natural chain), ^{238}U (natural chain), ^{60}Co, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{154}Eu, and ^{241}Am. A special study was also performed to compare the value of in-situ versus soil-sampling-derived data to estimate isopleths of $^{239,240}Pu$ concentration (Kirby et al., 1977b). The results indicated that the in-situ data were far superior; this is primarily because the in-situ detector surveys tonnes of soil, whereas a soil sample typically consists of a few grams.

Largely because of these results, the decision was made to change to in-situ spectrometry as the primary measurement method for the inventory and distribution work. Thus, during the last half of 1976, two high-purity Ge detectors were purchased by the Reynolds Electrical and Engineering Co. (REECo), and EG&G was given the task to outfit a van with appropriate supporting equipment so that in-situ spectrometry measurements could be made on a full-time basis at the NTS (Dunaway and Markwell, 1980). After the system was fabricated, it was transferred to the University of Nevada Desert Research Institute (DRI) in February 1977 for operation at NTS. DRI extensively modified the electrical supply system in 1977 and began taking data in 1978.

During 1977, EG&G also equipped three Thiokol IMPs (a small, lightweight, tracked vehicle) for in-situ spectrometry measurements at Enewetak Atoll. These systems used essentially identical detectors (high-purity Ge, 16-mm thick, 19-cm^2 area) as those originally purchased for the NTS survey. The systems worked well on Enewetak, but several detector failures occurred. This resulted in a competition for detectors, and the detectors at NTS were shipped to Enewetak on four occasions (Jaffe, 1980).

The DRI made 976 measurements in Area 5 during 1978 and 1979, and the results are reported by Barnes et al. (1980) on ^{60}Co, ^{137}Cs, ^{152}Eu, ^{155}Eu, ^{241}Am, and ^{239}Pu (inferred from the ^{241}Am measurements). The validity of the results, however, is uncertain because the detectors were improperly calibrated.

The DRI made additional, unreported measurements in Area 5; started collecting data in Yucca Basin; and was then instructed to measure the radionuclides on the perimeter of NTS until the project was suspended in February 1980.

The off-site part of the inventory and distribution project was conducted separately from the on-site activities. This study was conducted by the Environmental Protection Agency (EPA) and consisted of soil sampling and analysis of $^{239,240}Pu$ by radiochemistry and gamma counting for other radionuclides. The results for $^{239,240}Pu$ have been reported (Bliss and Jakubowski, 1977), but results for gamma emitters are not yet available.

In addition to these ground-based studies, several airborne surveys have been conducted. The NTS was overflown about 10 years ago, but the resolution was not very good and much of the area was not surveyed because of flight limitations of the fixed-wing aircraft in areas of rapidly changing topography. More recently, areas have been resurveyed by helicopter at lower flight speeds and elevations to provide better resolution and coverage. Results for external exposure rates are available for Areas 5, 11, 13, 18, 20, 25, 26, Yucca Valley, and part of the Tonopah Test Range. In general, these surveys provide excellent data but do not quantify concentrations of specific radionuclides.

In early 1980, the LLNL was requested by the NVO to provide an assessment and evaluation of the radionuclide inventory and distribution activities. The resulting report emphasized the need for an explicit formulation of goals and the adoption of appropriate methods that could achieve these goals within a specified time (Anspaugh and Kordas, 1980).

The LLNL was subsequently asked to prepare a workplan for a comprehensive Radionuclide Inventory and Distribution Program (RIDP), which would involve NVO, LLNL, EG&G, REECo, and DRI. The final version of this workplan was submitted in April 1981 and is included as Appendix A.

B. OBJECTIVE

The basic objective of the RIDP is to inventory the significant radionuclides of NTS origin in NTS surface soil. This includes estimating both the distribution of each radionuclide and also its concentration integrated over the surface of the NTS. Radionuclides of natural origin will also be included.

An important secondary goal is to provide the above data and complete the project in five years.

The accuracy required for the measurements has not been specified by end-use criteria. Our overall goal is to provide a final inventory that is known with 95% confidence within at least a factor of two.

C. METHODS

Three major methods of analysis will be used in this study.

(1) Airborne surveys of external exposure rate.

(2) Ground-based, in-situ spectrometry analysis of external exposure rate and radionuclide concentration.

(3) Soil sampling and analysis of the concentration of alpha, beta, and gamma emitters and their distribution with depth.

The airborne surveys provide rapid, broad areal coverage but produce reliable data only in terms of the total external exposure rate from terrestrial sources. They cannot be used alone to construct radionuclide concentrations in soil. Ground-based, in-situ spectrometry with Ge detectors is much slower than aerial surveys but can provide excellent close-in data of the concentration and external exposure rate for each individual radionuclide (Anspaugh, 1976; Beck et al., 1972). Because both the aerial survey data and in-situ spectrometry data can produce the common measurement of total external exposure rate, the in-situ spectrometry data can be used to calibrate the aerial survey data. However, the in-situ spectrometry data must also be calibrated or supported by additional data that can best be obtained by soil sampling and analysis. This is becaus- calibration of in-situ spectrometry data at a particular location depen , on knowledge of radionuclide distribution with depth, soil density, and the soil mass attenuation coefficient. In addition, in-situ spectrometry cannot measure radionuclides that emit only beta or alpha particles. Thus, in-situ spectrometry data must be calibrated by soil sampling and analysis, and aerial survey data must be calibrated by in-situ spectrometry data. The combination of all three data sets represents an optimum strategy for rapid determination of radionuclide inventory and distribution.

II. ORGANIZATION

A. NEVADA OPERATIONS OFFICE

The NVO has overall management responsibility for the project. As the funding agency, they have ultimate responsibility for the program and sole authority to determine the goals and schedule according to budgetary constraints. This authority is vested in the Manager (Mr. Mahlon Gates) and has been delegated to the Health Physics Division Director (Mr. Bruce Church). The NVO Program Director in the Health Physics Division is Mr. Paul Dunaway. The Deputy Program Director is Mr. Thomas M. Humphrey. The Project Officer, who will supervise the day-to-day operations, is Ms. JoAnne C. Burrows.

B. LAWRENCE LIVERMORE NATIONAL LABORATORY

The NVO has asked LLNL to provide the overall technical direction of the RIDP. Dr. Lynn Anspaugh is designated as the Technical Director and Mr. Joseph Kordas as the Deputy Technical Director. The Technical Directors, operating under the guidance of NVO, will determine the methods to be used in the study and the detailed schedules. They also have responsibility for in-situ detector calibration, data quality, data processing methods, and reports.

C. The EG&G, INC.

The EG&G will be responsible for conducting aerial measurements and supplying the analyzed data in a timely fashion. They will also have responsibility for fabricating and maintaining all in-situ measurement systems and will operate the systems in the field to accumulate data. The EG&G supervisor for this project is Dr. W. John Tipton.

D. DESERT RESEARCH INSTITUTE OF THE UNIVERSITY OF NEVADA

The DRI will be responsible for the design of all in-situ sampling plans and will process all in-situ spectrometry data according to procedures established by LLNL. They will also perform appropriate statistical analyses needed to evaluate, summarize, and report data. The DRI will receive all data generated by the project and establish a data base. As custodian of the data base, DRI will have a major responsibility in preparing data and writing reports; this responsibility will be shared with the Technical Directors. Dr. Forrest Miller will be the DRI contact.

E. REYNOLDS ELECTRICAL AND ENGINEERING CO., INC.

As requested by the Technical Directors, REECo will provide a variety of field support, sample collection, and analytical services. These activities may include

- Surveys of measurement points.
- Radiological health and safety support.
- Soil sample collection.
- Gamma spectroscopy of soil samples.
- Radiochemical analysis of soil samples for ^{90}Sr, ^{238}Pu, ^{239}Pu, ^{241}Am, etc.
- Measurements of soil density.
- Measurements of soil mass attenuation coefficients.

Mr. Earl Sorom will be the REECo supervisor for this project.

III. OPERATION

A. GENERAL

The operation schedule is shown in Table 1. Individual reports will be issued for each general area at NTS at the completion of the ground survey in that area. These reports will include isotopic contours and total inventory for all isotopes of interest. Raw ground measurement data and soil sampling data will be included as an appendix. Each report will be issued no later than four months after the completion of the ground survey.

TABLE I. OPERATION SCHEDULE FOR NEVADA TEST SITE

Area	Prominent site	Estimated site area (mi^2)	Distinct ground zeros	Number of sampling points	Completion date for ground measurements
1	Galileo	5	1	132	1 Dec. 1981
5	Corroborative measurements	--	--	25	1 Jan. 1982
4	Kepler	6	1	150	1 March 1982
2	Shasta, Diablo	7	3	240	1 May 1982
8	Baneberry	7	2	200	15 July 1982
8	Smoky	3	1	80	15 Aug. 1982
10	Sedan	12	1	250	15 Oct. 1982
9	Wilson	6	3	200	1 Dec. 1982
7	Boltzmann, Franklin Prime, Doppler	5	3	180	1 Feb. 1983
3	Pascal-A, Franklin	7	4	250	1 April 1983
Yucca	Not identified	--	--	200	1 June 1983
5	GMX, Snap capsule, others	--	--	200	1 Aug. 1983
18	Little Feller I & II, Johnny Boy, Sulky, Danny Boy	--	5	600	1 Jan. 1984
11	Project 56, Pin Stripe, Diana Moon	--	--	400	1 April 1984
13	Project 57	--	1	150	1 June 1984
20	Palanquin, Cabriolet, Schooner	--	3	450	1 Oct. 1984
26	--	--	--	60	1 Nov. 1984
25	--	--	--	300	1 Feb. 1985
16	Double Play	--	--	130	15 March 1985
12	Red Hot, Des Moines	--	--	600	15 July 1985
19	--	--	--	200	15 Sept. 1985
15	--	--	--	130	14 Nov. 1985
30	Buggy	--	--	400	15 March 1986

B. SCHEDULE ASSUMPTIONS

The following assumptions have been made during preparation of the program schedule.

(1) All locations of interest are visible on exposure-rate contour maps obtained from helicopter data. Spatial resolution of the contours derived from ground measurement will be no better than that of the flyover data.

(2) Each area of interest requires the same number of sampling points per unit area as Galileo except that 30 points are added for each additional ground zero in that area.

(3) Helicopter flyover exposure-rate contours are available two months before the scheduled ground survey begins.

(4) The IMP availability.

(a) One operational IMP until April, 1982; thereafter two IMPs with a third as a spare.

(b) A 75% IMP uptime.

(c) A total of 48 work weeks per year.

(d) A data collection rate of eight samples per IMP day within Yucca six per IMP day outside Yucca.

(e) A two IMP-week contingency for each area.

(f) One extra week when moving in a new area within Yucca and two extra weeks when outside Yucca.

IV. SITE LOGISTICS AND ACTIVITIES

A. FACILITIES

The EG&G Cane Springs building and associated trailers will be the main facility for RIDP. Power has been installed at RIDP's expense. The building will be used for detector calibration, instrument trouble shooting, and IMP repairs. Office space is available in the trailers. Other contractors involved in the program such as LLNL, DRI, and REECo will supply their own facilities for completion of their respective tasks.

B. VEHICLES

Currently the program has three measurement tracked vehicles (IMPs), one Suburban measurement van, and one IMP trailer assigned to it. Two of the IMPs have been renovated for this program--the third has not and is marginal. The Suburban is presently not being used as a measurement van but as a spare vehicle. The EG&G will be responsible for supplying other miscellaneous vehicles required by the ground measurement program and will maintain the IMPS. The REECo will supply their own vehicles as necessary and will maintain all other vehicles used by the program at the site.

C. OCCUPATIONAL HEALTH AND SAFETY

Each contractor will be responsible for their employee's occupational health and safety. All contractors will consult REECo radiation monitors for proper procedures before entering any fenced radiation area. No personnel will enter craters.

V. SUPPORT PLAN

A. AERIAL SUPPORT--EG&G

The sampling scheme for ground measurements of each area at the NTS is based on flyover exposure-rate contour maps. Therefore, it is imperative that such maps be available for each area at least two months in advance of the ground survey. Exposure-rate contour maps already exist for all of Yucca Valley, Area 13, and Areas 25 and 26. Data has been collected for Areas 5, 11, 18, and 20 but not yet processed. A proposed schedule for when processed flyover data will be required follows. Schedules for aerial surveys will be arranged through the Nuclear Systems division of NVO.

Area	Required Date for Processed Flyover Data
5	May 1982
18	Nov. 1983
11	Feb. 1984
20	Aug. 1984
16	Jan. 1985
12	May 1985
19	July 1985
15	Sept. 1985
30	Jan. 1986

B. FIELD SUPPORT - REECo

The REECo will supply the following support to the field program in addition to that outlined under Organization.

(1) Mobile electricity generators for supplying the IMPs with power in the field during nights and weekends. Movement of these generators will be performed as required by the field program. The EG&G will request these generators and REECo will charge EG&G's account for them.

(2) Mobile gasoline supply that will be used to fuel the IMPs. The REECo will maintain and move the fuel supply as required by the program.

(3) Miscellaneous survey support for locating microwave reference stations and as a backup to the microwave locators.

(4) Radiation monitoring support as required by the field program.

This support will be charged to the REECo budget for the program.

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Appendix A

WORKPLAN

FOR

THE NEVADA TEST SITE RADIONUCLIDE
INVENTORY AND DISTRIBUTION PROGRAM (RIDP)

Submitted to

Nevada Operations Office
U.S. Department of Energy
Las Vegas, Nevada

by

Environmental Sciences Division
Lawrence Livermore National Laboratory
University of California
Livermore, California

4 March 1981
Revised 7 April 1981

INTRODUCTION

Since 1951, the Nevada Test Site (NTS) has been used to test nuclear weapons, nuclear ramjets and nuclear engines, and to conduct cratering experiments. As a result of these activities, the NTS has been contaminated with fission products, residual nuclear materials (e.g., Pu and tritium), and activation products including the activation of native soil by intense neutron fluxes.

In recent times, there has been a strong interest in determining the inventory and distribution of these radionuclides. Of primary interest are the radionuclides that are contained on the surface and near surface of the soil. These are accessible to the present work population and to future populations; in some areas the levels are such that an occupational safety problem can exist and such areas are candidates for remedial action. The NTS as a whole also constitutes a large area source of resuspendible material. This is not believed to be a significant problem at present, but an adequate evaluation depends upon an adequate knowledge of radionuclide inventory and distribution.

Several partial studies have already been conducted. Immediately following events, surveys with hand-held meters were conducted and many exclusion areas were established, particularly where alpha-emitting radionuclides were present. More sophisticated studies have been done of all major areas of plutonium contamination and inventories have been published. A major soil sampling and analysis project was conducted at numerous sites, but these results have not been synthesized and reported. A study of the Frenchman Lake Region of Area 5 has been reported; this study used in situ spectrometry, but the detector was not calibrated properly for high-energy gammas.

In addition to these ground-based studies, several airborne surveys have been conducted. Nearly the entire NTS was overflown about 10 years ago, but the resolution was not very good. More recently, areas have been resurveyed at lower flight speeds and elevations in order to provide better resolution. Results for external exposure rates are available for Areas 13, 18, 20, 25, 26, Yucca Valley, and part of the Tonopah Test Range. In general, these surveys provide excellent data, but they do not quantify concentrations of specific radionuclides.

OBJECTIVE

The basic objective of this study is to provide a complete inventory of all radionuclides of NTS origin in NTS surface soil, and to provide maps (isopleths) that show where the radionuclides are located. Radionuclides of natural origin will be included in the study.

An important secondary goal is to provide the above data and complete the project in five years.

The accuracy required for the measurements has not been specified. Our overall goal is to provide a final inventory that is known with 95% confidence within at least a factor of two.

METHODS

This study will rely heavily upon in situ spectrometry for primary results. However, in order to finish the project in five years, these measurements must be supplemented with airborne surveys. As will be discussed in detail later, we intend to "calibrate" the airborne survey data with ground based measurements.

In order to provide accurate data from in situ spectrometry, some measurements on a few soil samples are required. Three parameters are of interest; the most important of these is the distribution of radionuclide concentration with depth. This can be measured by counting depth increments of a few soil samples. Also of interest are the mass attentuation coefficient of soil and the soil density. We will measure both directly.

Finally, we do propose to infer the concentration of ^{239,240}Pu from ^{241}Am. This can only be done if both are measured in a few soil samples (^{239,240}Pu has no prominent gamma rays that can be detected by in situ spectrometry).

TASK DESCRIPTIONS

CALENDAR YEAR 1981 (DEVELOPMENTAL STAGE)

Lawrence Livermore National Laboratory (LLNL)

Task 1: Technical Direction. LLNL will provide overall technical direction of the RIDP, subject to the agreed upon general directions and objectives. This will include assumption of the agreed objective -- a completed project in five years. Technical direction will include the assumption of responsibility for the summarization of past work, planning a measurement strategy, development of measurement techniques, scheduling of measurements, documentation of methodology, summarization of results, and overall quality control.

Schedule: This task will continue throughout calendar year 1981. A workplan will be delivered in March, and a summary of 1981 work in January, 1982.

Deliverables: 1.1. Workplan
1.2. Summary Report of Developmental Stage

Task 2. Evaluation and Summarization of Past Data. Of the past major studies, two are incomplete. These are the in situ measurements in the Frenchman Lake Region of Area 5 and the major soil sampling and analysis study. The in situ measurements need to be recalculated to provide proper concentration results based upon a complete calibration of the in situ methodology. This will include a complete calibration of detector 513 by LLNL, and the collection and analysis of sufficient soil samples to determine the distribution of radionuclides with depth, the soil density and soil mass attenuation coefficient, and the ratio of $^{239,240}Pu$ to ^{241}Am. LLNL will also review the status of the approximately 6000 soil samples analyzed by REECo, and attempt to recover and synthesize these data.

Schedule: The calibration measurements for detector 513 have been completed. The calculations will be completed and documented in April, 1981. Soil samples will be taken, analyzed, and data reported in June, 1981 so that DRI can proceed with recalculation of the Area 5 data. LLNL will examine the available historical soil sampling data and determine its usefulness. A report either synthesizing the data, or explaining the status of the data will be prepared in September, 1981.

Deliverables:

2.1. Complete calibration calculation for detector 513 documented in a report.

2.2. Characterization of soil samples from the Frenchman Lake Region of Area 5.

2.3. Report synthesizing historical soil sample data (or as a minimum detailing the status of that data).

Task 3. Development of a Measurement Strategy. A key to the success of the inventory and distribution program is to find methods of more rapidly acquiring the necessary data. Three experiments have been proposed that, if successful, can greatly speed the process. First, DRI will use the data currently available from Area 5 that were acquired by in situ spectrometry, and do a computational experiment to determine the optimal density of data. Second, we will examine the feasibility of making more extensive use of airborne data by performing a major experiment at the site of the Galileo shot. From the airborne data, we have contours of external exposure rate, but no quantification of radionuclides. The nature of the experiment will be to determine if the airborne data can be "calibrated" with a few ground-based in situ spectrometry measurements and soil samples. Third, we have many original measurements of the external gamma exposure rate fields soon after detonation. It is possible to calculate the original radionuclide inventory from a shot, and interpret the original isopleths in terms of the radionuclide inventory present today. We will perform an experiment of this nature for shot Galileo, and attempt to construct a local inventory based upon the original measurements of external exposure rate, calculations of radionuclide inventory, and a few modern ground-based in situ spectrometry measurements.

Schedule: All three experiments should be completed by October, 1981. Based upon these results, a sampling strategy will be worked out with the assistance of DRI, and reported in December, 1981.

Deliverables: 3.1. Report on the measurement strategy for the remainder of the program.

Task 4. Development of Measurement Techniques: Calibration. LLNL will assume primary responsibility for the procedures for calibration of the ground-based in situ detectors, but will work closely with EG&G so that both organizations agree completely on the correctness of the final calibrations. This task consists of thoroughly documenting all calibration measurement and calculation procedures, and of providing thorough documentation of the calibration of every detector used in the program.

Schedule: The generic calibration measurement and calculation procedures will be published by December, 1981. Reports describing the results of calibrations of individual detectors will be provided as needed.

Deliverables: 4.1. Report documenting detector calibration measurement and calculation procedures.

4.2. Reports documenting the results of detector calibration for every detector used in the program.

Task 5. Development of Measurement Techniques: Software for Quantification of Radionuclides from In-Situ Spectrometry Data. Two techniques will be used to quantify radionuclide concentrations from ground-based in situ spectrometry measurements. EG&G (see following task description) will modify the existing IMP software to provide a quantification of the major radionuclides in the field as data are accumulated. This task consists of providing more sophisticated software that will operate on the spectra stored on magnetic tapes. The more complete analysis will quantify every identifiable peak, and for radionuclides with more than one peak will compute a weighted average concentration. Both methods will depend upon the calibration of individual detectors, and the latter will be fine tuned to account for determined values of radionuclide distribution with depth, soil density, and soil mass attenuation coefficients.

Schedule: The software will be completed and documented by December, 1981. Calculations needed before then will be performed using existing, but more laborious, techniques.

Deliverable: 5.1. Documented software package for the determination of the concentration of radionuclides in soil from ground based *in situ* spectrometry measurements.

Task 6. Development of Measurement Techniques: Evaluation of Detectors and Collimators. Two major types of detectors can be used - planar or coaxial - and they have markedly different responses as a function of angle. (The response of a planar detector is essentially zero at 90°, whereas the response of a coaxial detector is essentially uniform from 0 to 90°.) The possible utility of a collimator is thus markedly different for the two types, and there is also some tradeoff between the detector's height above ground and the use of a collimator. The usefulness of a collimator may also be limited by the weight of absorbing material that can be supported, and this may be insufficient to provide effective collimation at high energies. The purpose of this task is to provide an evaluation of different combinations of detector types, heights of measurements, and collimators. The first priority will be to evaluate heights of measurement and collimator configurations for the existing detectors.

Schedule: We will finish the evaluation of detector height of measurement and collimator configuration in June, 1981. Other detectors and collimators will be evaluated as basic measurements become available.

Deliverables: 6.1. Report evaluating the detector height of measurement and collimator configuration for existing detectors.

6.2. Other evaluations as data become available.

Task 7. Procedure for Soil Sampling and Analysis. A few soil samples are needed so that the radionuclide distribution with depth, soil density, soil mass attenuation coefficient, and ratio of $^{239,240}Pu$ to ^{241}Am can be determined. Samples must be collected very carefully so that precise increments of surface soil are collected. This task consists of specifying the procedures for collecting, processing, and analyzing soil samples.

Schedule: The procedures will be prepared by May 1, 1981.

Deliverable: 7.1. Informal report that specifies soil sampling, processing, and analysis procedures.

EG&G, Inc.

Task 8. Preparation of IMPs and Associated Equipment. The small, lightweight tracked vehicle in situ measurement systems (IMPs) used in Enewetak will be completely reconditioned for the NTS radionuclide inventory and distribution program. This reconditioning will include refurbishment of the vehicles, a complete overhaul of the Onan generators and retractable booms, a careful examination and repair of the measurement systems and incorporation of the MRS-III microwave locator and high pressure ionization chamber into the measurement system. The Suburban measurement system will be modified to operate off of Onan power. This will make its measurement system completely compatible and interchangeable with the IMP systems.

Schedule: One IMP system will be fully reconditioned and ready for detector calibration by May 15, 1981. A second IMP system will be fully conditioned and ready for detector calibration by October 1, 1981. The modifications to the Suburban will be completed and the vehicle readied for field measurements by August 1, 1981. However, the successful inclusion of the microwave locators and ionization chambers in the IMP and suburban measurement systems depends on the availability of capital equipment money and the delivery schedule for these items.

Deliverables: 8.1. Two field ready IMP in situ measurement systems.
8.2. One field ready Suburban in situ measurement system.

Task 9. Detector Calibration Measurements. Two high purity germanium detectors will be completely calibrated over the energy ranges 0-1500 keV and at 1765 and 2614 keV. This calibration will include the measurement of the detector's angular response and its absolute efficiency at 0°, as a function of energy. The detector configuration (i.e., collimated versus uncollimated, planar versus coaxial) will be determined prior to calibration.

Schedule: The detectors will be completely calibrated and ready for field use by June 15, 1981, if currently available detectors are used. LLNL will supply a detector calibration procedure for these planar detectors by May 15, 1981.

Deliverables: 9.1. Two calibrated field ready detectors.

Task 10. IMP Field Software. Currently available IMP field software will be modified to include quantification of major man-made and naturally occurring gamma emitters, and acceptance and storage of microwave locator readings and high pressure ionization chamber readings.

Schedule: The IMP field software will be ready for field use by June 15, 1981.

Deliverable: 10.1. Modified IMP field software.

Task 11. IMP Field Measurements and Maintenance. This task consists of making in situ field measurements of the surface concentration of the man-made and natural gamma emitters in Yucca Valley in support of the Gallileo experiment and in selective locations in Areas 18 and 20 in support of the EG&G integration experiment. A measurement procedure will be provided to EG&G by LLNL prior to commencement of the measurement program. A listing of measurement locations will be provided by LLNL at least one week in advance of actual measurement of the locations. The IMPs and associated equipment will be maintained by EG&G during the measurement program.

Schedule: Measurements will begin in the Yucca Valley area by July 1, 1981 and continue as necessary through September, 1981. One IMP will be used during this initial measurement period. Measurements will also be made in Areas 18 and 20 as time permits.

Deliverables: 11.1. Ground-based *in situ* spectrometry measurements in Yucca Valley, and Areas 18 and 20.

Task 12. Experimentation with Integration Techniques. EG&G currently has the ability of producing computer-drawn exposure-rate contours for data obtained by aerial measurements. This task consists of determining the feasibility of producing isotopic contours using the presently available aerial exposure-rate data in conjunction with selective IMP measurements. This experiment will utilize aerial exposure-rate data and IMP isotopic data collected in Yucca Valley if possible, otherwise in Areas 18 and 20.

Schedule: This task will be completed by October 1, 1981, and a report issued by January 1, 1982.

Deliverable: 12.1. Report on the feasibility of using EG&G's integration techniques to define area inventories.

Desert Research Institute (DRI)

Task 13. Sample Strategy Planning and Evaluation. DRI will assist LLNL with the planning and evaluation of the sampling strategy for the Galileo experiment. This also includes assistance with the preparation of the final document discussing the development of a measurement strategy for the NTS Inventory and Distribution Program. For more information on the Galileo experiment, see the LLNL task descriptions.

Schedule: The sampling plan for the Galileo experiment will be completed and the sampling point coordinates specified by June 1, 1981. The final document on measurement strategy will be completed by December, 1981.

Deliverables: 13.1. A sampling plan for the Galileo experiment.

13.2. Report describing the development of the measurement strategy for the NTS RIDP.

Task 14. Data Processing: Reprocessing of Area 5 Data. DRI will reprocess Area 5 data and will utilize updated calibration factors and soil parameters supplied by LLNL, and issue a revised report on Area 5 containing updated contours and inventory estimates.

Schedule: LLNL will provide DRI with updated calibration factors and necessary soil parameters by July 1, 1981. DRI will reprocess the data and issue a revised report by September 1, 1981.

Deliverable: 14.1. Revised report on the Frenchman Lake Region of Area 5 that reflects the updated measurement system calibration factors.

Task 15. Data Processing: Sampling Density Study. Much of the in situ data collected in Area 5 was collected on a 100 ft by 100 ft grid. DRI and LLNL believe that this sampling density can be reduced substantially without greatly affecting the inventory and contour estimates. DRI will explore the relationship between sampling density, contour positions and inventory estimate. Data collected in Area 5 will be used for this computational experiment.

Schedule: DRI will complete this computational experiment and compile the results in the form of a technical note by October 1, 1981.

Deliverable: 15.1. Report describing the results of this computational experiment.

Task 16. Data Processing: Galileo Experiment. DRI will be responsible for processing the Galileo measurement data. This includes spectrum analysis, isotope quantification, exposure-rate quantification, contour mapping and inventory estimation. DRI will transfer the field spectra to magnetic tape and send the tapes to LLNL for spectrum analysis and isotope quantification. The results from the LLNL analysis will be returned to DRI for contour mapping and inventory estimation.

Schedule: EG&G will begin making *in situ* measurements in the Galileo area by July 1, 1981, and continue as necessary through September, 1981. Data will be transferred to DRI on a weekly basis. DRI, within one week of reception of the data, will transfer to LLNL both the field spectra on magnetic tape and a hard copy of isotope concentrations as determined by the field measurement systems. LLNL will transfer the results of the spectrum analysis back to DRI within one week of reception of original data.

Deliverable: 16.1. Processed Galileo data.

Task 17. Data Processing: The Implementation of Spectrum Analysis Software on the NVO Computer System. This task consists of transferring software to do peak search, isotope identification, isotope concentration quantification and exposure-rate determination from the LLNL CDC-7600 to the NVO computer system. For additional detail see the LLNL task descriptions.

Schedule: This software will be up and running on the NVO computer system by March 1, 1982.

Deliverable: 17.1. Fully implemented software on the NVO computer system that will provide complete data processing of the *in situ* spectrometry data.

Task 18. Data Base Management. DRI will develop and maintain a data base that will archive raw field spectra and associated data, processed data consisting of isotope concentrations and calculated exposure rates, and area contours and inventory estimates. This data will be stored in a form that is easily retrieved and updated.

Schedule: This data base will be operational by August 1, 1981.

Deliverable: 18.1. An operational computer-based data base for the NTS RIDP.

Reynolds Electrical and Engineering Company (REECo)

Task 19. Summarization of Past Soil Sampling and Analysis Data. Through 1975, over 6000 soil samples were collected in Areas 1, 4 and 5 of the NTS. These soil samples may be useful for obtaining isotopic depth distributions, and in providing input for total inventory. REECo will assist LLNL in retrieving these soil sample data from the NAEG data bank and in evaluating their usefulness to the inventory program.

Schedule: These data will be retrieved and evaluated by July 1, 1981. The results will be summarized in a report that will be issued by September, 1981.

Deliverable: 19.1. *Soil sample data and assistance in evaluation.*

Task 20. Field Support. EG&G will begin making in situ field measurements in support of the Galileo experiment by July 1, 1981. REECo will supply construction, maintenance machinist, and health and safety monitoring support to EG&G as necessary.

Schedule: Field support will be supplied by REECo on a continuing basis as necessary beginning June 1, 1981.

Deliverable: 20.1. Construction, maintenance machinist, and health and safety support.

Task 21. Soil Sample Collection, Preparation, and Analysis. REECo will collect, prepare, and analyze soil samples as prescribed by LLNL. These analyses will be used to obtain Pu/Am ratios, isotopic depth distributions and soil mass attentuaton coefficients. REECo will also operate the necessary field equipment for determining soil density and moisture content. LLNL will provide REECo with procedures for collection, preparation, and analysis of soil samples and for field measurement of soil density and moisture content.

Schedule: REECo will begin soil sample collection, preparation and analysis in support of the Galileo experiment and Area 5 inventory revision by June 1, 1981. LLNL will supply the procedures and initial coordinates for soil sampling by May 15, 1981. The date by which REECo begins to make field measurements of soil density and moisture content depends on the availability of capital equipment money and the delivery leadtime for the equipment.

Deliverable: 12.1. Soil sample data consisting of Pu/Am ratios, isotopic depth distributions, soil mass attenuation coefficients, soil density and soil moisture content for preselected locations in Area 5 and Yucca Valley.

MARCH, 1982, TO MARCH, 1986 (OPERATIONAL STAGE)

All following task descriptions are subject to some changes depending upon the results of the experimental studies discussed above.

Lawrence Livermore National Laboratory (LLNL)

Task 22. Technical Direction: Program Overview. LLNL will maintain a comprehensive cognizance of the entire Radionuclide Inventory and Distribution Program and guide the program so that it will achieve its objective in the specified five-year time frame. LLNL will notify the Nevada Operations Office (NVO) concerning any occurrence that might affect either the program quality or its time frame.

Schedule: Ongoing for the life of the program.

Deliverables:
22.1. Program completion in the specified five-year time period.
22.2 Area inventory and distribution reports completed individually as the work is completed.
22.3. Final report.

Task 23. Technical Direction: Area Measurement Plans. LLNL asisted by DRI will develop a measurement plan for each area of NTS and supply EG&G with measurement point coordinates at least two weeks before the actual measurements are made. LLNL will also provide REECo with coordinates for soil sampling. Regional priority will be established by consultation with NVO.

Schedule: Ongoing for the life of the program.

Deliverables: 23.1. Specifications of measurement locations for EG&G.
23.2. Specification of soil sampling locations for REECo.

Task 24. Quality Control. LLNL will develop and maintain a quality control program for *in situ* measurements, soil sample analyses, data processing and area inventory reports. This program will include cross checks of field measurements, analyses and data processing by LLNL and other selected laboratories and outside review of area inventory reports.

Schedule. This quality assurance program will be operational by March 1, 1982.

Deliverable: 24.1. A quality control program for field measurements, soil sample analyses, data processing and area inventory reporting.

EG&G, Inc.

Task 25. Detector Calibration Measurements. EG&G will calibrate *in situ* detectors over the energy range 0-1500 keV and at 1765 and 2614 keV as needed by the program. All reworked detectors and new detectors will be calibrated before being used in the field. This calibration will include the measurement of the detector's angular response and its absolute efficiency at 0°, both as a function of energy. The detector configuration (collimated versus uncollimated, planar versus coaxial, etc.) will be determined jointly by LLNL and EG&G prior to calibration. The intrinsic efficiency at 0° will be measured as a function of energy and formally recorded for all field detectors in use, on a weekly basis. This is in addition to the daily informal efficiency checks.

Schedule: Ongoing, as necessary, for the life of the program.

Deliverable: 25.1 Calibrated *in situ* detectors for the operational phase of RIDP.

Task 26. In Situ Field Measurements and Maintenance. EG&G will operate and maintain three *in situ* measurement systems at the NTS, two IMPs and one Suburban van. Two vehicles will be operated simultaneously with the third vehicle held in reserve in a state of readiness. A measurement procedure will be provided to EG&G by LLNL prior to commencement of the measurement program. LLNL will provide EG&G with a listing of measurement coordinates at least one week in advance of the actual measurement of those points. Maintenance includes maintenance of both vehicles and measurement systems. EG&G will immediately notify LLNL of any equipment failures that might impact the program.

Schedule: The measurement process will be ongoing beginning in October, 1981 and continue as necessary through March, 1986. Maintenance will be performed as necessary.

Deliverables: 26.1 Field measurements on a continuing basis.
26.2 Two IMPs and one Suburban van *in situ* measurement systems kept in a state of readiness.

Task 27. Periodic Data Review. EG&G will review the *in situ* data produced by the measurement systems on a weekly basis before it is transferred to DRI for processing. EG&G will notify LLNL regarding any irregularities.

Schedule: Ongoing on a weekly basis before transfer to DRI.

Deliverable: 27.1 *In situ* data examined for irregularities.

Desert Research Institute (DRI)

Task 28. Area Measurement Plans. DRI will assist LLNL with the development of a measurement plan for each area of the NTS. For additional detail, see LLNL Task 23.

Schedule: Ongoing for the life of the program.

Deliverables: 28.1 Specification of measurement locations for EG&G.
28.2 Specification of sampling locations for REECo.

Task 29. Data Processing. DRI will be responsible for processing all in situ measurement data. This includes spectrum analysis, isotope quantification, exposure-rate quantification, contour mapping and inventory estimation. DRI will receive data from EG&G on a weekly basis. This data will be processed within one week of reception and the results along with the EG&G field calculations sent to LLNL for inspection.

Schedule: Ongoing for the life of the program.

Deliverable: 29.1 Processed area field data.

Task 30. Data Base Management. DRI will maintain a data base for RIDP that will archive raw field spectra and associated data, processed data consisting of isotope concentrations and calculated exposure rates, and area contours and inventory estimates. This data will be stored in a form that is easily retrieved and updated.

Schedule: Ongoing for the life of the program.

Deliverable: 30.1 An operational, maintained computer-based data base for the NTS RIDP.

Task 31. NTS Area Inventory and Distribution Reports. DRI will be responsible for the preparation of all area inventory and distribution reports. These area reports will be completed individually as the work in that area is completed. LLNL will specify the form and content of these reports.

Schedule: Completed individually within four months of the day of the last *in situ* measurement in that area.

Deliverable: 31.1 Completed individual area inventory and distribution reports.

Reynolds Electrical and Engineering Company (REECo)

Task 32. Field Support. EG&G will be making *in situ* measurements at the NTS on a continuing basis from October, 1981 through February, 1986. During this time, REECo will supply construction, maintenance machinist, and health and safety monitoring support to EG&G as necessary.

Schedule: Field support will be supplied by REECo on a continuing basis as necessary beginning October, 1981, through February, 1986.

Deliverable: 32.1 Construction, maintenance machinist, and health and safety support.

Task 33. Soil Sample Collection, Preparation, and Analysis. REECo will collect, prepare and analyze soil samples as prescribed by LLNL and also operate the necessary field equipment for determining soil density and moisture content. These analyses and measurements will be used to obtain Pu/Am ratios, isotopic depth distributions, soil density, and soil mass attenuation coefficients.

Schedule: These soil analyses and field measurements will be ongoing for the life of the program.

Deliverable: 33.1 Soil sample data consisting of Pu/Am ratios, isotopic depth distributions, soil mass attenuation coefficients, soil density and soil moisture content for locations selected by LLNL in various areas of the NTS.

Task 34. Soil Sample Report Preparation. REECo will summarize their soil sampling results and field measurements in a report for each individual area of the NTS as the analyses and measurements in that area are completed. LLNL will specify the contents and format of this report.

Schedule: Completed individually within two months of the day of the last *in situ* field measurement in that area.

Deliverable: 34.1 Completed area reports summarizing soil sample data consisting of Pu/Am ratios, isotopic depth distributions, soil mass attentuation coefficients, soil density and moisture content for locations selected by LLNL.

RELATIONSHIP TO OTHER PROGRAMS

The program described here does not include the measurements of external exposure rate and gamma spectra accumulation from airborne platforms. However, such data are absolutely essential for the timely completion of this program.

At the present time, there is sufficient airborne data available for at least several months of effort. However, it is essential that aircraft measurement times be scheduled for this effort beginning in 1982.

Appendix B

A COMPENDIUM OF ATMOSPHERIC AND VENTED UNDERGROUND EVENTS AT THE NEVADA TEST SITE AND THEIR LOCATIONS

APPENDIX B

Event Name	Date	Operation	Location	NV Grids	Yield	Description
			AREA 1			
Easy	5- 7-52	Tumbler-Snapper	T-1	N838781 E664589	12 kT	Tower
Simon	4-25-53	Upshot-Knothole	T-1	N838781 E664589	43 kT	Tower
Apple II	5- 5-55	Teapot	T-1	N838781 E664589	29 kT	Tower
Galileo	9- 2-57	Plumbbob	T-1	N838781 E664589	11 kT	Tower
			AREA 4			
Fox	5-25-52	Tumbler-Snapper	T-4	N854233 E664462	11 kT	Tower
Nancy	3-24-53	Upshot-Knothole	T-4	N854233 E664462	24 kT	Tower
Apple I	3-29-55	Teapot	T-4	N854233 E664462	14 kT	Tower
Kepler	7-24-57	Plumbbob	T-4	N854233 E664462	10 kT	Tower
Ray	4-11-53	Upshot-Knothole	T-4a	N855494 E667452	0.2 kT	Tower
			AREA 5			
Able	1-27-51	Ranger		N746942 E709822	1 kT	Airdrop
Baker	1-28-51	Ranger		N746942 E709822	8 kT	Airdrop
Easy	2- 1-51	Ranger		N746942 E709822	1 kT	Airdrop
Baker-2	2- 2-51	Ranger		N746942 E709822	8 kT	Airdrop
Fox	2- 6-51	Ranger		N746942 E709822	22 kT	Airdrop
Able	4- 1-52	Tumbler-Snapper		N746250 E714056	1 kT	Airdrop
Encore	5- 8-53	Upshot-Knothole	Bfa	N746250 E716000	27 kT	Airdrop
Grable	5-25-53	Upshot-Knothole	Bfa	N746250 E716000	15 kT	Airburst 280mm-gun
Met	4-15-55	Teapot	Bfa	N746250 E716000	22 kT	Tower
Priscilla	6-24-57	Plumbbob	Bfa	N746250 E716000	37 kT	Balloon
Wrangell	10-22-58	Hardtack II	Bfa	N746250 E716000	115 Tons	Balloon
Sanford	10-26-58	Hardtack II	Bfa	N746250 E716000	4.9 kT	Balloon
Hamilton	10-15-58	Hardtack II	Tfi	N747820 E715029	1.2 Tons	Tower
Smallboy	7-14-62	Storax		N747908 E717118	Low	Tower
GMX						
Snap Capsule						

AREA 5 (cont)

Event Name	Date	Operation	Location	NV Grids	Yield	Description
Wishbone	2-18-65	Whetstone	T-5a	N753500 E710000	< 20 kT	Shaft
Diluted Waters	6-16-65	Whetstone	T-5b	N753500 E708000	< 20 kT	Shaft
Derringer	9-12-66	Latchkey	T-5i	N774957 E709432	< 20 kT	Shaft

AREA 2

Event Name	Date	Operation	Location	NV Grids	Yield	Description
How	6- 5-52	Tumbler-Snapper	T-2	N869835 E659989	14 kT	Tower
Badger	4-18-53	Upshot-Knothole	T-2	N869835 E659989	23 kT	Tower
Turk	3- 7-55	Teapot	T-2	N869840 E660058	43 kT	Tower
Whitney	9-23-57	Plumbbob	T-2	N869823 E660103	19 kT	Tower
Diablo	7-15-57	Plumbbob	T-2b	N874146 E662634	17 kT	Tower
Shasta	8-18-57	Plumbbob	T-2a	N866030 E663323	17 kT	Tower
Alpaca	2-12-65	Whetstone	T-2a	N879402 E671952	< 20 kT	Shaft
Tee	5- 7-65	Whetstone	T-2ab	N870621 E674890	< 20 kT	Shaft
Drill	12- 5-64	Whetstone	T-2ai	N868402 E674001	3.4 kT	Shaft
Tapestry	5-12-66	Flintlock	T-2an	N868401 E673602	< 20 kT	Shaft
Scuttle	11-13-69	Mandrel	T-2bh	N879441 E672451	< 20 kT	Shaft
Nash	1-19-67	Latchkey	T-2ce	N871700 E654902	20-200 kT	Shaft
Pod	10-29-69	Mandrel	T-2ck	N870453 E656281	20-200 kT	Shaft
Tyg	12-12-68	Bowline	T-2DC4	N863482 E670880	< 20 kT	Shaft
			T-2DC5	N862306 E671178		
Riola	9-25-80	Tinderbox	T-2eq	N861705 E675554	< 20 kT	Shaft
Alva	8-19-64	Whetstone	T-2j	N877382 E670055	< 20 kT	Shaft
Hupmobile	1-18-68	Crosstie	T-2y	N872523 E675162	10 kT	Shaft

AREA 3

Event Name	Date	Operation	Location	NV Grids	Yield	Description
George	6- 1-52	Tumbler-Snapper	T-3	N837026 E688416	15 kT	Tower
Annie	3-17-53	Upshot Knothole	T-3	N837026 E688416	16 kT	Tower
Moth	2-22-55	Teapot	T-3	N837026 E688416	2 kT	Tower
Franklin	6- 2-57	Plumbbob	T-3	N837026 E688416	140 Tons	Tower
Harry	5-19-53	Upshot-Knothole	T-3a	N834301 E687164	32 kT	Tower
Hornet	3-12-55	Teapot	T-3a	N834301 E687164	4 kT	Tower
Coulomb-A	7- 1-57	Plumbbob	S-3h	N834700 E686997	0	Safety Exper.
Coulomb-B	9- 6-57	Plumbbob	S-3g	N835204 E686639	0.3 kT	Safety Exper.

APPENDIX B (continued)

AREA 3 (cont)

Event Name	Date	Operation	Location	NV Grids	Yield	Description
Fizeau	9-14-57	Plumbbob	T-3b	N831773 E685427	11 kT	Tower
Pascal-C	12- 6-57	Plumbbob	U-3e	N837768 E685540	Slight	Shaft-Safety Exper.
Coulomb-C	12- 9-57	Plumbbob	S-3i	N836002 E686070	0.5 kT	Safety Exper.
Rio Arriba	10-18-58	Hardtack II	T-3s	N834517 E687007	90 Tons	Tower
Catron	10-24-58	Hardtack II	T-34	N835229 E686690	21 Tons	Tower Safety Exper.
Chavez	10-27-58	Hardtack II	T-3u	N835857 E685867	0.6 Tons	Tower Safety Exper.
Humboldt	10-29-58	Hardtack II	T-3v	N836984 E687378	7.8 Tons	Tower
Boomer	10- 1-61	Nougat	T-3aa	N837180 E684482	Low	Shaft
Shrew	9-16-61	Nougat	T-3ac	N837224 E684980	Low	Shaft
Fischer	12- 3-61	Nougat	T-3ah	N836288 E686482	13.4 kT	Shaft
Pampas	3- 1-62	Nougat	T-3al	N834615 E686201	Low	Shaft
Armadillo	2- 9-62	Nougat	T-3ar	N835437 E683196	7.1 kT	Shaft
Haymaker	6-27-62	Nougat	T-3au	N834722 E684283	67 kT	Shaft
Wolverine	10-12-62	Storax	T-3av	N837344 E685051	Low	Shaft
Bandicoot	10-19-62	Storax	T-3bj	N834002 E687419	Low	Shaft
Gundi	11-15-62	Storax	T-3bm	N834801 E687602	Low	Shaft
Pike	3-13-64	Niblick	T-3cy	N838000 E691202	< 20 kT	Shaft
Gundi Prime	5- 9-63	Storax	T-3db	N837602 E690001	Low	Shaft
Screamer	9- 1-65	Flintlock	T-3dg	N828001 E692001	< 20 kT	Shaft
Parrot	12-16-64	Whetstone	T-3dk	N832302 E691002	1.3 kT	Shaft
Umber	6-29-67	Latchkey	T-3em	N830001 E686001	< 20 kT	Shaft
Snubber	4-21-70	Mandrel	T-3ev2s	N839657 E698002	< 20 kT	Shaft

AREA 7

Event Name	Date	Operation	Location	NV Grids	Yield	Description
Baker	10-28-51	Buster	T-73	N850553 E688624	3.5 kT	Airdrop
Charlie	10-30-51	Buster	T-73	N850552 E688543	14 kT	Airdrop
Dog	11- 1-51	Buster	T-73	N850452 E688706	21 kT	Airdrop
Baker	4-15-52	Tumbler-Snapper	T-73	N850250 E688788	1 kT	Airdrop
Charlie	4-22-52	Tumbler-Snapper	T-73	N850350 E688544	31 kT	Airdrop
Dog	5- 1-52	Tumbler-Snapper	T-73	N850249 E688545	19 kT	Airdrop

APPENDIX B (continued)

AREA 7 (cont)

Event Name	Date	Operation	Location	NV Grids	Yield	Description
Dixie	4- 6-53	Upshot-Knothole	T-73	N850425 E688685	11 kT	Airdrop
Able	10-22-51	Buster	T-75e	N850140 E687492	0.1 kT	Tower
Easy	11- 5-51	Buster	T-71	N853072 E687311	31 kT	Airdrop
Ruth	3-31-53	Upshot-Knothole	T-73a	N850673 E688252	0.2 kT	Tower
Climax	6- 4-53	Upshot-Knothole		N851500 E689100	61 kT	Airdrop
Wasp	2-18-55	Teapot	T-74	N851124 E688074	1 kT	Airdrop
Wasp Prime	3-29-55	Teapot	T-74	N851124 E688074	3 kT	Airdrop
Bee	3-25-55	Teapot	T-71a	N854124 E687502	8 kT	Tower
Zucchini	5-15-55	Teapot	T-71a	N854124 E687502	28 kT	Tower
Boltzmann	5-28-57	Pumbbob	T-7c	N854124 E687540	12 kT	Tower
Quay	10-10-58	Hardtack II	T-7c	N854124 E687540	79 Tons	Tower
Stokes	8- 7-57	Plumbbob	B-7b	N851125 E687540	19 kT	Balloon
Doppler	8-23-57	Plumbbob	B-7b	N851125 E687540	11 kT	Balloon
Franklin Prime	8-30-57	Plumbbob	B-7b	N851125 E687540	4.7 kT	Balloon
Laplace	9- 8-57	Plumbbob	B-7b	N851125 E687540	1 kT	Balloon
Newton	9-16-57	Plumbbob	B-7b	N851125 E687540	12 kT	Balloon
Eddy	9-19-58	Hardtack II	B-7b	N851125 E687540	83 Tons	Balloon
Mora	9-29-58	Hardtack II	B-7b	N851125 E687540	2 kT	Balloon
Hidalgo	10- 5-58	Hardtack II	B-7b	N851125 E687540	77 Tons	Balloon Safety Exper.
Lea	10-13-58	Hardtack II	B-7b	N851125 E687540	1.4 kT	Balloon
Dona Ana	10-16-58	Hardtack II	B-7b	N851125 E687540	37 Tons	Balloon
Socorro	10-22-58	Hardtack II	B-7b	N851125 E687540	6 kT	Balloon
De Baca	10-26-58	Hardtack II	B-7b	N851125 E687540	2.4 kT	Balloon
Santa Fe	10-30-58	Hardtack II	B-7b	N851125 E687540	1.3 kT	Balloon

AREA 9

Event Name	Date	Operation	Location	NV Grids	Yield	Description
Sugar	11-19-51	Jangle	T-90	N867452 E683100	1.2 kT	Surface
Post	4- 9-55	Teapot	T-9c	N864045 E684330	2 kT	Tower
Lassen	6- 5-57	Plumbbob	B-9a	N868640 E682437	0.5 kT	Balloon
Wilson	6-18-57	Plumbbob	B-9a	N868640 E682437	10 kT	Balloon
Hood	7- 5-57	Plumbbob	B-9a	N868640 E682437	74 kT	Balloon
Owens	7-25-57	Plumbbob	B-9a	N868640 E682437	9.7 kT	Balloon

AREA 9 (cont)

Event Name	Date	Operation	Location	NV Grids	Yield	Description
Wheeler	9- 6-57	Plumbbob	B-9a	N868640 E682437	197 Tons	Balloon
Charleston	9-28-57	Plumbbob	B-9a	N868640 E682437	12 kT	Balloon
Morgan	10- 7-57	Plumbbob	B-9a	N868640 E682437	8 kT	Balloon
Rushmore	10-22-58	Hardtack II	B-9a	N868634 E682418	188 Tons	Balloon
Vesta	10-17-58	Hardtack II	S-9e	N864269 E684269	24 Tons	Surface Safety Exper.
Juno	10-24-58	Hardtack II	S-9f	N864472 E683341	1.7 Tons	Surface Safety Exper.
Mazama	10-29-58	Hardtack II	T-9d	N865634 E682379	0	Tower
Ganymede	10-30-58	Hardtack II	S-9g	N865288 E680666	0	Surface Safety Exper.
Pleasant	5-29-63	Storax	T-9ah	N866191 E681970	Low	Shaft
Eagle	12-12-63	Niblick	T-9av	N867261 E681550	Low	Shaft
Brazos	3- 8-62	Nougat	T-9d	N864028 E680113	8.4 kT	Shaft
Anacostia	11-27-62	Storax	T-9i	N864301 E685903	Low	Shaft
Eel	5-19-62	Nougat	T-9m	N864204 E680599	Low	Shaft
Roanoke	10-12-62	Storax	T-9n	N864233 E679550	Low	Shaft
Allegheny	9-29-62	Storax	T-9x	N862062 E684821	Low	Shaft
Wichita	7-27-62	Storax	T-9y	N866763 E677680	Low	Shaft

AREA 10

Event Name	Date	Operation	Location	NV Grids	Yield	Description
Uncle	11-29-51	Jangle	T-10	N881390 E681854	1.2 kT	Crater
Ess	3-23-55	Teapot	T-10a	N880858 E681481	1 kT	Crater
John	7-19-57	Plumbbob	M-10	N877939 E678838	2 kT	Rocket
Sedan	7- 6-62	Storax	T-10h	N884002 E681001	104 kT	Crater
Tub	6- 6-68	Crosstie	T-10ajd	N880354 E681194	< 20 kT	Shaft

AREA 8

Event Name	Date	Operation	Location	NV Grids	Yield	Description
Smoky	8-31-57	Plumbbob	T-2c	N887690 E674450	44 kT	Tower
Oberon	10-22-58	Hardtack II	T-8a	N886103 E674276	0 kT	Tower-Safety Exper.
Ceres	10-26-58	Hardtack II	T-8b	N885540 E674236	0.7 Tons	Tower-Safety Exper.

Event Name	Date	Operation	Location	NV Grids	Yield	Description
			AREA 8 (cont)			
Titania	10-30-58	Hardtack II	T-8c	N884042 E674076	0.2 Tons	Tower-Safety Exper.
Baneberry	12-18-70	Mandrel	T-8d	N882493 E665431	10 kT	Shaft
			AREA 11			
Project 56 No. 1	11- 1-55	Wigwam			0	Safety surface
Project 56 No. 2	11- 3-55	Wigwam			0	Safety surface
Project 56 No. 3	11- 5-55	Wigwam			0	Safety surface
Project 56 No. 4	1-18-56	Wigwam			Slight	Safety surface
Pin Stripe	4-25-66	Flintlock	T-11B	N778801 E712301	< 20 kT	Shaft
Diana Moon	8-27-68	Bowline	T-11e	N775095 E715148	< 20 kT	Shaft
Minute Steak	9-12-69	Mandrel	T-11f	N775102 E715901	< 20 kT	Shaft
Diagonal Line	11-24-71	Grommet	T-11g	N775821 E714081	< 20 kT	Shaft
			AREA 12			
Feather	12-22-61	Nougat	T-12b.08	N890258 E633510	Low	Tunnel
Yuba	6- 5-63	Storax	T-12b.10	N890855 E633250	Low	Tunnel
Antler	9-15-61	Nougat	T-12e.03	N887720 E633675	2.6 kT	Tunnel
Red Hot	3- 5-66	Flintlock	T-12g.06	N882817 E633527	< 20 kT	Tunnel
Door Mist	8-31-67	Crosstie	T-12g.07	N883932 E633351	< 20 kT	Tunnel
Des Moines	6-13-62	Nougat	T-12j.01	N900262 E646900	Low	Tunnel
Platte	4-14-62	Nougat	T-12k.01	N900197 E648268	1.8 kT	Tunnel
Midi Mist	6-26-67	Latchkey	T-12n.02	N892871 E633631	< 20 kT	Tunnel
Mint Leaf	5- 5-70	Mandrel	T-12T.01	N898157 E640537	< 20 kT	Tunnel

AREA 16 (cont)

Event Name	Date	Operation	Location	NV Grids	Yield	Description
Double Play	6-15-66	Flintlock	T-16A.03	N822813 E635403	< 20 kT	Tunnel

AREA 18

Event Name	Date	Operation	Location	NV Grids	Yield	Description
Danny Boy	3- 5-62	Nougat	T-18a	N859537 E587978	0.43 kT	Crater
Little Feller II	7- 7-62	Storax			Low	Surface
Johnny Boy	7-11-62	Storax			0.5 kT	Crater
Little Feller I	7-17-62	Storax			Low	Surface
Sulky	12-18-64	Whetstone	T-18d	N849241 E594542	0.1 kT	Shaft

AREA 19

AREA 20

Event Name	Date	Operation	Location	NV Grids	Yield	Description
Palanquin	4-14-65	Whetstone	T-20k	N921074 E541638	4.3 kT	Crater
Cabriolet	1-26-68	Crosstie	T-20L	N921252 E544287	2.3 kT	Crater
Schooner	12- 8-68	Bowline	T-20u	N944011 E529301	30 kT	Crater

AREA 30

Event Name	Date	Operation	Location	NV Grids	Yield	Description
Buggy	3-12-68	Crosstie	T-30a	N821830 E586632	5.4 kT	Crater