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HAROLD L. BRODE

DNA 6029F

PROJECTS GNOME AND SEDAN The PLOWSHARE Program

United States Atmospheric Nuclear Weapons Tests
Nuclear Test Personnel Review

Prepared by the Defense Nuclear Agency as Executive Agency
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This report describes the activities of DOD personnel and other participants in Projects GNOME and SEDAN, the first two nuclear tests of the PLOWSHARE Program. The PLOWSHARE nuclear tests were conducted from 1961 to 1973 at the NTS and other locations. Activities engaging DOD personnel at GNOME and SEDAN included scientific experiments to improve U.S. capabilities in detecting underground nuclear explosions and to determine peacetime uses of nuclear explosives.

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Fact Sheet

dna

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Subject: Projects GNOME and SEDAN, The PLOWSHARE Program

The Atomic Energy Commission (AEC) established the PLOWSHARE program in June 1957, under the technical direction of the Lawrence Radiation Laboratory (LRL).* The program consisted of 27 nuclear detonations conducted at the Nevada Test Site (NTS) and other sites in Colorado and New Mexico from 1961 to 1973. The nuclear tests, identified in the first of the accompanying tables, were all underground, either shaft or cratering shots, and they had yields of no more than 200 kilotons. The PLOWSHARE nuclear detonations were designed to determine nonmilitary applications of nuclear explosives. The primary potential use envisioned was in large-scale geographic engineering, in such projects as canal, harbor, and dam construction, the stimulation of oil and gas wells, and mining. Considering the peaceful objectives of PLOWSHARE, the AEC took the name of the program from the Bible: "And they shall beat their swords into plowshares" (Isaiah 2:4).

Projects GNOME and SEDAN the first two nuclear detonations of the PLOWSHARE program, were selected for discussion because they were conducted during the period of U.S. atmospheric nuclear weapons testing, had documented (although limited) DOD participation, and had sufficient documentation for a discussion of the detonations and associated activities.

Department of Defense Involvement

The Department of Defense (DOD) did not conduct military exercises during the PLOWSHARE program and had limited involvement in the shots. The primary role of the military was to provide logistical support. However, technical participation was allowed, provided that it did not interfere with AEC activities.

Summaries of Projects GNOME and SEDAN

Project GNOME, a shaft detonation, was fired at 1200 hours Mountain Standard Time on 10 December 1961 at a site 40 kilometers southeast of Carlsbad, New Mexico. The first of the accompanying figures shows the site location. The device was buried 1,184 feet underground in bedded rock salt at the end of a

---

*Now known as the Lawrence Livermore National Laboratory.

1,116-foot hooked and self-sealing tunnel. A shaft 1,216 feet in depth and ten feet in diameter ended in a station room connected to the tunnel. The detonation, which had a yield of three kilotons, resulted in an underground dome-shaped chamber 60 to 80 feet high and 160 to 170 feet in diameter.

Although it had been planned as a contained explosion, GNOME vented to the atmosphere. A cloud of steam started to appear at the top of the shaft two to three minutes after the detonation. Gray smoke and steam, with associated radioactivity, emanated from the shaft opening about seven minutes after the detonation. Radioactive materials vented to the atmosphere about 340 meters southwest of ground zero. The highest measured onsite gamma intensity was 1 roentgen per hour (R/h). This intensity was recorded 1,300 meters northwest of the shaft opening at 1938 hours on shot-day. The highest offsite reading was 1.4 R/h, encountered 5.5 kilometers west of the Control Point on Highway 128 one hour after the detonation. Underground recovery operations were delayed, in part because of high radiation levels at the shaft opening (for example, 5 R/h at 0908 hours on the day after the detonation). Six days after the shot, an initial radiological and toxicological survey was conducted to the bottom of the shaft. After the survey was completed, underground recovery operations were permitted.

An extensive program of scientific and technical projects was conducted to obtain information on the characteristics of a nuclear detonation in an underground rock salt formation and to explore the feasibility of energy recovery, radioisotope recovery, and generated-neutron utilization. To emphasize the peaceful aims of Project GNOME, the AEC conducted an observer program involving, among others, Government officials, representatives of scientific and industrial groups, and news media personnel.

DOD personnel took part at GNOME in the VELA UNIFORM program, conducted by the DOD to develop U.S. capabilities in detecting and identifying underground nuclear detonations. The Advanced Research Projects Agency of the DOD administered the program, which consisted of 19 projects. The Air Force Technical Applications Center formulated technical requirements for the projects, and the Defense Atomic Support Agency developed and directed the activities. DOD personnel also conducted at least one other project: Design, Testing, and Field Pumping of Grout Mixtures. In addition, the Air Force Special Weapons Center (AFSWC) conducted photography, cloud-sampling, and cloud-tracking missions at the shot.

Project SEDAN, a nuclear cratering experiment, was detonated with a yield of 104 kilotons at 0900 hours Pacific Standard Time on 6 July 1962. The shot was fired in Area 10 of the NTS, shown in the second of the accompanying figures. The device was buried 635 feet underground in desert alluvium, and the detonation

resulted in a crater with a volume of about 6.5 million cubic yards. The crater radius was 607 feet and the depth 323 feet. The lip of the crater ranged in height from 18 to 95 feet above the preshot surface. Two and one-half hours after the detonation, the 10 R/h line extended 3.3 kilometers to the west and 3.1 kilometers to the south, and the 1 R/h line extended 3.5 kilometers to the west and 3.3 kilometers to the south. The radiation isointensity contours were not completely plotted to the north and east, the direction of the fallout. Two days later, intensities of 1 R/h were confined to within 3.2 kilometers of ground zero.

The purposes of Project SEDAN were to extend knowledge of cratering effects from detonations with yields of 100 to 200 kilotons and to provide safety data related to nuclear cratering detonations. To collect information, the LRL conducted an extensive program of scientific and technical projects.

DOD personnel took part in four projects studying peaceful uses of nuclear detonations. In addition, they participated in five VELA UNIFORM projects. Participating DOD agencies were:

- Defense Atomic Support Agency
- Army Engineer Nuclear Cratering Group
- Army Engineer Waterways Experiment Station
- Naval Radiological Defense Laboratory
- Air Force Technical Applications Center.

AFSWC and other Air Force personnel conducted cloud-sampling, cloud-tracking, and support missions at the shot.

Safety Standards and Procedures

To minimize the exposures of PLOWSHARE personnel to ionizing radiation, the AEC established an individual exposure limit of 3 roentgen equivalent man (rem) of gamma and neutron radiation per quarter calendar year and not more than 5 rem annually. The radiological safety programs for Projects GNOME and SEDAN operated within these exposure guidelines. The AEC provided onsite radiological support, which included:

- Issuing anticontamination clothing and equipment to personnel entering radiation areas
- Monitoring radiation areas and controlling access into these areas
- Plotting isointensity contour maps of radiation areas and providing radiation information to personnel entering radiation areas

- Decontaminating personnel, vehicles, and equipment

- Maintaining film badge and exposure records to determine the exposure of each participant to gamma radiation.

Neutron exposures were to be assessed on a case-by-case basis. Such exposures would occur, however, only if personnel were positioned close-in at shot-time. Personnel were not permitted into areas of 10 R/h or greater unless they had special permission from the AEC.

U.S. Public Health Service (USPHS) personnel conducted offsite monitoring. Their activities involved:

- Monitoring for offsite radiation

- Conducting environmental monitoring of air, water, and milk

- Collecting data on fallout patterns.

USPHS personnel prepared reports, maps, and records describing results of the monitoring and data collection.

Radiation Exposures at Projects GNOME and SEDAN

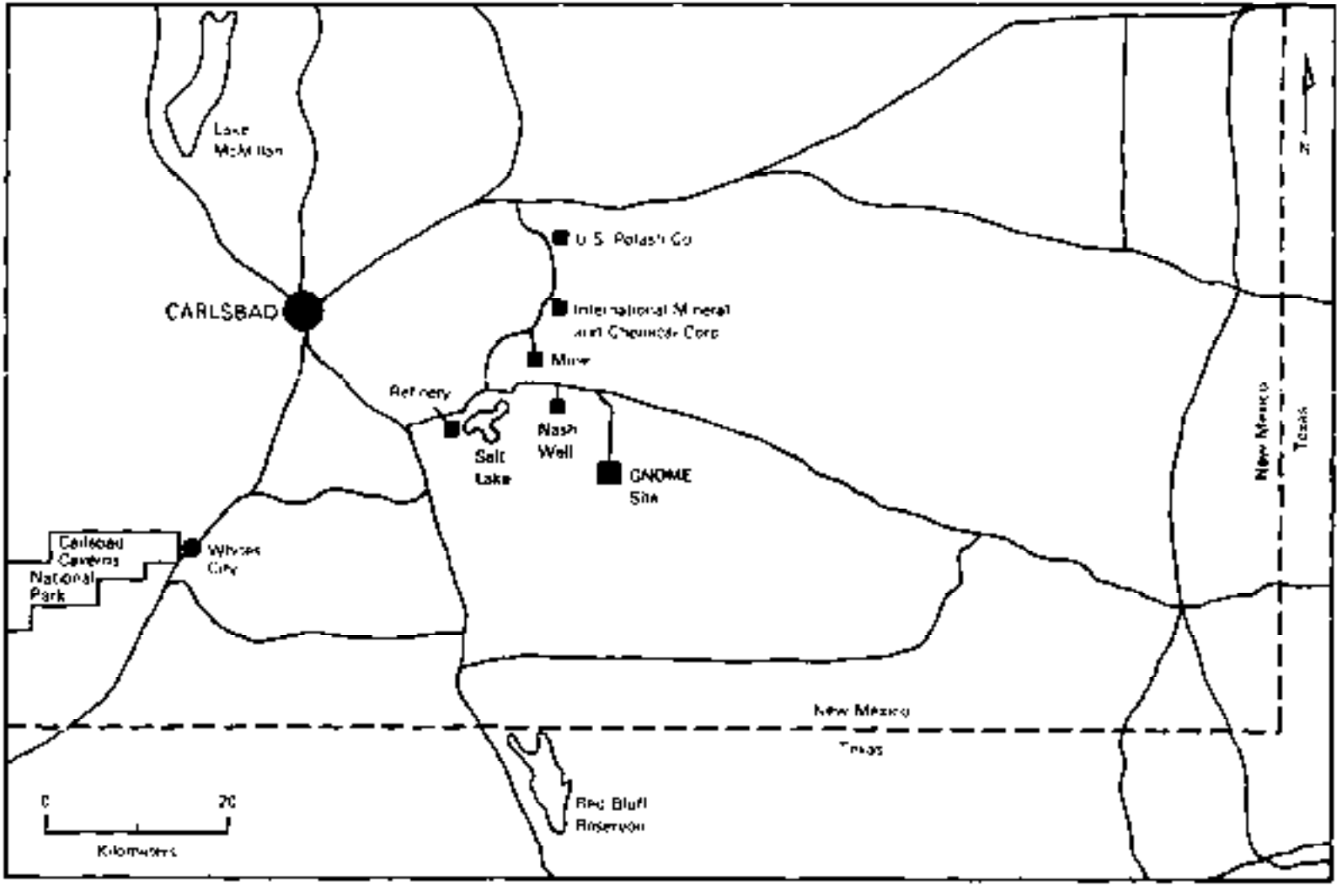
Available documentation indicates that two radiation exposures exceeded the 3 rem limit. The accompanying table summarizing dosimetry information presents film badge exposure data for PLOWSHARE participants by service.

PLOWSHARE EXPERIMENTS

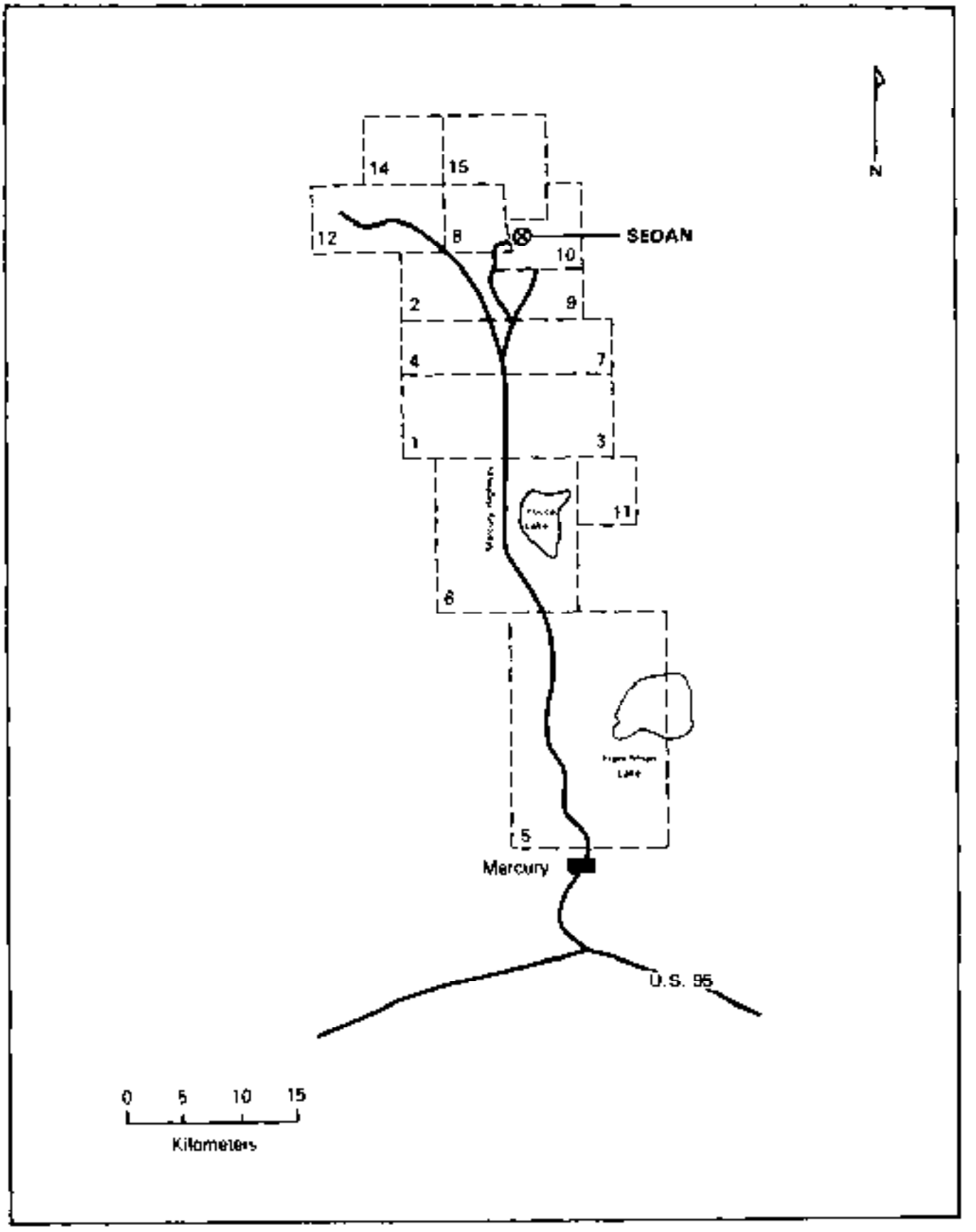
Event	Date	Location	Type	Yield (kilotons)
GNOME	12/10/61	Carlsbad, NM	Shaft	3
SEDAN	07/06/62	NTS	Crater	104
ANACOSTIA	11/27/62	NTS	Shaft	less than 20
KAWEAH	02/21/63	NTS	Shaft	less than 20
TORNILLO	10/11/63	NTS	Shaft	less than 20
KLICKITAT	02/20/64	NTS	Shaft	20 to 200
ACE	06/11/64	NTS	Shaft	less than 20
DUB	06/30/64	NTS	Shaft	less than 20
PAR	10/09/64	NTS	Shaft	38
HANDCAR	11/05/64	NTS	Shaft	12
SULKY	12/18/64	NTS	Shaft	0.092
PALANQUIN	04/14/65	NTS	Crater	4.3
TEMPLAR	03/24/66	NTS	Shaft	less than 20
VULCAN	06/25/66	NTS	Shaft	25
SAXON	07/28/66	NTS	Shaft	less than 20
SIMMS	11/05/66	NTS	Shaft	less than 20
SWITCH	06/22/67	NTS	Shaft	less than 20
MARVEL	09/21/67	NTS	Shaft	less than 20
GASBUGGY	12/10/67	Farmington, NM	Shaft	29
CABRIOLET	01/26/68	NTS	Crater	2.3
BUGGY	03/12/68	NTS	Crater	5.4
STODDARD	09/17/68	NTS	Shaft	20 to 200
SCHOONER	12/08/68	NTS	Crater	30

PLOWSHARE EXPERIMENTS (continued)

Event	Date	Location	Type	Yield (kilotons)
BULLSON	09/10/69	Grand Valley, CO	Shaft	40
FLASK	05/26/70	NTS	Shaft	105
MISLATA	07/08/71	NTS	Shaft	83
RIO BLANCO	05/17/73	Rifle, CO	Shaft	33 (for each of three devices)



PROJECT GNOME SITE



SEDAN GROUND ZERO WITHIN THE NEVADA TEST SITE

SUMMARY OF DOSIMETRY FOR PLOWSHARE PROGRAM AS OF DECEMBER 1982*

Units	Personnel Identified by Name	Personnel Identified by Name and by Film Badge	Gamma Exposure (rem)					Number of Personnel with Zero Gamma Exposure**	Average Gamma Exposure (rem)	Maximum Gamma Exposure (rem)
			< 0.1	0.1-1.0	1.0-3.0	3.0-5.0	5.0 +			
Army	3	1	0	0	1	0	0	0	1.296	1.296
Navy	82	62	8	25	27	1	1	5	1.033	5.790
Marine Corps	1	1	0	1	0	0	0	0	0.330	0.330
Scientific Personnel, Contractors, and Affiliates	632	632	632	0	0	0	0	629	0	0.080
Air Force (Total)	26	23	14	9	0	0	0	11	0.119	0.670
SEDAN (Air Force Subtotal)	(13)	(11)	(9)	(2)	(0)	(0)	(0)	(7)	(0.049)	(0.286)
GNOME (Air Force Subtotal)	(12)	(12)	(5)	(7)	(0)	(0)	(0)	(4)	(0.184)	(0.670)
Total	743	719	654	35	28	1	1	645	0.095	

* Data are for SEDAN participants, except as noted.

** The number of personnel in this column is also represented in the <0.1 gamma exposure column.

PREFACE

From 1945 to 1962, the U.S. Government, through the Manhattan Engineer District and its successor agency, the Atomic Energy Commission (AEC), tested nuclear devices at sites in the United States and in the Atlantic and Pacific Oceans. In all, an estimated 220,000 Department of Defense (DOD) participants, both military and civilian, were present at the tests.

In 1977, 15 years after the last above-ground nuclear weapons test, the Center for Disease Control* noted a possible leukemia cluster among a group of soldiers present at Shot SMOKY, a test of Operation PLUMBBOB, the Nevada test series conducted in 1957. Since that initial report by the Center for Disease Control, the Veterans Administration has received a number of claims for medical benefits from former military personnel who believe their health may have been affected by their participation in the weapons testing program.

In late 1977, the DOD began a study to provide data on the potential exposure to ionizing radiation among the DOD military and civilian participants in atmospheric nuclear testing. The DOD organized an effort to:

- Identify DOD personnel who had taken part in atmospheric nuclear weapons tests and other nuclear tests
- Determine the extent of the participants' exposure to ionizing radiation
- Provide public disclosure of information concerning participation by DOD personnel in the atmospheric nuclear weapons tests and other nuclear tests.

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*The Center for Disease Control is part of the U.S. Department of Health and Human Services (formerly the U.S. Department of Health, Education, and Welfare).

METHODS AND SOURCES USED TO PREPARE THIS VOLUME

The Defense Nuclear Agency compiled information for this volume from available documents that record scientific and technical activities conducted generally during the PLOWSHARE program, the series of nuclear tests conducted from 1961 to 1973, and specifically during Projects GNOME and SEDAN, the first two nuclear detonations of the program. These records, most of which were developed by individuals and organizations participating in PLOWSHARE, are kept in numerous document repositories throughout the United States. In compiling information for this report, teams of historians, health physicists, radiation specialists, and information analysts canvassed the document repositories, including armed services libraries, Government agency archives and libraries, Federal repositories, and libraries of scientific and technical laboratories. The teams examined classified and unclassified documents containing information on DOD participation in PLOWSHARE activities, recorded relevant information concerning the involvement of DOD personnel, and catalogued the data sources. Many of the documents pertaining specifically to DOD participation were found in the Defense Nuclear Agency Technical Library. In most cases, however, the surviving historical documentation of activities conducted at Projects GNOME and SEDAN addresses test specifications and technical information rather than personnel data.

For several of the activities discussed in this volume, the only documents available are the schedules of events for Projects GNOME and SEDAN, the "Department of Defense Technical Operational Plan for VELA UNIFORM Participation in Project GNOME," and the "Technical Director's Operation Plan, Project SEDAN." These sources detail the plans developed by AEC and DOD personnel prior to GNOME and SEDAN; the documents do not report on the experiments as actually conducted. Plans and operations orders should, however, provide a reasonably accurate account of personnel

activities since accomplishment of Projects GNOME and SEDAN objectives required detailed planning and adherence to operations orders. The references indicate whether the description is according to specifications given in the schedules of events, operational plans, or scientific reports.

ORGANIZATION OF THIS VOLUME

This volume describes the PLOWSHARE program and discusses Projects GNOME and SEDAN. These two shots were selected for discussion because they were conducted during the period of U.S. atmospheric nuclear weapons testing, had documented (although limited) DOD participation, and have been sufficiently documented to permit a discussion of the detonations and associated activities.

Chapter 1 of this volume provides background information, including summaries of the historical context, objectives, and organization of the PLOWSHARE program. Chapter 2 discusses Project GNOME, conducted at a location southeast of Carlsbad, New Mexico, and chapter 3 discusses Project SEDAN, conducted at the Nevada Test Site (NTS). In addition to identifying the particular test site, each chapter describes the scientific and technical activities conducted by military and DOD civilian personnel and the radiological safety criteria and procedures in effect at the shots. The two chapters also present the information accessible on DOD personnel dosimetry.

The information in this report is supplemented by the Reference Manual: Background Materials for the CONUS Volumes. The manual summarizes information on radiation physics, radiation health concepts, exposure criteria, and measurement techniques. It also lists acronyms and a glossary of terms used in the DOD reports addressing test events in the continental United States.

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LIST OF ABBREVIATIONS AND ACRONYMS

The following abbreviations and acronyms are used in this volume:

AEC	Atomic Energy Commission
AFB	Air Force Base
AFSWC	Air Force Special Weapons Center
AFTAC	Air Force Technical Applications Center
DASA	Defense Atomic Support Agency
DOD	Department of Defense
EG&G	Edgerton, Germeshausen, and Grier, Incorporated
NRDL	Naval Radiological Defense Laboratory
NTS	Nevada Test Site
NTSO	Nevada Test Site Organization
LASL	Los Alamos Scientific Laboratory
LRL	Lawrence Radiation Laboratory
REECo	Reynolds Electrical and Engineering Company
rem	roentgen equivalent man
R/h	Roentgens per hour
USPHS	United States Public Health Service

CHAPTER 1
INTRODUCTION

The involvement of the U.S. Government in nuclear research dates from the beginning of World War II. At the outbreak of the war, emigre scientists from Europe urged President Franklin D. Roosevelt to build a nuclear weapon for use in the conflict before the Germans did. The U.S. nuclear weapons test program, begun during the war, evolved throughout the 1940s and into the 1950s. Influenced by its post-World War II relations with the Soviet Union and anticipating Soviet advances in nuclear weapons, the United States continued to expand its nuclear weapons test program and its nuclear arsenal to maintain an advantage over its greatest potential adversary (9; 20).*

Even in the earliest days of nuclear research and nuclear weapons testing, however, scientists were aware of the potential for peaceful applications of nuclear energy, including nuclear detonations. With the founding of the United Nations following the Second World War, world leaders established as their goal and motto the fulfillment of Isaiah's prophecy, "And they shall beat their swords into plowshares." Nuclear power generation research was reestablished as an important priority, and nuclear weapons researchers again considered peaceful applications of the energy released by a detonation (42).

The opportunity for American scientists to apply nuclear detonations to peacetime problems in large-scale engineering was delayed by several factors, including the greater priority of developing efficient weapons applications, concern over

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*All sources cited in the text are listed alphabetically and numbered in the Reference List at the end of this volume.

radioactive contamination, political uncertainty, and international suspicion of the intent of the research and the applications being considered. Nevertheless, the AEC ultimately succeeded in initiating the PLOWSHARE program, designed to explore the feasibility of peaceful applications of the explosive power released by nuclear detonations. PLOWSHARE was planned in the last years of the 1950s and conducted intermittently throughout the 1960s and until 1975. The participation of the Department of Defense in PLOWSHARE activities was limited, involving primarily logistic support to the AEC (12: 44).

1.1 HISTORICAL BACKGROUND

The peaceful uses of nuclear fission were a low priority for the U.S. Government before and during World War II. The rise of fascism in Europe and the emigration of European scientists to the United States in the mid-1930s encouraged the involvement of the U.S. Government in nuclear research. These scientists, who were aware of important developments in nuclear physics research in Germany, were concerned that Germany might put the atom to military use. Their fears deepened when it was revealed in 1938 that two German scientists had successfully split the uranium atom, thus proving that an artificially induced nuclear chain reaction was possible. In 1939, the emigre scientists drafted a letter to President Franklin D. Roosevelt. Signed by Albert Einstein, the letter informed the President about German nuclear experiments and the possibilities of a German nuclear weapon. The letter, and the extensive planning and preparation that followed, led eventually to the creation in 1942 of the Manhattan Engineer District.

Established under the Army Corps of Engineers, the Manhattan Engineer District oversaw the Manhattan Project, the American Government's effort to construct a nuclear weapon before the Germans did. The Manhattan Project proved successful, first with

the detonation of TRINITY, the world's first nuclear explosive device, at Alamogordo, New Mexico, on 16 July 1945, and then with the detonation of two nuclear weapons over Japan the following month, which brought about the end of World War II (20).

After the war, and having witnessed the destructive power of nuclear detonations, scientists and laymen desired to harness nuclear energy for peaceful applications. The recognition that nuclear energy had both military and peaceful applications became U.S. policy in the Atomic Energy Act of 1946, which stated that "atomic energy is capable of application for peaceful as well as military purposes." The act specified that (1; 2):

> A. The development, use, and control of atomic energy shall be directed so as to make the maximum contribution to the general welfare, subject at all times to the paramount objective of making the maximum contribution to the common defense and security....
>
> B. The development, use, and control of atomic energy shall be directed so as to promote world peace, improve the general welfare, increase the standard of living, and strengthen free competition in private enterprise.

The establishment of the Atomic Energy Commission as a civilian agency, separate from the Department of Defense, underscored the U.S. Government's position that peacetime uses of atomic energy would be a major emphasis and that even weapons-related research would remain under the control of civilian administrators at all times (42).

In the late 1940s, the mathematician John von Neumann again proposed using nuclear explosives for peaceful purposes (42). However, at that time the available technology had several drawbacks, including the high cost of fissionable materials, the limits on the total yield, and the high level of radioactive products. These factors, coupled with the increasing tension between the Soviet Union and the West, led the United States to

continue to direct most of its nuclear research toward weapons development and defense (42).

In the fall of 1952, the United States conducted the first thermonuclear or fusion detonation at Enewetak Atoll in the Marshall Islands. The achievement of a fusion detonation was significant for three reasons (15; 23):

- Fusion fuels are far more abundant and, hence, cheaper than fission fuels.
- The radioactivity generated by the lower relative fission yield is greatly reduced.
- The potential exists for much higher yields.

These factors were also important considerations for the peaceful applications of nuclear detonations.

In the fall of 1956, Dr. Harold Brown, then director of the Lawrence Radiation Laboratory (LRL) in Livermore, California, studied the possibility of using nuclear explosives to assist in excavating an alternate sea-level canal across Israel (15; 42). A second, similar proposal addressed the use of nuclear devices to excavate a second canal between the Atlantic and Pacific Oceans, either across the Isthmus of Panama or through Nicaragua or Colombia (15). Also in 1956, Camille Rougeron, a French engineer who had long advocated the use of thermonuclear explosives for peaceful purposes, published a book on the subject, Les Applications de l'Explosion Thermonucleaire (42).

In February 1957, as the construction of the first commercial nuclear-powered electrical generator was nearing completion in Shippingport, Pennsylvania, Dr. Brown organized a symposium involving the joint participation of the Los Alamos Scientific Laboratory (LASL), the Sandia Corporation Laboratory, and the LRL to discuss peaceful uses of nuclear explosives. Under the leadership of Dr. Brown, a group was formed at the LRL

in the summer of 1957 to explore the range of potential engineering uses of nuclear explosives. The symposium and the subsequent meetings of this group, together with the inauguration of the Shippingport nuclear power reactor by President Dwight D. Eisenhower later in 1957, stimulated scientific and public interest in the nonmilitary uses of nuclear energy (23).

In a separate line of development that would later prove significant and following the suggestions of several LRL scientists, the AEC had embarked upon a program of underground nuclear weapons testing. Shot RAINIER, the first contained underground nuclear detonation, was fired at the Nevada Test Site in September 1957 as part of Operation PLUMBBOB. The successful containment of the RAINIER event and some underground tests conducted in 1958 added to the speculations concerning engineering and other civil applications of contained nuclear detonations (15).

Ideas stimulated by these experiments were first reported at the second Atoms for Peace Conference held in Geneva, Switzerland, in the fall of 1958. At this conference, however, the Soviet Union attacked U.S. proposals to use nuclear detonations for industrial and civil purposes and scoffed at the idea of nuclear weapons as a peacetime engineering resource (19).

In late 1958, the nuclear test moratorium caused a postponement of the nuclear weapons development program. The USSR suggested the moratorium when, in March of 1958, it unanimously adopted a resolution calling for the unilateral termination of fission and fusion weapons testing by the Soviet Union and the initiation of an international conference aimed at banning further tests. Even though they had not secured an agreement on the moratorium with the Soviets, the United States and Great Britain suspended nuclear weapons tests on 31 October 1958, the opening day of the Geneva Conference on the

Discontinuance of Nuclear Weapons Tests. The Soviets suspended nuclear testing a few days later, after a detonation on 3 November 1958. During the next six months, the Soviet and Western governments conducted negotiations to end nuclear weapons testing (9; 19).

Peaceful applications of nuclear detonations became a complicating factor at the nuclear test ban treaty negotiations in Geneva. On 30 January 1959, the United States introduced a proposal for the development of peacetime applications of nuclear explosives under international controls. The Soviets opposed this motion and charged the United States with desiring to continue fission and fusion weapons tests under the guise of exploring the use of nuclear explosives for peaceful purposes (9; 19).

The test ban treaty talks continued intermittently until they were suspended in May 1960. Pointing to concerns raised by the Berlin crisis, the Soviet Union announced on 31 August 1961 its unilateral decision to resume nuclear weapons testing, thus ending its self-imposed moratorium. The United States resumed underground testing at the NTS on 15 September 1961, after the Soviet Union had detonated three nuclear weapons above ground. The United States resumed atmospheric nuclear weapons tests in the Pacific at the end of April 1962 (9; 19).

On 5 August 1963, two years after the resumption of weapons testing, a limited test ban treaty was signed in Moscow. For the signatory states, this treaty ended the testing of nuclear explosive devices in the atmosphere, on land, and underwater, but not underground. Article 1 of the limited test ban treaty reads (19):

> (1) Each of the parties to this treaty undertakes to prohibit, to prevent, and not to carry out any nuclear weapon test explosion, or any other

nuclear explosion, at any place under its jurisdiction or control:

(a) In the atmosphere; beyond its limits, including outer space; or underwater, including territorial waters or high seas; or

(b) In any other environment if such explosion causes radioactive debris to be present outside the territorial limits of the State under whose jurisdiction or control such explosion is conducted...

The Soviet Union insisted on the insertion of the phrase "or any other nuclear explosion," which precluded atmospheric nuclear detonations for peaceful purposes. In addition, the treaty prohibited the use of nuclear explosives for peacetime projects at or within the territorial limits of other countries or at underwater locations (24; 42).

1.2 THE PEACEFUL POTENTIAL OF NUCLEAR DETONATIONS

The primary peaceful potential for nuclear detonations was that of large-scale geographic engineering. The AEC conducted many experiments with high explosives during the test moratorium, from 1958 to 1961, to aid research in this area. To extrapolate results to nuclear detonations, scientists studied the relationship of the explosive yield to the depth at which the explosive was buried and the dimensions of the resultant craters to the kind of rock in the shot area. Thus, considerable data were available for the PLOWSHARE program when nuclear testing was resumed at the end of the moratorium in 1961 (15).

Another application considered for nuclear explosives was the development of water resources. It was thought that nuclear explosives might improve fresh water supplies by greatly expanding the underground storage of water, by ensuring better distribution of surface water, by constructing earthfill dams, and by making possible economical water desalinization. Projects

were proposed for redirecting river courses or diverting one river system into another, draining swamps and eliminating salt lakes, blasting deep lake basins, building landslide dams and creating channels through natural earthfall dams, and creating and enhancing underground aquifers (42).

Nuclear scientists and planners believed that nuclear excavation techniques would prove functional in mining, particularly in the recovery of lower grade ores. They contemplated using nuclear blasting for three kinds of surface mining: strip, open pit, and quarry. They thought the use of nuclear explosives in surface mining would produce large quantities of fragmented ore, thus reducing the number of drilling and blasting operations needed to mine the ore. Nuclear blasting was considered even more attractive for subsurface mining, block caving, and especially in-situ leaching. The advantage in block-caving mining was that the nuclear blast would shatter ore not otherwise recoverable and would obliterate structures detrimental to block caving (42).

It was hoped that mining techniques using nuclear explosives to extract oil from tar sands and shale might provide a solution to the long-term petroleum problem. Furthermore, scientists envisioned nuclear techniques that would allow the mining of large deposits of hard taconite and thus resolve some of the difficulties in steel production (42).

One of the more novel applications suggested for nuclear explosives was changing raw materials very deep in the earth to chemicals important to science and industry. Scientists also eyed PLOWSHARE as a tool for improving seismology, since an underground nuclear blast is actually a controlled seismic disturbance. There were even considerations of using nuclear blasts for weather control. In addition, scientific experiments were suggested using nuclear explosives to power vehicles for the exploration of deep space (42).

The research program proposed included plans for more specific nuclear projects. Among the projects under consideration were those that would use nuclear explosives to (15):

- excavate a sea-level canal across the Central American isthmus either through Panama or Colombia
- Create canals to join the Qatara Depression and Chotts Depression in Egypt with the Red Sea
- Excavate harbors along the west coasts of Africa, Australia, and South America, and in northern Alaska (Project CHARIOT)
- Recover oil from the Athabaska Tar Sands in Alberta, Canada (Project OILSAND).

1.3 THE PLOWSHARE PROGRAM

In the mid-1950s, after nearly 20 years of research, the peacetime benefits of the controlled nuclear reaction were being demonstrated. U.S. policy-makers and researchers alike were eager to apply the massive energy released by a nuclear detonation to civil engineering. However, concern was increasing over the radioactive fallout produced by nuclear detonations in the atmosphere. When the United States successfully contained a small nuclear detonation in a sealed tunnel at Shot RAINIER in Nevada in late 1957, a safer alternative means of continuing research on both nuclear weapons and civilian applications was demonstrated.

Although the PLOWSHARE program was delayed during the nuclear testing moratorium, detailed planning studies were conducted for several PLOWSHARE projects. In addition, President Eisenhower had authorized the preparation of a site near Carlsbad, New Mexico, for conducting a nuclear test deeply buried in a bedded salt formation. Among other purposes, the detonation was intended to enable studies of power production and isotope recovery. In October 1961, President Kennedy authorized the

first PLOWSHARE project, Shot GNOME, at the Carlsbad site. The GNOME event was conducted on 10 December 1961 (42).

By the end of 1963, after five PLOWSHARE experiments and many weapons tests, the program to contain radioactivity had made a successful start. Results showed that projected fallout in excavation projects would be 100 times less than that forecast at the start of the moratorium in 1958 (23).

After the signing of the limited test ban treaty, another 22 PLOWSHARE experiments were conducted underground. Table 1-1 lists these experiments and the others within the program. The PLOWSHARE program was concluded in 1975, two years after the last detonation (8).

The major goals of the PLOWSHARE experiments conducted after the 1963 treaty, as stated at the Third PLOWSHARE Symposium, Engineering with Nuclear Explosives, were to make nuclear explosives cleaner and cheaper and to assure their performance and reliability in production prototypes. Scientists and planners responsible for the program believed that these goals could and would be met. They thought that PLOWSHARE presented a new technology that would eventually contribute to the economic growth of the United States and of many other nations.

The ultimate goal of PLOWSHARE, peaceful applications of nuclear explosives, was never realized. The 1963 atmospheric nuclear test ban treaty caused cancellations of many of the plans, such as those for dredging canals and excavating harbors. Other factors contributing to the failure of PLOWSHARE to fulfill its goal were changes in national priorities, Government and industry's disinterest in the program, public concern over the health and safety aspects of using nuclear power for civil applications, and shortages in funding. Although the program remained alive within the Atomic Energy Commission until 1975, it

Table 1-1 PLOWSHARE EXPERIMENTS

Event	Date	Location	Type	Yield (kilotons)
GNOME	12/10/61	Carlsbad, NM	Shaft	3
SEDAN	07/06/62	NTS	Crater	104
ANACOSTIA	11/27/62	NTS	Shaft	less than 20
KANEAB	02/21/63	NTS	Shaft	less than 20
TORNILLO	10/11/63	NTS	Shaft	less than 20
KLICKITAT	02/20/64	NTS	Shaft	20 to 200
ACE	06/11/64	NTS	Shaft	less than 20
DOB	06/30/64	NTS	Shaft	less than 20
PAR	10/09/64	NTS	Shaft	38
HANDCAR	11/05/64	NTS	Shaft	12
SULKY	12/18/64	NTS	Shaft	0.092
PALANQUIN	04/14/65	NTS	Crater	4.3
TEMPLAR	03/24/66	NTS	Shaft	less than 20
VULCAN	06/25/66	NTS	Shaft	25
SAXON	07/28/66	NTS	Shaft	less than 20
SIMMS	11/05/66	NTS	Shaft	less than 20
SWITCH	06/22/67	NTS	Shaft	less than 20
MARVEL	09/21/67	NTS	Shaft	less than 20
GASBUGGY	12/10/67	Farmington, NM	Shaft	29
CABRIOLET	01/26/68	NTS	Crater	2.3
BUGGY	03/12/68	NTS	Crater	5.4
STODDARD	09/17/68	NTS	Shaft	20 to 200
SCHOONER	12/08/68	NTS	Crater	30

Table 1-1: PLOWSHARE EXPERIMENTS (continued)

Event	Date	Location	Type	Yield (kilotons)
HULISON	09/10/69	Grand Valley, CO	Shaft	40
FLASK	05/26/70	NTS	Shaft	105
MINIATA	07/08/71	NTS	Shaft	83
RIO BLANCO	05/17/73	Rifle, CO	Shaft	33 (for each of three devices)

was clear that the most practical peaceful applications of nuclear energy had been achieved in the further development and construction of nuclear power generators during the 1960s and 1970s. The enormous energy release provided by nuclear detonations remained within the domain of weapons research and national defense.

1.4 PLOWSHARE PROGRAM ORGANIZATION AND DEPARTMENT OF DEFENSE PARTICIPATION

During PLOWSHARE's planning stages and during periods of testing, the General Manager of the AEC in Washington, D.C., provided overall supervision of the PLOWSHARE program. He was aided by his staff office, the Peaceful Nuclear Explosions Division. The AEC Nevada Operations Office administered most field activities, while the AEC Albuquerque Operations Office gave support and construction assistance. The AEC San Francisco Operations Office was responsible for administration and program development, including industrial participation (15; 42).

The AEC General Manager reported to the AEC Commissioners, who were responsible for policy decisions. The PLOWSHARE Advisory Committee, chaired by an AEC Commissioner and composed of eminent scientists, industrialists, and other prominent individuals, assisted the Commission.

The LRL, under contract to the AEC, designed and supervised the technical aspects of the PLOWSHARE program. For certain tasks, such as research and development activities, specialized support services, and consultation on the safety or technical aspects of the experiments, LRL used the services of other AEC laboratories, other contractors, Government agencies, or private individuals. Since the PLOWSHARE program spanned a period of more than 15 years, the organizational structure for specific detonations varied according to the date of the detonation, the location of the event, and the participating agencies (15; 42).

The role of the military in the PLOWSHARE program was primarily one of providing logistical support. Technical participation was also allowed if the involvement did not interfere with AEC activities. The Manager of the San Francisco Operations Office specified criteria to be used in determining military participation in PLOWSHARE. Among these guidelines were (18; 44):

A. The basic scientific and technical design of each PLOWSHARE experiment must be directed to peaceful objectives and should constitute a potentially useful contribution to the science of peaceful uses of nuclear explosives.

B. Assistance of the military in the area of logistical-operational support and the use of military equipment solely for this purpose is endorsed where economical and where the military is willing to furnish such support.

C. Technical participation of the Department of Defense or its contractors, as distinguished from support, in any given experiment must be approved by DMA (Division of Military Application) on an individual basis.

PROJECT GNOME

SYNOPSIS

AEC TEST SERIES:	PLOWSHARE
DATE/TIME:	10 December 1961, 1200 hours
YIELD:	3.1 kilotons
HEIGHT OF BURST:	1,184 feet underground
LOCATION:	Carlsbad, New Mexico

Purpose of Test: To obtain information on the characteristics of an underground nuclear detonation in a salt medium and to explore the feasibility of energy recovery, radioisotope recovery, and generated-neutron utilization.

Weather: At shot-time, the temperature was 7.4° Celsius, and the surface atmospheric pressure was 909 millibars. Winds were four knots from the southeast at the surface and 14 knots from the southeast at 100 feet.

Radiation Data: Radioactive materials vented to the atmosphere about 340 meters southwest of ground zero. On shot-day, the highest measured onsite gamma intensity was 1 roentgen per hour (R/h), recorded 1,300 meters northwest of the shaft opening at 1938 hours. The highest offsite reading was 1.4 R/h, measured 5.5 kilometers west of the Control Point one hour after the detonation. Underground recovery operations were delayed in part because of high radiation levels at the shaft opening (5 R/h at 0908 hours on the day after the detonation).

Participants: Army Engineer Waterways Experiment Station; Defense Atomic Support Agency; Air Force Special Weapons Center; Air Force Tactical Applications Center; Lawrence Radiation Laboratory; Oak Ridge National Laboratories; Sandia Corporation; Stanford Research Institute; U.S. Coast and Geodetic Survey; U.S. Weather Bureau; Holmes and Narver, Inc.; Edgerton, Germeshausen, and Grier, Inc.; U.S. Public Health Service; Reynolds Electrical and Engineering Company; Federal Aviation Agency; U.S. Geological Survey; Space Technology Laboratories; Texas Instruments; Geotechnical Corporation; other contractors; AEC civilians.

CHAPTER 2
PROJECT GNOME

The Project GNOME detonation at 1200 hours Mountain Standard Time on 10 December 1961 was the first nuclear test of the PLOWSHARE program. It was also the first continental nuclear test conducted outside the Nevada Test Site since TRINITY was detonated near Alamogordo, New Mexico, on 16 July 1945. On 1 July 1958, the Atomic Energy Commission selected an area 40 kilometers* southeast of Carlsbad, New Mexico, as the location for GNOME. The AEC originally scheduled the detonation for 1 July 1959. The nuclear device, to be emplaced at a depth of 1,200 feet, was initially planned to have a yield of ten kilotons (14; 27).

In August 1958, the AEC made a public announcement of its plans for Project GNOME. Shortly after the announcement, the Carlsbad potash industry objected to the plans because of the possible effects of the detonation on mines and refineries in the area, on gas wells located nearby, on farmlands, on ground water, and on the Carlsbad Caverns. In response to these objections, the AEC convened a panel of experts recommended by the National Academy of Sciences. The experts studied potential health and safety issues associated with the use of the projected site for GNOME. They reviewed the geology of the region, appraised ground water conditions, and evaluated the expected seismic effects. They concluded that the area was suitable for the GNOME detonation (4; 15; 27; 43).

In late 1958, the nuclear test moratorium caused a postponement of Project GNOME. In anticipation of the eventual

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*Throughout this report, surface distances are given in metric units. The metric conversion factors include: 1 meter = 3.28 feet; 1 meter = 1.09 yards; 1 kilometer = 0.62 miles. Altitudes and other vertical distances are given in feet.

end of the moratorium, however, the AEC continued developing plans for the detonation. In March 1960, President Eisenhower directed the AEC to proceed with design and construction plans. The AEC then rescheduled the shot for 1 May 1961 and, later, for 10 December 1961. It revised its plans for a detonation of ten kilotons to one of five kilotons. On 25 October 1961, President Kennedy authorized the experiment, describing it as a "further example of this country's desire to turn the power of the atom to man's welfare rather than his destruction" (42). To prepare for GNOME and other PLOWSHARE experiments, the AEC conducted a high-explosive detonation program from 1958 to 1961 at the NTS and other sites, including the Carlsbad location (15; 38; 42).

Since one of the purposes of GNOME was to obtain information on the characteristics of underground detonations in another medium--salt--the device was to be fired in a bedded salt formation. In selecting the site, scientists engaged by the AEC specified that they wanted a relatively pure salt formation that had a low water content, the top of which was less than 800 feet below the surface. In addition, they wanted an area of low population that was on Government land. Assisted by the U.S. Geological Survey, the scientists eventually selected the site 40 kilometers southeast of Carlsbad, in Eddy County. Figure 2-1 shows the site location. The site was in the Salado formation of the Delaware Basin. This geologic formation consists principally of halite (rock salt), with minor traces of anhydrite, polyhalite, silt, and claystone. The top of the salt formation was approximately 710 feet below the site surface. The GNOME site was about ten kilometers from the nearest oil well, 14 kilometers from the nearest underground potash mine in operation, and 55 kilometers from the nearest edge of the Carlsbad Caverns. After this location had been selected, the land surrounding the site was withdrawn from the public domain and placed under AEC control (12; 15).

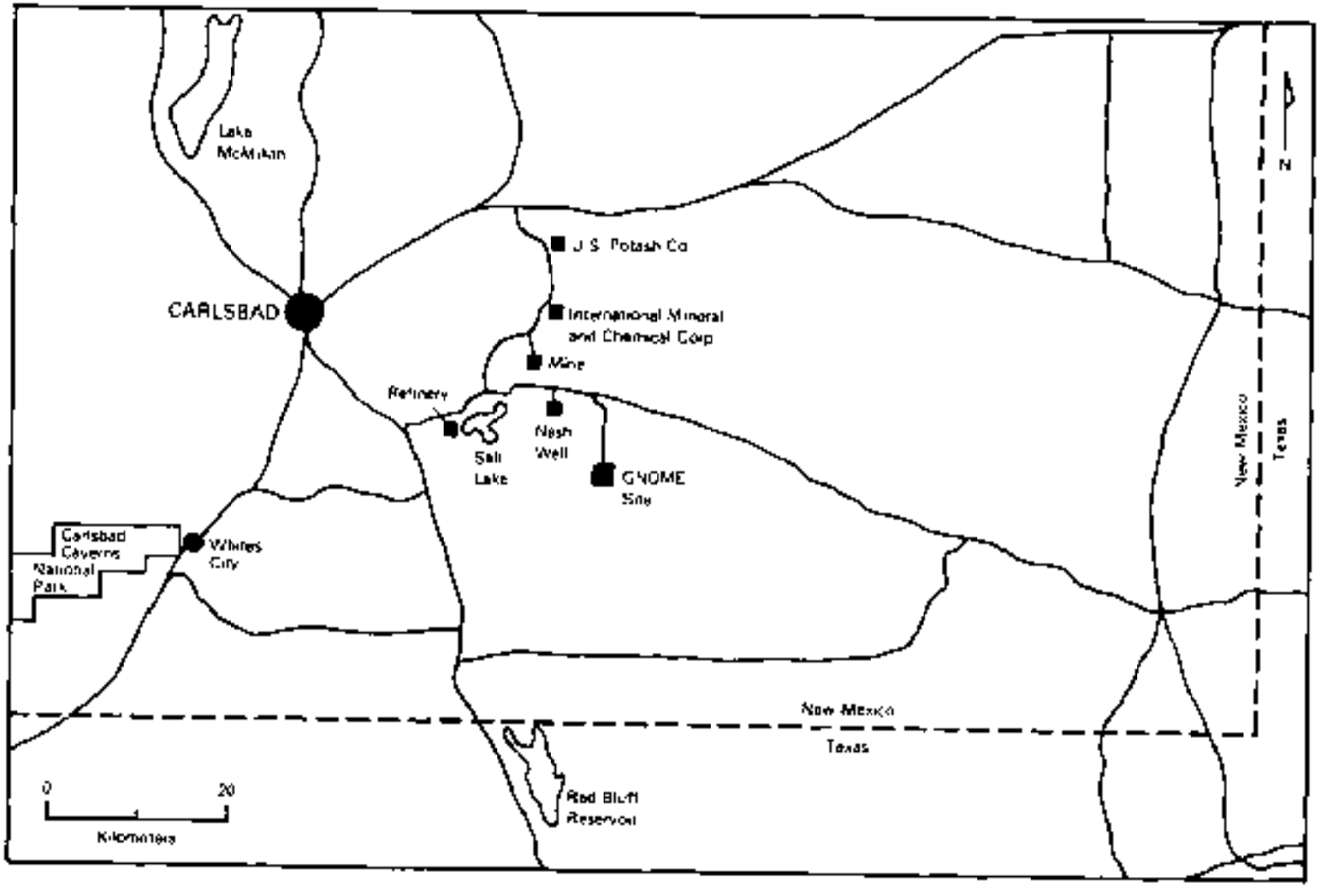

Figure 2-1: PROJECT GNOME SITE

Several contractors began the planning and construction work at the Carlsbad site in the summer of 1961. Holmes and Narver, Incorporated, prepared the engineering and construction plans, for which the Lawrence Radiation Laboratory had developed technical specifications. Many companies constructed the shaft and the emplacement tunnel that went from the bottom of the shaft to the detonation point. The Reynolds Electrical and Engineering Company (REECo) and several New Mexico contractors performed general support and other construction tasks (15).

LRL assembled and emplaced the nuclear device, which was armed by the Sandia Corporation. Edgerton, Germeshausen, and Grier, Incorporated (EG&G) designed and installed the timing and firing equipment. Under the technical direction of LRL, many agencies performed research and development experiments. These agencies included the Los Alamos Scientific Laboratory, Sandia Laboratory, Stanford Research Institute, Oak Ridge National Laboratory, the U.S. Bureau of Mines, and the U.S. Coast and Geodetic Survey. The LRL also conducted experiments (15).

The GNOME device was emplaced 1,184 feet underground in bedded rock salt at the end of a 1,116-foot hooked tunnel meant to be self-sealing. A shaft 1,216 feet deep and ten feet wide ended in a station room connected to the tunnel. Figure 2-2 shows the GNOME detonation site, including ground zero and the shaft opening.

GNOME was detonated with a yield of 3 kilotons. At shot-time, the surface temperature was 7.4 degrees Celsius, and the surface atmospheric pressure was 906 millibars. Winds were four knots from the south-southeast at the surface and 14 knots from the southeast at 100 feet. Although it had been planned as a contained explosion, GNOME vented to the atmosphere. A cloud of steam started to appear at the top of the shaft two to three

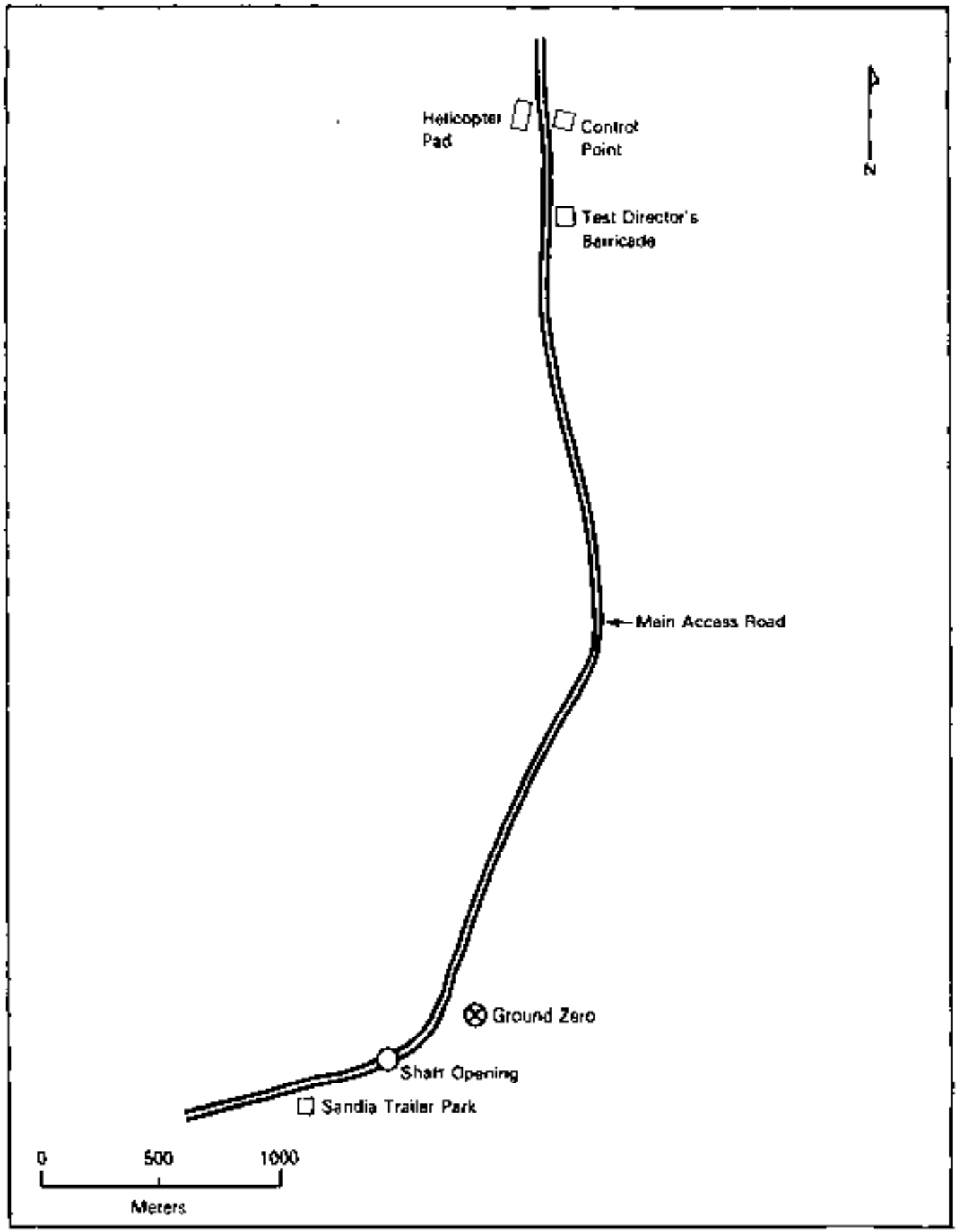

Figure 2-2: PROJECT GNOME DETONATION SITE

minutes after the detonation. Gray smoke, steam, and associated radioactivity emanated from the shaft opening about seven minutes after the detonation. Within 11 minutes after shot-time, both the shaft and ventilation lines were issuing large quantities of steam. During the next 30 minutes, the large flow continued and then began to decrease gradually. The surface radioactivity resulting from the escape of steam decayed rapidly. On the following day, a small flow of steam was still detectable (8; 14; 17).

The detonation produced a nonspherical cavity with a volume of about 960,000 cubic feet and melted about 2,400 tons of rock. Pressure produced in the surrounding rock imploded about 13,000 tons of salt rock into the cavity. The cavity roof and walls subsequently collapsed, resulting in an additional 15,000 tons of solid rock salt being dumped into the cavity. The chamber was then 60 to 80 feet high and 160 to 170 feet wide. The cavity floor was at about the level of the original detonation point. The material originally melted by the detonation and that which fell from the roof and walls of the cavity comprised the lower portion of the cavity. Most of the nongaseous radioactive residue was trapped in the mixture of rubble and once-molten salt that made up the floor of the chamber. When workers reentered the cavity on 17 May 1962, they found temperatures around 60 degrees Celsius but only small amounts of residual radiation. The earlier intense radiation had colored the salt of the cavity walls various shades of blue, green, and violet (15; 17).

2.1 OBJECTIVES OF PROJECT GNOME

GNOME was the first nuclear detonation with the objective of developing nuclear explosives for peaceful applications. Along with expanding data on an underground nuclear detonation in a salt medium, the primary objectives were to (12; 15):

- Study the possibility of converting the heat produced by a nuclear explosion into steam for the production of electric power

- Explore the feasibility of recovering radioisotopes for scientific and industrial applications

- Use the high flux of neutrons produced by the detonation for a variety of measurements that would contribute to scientific knowledge in general and to the reactor development program in particular.

Measurements of an earlier underground detonation, Shot RAINIER, had indicated that roughly one-third of the energy was deposited in the melted rock at temperatures above 1,090 degrees Celsius. This information encouraged hopes that a nuclear detonation in a dry medium might cause heat to be stored long enough to permit efficient recovery. GNOME was developed with the idea that a nuclear detonation in a salt deposit would create a large volume of hot melted salt from which heat might be extracted. The possibilities to be investigated for the production of power were the tapping of the steam created by the detonation itself and the generation of high-density, high-pressure steam by the circulation of some heat-absorbing fluid, like water, over the heated salt. This generated steam would be used to drive a steam or hot gas turbine coupled with an electric generator (17; 42).

Because of the widely increased use of radioisotopes in scientific experiments, medical diagnosis and therapy, agriculture, and industrial production, PLOWSHARE scientists sought to find new means for manufacturing and recovering radioisotopes. Shot RAINIER had demonstrated that large quantities of radionuclides become entrapped in the molten rock formed by an underground nuclear explosion. Since recovery is difficult when the rock solidifies, a new medium of transport for the radionuclides was sought. It was hoped that salt, being water soluble, could be processed to recover the radionuclides more cheaply and simply than from an insoluble, low-grade ore (15; 42).

Nuclear detonations produce neutrons in such high quantity and density that it was thought they would make possible new and significant scientific experiments that had been essentially impossible with conventional sources. To obtain information on the structure and properties of the atomic nucleus, scientists at GNOME designed and installed equipment in the tunnel so that various sample materials would be irradiated by different portions of the neutron energy spectrum (15; 42).

2.2 OBSERVER PROGRAM

To emphasize the peaceful aims of the GNOME experiment, the AEC welcomed observers from interested countries of the United Nations, as well as representatives of the press and scientific community, and made all information, except that pertaining to the design of the nuclear explosive, available to the public. In addition, the Commission undertook an extensive information program prior to the detonation (11; 15; 42).

Briefings were held in Carlsbad on 25 and 26 November 1961. After the latter briefing, participants made a surface and underground visit to the test site. The following listing identifies the number of participants and their affiliation (10):

	Briefing	Tour
International observers	16	14
News media	71	65
Government	27	26
Science and industry	40	45
Carlsbad visitors	43	51
	197	201

United Nations representatives were among the participants. The official Carlsbad visitors included representatives from the city and county government, the state legislature, the potash industry and other local businesses, the Chamber of Commerce, and

education and labor groups. News media personnel were from ABC and CBS radio and television, Movietone News and Telenews, Associated Press and United Press International, Life, Time, Business Week, U.S. News and World Report, New York Times, San Francisco Chronicle, and the local media (10).

Another briefing was held on 9 December 1961 in the Carlsbad High School auditorium. On 10 December, many scientists and some 400 other observers saw the GNOME detonation from a site 7.2 kilometers from ground zero (10; 42).

2.3 PROJECT GNOME ORGANIZATION

The AEC established the Project GNOME Organization to plan and conduct the detonation. The organization consisted primarily of AEC, DOD, and contractor personnel.

The Director of the Division of Military Application, who customarily supervised nuclear test operations from AEC headquarters in Washington, D.C., shared responsibility for Project GNOME with the Director of the Division of Biology and Medicine and the Director of the Division of Peaceful Nuclear Explosions. The AEC assigned overall control of GNOME planning to the AEC San Francisco Operations Office. The San Francisco Office signed an agreement with the AEC Albuquerque Operations Office giving the Albuquerque Office responsibility for GNOME field operations. The Assistant Manager for Field Operations, Albuquerque Operations Office, was the GNOME Project Manager (12; 33).

The principal DOD agencies coordinating military activities were the Air Force Technical Applications Center (AFTAC) and the Defense Atomic Support Agency (DASA). These two agencies participated in the VELA UNIFORM program, developed by DOD to improve U.S. capabilities in detecting and identifying

underground nuclear detonations. AFTAC formulated the technical requirements for the VELA UNIFORM program, conducted offsite measurements, and developed onsite inspection techniques. Working with these requirements, DASA developed and directed the projects. The Advanced Research Projects Agency, a DOD office administering the VELA UNIFORM program, supervised DASA and AFTAC activities (12). Figure 2-3 shows the line of authority from the President through the AEC and DOD to the Project GNOME Organization. Figure 2-4 shows the Project GNOME Organization.

The GNOME Project Manager was in charge of the overall planning and conduct of field operations. He was assisted by the Military Deputy Project Manager, an officer from Field Command, DASA, who was responsible for all VELA UNIFORM matters and DOD participation in GNOME. The Scientific Advisor and a board of consultants from the Government and scientific community aided the Project Manager in deciding whether conditions were safe for the detonation (12). The Project Manager, Scientific Advisor, and consultants based their decision on findings of the Weather and Radiation Prediction Unit. The chief meteorologist of the U.S. Weather Bureau Station in Las Vegas, Nevada, was director of the unit. The Weather Bureau provided personnel and technical equipment (49).

In addition to his other duties, the Project Manager was responsible for disseminating information about GNOME. To accomplish this, he established the Office of Information in Carlsbad. This office issued all press releases to the public and oversaw the flow of information through GNOME participants to the media (34).

The Technical Group was responsible for implementing experiments at GNOME that were not part of VELA UNIFORM and for implementing onsite radiological safety procedures. The Technical Group Director, an LRL scientist, headed this

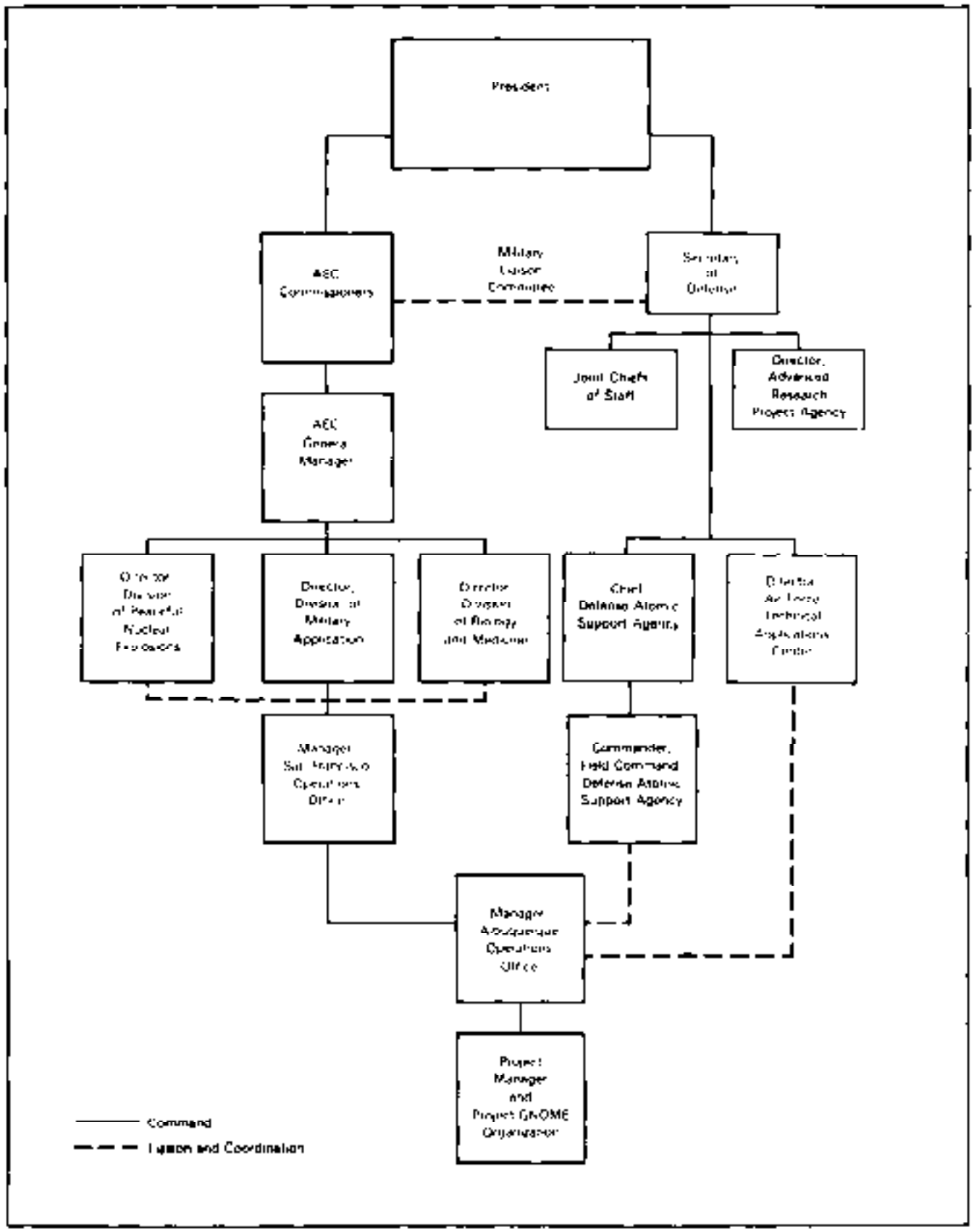

Figure 2-3: FEDERAL GOVERNMENT STRUCTURE FOR PROJECT GNOME

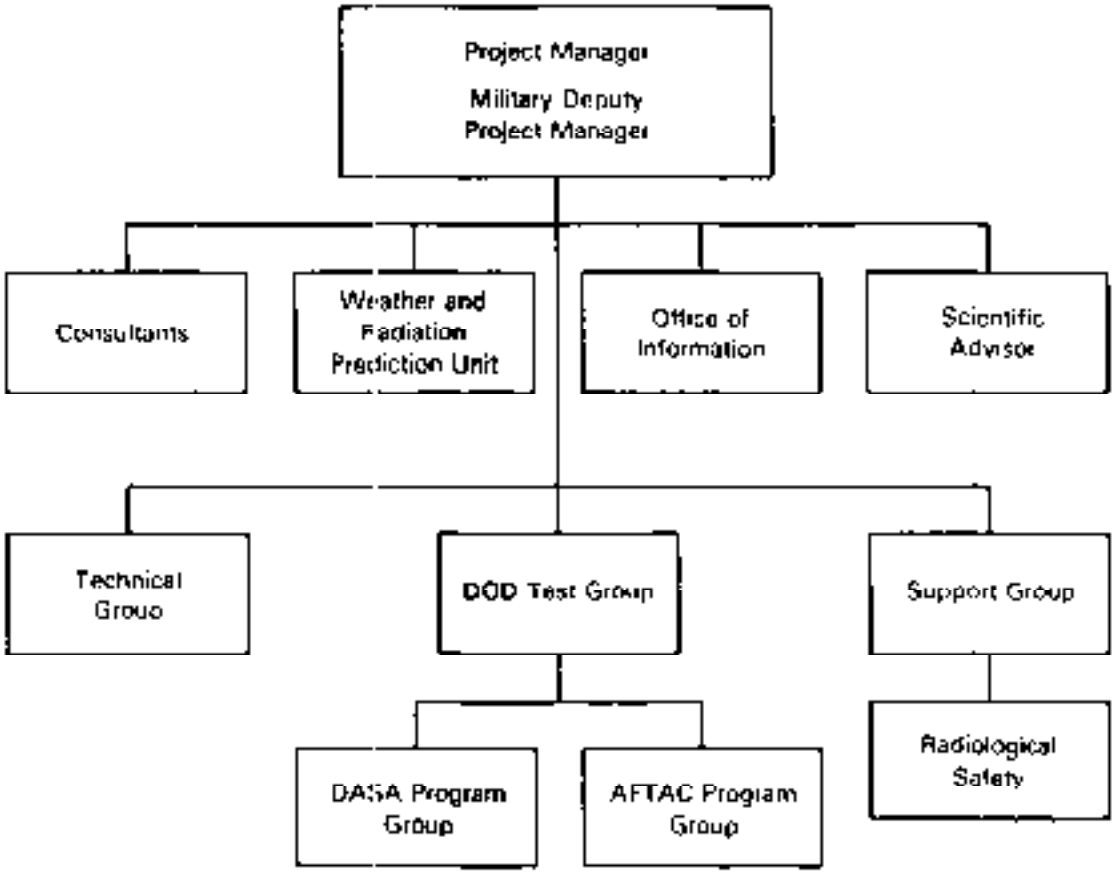

Figure 2-4: PROJECT GNOME ORGANIZATION

organization. The DOD Test Group, consisting of the DASA Program Group and the AFTAC Program Group, conducted the VELA UNIFORM experiments. The Support Group, administered by the Support Director, provided technical and logistical support to both the Technical Group and DOD Test Group. This included the management of contractor support, engineer support, construction support, and radiological safety activities (12).

2.4 SCIENTIFIC AND TECHNICAL PROJECTS CONDUCTED AT PROJECT GNOME

Extensive scientific and technical experiments were conducted at GNOME. Most of the projects involving DOD participation were part of the VELA UNIFORM program.

2.4.1 VELA UNIFORM Projects

Concern over the ability of foreign powers to conduct nuclear weapons tests undetected led to the establishment of the VELA program, directed toward improving U.S. ability to detect and identify underground and high-altitude nuclear detonations. VELA UNIFORM was the phase concerned with detecting underground detonations. The program consisted of continuing research, systems development, and an experimental field program conducted by various research agencies. Because VELA UNIFORM had no relation to the primary PLOWSHARE goals of GNOME, the program was conducted strictly on a noninterference basis.

The primary VELA UNIFORM objective in GNOME was to determine how the signals and effects of a nuclear device of five kilotons detonated in bedded salt differed from the signals and effects of nuclear detonations of different yields and in different media. The specific goals were to (12):

- Study the origin, development, and transmission of seismic signals by comparing data from shots of various yields and depths and in various media

against earthquake data to determine the differences between artificially and naturally generated signals

- Study the characteristics of electromagnetic and associated signals to determine their potential use in the detection and identification of underground nuclear detonations

- Study onsite inspection techniques, including surveys of the shot area before and after the detonation to determine any change

- Identify any other types of data or effects potentially useful in the detection and identification of underground nuclear tests.

Table 2-1 lists the VELA UNIFORM projects conducted at GNOME.

Project 1.1, Particle Motion Studies near Source, was conducted by the Sandia Corporation. The objectives were to observe free-field particle motion in rock from ground zero to the region of elastic response and to compare data obtained with measurements from other underground shots. An Air Force crew manning an H-21 helicopter participated in the project. Ten minutes before the detonation, the crew and helicopter were on standby at the Control Point, shown in figure 2-2, for recovery activities. Five hours after the detonation, the helicopter transported six project personnel to the Sandia trailer park, 760 meters southwest of ground zero. The H-21 then participated in the U.S. Public Health Service (USPHS) radiological safety mission, as indicated in section 2.5. The six project personnel stayed at the trailer park for the remainder of the day, monitoring cavity temperature and pressure, tunnel pressure, and cavity collapse. Upon completion of their assignment, they returned in a truck to the Control Point (5; 12).

Project 1.3, Surface Motion Study, was conducted by FGAG. The objective was to study vertical surface motion by using a camera 1,280 meters southeast of ground zero to photograph:

- Two arrays of targets between 20 and 280 meters from ground zero on two radial lines northeast and southeast of ground zero

Table 2-1: VELA UNIFORM TECHNICAL EXPERIMENTS AT PROJECT GNOME

Project Number	Title	Agency
	DASA-SPONSORED PROJECTS	
1.1	Particle Motion Studies near Source	Sandia Corporation
1.3	Surface Motion Study	Edgerton, Germeshausen, and Grier, Incorporated
1.7	Shock Spectrum Measurements--Reed Gauge Incorporated	Space Technology Laboratories,
1.8	Microbarographic Measurements	Sandia Corporation
	AFTAC-SPONSORED PROJECTS	
6.1	Study of Electric and Magnetic Effects	U.S. Geological Survey
6.2	Electromagnetic Waves from Underground Detonations	Sandia Corporation
6.3	Subsurface Electromagnetic Waves	Edgerton, Germeshausen, and Grier, Incorporated
6.4	Earth Currents from Underground Detonations	Space General Corporation
7.3	Reflectance Studies of Vegetation Damage	Engineer Research and Development Laboratories (Army)
7.5	Visual and Photographic Onsite Inspection	Stanford Research Institute
7.6	Seismic Noise Monitoring and Surface Subsidence Measurement	Stanford Research Institute

Table 2-1: VELA UNIFORM TECHNICAL EXPERIMENTS AT PROJECT GNOME (Continued)

Project Number	Title	Agency
7.7	Soil Density Studies	Engineer Research and Development Laboratories
7.8	Geochemical and Radiation Surveys	Texas Instruments, Incorporated
7.9	Solid State Changes in Rock	U.S. Geological Survey
7.11	Radon Studies	Edgerton, Germeshausen, and Grier, Incorporated
7.13	Aeromagnetic and Aeroradiometric Surveys	U.S. Geological Survey
7.14	Onsite Resistivity and Self Potential Measurements	Allied Research Associates
8.1	Intermediate Range Seismic Measurements	U.S. Coast and Geodetic Survey
8.4	Long Range Seismic Measurements	Geotechnical Corporation
9.3	[support photography]	Lawrence Radiation Laboratory

- Three inertial weight target systems about 20, 140, and 280 meters northeast of ground zero.

From about 0900 to 1800 hours on the day before the detonation, three personnel rehearsed project activities and performed final instrumentation at the inertial weight target stations. After the shot, when recovery hour was declared, the same three personnel left the Control Point in two vehicles to retrieve film from these stations. They spent about 45 minutes in recovery activities and then returned to the Control Point. Another three participants also left the Control Point after the announcement of recovery hour and drove in one vehicle to the camera station 1,280 meters southeast of ground zero. They spent about 20 minutes recovering film and then returned to the Control Point (5; 12).

Project 1.7, Shock Spectrum Measurements--Reed Gauge, was conducted by Space Technology Laboratories, Incorporated, to measure the displacement spectra of the ground shock in salt. On the day before the detonation, from 0800 to 1200 hours, project personnel placed four gauges at two stations in the tunnel floor about 280 and 320 meters from the point of detonation. Personnel also placed seven more gauges at four surface stations about 30, 310, 610, and 910 meters north of ground zero. In addition, they positioned a gauge underground about 15 kilometers away. At about 1415 hours on shot-day, three participants traveled from the Control Point to the surface stations, where they spent about four hours collecting data and instruments. They then returned to the Control Point (5; 12; 13).

Project 1.8, Microbarographic Measurements, was conducted by the Sandia Corporation to study acoustic signals in the atmosphere generated by an underground detonation. To obtain data, project participants conducted a calibration shot, to be fired as close in time and space to the nuclear detonation as

possible. A calibration shot of 1,090 kilograms of high explosives was fired from a tower 2.5 kilometers north-northwest of the GNOME ground zero (12).

At 1300 hours on the day before the detonation, seven personnel finished loading high explosives onto the tower and rehearsed the detonation, an activity that took about four hours. At about 1515 hours on shot-day, the same three participants proceeded from the Control Point to the shot-tower to inspect the area for small fires and unburned high explosives. They then returned to the Control Point. In addition to these activities, participants took measurements of the calibration shot and the nuclear detonation from instrumented stations 20, 310, and 760 meters on a radial line from ground zero and at two stations in Big Springs and Abilene, Texas (5).

Project 6.1, Study of Electric and Magnetic Effects, was conducted by the U.S. Geological Survey. The objectives were to study fluctuations in electric and magnetic fields caused by an underground detonation and to evaluate these effects to determine their potential use in detecting nuclear detonations. Measurements were made at stations eight and 19 kilometers north of ground zero (12).

Project 6.2, Electromagnetic Waves from Underground Detonations, was conducted by the Sandia Corporation to characterize electromagnetic waves and to determine their mode of propagation. On the day before the detonation, two personnel set up equipment and conducted a rehearsal of the project in a trailer approximately 2.5 kilometers north of ground zero. From 0400 to 1000 hours on shot-day, two personnel made final calibrations of the instruments and hooked them up for remote control. At approximately 1315 hours, participants returned to the trailer and spent several hours playing back preliminary data (5; 12).

Project 6.3, Subsurface Electromagnetic Waves, was conducted by EG&G. The objective was to characterize the electromagnetic fields generated by an underground nuclear detonation and to determine the multipolar character of the source. Two detector sites were established: one on the surface about 80 meters from ground zero and the other in the horizontal tunnel about 130 meters from the point of detonation. Signals were recorded at a surface station near the elevator shaft.

From 0800 to 2400 hours on the day before the detonation, two personnel calibrated equipment in the surface station and in the tunnel. At about 1515 hours on shot-day, three participants, including one monitor, traveled in one vehicle from the Control Point to a shelter about 410 meters southwest of ground zero, where they picked up a second monitor. The four personnel then went to the surface station to recover data, a process taking about 20 minutes. After collecting the data, the second monitor returned to the shelter 410 meters southwest of ground zero, and the other three participants returned to the Control Point (5; 12).

Project 6.4, Earth Currents from Underground Detonations, was conducted by the Space General Corporation. As for Project 6.3, the objective was to characterize the electromagnetic waves created by an underground nuclear detonation and to determine their modes of propagation. At 0800 hours on the day of the detonation, four project personnel proceeded to an instrumented station 7.2 kilometers southeast of ground zero, where they remained during the shot and for several hours after. Also at 0800 hours on shot-day, another three participants traveled to a shelter 410 meters southwest of ground zero to check instruments. They left the shelter at 1000 and returned to the Control Point. At about 1315 hours, they returned to the shelter to collect data, taking about 30 minutes. They then went back to the Control Point (5; 12).

Project 7.3, Reflectance Studies of Vegetation Damage, was conducted by the Engineer Research and Development Laboratories, Army. The objective of this project was to obtain *in situ* reflectance data of the vegetation as affected by an underground explosion. Participants collected data on vegetation before and after the detonation. Personnel also conducted pre- and postshot surveys to determine the total displacement of the surface (12).

Project 7.5, Visual and Photographic Onsite Inspection, was conducted by the Stanford Research Institute. The objective was to determine the presence of unusual terrain features and activity associated with the explosion by conducting aerial photography studies and visual ground inspections of the area both before and after the shot. From 0800 to 1200 hours on the day preceding the detonation, four project personnel made visual inspections of the shot area at a distance of 800 meters from ground zero. They also conducted a final inspection of the tunnel leading to the point of detonation. At about 1315 hours on shot-day, three participants traveled from the Control Point to the ground zero vicinity to observe and photograph the effects of the detonation. In addition, in support of both Projects 7.3 and 7.5, two photographers left the Control Point heliport in a security helicopter at about 1345 hours to photograph the ground zero area. They completed their mission in approximately one hour (5; 12).

Project 7.6, Seismic Noise Monitoring and Surface Subsidence Measurement, was conducted by the Stanford Research Institute. The objective was to record the seismic disturbances after the detonation so that the feasibility of using such records for onsite inspections could be determined. At 0800 hours on the day of detonation, four personnel left the Control Point to establish a station 800 meters north of ground zero. They returned to the Control Point at 1000 hours. Five minutes after the detonation, the four personnel returned to the station to monitor geophones

and supply information to the Technical Director. They remained at the station throughout the day. About the same number of participants manned another station approximately eight kilometers northwest of ground zero during the shot (5; 12).

Project 7.7, Soil Density Studies, was conducted by the Engineer Research and Development Laboratories. The objective was to determine the potential for detecting soil density changes caused by an underground nuclear explosion using ground infrared equipment. Both pre- and postshot thermal images were taken of vegetation and soil at various locations in the test area.

Project 7.8, Geochemical and Radiation Surveys, was conducted by Texas Instruments, Incorporated. The objective was to establish the presence of chemical indicators and fission products in the soil so as to determine their potential use for locating underground nuclear explosions. After the shot, personnel drilled 50-foot holes in a radial pattern centered at ground zero (12).

Project 7.9, Solid State Changes in Rock, was conducted by The U.S. Geological Survey, assisted by the Naval Radiological Defense Laboratory. The objective was to determine the potential of using thermoluminescence as a detection device for underground nuclear explosions. After the shot, participants drilled holes of various depths at various distances from ground zero (12).

Project 7.11, Radon Studies, was conducted by EG&G to determine the potential of using radon-sampling procedures to detect underground nuclear explosions. Participants drilled holes at various distances from ground zero after the shot (12).

Project 7.13, Aeromagnetic and Aeroradiometric Surveys, was conducted by the U.S. Geological Survey. The objective was to

determine the detectability of substantial amounts of ferromagnetic material in the area by the use of aerial magnetometer surveys and magnetic detecting equipment, specifically a magnetometer and a radiometer. On the day before the detonation, two personnel conducted an aerial survey over an area about eight kilometers in radius in the vicinity of ground zero. After the flyover, a ground survey team made a visual inspection of the area. At about 1315 hours on shot-day, five personnel in a DC-3 aircraft surveyed the same area. Subsequent to this flyover, a ground survey team made a visual inspection of the area. The inspections took about three hours (5; 12).

Project 7.14, Onsite Resistivity and Self Potential Measurements, was conducted by Allied Research Associates to determine differences in potential created by an underground nuclear explosion. Personnel buried ceramic probes a few inches beneath the surface starting approximately 150 meters from ground zero and continuing at 800-meter intervals to a distance of three kilometers. They installed three or four probes on a northerly line from ground zero and one on a line at right angles to the others. All pairs of probes were connected to a central recording station near the Control Point. On the day before the detonation, from 0800 to 2400 hours, six personnel recorded differences in potential at the stations 150 meters to three kilometers from ground zero. After 1315 hours on shot-day, four personnel spent about two hours checking electrodes in the ground (5; 12).

Project 8.1, Intermediate Range Seismic Measurements, was conducted by the U.S. Coast and Geodetic Survey. The objective was to record seismic data at six locations 30 to 160 kilometers from ground zero (12).

Project 8.4, Long Range Seismic Measurements, was conducted by the Geotechnical Corporation. The objective was to record and

analyze long- and short-period seismic signals at distances ranging 75 to 4,000 kilometers from ground zero. Approximately 40 seismic teams fielded this experiment. Volunteers from several commercial geophysical companies also participated (12).

Available documentation indicates that Project 9.3 [support photography] was also conducted at GNOME. The [R] conducted the project, the objective of which was to photograph the ground zero area. Thirty minutes before the detonation, six Air Force personnel flew from the Control Point heliport in an H-21 helicopter. The helicopter orbited at 500 feet about 800 meters southwest of ground zero from one minute before to 15 minutes after the detonation. After completing the mission, the H-21 returned to the Control Point heliport (5).

2.4.2 Other Scientific and Technical Projects

In addition to the VELA UNIFORM projects, many other scientific and technical experiments were conducted at GNOME. These experiments were part of four programs developed to meet the primary objectives of the detonation. Participants conducted a physical effects program to document both dynamic measurements and conditions in the ground zero area after the detonation. They performed power generation studies to test the theory that several times the energy of the detonation would be recovered from the hot rock, or from the pressurized steam that was generated, or from both. An isotopes program sought to recover radioisotopes for use as tracers, as power sources, and as verification of the yield of the nuclear explosive. Two physics and radiochemistry research programs were included that used the high-intensity pulse of neutrons to perform neutron measurement experiments. DOD personnel participated in only one of these studies, discussed below (12; 15).

Design, Testing, and Field Pumping of Grout Mixtures was conducted by the Army Corps of Engineers Waterways Experiment Station, which provided a variety of laboratory and field support activities at GNOME. The laboratory work consisted of performing physical tests on extracted salt cores and developing a variety of grout mixtures for use in structural work and for other miscellaneous purposes. A consultant assisted in the drilling of line-of-sight and instrument holes at the tunnel areas and in pumping the grout mixtures in various holes at the site. The holes were drilled for embedding scientific instruments and as postshot recovery holes. Personnel grouted 25 horizontal and vertical instrument holes in the tunnel, nine surface holes, and nine holes for special use (31).

2.5 AIR FORCE SPECIAL WEAPONS CENTER ACTIVITIES AT PROJECT GNOME

The Air Force conducted several support missions at Shot GNOME. Available documents suggest that various Air Force units under the operational control of the Air Force Special Weapons Center conducted a security sweep, cloud-sampling mission, cloud-tracking and radiological safety sweep, and support missions.

Security Sweep

An Air Force H-21 helicopter with a two-man crew made a security sweep of the area in an eight-kilometer radius of ground zero. The helicopter began the sweep two hours before the detonation and concluded it 90 minutes later. The helicopter then moved to a position over New Mexico Highway 128, north of the Control Point, to observe traffic and to ensure that no unauthorized vehicles were in the shot area.

Cloud Tracking and Radiological Safety Sweep

An Air Force H-21 helicopter and crew, likely the same one that conducted the security sweep, conducted a cloud-tracking and radiological safety sweep beginning one minute after the detonation and continuing for two or three hours (3; 30).

Support Missions

AFSWC provided support to Projects 1.1, 7.3, 7.5, 7.13, and 9.3, as discussed in section 2.4.1. In addition, the H-21 helicopter that participated in Project 1.1 also supported the U.S. Public Health Service radiological safety mission (5).

2.6 RADIATION PROTECTION AT PROJECT GNOME

To minimize the exposures of PLOWSHARE personnel to ionizing radiation, the Atomic Energy Commission implemented radiological safety procedures. In addition, the AEC recommended an individual exposure limit of 3 rem of gamma and neutron radiation per quarter calendar year and not more than 5 rem annually. This was the occupational exposure limit recommended for radiation workers by the National Committee on Radiation Protection and Measurements. The GNOME radiological safety program operated within this recommended limit.

2.6.1 Organization of Radiological Safety Program

The Project Manager had overall responsibility for the radiological safety of participants in Project GNOME. Within his organization, he was assisted by the AEC Support Director and the Technical Director, from LRL. The Support Director was responsible for the conduct of the radiological safety program. During the preparation for and completion of the detonation, beginning the day before the detonation and ending when postshot experiments and recovery operations were finished, the Technical

Director was responsible for implementing radiological safety procedures. The Radiological Safety Division of Reynolds Electrical and Engineering Company provided all onsite radiological support. The Onsite Radiological Safety Officer was a REECo Radiological Safety Division supervisor. The USPHS provided offsite radiological safety support. An Offsite Radiological Safety Officer from the AEC supervised these activities (3; 39). Figure 2-5 shows the organization of the radiological safety program.

2.6.2 Onsite Operations

The onsite radiological safety program was designed to provide radiological safety for all test participants within an eight-kilometer radius of ground zero. The program was to minimize the radiation exposures of participating personnel and observers, to prevent the spread of radioactive material to uncontrolled areas, to assist in security, to provide health and safety support, and to control personnel access into radiation areas. In fulfilling its responsibilities, the REECo Radiological Safety Division (39):

- Trained radiological safety monitors
- Issued anticontamination clothing, radiation detection equipment, film badges, and pocket dosimeters to all personnel entering radiation areas
- Collected body fluid samples, performed analyses, and assigned internal doses
- Maintained film badge and exposure records to determine the accumulated exposure of each participant to gamma radiation
- Took air samples and monitored the test site, prepared isointensity contour maps of radiation areas, and provided radiation information to personnel entering radiation areas
- Decontaminated personnel, vehicles, and equipment as needed.

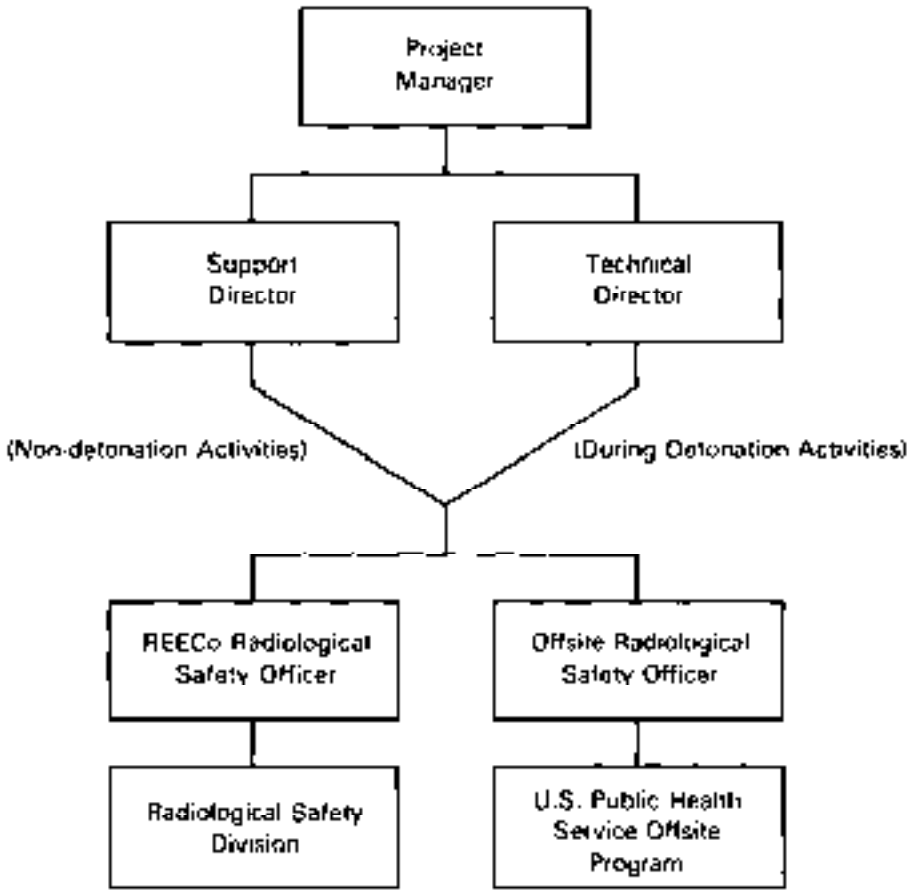

Figure 2-5: RADIOLOGICAL SAFETY ORGANIZATION AT PROJECT GNOME

Protective Equipment and Personnel Dosimetry

Radiological safety personnel procured, issued, maintained, repaired, and stored protective equipment and supplies for monitors and personnel entering the GNOME test area. The equipment included radiation detection instruments, environmental sampling equipment, and anticontamination clothing. This clothing was issued to participants as they passed through the main Control Point, shown in figure 2-2 (39).

Each individual entering the test area received a film badge and a pocket dosimeter. The film badge was attached to the participant's security badge, and both the film badge and pocket dosimeter were worn on the shirt pocket. Whenever participants left the test area, they turned in their pocket dosimeters to radiological safety personnel at the Control Point. Film badges were exchanged when an exposure of 0.1 rem was suspected and at the end of each month. The film badges were transported by air to the NTS for developing and processing. Film badge results were then telephoned to radiological safety personnel at the Carlsbad site (3; 39). Arrangements for air transportation of exposed film were made with Eberline Instrument Corporation of Santa Fe, New Mexico, to provide emergency dosimetry processing, if necessary (39).

A list of personnel entering and leaving the test area was maintained at the main Control Point. There, radiological safety personnel logged dosimetry information for each participant, indicating previous accumulated exposure for the year and for the quarter. As each person left the radiation area, his pocket dosimeter reading was entered in the register. If the dosimeter reading was 0.1 rem or more, the person's film badge was exchanged. The dosimeter reading was added to the cumulative exposure until the next day's exposure report was received, which reflected the actual film badge reading for each participant in the new cumulative exposure total (39).

The REECo "Onsite Radiological Safety Report" lists aggregate radiation doses for GNOME personnel. The exposures of six participants exceeded 1 rem, ranging up to 2.47 rem. There is no indication, however, that any of these participants were DOD personnel (38).

Table 2-2 presents the gamma exposure data available from film badge records for Air Force participants in GNOME. Table 2-3 presents gamma exposure information available from film badge records for scientific personnel, contractors, and affiliates who took part in the PLOWSHARE Program. The documentation used for table 2-3 did not identify the participants according to specific PLOWSHARE event. Tables 2-2 and 2-3 indicate the following information by unit (7):

- The number of personnel identified by name
- The number of personnel identified by both name and film badge
- The average gamma exposure in rem
- The distribution of these exposures.

Access Control

Before the detonation, radiological safety personnel cleared the test area, closed and barricaded all incoming roads, and erected warning signs to prevent entry into the area. They also barricaded the main access road and established a check station to ensure that personnel entering the test area had the proper identification badges and authorization forms. This station, called the Test Director's Barricade, was on the access road about six kilometers north of ground zero. Besides functioning as a check station, the Test Director's Barricade served as the base of operations for radiation monitoring teams and as a decontamination facility for vehicles and personnel leaving the test area.

Table 2-2: DISTRIBUTION OF GAMMA RADIATION EXPOSURES FOR AIR FORCE PERSONNEL AND AFFILIATES AT PROJECT GNOME, PLOWSHARE PROGRAM

Units	Personnel Identified by Name	Personnel Identified by Name and by Film Badge	Average Gamma Exposure (rem)	Gamma Exposure (rem)				
				<0.1	0.1-1.0	1.0-3.0	3.0-5.0	5.0 +
Aerospace Audiovisual Service	1	1	0.210	0	1	0	0	0
Air Force Flight Test Center, Headquarters	2	2	0.686	0	2	0	0	0
Air Force Special Weapons Center, Headquarters	2	2	0.110	0	2	0	0	0
Eglin Air Base Group	3	3	0.203	1	2	0	0	0
Unit Unknown	4	4	0	4	0	0	0	0
Total	12	12	0.184	5	7	0	0	0

Table 2-3: DISTRIBUTION OF GAMMA RADIATION EXPOSURES FOR SCIENTIFIC PERSONNEL, CONTRACTORS, AND AFFILIATES, PLOWSHARE PROGRAM*

Units	Personnel Identified by Name	Personnel Identified by Name and by Film Badge	Average Gamma Exposure (rem)	Gamma Exposure (rem)				
				<0.1	0.1-1.0	1.0-3.0	3.0-5.0	5.0+
Armour Research Foundation	9	9	0	9	0	0	0	0
Bendix Aviation Corporation	85	85	0	85	0	0	0	0
Chance Vought	6	6	0	6	0	0	0	0
DNA Albuquerque Base	16	16	0	16	0	0	0	0
DNA Lake Meade Base	17	17	0	17	0	0	0	0
DNA Mercury Base	7	7	0	7	0	0	0	0
DNA Headquarters, Washington, DC	20	20	0	20	0	0	0	0
FCDNA Detachment, Kirtland AFB	11	11	0.007	11	0	0	0	0
FCDNA NTS Detachment	12	12	0.002	12	0	0	0	0
Marquardt Aircraft	31	31	0	31	0	0	0	0
Martin	7	7	0	7	0	0	0	0
Office of Test Information	1	1	0	1	0	0	0	0
Office of the Secretary of Defense	47	47	0	47	0	0	0	0
Stanford Research Institute	13	13	0.003	13	0	0	0	0
UC Livermore	306	306	0	306	0	0	0	0
Universities	34	34	0	34	0	0	0	0
Total	632	632	0	632	0	0	0	0

*Information is not available on personnel participation according to specific PLOWSHARE event.

Radiological safety personnel established another check station at the Control Point. The Control Point housed administrative, technical, and security personnel during Project GNOME. It was also a checkpoint for recovery parties entering the test area in vehicles and helicopters. A helicopter pad was across the road from the Control Point, as indicated in figure 2-2. In addition, the observers witnessed the detonation from the Control Point.

After the detonation, Radiological Safety Division personnel at the Control Point and the Test Director's Barricade checked each group of entering personnel for an access permit. Authorized by the Project Manager, the permit gave such information as the names and numbers of those permitted to enter, the purpose of their mission, and the estimated time required to complete the mission. Radiological safety personnel also checked to ensure that each individual was wearing anticontamination clothing, a film badge, and a pocket dosimeter (3; 39).

Monitoring

Onsite monitoring activities of the Radiological Safety Division were limited to an eight-kilometer radius of ground zero. These activities included (3; 39):

- Performing initial surveys and resurveys of areas around ground zero after the detonation
- Establishing and operating checkpoints
- Marking and establishing the radiation exclusion areas
- Serving as monitors for personnel who were required to enter radiation exclusion areas.

Before the detonation, the Onsite Radiological Safety Officer briefed the initial radiation survey team on the pattern to be followed. After the detonation, the Project Manager delayed this survey because of the unexpected venting of

radioactive materials from the shaft opening, about 340 meters southwest of ground zero. At 1258 hours, a group of men left the Test Director's Barricade to begin the initial survey. They traveled along the main access road toward ground zero, using vehicle odometers to determine how far intensities of 0.01, 0.1, and 1 R/h were from previously established reference stakes. They then radioed this information to radiological safety personnel at the Control Point, where the isointensity lines were plotted and mapped. The maps were made available to project personnel planning to enter the radiation areas to retrieve equipment and data. The team continued the initial survey until they reached stake A3, about 1,100 meters north of the shaft opening. There, they encountered a gamma intensity of 0.035 R/h. At 1315 hours, they returned to the Test Director's Barricade to begin monitoring assignments. Gamma intensities were near background level at the barricade (39). The map resulting from the initial survey has not been found.

A subsequent survey conducted between about 1500 and 1600 hours on shot-day found gamma intensities up to 0.12 R/h at stake A1, about 300 meters north of the shaft opening. The highest gamma intensity found by a later survey was 1 R/h, encountered about 1,300 meters northwest of the shaft opening at 1938 hours on shot-day. Surveys of the actual shaft opening were not made on shot-day. A survey of the shaft opening and the surrounding area was performed on 11 December, the day after the detonation. The highest gamma reading of 5 R/h was recorded at the shaft opening at 0908 hours. Lower gamma intensities (as low as 0.1 R/h) were encountered about 30 meters west of the shaft opening. Radiation readings of less than 0.1 R/h were registered in the area around ground zero, which was about 340 meters northeast of the shaft opening (39).

Radiological safety personnel were responsible for monitoring activities after the detonation. A major activity was the

Radiological Chemistry Core drilling operation. On the day after the detonation, personnel positioned two drill rigs at ground zero to obtain deep-earth core samples. Drilling began two days after the detonation and continued for about seven weeks. Radiological safety monitoring for this operation was provided continuously (39).

Another major postshot activity was the survey of the shaft and recovery of experimental equipment in the shaft and station room. Underground recovery operations were delayed until six days after the detonation. At this time, a radiation survey of the shaft was performed, and it was determined that it was safe for recovery operations to begin (39).

Each group entering areas with radiation intensities greater than 0.1 R/h was accompanied by a radiological safety monitor. The Radiological Safety Division supplied the monitors from personnel stationed at the Control Point or at the Test Director's Barricade (3; 39).

Decontamination

The Radiological Safety Division operated a decontamination facility at the main Control Point. At this station, they monitored personnel, vehicles, and equipment leaving the test area. Decontamination was required if radioactivity exceeded the following limits (3; 39)

- Personnel: 0.007 R/h (beta and gamma) or 1,000 counts per minute (alpha) on anticontamination clothing and shoes 0.001 R/h (gamma) or 200 counts per minute (alpha) on surface of skin or underclothing
- Vehicles and Equipment: 0.007 R/h (gamma) on outer surfaces

  0.007 R/h (beta and gamma) or 10,000 counts per minute (alpha) on inner surfaces.

The first step in decontaminating personnel returning from the radiation area was to clean them of surface contamination by vacuuming the dust and dirt from their garments. Returning personnel then turned in their respirators, film badges, and pocket dosimeters. Radiological safety personnel next monitored each individual. If the radioactivity reading exceeded the limit, the person was required to remove contaminated clothing and, if the reading was still too high, take a shower. Radiological safety personnel monitored the individual again after the shower. If the radiation reading was less than 0.001 R/h on the surface of the skin, the individual received fresh clothing and was released (3; 39).

Vehicles returning from radiation areas were parked in designated areas adjacent to the Control Point. Members of the Radiological Safety Division monitored the vehicles. If they recorded readings of 0.007 R/h or greater, the vehicles had to be decontaminated. Radiological safety personnel first vacuumed all surfaces, including running boards, floorboards, and the undersides of fenders. They then resurveyed the vehicles and, if the vehicles were still contaminated, sprayed and washed them with a liquid detergent and rinsed them with water. Once measured gamma radiation intensities were less than 0.007 R/h, radiological safety personnel returned the vehicles to service (3; 39).

Buildings and equipment in the shop area adjacent to the shaft opening and the drilling equipment used in the Radiological Chemistry Core drilling operation were also decontaminated. Techniques included removal and burial of contaminated scrap, vacuuming, high-pressure water washing with added detergents, and washing with solvents (39).

2.6.3 Offsite Operations

The Project Manager was responsible for offsite radiological safety, but the Offsite Radiological Safety Officer had operational control of the program. USPHS personnel provided operational support services, and REECo provided film badges and radiation detection equipment. Offsite operations were in effect within a radius of eight to 160 kilometers from ground zero.

The objectives of the offsite radiological safety program were to (30; 32):

- Assess the offsite radiation resulting from the detonation
- Collect data on fallout patterns
- Conduct environmental monitoring of air, water, and milk
- Produce reports, maps, and records describing the findings of the monitoring and data collection
- Establish and maintain public relations activities.

Dosimetry

Offsite monitors conducted a film badge program to obtain data on radiation exposures of the civilian population. They placed 330 film badges on individuals and structures within a 160-kilometer radius of the test area. They issued the badges on 7, 8, and 9 December and collected them 30 days later. The highest film badge reading was 0.14 roentgens obtained from a resident at Hudson Farm, 29 kilometers north-northwest of ground zero. All other film badges had zero readings (30).

Monitoring

Before the detonation, 11 monitoring teams in radio-equipped vehicles went to offsite areas within 80 kilometers of ground zero. These teams were then in position to perform ground surveys if the GNOME cloud drifted over their locations. In

addition, the USPHS performed aerial monitoring in an Air Force H-21 helicopter (3; 30).

Results of the aerial survey indicated that the cloud drifted to the northwest toward Artesia, New Mexico. This information was reported to the ground survey teams, who began reporting radiation readings within 40 minutes of the detonation. The teams performed monitoring along all highways and populated areas in the path of the cloud. The highest gamma intensity was 1.4 R/h, registered at 1310 hours on shot-day 5.5 kilometers west of the Control Point. By 1335 hours, the intensity at this location had decreased to 0.19 R/h; by 1455 hours, it had decreased to 0.09 R/h. All other offsite areas surveyed had gamma intensities of less than 0.15 R/h. The highest gamma intensity recorded in any populated area was 0.08 R/h, encountered at 1400 hours on shot-day near Hudson Farm (30).

Other Activities

An Army Veterinary Officer assigned to the AEC Office of Field Operations, Las Vegas, provided support to the offsite radiological program. He assisted in a study of radioactivity levels in animal tissue before and after the detonation (30).

PROJECT SEDAN

SYNOPSIS

AEC TEST SERIES: PLOWSHARE
DATE/TIME: 6 July 1962, 0900 hours
YIELD 104 kilotons
HEIGHT OF BURST: 635 feet below ground

Purpose of Test: To extend knowledge of cratering effects and phenomenology to the 100-kiloton range of yields and to provide data on the general nature of the safety problems created by nuclear cratering detonations.

Weather: At shot-time, the temperature was 28.5° Celsius, and the atmospheric pressure was 868 millibars. Winds were ten knots from the south-southeast at surface level and 16 knots from the south-southwest at 10,000 feet.

Radiation Data: The initial ground survey was completed by approximately 1130 hours. The 10 R/h line extended 3.3 kilometers to the west and 3.1 kilometers to the south, and the 1 R/h line extended 3.5 kilometers to the west and 3.3 kilometers to the south. These contours were not closed to the north and east, the direction of the fallout. Two days later, 1 R/h intensities were confined to within 3.2 kilometers of ground zero.

Participants: Army Engineer Waterways Experiment Station; Naval Radiological Defense Laboratory; Army Engineer Nuclear Cratering Group; Air Force Special Weapons Center; Lawrence Radiation Laboratory; Sandia Corporation; Space Technology Laboratories, Incorporated; Coast and Geodetic Survey; Boeing Company; Geological Survey; Edgerton, Germeshausen, and Grier, Incorporated; Brigham Young University; UCLA School of Medicine; Public Health Service; Weather Bureau; Bureau of Mines; Federal Aviation Agency; Reynolds Electrical and Engineering Company; other contractors; AEC civilians.

CHAPTER 3

PROJECT SEDAN

Project SEDAN, a nuclear-cratering experiment, was detonated with a yield of 104 kilotons at 0900 hours Pacific Standard Time on 6 July 1962. Figure 3-1 shows the detonation (51). The project was fired in Area 10 of the Nevada Test Site, described in section 3.1. At ground zero, UTM coordinates 847147,* the desert alluvium was 1,410 feet deep. The device was placed in a cased hole with a diameter of 91 centimeters (36 inches) at a depth of 635 feet. The neutron-absorbing mineral colemanite was placed around the device, and the rest of the hole was filled to the surface with dry sand (28).

In the first three seconds after the detonation, a roughly hemispherical dome of earth 180 to 250 meters in diameter rose to a height of about 300 feet. Large quantities of incandescent gases were then vented. Earth materials and gases continued to rise to about 2,000 feet. The larger particulate earth materials then fell back to earth. A base surge was created that expanded radially to a distance of approximately four kilometers crosswind and 3.2 kilometers upwind. Figure 3-2 shows the base surge and the cloud (51). The main cloud, composed of gaseous products and fine particulate matter, rose to a height of about 12,000 feet above the ground, where there was an inversion in the atmosphere (28; 48). This cloud drifted north-northeast from the test site (14; 29).

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*Universal Tranverse Mercator (UTM) coordinates are used in this report. The first three digits refer to a point on an east-west axis, and the second three refer to a point on a north-south axis. The point so designated is the southwest corner of an area 100 meters square.

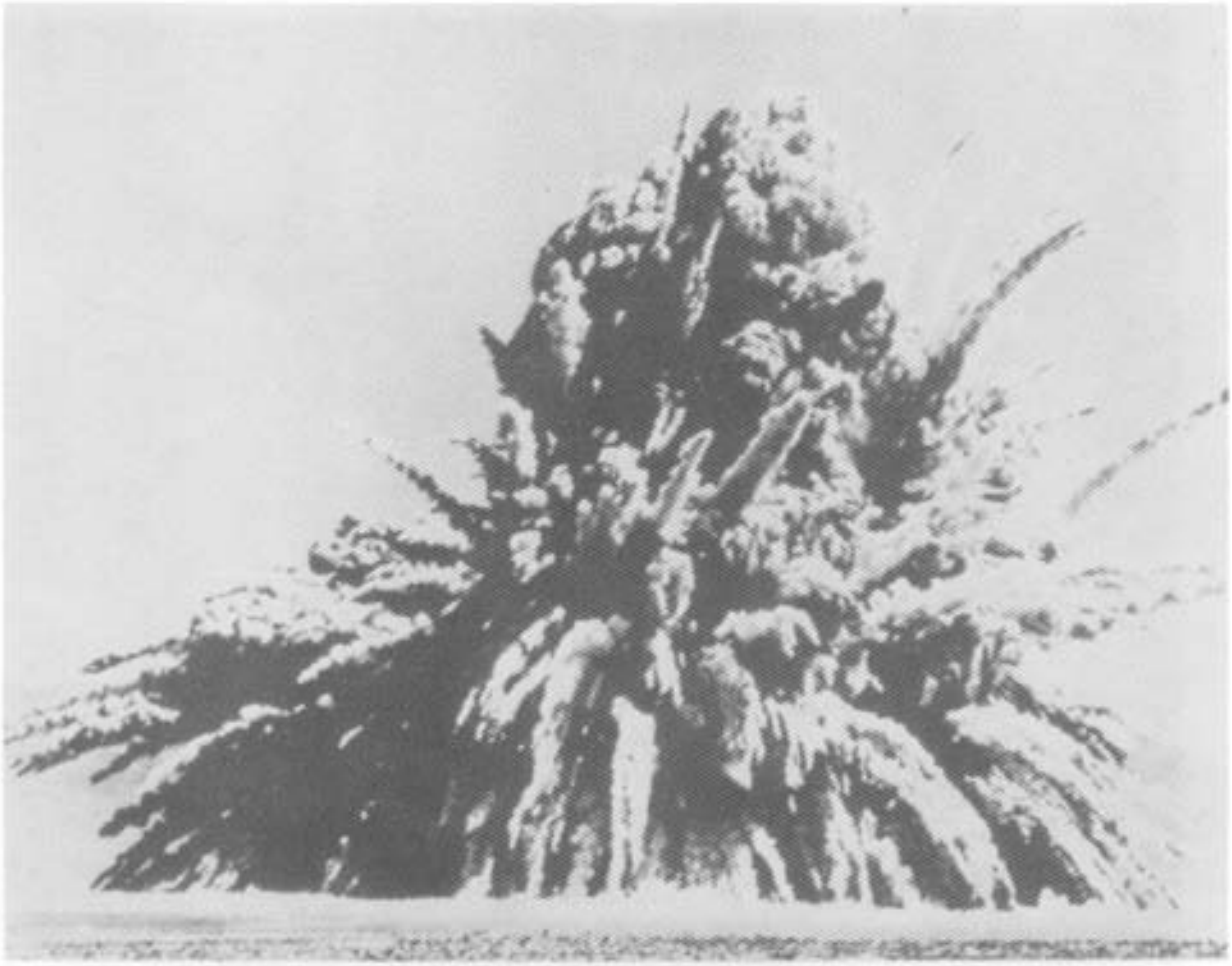

Figure 3-1: PROJECT SEDAN, DETONATED AT 0900 HOURS ON 6 JULY 1962

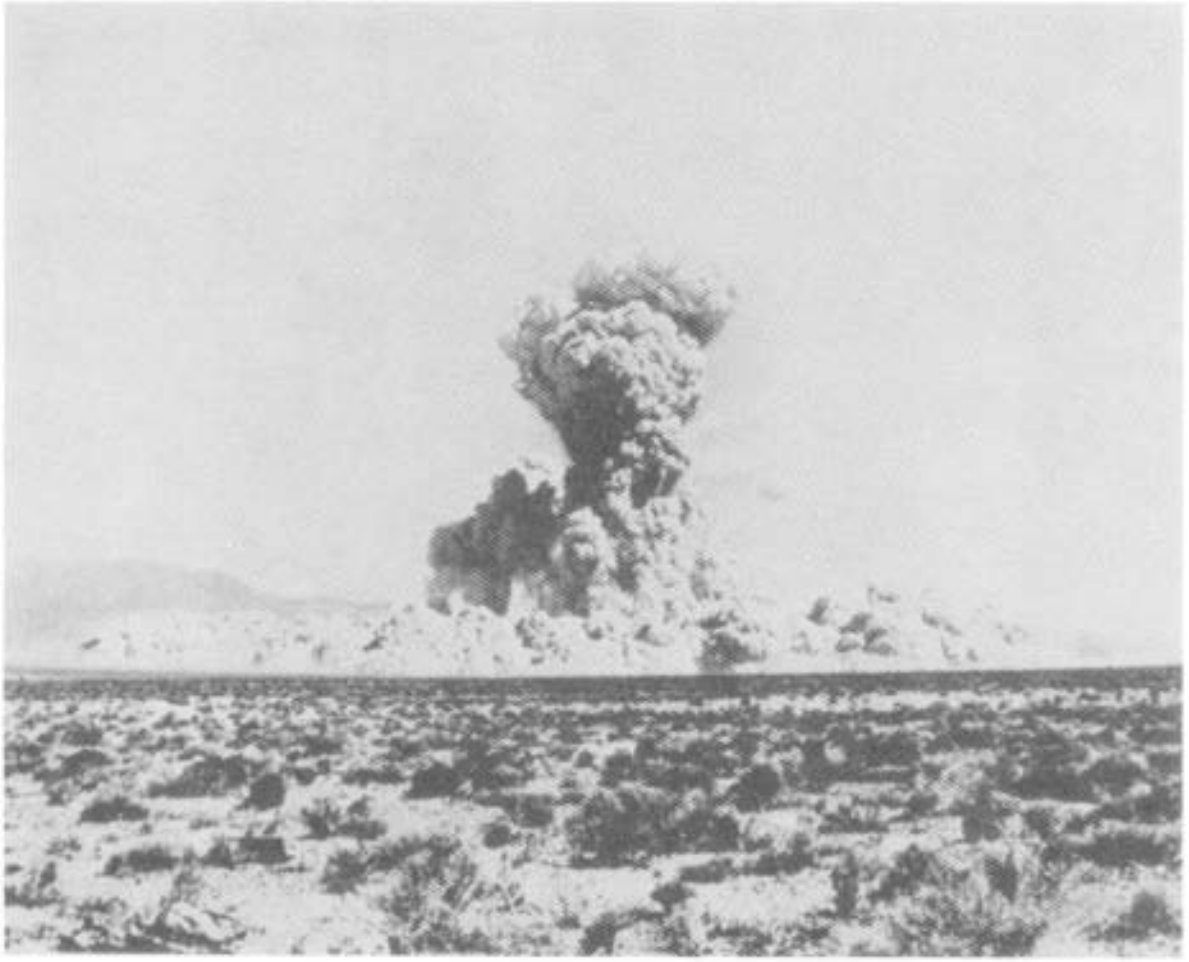

Figure 3-2: PROJECT SEDAN BASE SURGE AND CLOUD

The dust cloud rose higher than had been expected because of atmospheric conditions and the large volume of gaseous vapors resulting from the moisture content of the alluvium, which was higher than had been thought. The cloud deposited nearly five times as much fallout on and near the test site than had been predicted. Some fallout was deposited in Frenchman Flat and occasionally triggered sensitive project instruments emplaced for Shot SMALL BOY, detonated on 14 July 1962 as part of Operation DOMINIC II (50). Only a small fraction of the radioactivity escaped in the cloud. The remainder was retained in the crater. The terrain affected the low-level winds and, hence, the lower-cloud path and more concentrated fallout pattern (28; 29).

The AEC PLOWSHARE program for the industrial and civil applications of nuclear explosives sponsored Project SEDAN. Conducted under the technical direction of the Lawrence Radiation Laboratory, SEDAN was planned as the first of a series of nuclear tests to develop nuclear excavation techniques applicable to canals, harbors, and similar digging projects. The specific purposes of the project were to:

- Provide safety data related to the release and distribution of radioactivity, seismic effects, and airblast
- Extend knowledge of cratering effects to detonations with yields in the range of 100 to 200 kilotons
- Determine if scaling models concerning crater depth versus yield were valid for detonations with yields of 100 to 200 kilotons.

Since previous nuclear cratering experience had been limited to detonations of about one kiloton, the validity of using those data to predict results of detonations in the 100-to-200 kiloton range was uncertain.

Figure 3-3 shows the crater formed by the detonation. This crater had a volume of about 6.5 million cubic yards. The crater radius was 607 feet and the depth 323 feet. The lip of the

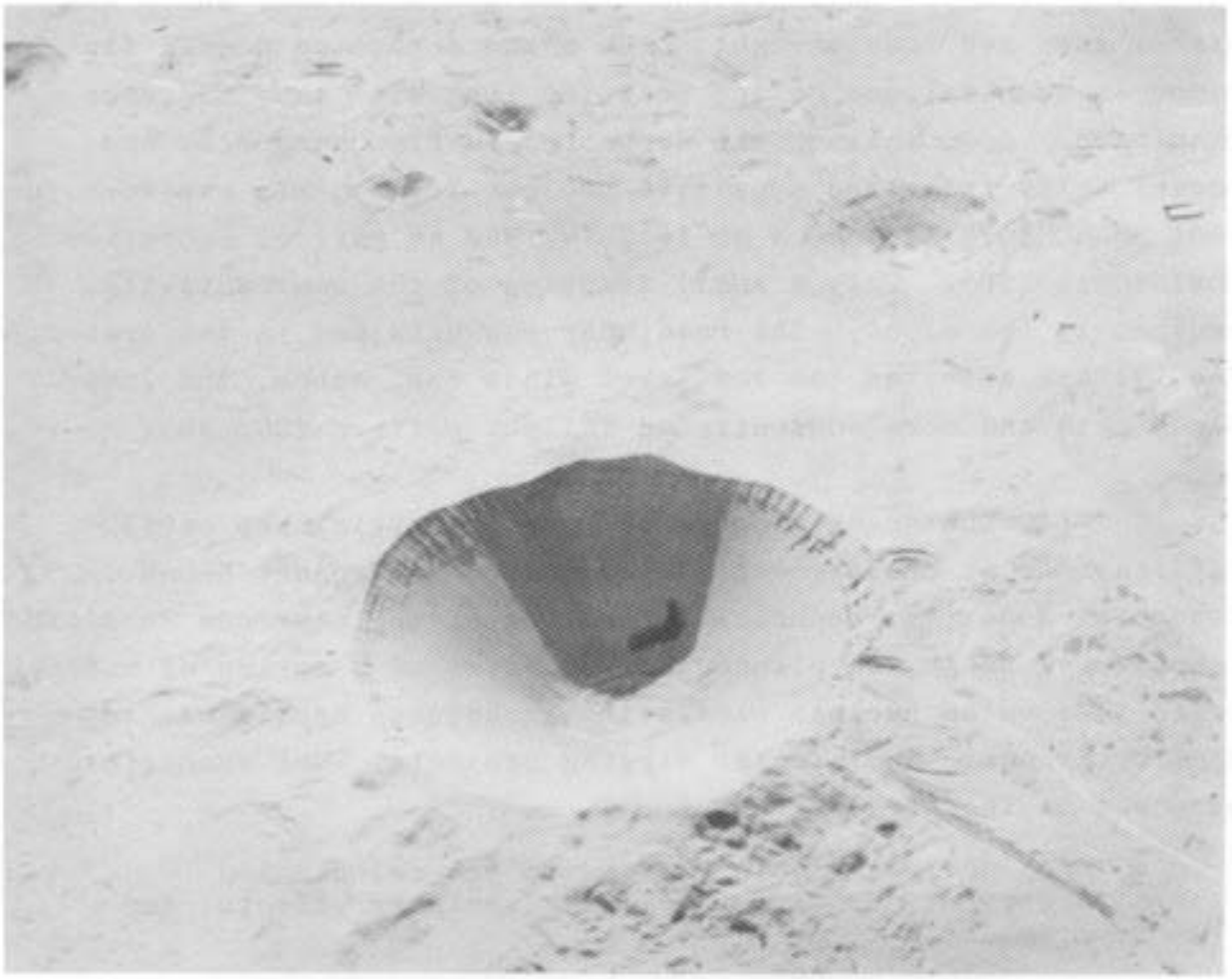

Figure 3-3: PROJECT SEDAN CRATER

crater ranged in height from 18 to 95 feet above the preshot surface (15).

3.1 THE NEVADA TEST SITE

The NTS, originally established by the AEC in December 1950, is located in the southeastern part of Nevada, 100 kilometers northwest of Las Vegas, as shown in figure 3-4. The NTS is in an area of high desert and mountain terrain in Nye, Lincoln, and Clark Counties. On its eastern, northern, and western boundaries, the NTS adjoins the Nellis Air Force Range, of which it was originally a part. The NTS has been the location for most of the nuclear weapons tests conducted within the continental United States from 1951 to the present.

Figure 3-5 shows the location of the SEDAN ground zero. Area 10, site of the SEDAN detonation, is part of Yucca Flat, a 320-square-kilometer desert valley surrounded by mountains in the northern part of the NTS. Camp Mercury, situated at the southern boundary of the NTS, was the base of the Nevada Test Site Organization (NTSO). Camp Mercury provided office and living quarters, as well as laboratory facilities and warehouses, for personnel participating in various test activities.

Indian Springs Air Force Base is 30 kilometers east of Camp Mercury. This base served as the principal staging and decontamination area for Air Force aircraft participating in the atmospheric nuclear testing programs.

3.2 NEVADA TEST SITE ORGANIZATION FOR PROJECT SEDAN

The Atomic Energy Commission delegated responsibility to the NTSO to plan, manage, and conduct Operation STORAX, the series of atmospheric nuclear tests conducted from 1 July 1962 to 30 June 1963. Since the purposes of the project were essentially

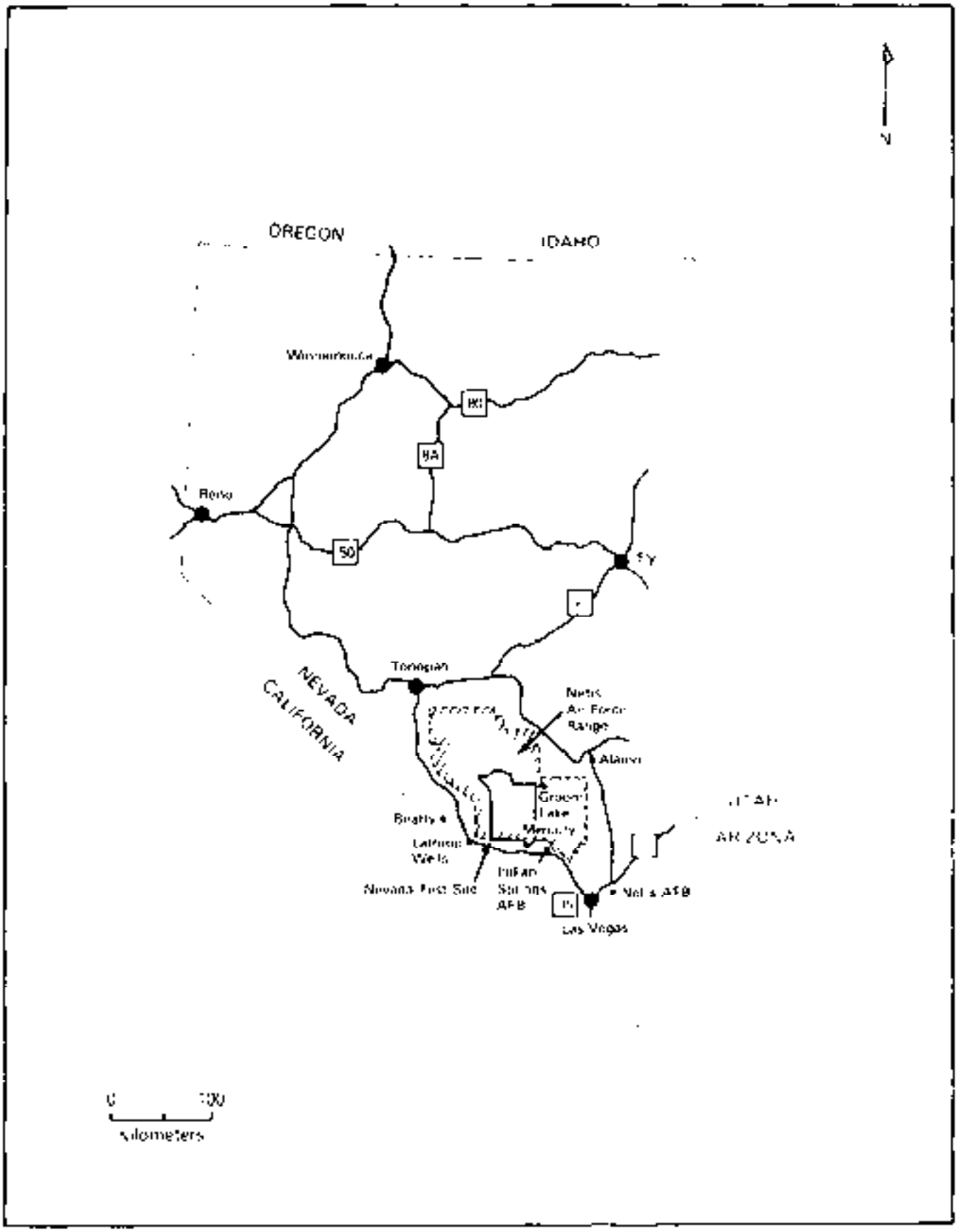

Figure 3-4: LOCATION OF NEVADA TEST SITE

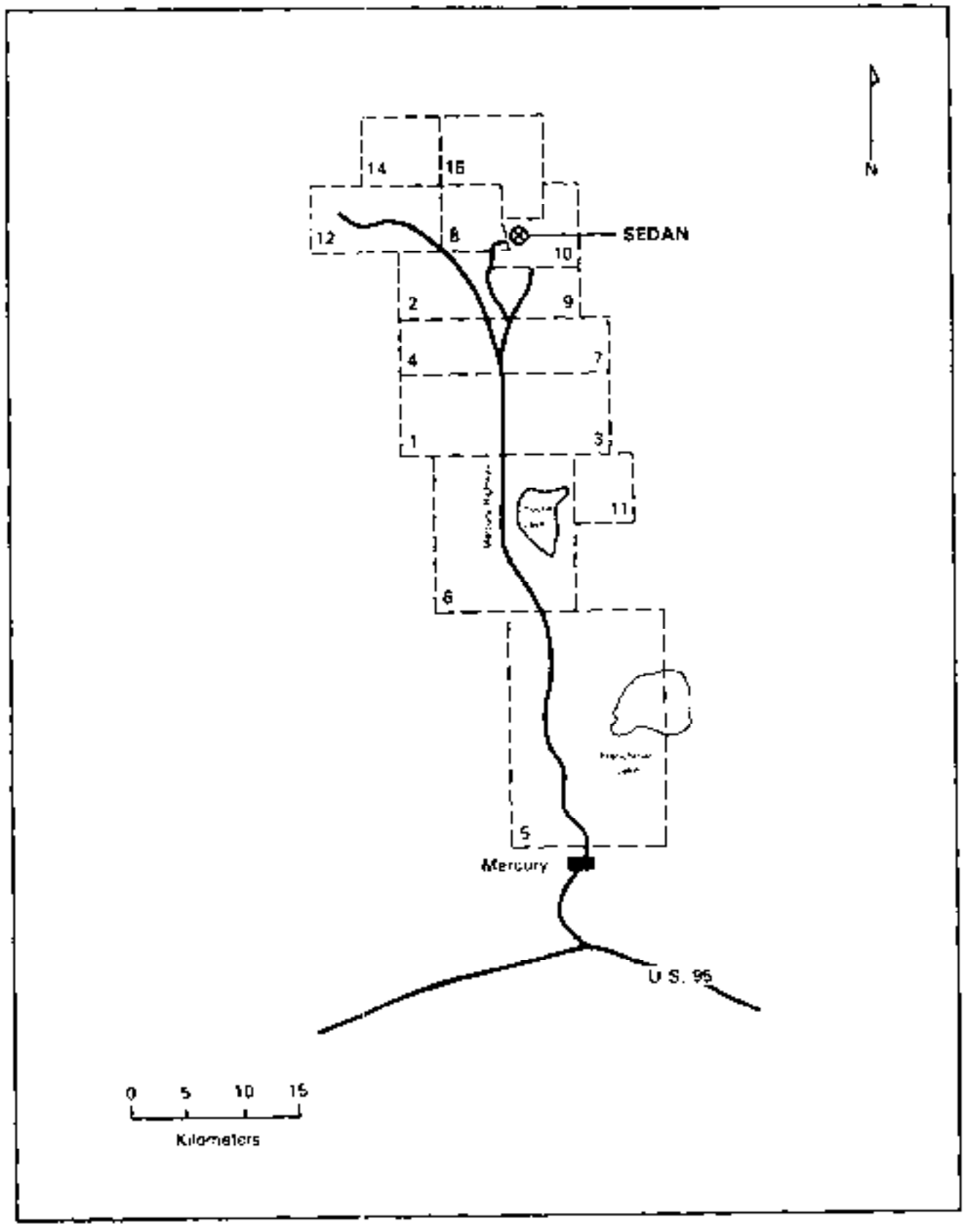

Figure 3-5: SEDAN GROUND ZERO WITHIN THE NEVADA TEST SITE

nonmilitary, the Director of the Division of Military Application, who customarily supervised nuclear test operations from AEC headquarters in Washington, D.C., shared responsibility for Project SEDAN with the Director of the Division of Biology and Medicine and the Director of the Division of Peaceful Nuclear Explosions. The Manager of the AEC Nevada Operations Office in Las Vegas was the Project Manager for SEDAN. He supervised activities of the two principal sections of the NTSO, the Project Manager's Organization and the Technical Organization, and he assigned the chief officials to direct the nuclear test series.

The principal DOD agency coordinating activities conducted by the military at Project SEDAN was the Defense Atomic Support Agency. The Chief, DASA, assigned responsibility for the DOD test preparations to the Commander, Field Command, DASA, in Albuquerque, New Mexico. This responsibility included the planning and funding of DOD test activities and the assignment of DOD personnel to the NTSO. Figure 3-6 shows the line of authority from the President through the AEC and DOD to the NTSO (22).

3.2.1 Project Manager's Organization

The Project Manager's Organization administered Project SEDAN and provided support services to the Technical Organization, which conducted the scientific and technical experiments associated with the project. The Project Manager was assisted by the Military Deputy, an officer from Field Command, DASA, who supervised all DOD participants in Project SEDAN. Figure 3-7 shows the structure of the Project Manager's Organization (22).

The Project Manager consulted a team of scientific advisors and an Advisory Panel for matters relating to the scientific and technical aspects of SEDAN. He received advice from the Advisory Panel on the scheduling of the detonation. The Advisory Panel and the Project Manager received information from the Prediction

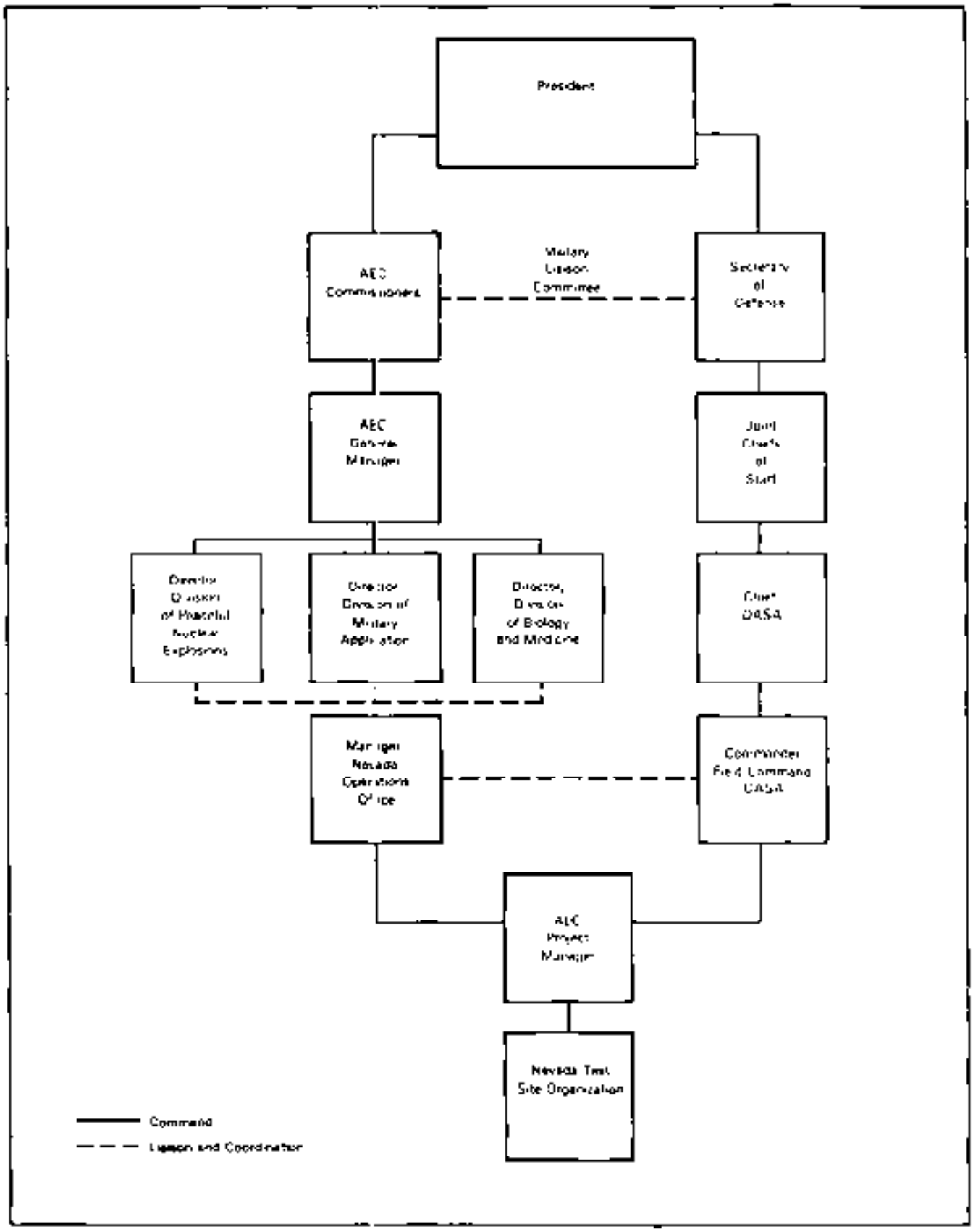

Figure 3-6: FEDERAL GOVERNMENT STRUCTURE FOR PROJECT SEDAN

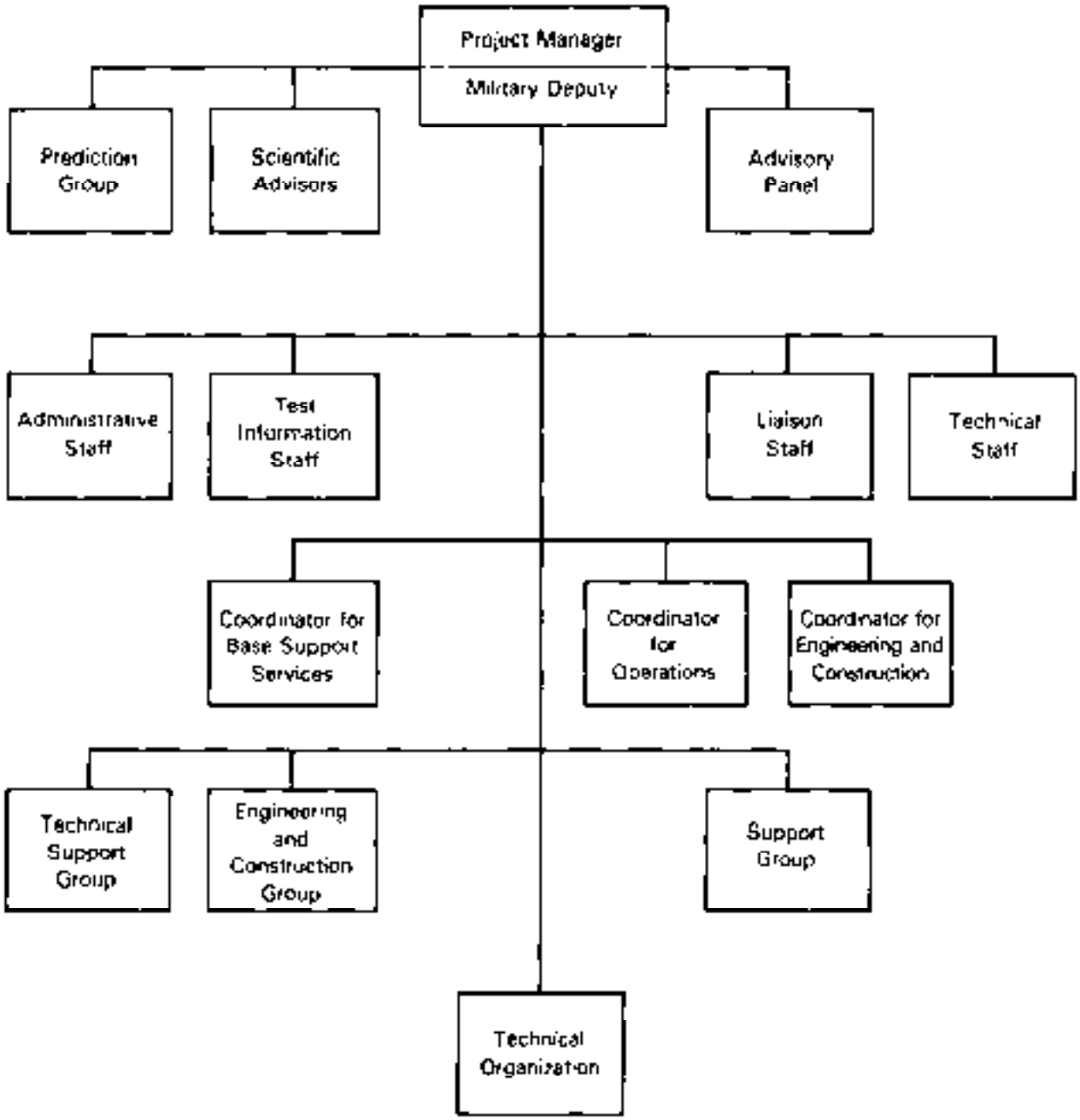

Figure 3-7: PROJECT MANAGER'S ORGANIZATION FOR PROJECT SEDAN

Group, who described expectations for the weather on the scheduled shot-day and the fallout and blast that would result from the detonation. The group was staffed by personnel from the U.S. Weather Bureau, for weather and fallout prediction, and the Sandia Corporation, for blast prediction.

Four staffs advised the Project Manager:

- Administrative
- Test Information
- Liaison
- Technical.

The Administrative Staff consisted of AEC employees who handled clerical and administrative matters for the Project Manager, including coordination with the Federal Aviation Administration and the U.S. Public Health Service. The Test Information Staff informed the public of activities at the Nevada Test Site. The Liaison Staff maintained contact between the NTSO and Federal agencies, contractors, and the Lawrence Radiation Laboratory, the developer of the SEDAN nuclear device. This staff included personnel from the AEC San Francisco Operations Office and from the Divisions of Military Application, Biology and Medicine, and Peaceful Nuclear Explosions. The Technical Staff, consisting of AEC and contractor employees, had responsibility for the safety, including the onsite radiological safety, of test participants.

The Project Manager appointed coordinators among the NTSO participants for base support services, operations, and engineering and construction. The titles of the coordinators, with the exception of the Coordinator for Operations, indicate their general responsibilities. The Coordinator for Operations arranged air support, including the use of Navy aircraft, for Project SEDAN.

The Technical Support Group aided the Technical Organization in matters relating to weather predictions, radiological safety

procedures, device assembly and arming, and the timing and firing of the device. This group also provided services, such as procedures for offsite radiological safety, for the Project Manager. The group was staffed by the following contractors and Government agencies (22):

- EG&G
- REECo
- Sandia Corporation
- U.S. Coast and Geodetic Survey
- U.S. Public Health Service
- U.S. Weather Bureau.

The Engineering and Construction Group built and assembled the facilities and installations necessary for the scientific experiments. The Support Group provided transportation, communications, medical, and maintenance services. Both groups were staffed by AEC and contractors, particularly Holmes and Narver, Incorporated, and REECo.

The Department of Defense did not have any specific groups within the Project Manager's Organization, except for the Military Deputy and his staff. The function of the Military Deputy was to coordinate the activities of the DOD participants in the various groups and staffs of the NTSO.

3.2.2 Technical Organization

The Technical Organization assembled and armed the SEDAN nuclear device. In addition, it conducted a number of scientific and technical experiments. The group was headed by the Technical Director, an LRL scientist. He was assisted by a Deputy Technical Director from LRL and two scientific advisors, one from

LRL and the other from the AEC Division of Biology and Medicine. The Technical Director was supported by five sections (22):

- Operations
- Engineering and Construction
- Safety
- Assembly and Arming
- Timing and Firing.

The Operations Section coordinated the operational requirements of all Technical Organization participants. The Engineering and Construction Section was the chief liaison between the Technical Organization and the Engineering and Construction Group of the Project Manager's Organization. The Safety Section was responsible for personnel safety, including radiological safety, before and after the shot. Radiological safety responsibilities were coordinated with those of the Technical Section, Project Manager's Organization. The Assembly and Arming and the Timing and Firing Sections prepared the SEDAN device for detonation. With the exception of the Timing and Firing Section, manned by EG&G personnel, LRL personnel supervised the support staffs. The scientific and technical experiments were conducted by individual groups, supervised by the Technical Director and supported by the sections of the technical organizations (22).

3.3 DEPARTMENT OF DEFENSE PARTICIPATION IN SCIENTIFIC AND SUPPORT ACTIVITIES AT PROJECT SEDAN

Department of Defense personnel took part in some of the scientific and technical experiments conducted at Project SEDAN. Most of these experiments were designed to study peaceful applications of nuclear detonations. The other experiments were VELA UNIFORM projects, developed to detect underground detonations.

After the detonation, some project personnel went into the shot area to recover equipment and data. Recovery hour probably

occurred at about 1200, or about three hours after the detonation. The initial survey of the shot area had been completed by this time.

3.3.1 Scientific Tests

The Technical Organization conducted a number of programs at Project SEDAN to document the effects of a nuclear cratering detonation. These programs included (17; 29):

- Fallout collection and measurement, using fallout trays and collectors positioned throughout the planned fallout sector
- Bio-environmental effects, using materials arranged throughout the test area
- Ground shock (seismic monitoring) and airblast, both onsite and offsite
- Close-in ground motion and cloud dimensions, using high-speed photography and underground pressure transducers
- Total mass distribution, using tarpaulins, trays, and measuring rods
- Particle trajectory, using radioactive pellets emplaced in holes near ground zero.

According to available documentation, Department of Defense personnel participated in four projects, described below, that were part of technical programs studying peaceful uses of nuclear detonations. In addition, they participated in support activities for these studies.

<u>Stability of Cratered Slopes</u> was conducted by the Soils Division of the Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. The study was sponsored by the Army Engineer Nuclear Cratering Group, Livermore, California, and the LRL. The purposes were to determine the effects of the detonation on the properties of the subsurface soil adjacent to the

crater and the stability of the resultant crater slopes. Data on the effects were needed if nuclear detonations were to be used in excavation for such structures as canals, buildings, bridges, piers, and docks. The Nuclear Cratering Group provided overall technical direction for this study. The Waterways Experiment Station supervised the exploratory trenching, conducted exploratory drilling, and analyzed the drill samples. The LRL performed initial geological mapping, provided continuing geological consultation and photography support, and coordinated radiological safety activities (16). Preshot field work, conducted in June 1962, consisted of field mapping exposed geologic units, boring in the vicinity of ground zero, geophysical logging of the drill holes, and laboratory testing (45).

On 9 January 1963, the Test Manager authorized the Nuclear Cratering Group to begin postshot explorations of the SEDAN crater. He gave authorization with the understanding that written permission to enter the SEDAN area would be obtained from LRL and that explorations of the area would not interfere with other NTS activities (35). An estimated six personnel from the Nuclear Cratering Group and the Waterways Experiment Station were in residence at the NTS, starting about 14 January 1963. The explorations were concluded in August 1963. These postshot field investigations involved mapping the exposed crater and throwout surfaces, mapping an inspection trench excavated through the crater lip, and making various other borings, geophysical logs, and field density determinations (16; 45). Figure 3-8 shows the slope of the SEDAN crater.

Naval Aerial Photographic Analysis was conducted by the Naval Radiological Defense Laboratory (NRDL). Because this activity was scheduled only a few days before the shot, the objectives were not formally stated or documented. It is

Figure 3-8: PROJECT SEDAN CRATER SLOPE

believed, however, that the project participants were to use high-performance photography aircraft to (47):

- Photograph the preshot ground zero area
- Map the crater
- Evaluate the advantages of this type of aerial photography for future PLOWSHARE demonstrations.

At the time of Project SEDAN, NRDL was providing aerial photography support for a number of projects at Operation DOMINIC I, also conducted at the NTS during July 1962. The Military Field Operation Office of NRDL, which was responsible for these missions, supervised similar aerial photography coverage of SEDAN. NRDL requested aerial photo support for Project SEDAN from the Commander, Fleet Air, San Diego, who then authorized the Light Photographic Squadron Sixty-Three (VFP-63) to provide that support. The photo squadron was based at the Naval Air Station in Miramar, California. Upon NRDL's request for a squadron representative, a Master Chief Petty Officer arrived at the NTS on 4 July as the VFP-63 liaison officer to the Military Field Operation Office. He remained at the NTS for three weeks to coordinate the aerial photography missions at SEDAN and other shots (47).

Two F8U-1P aircraft, the photo version of the Pacific Fleet's supersonic Crusader jet aircraft, conducted four photography missions at Project SEDAN. The aircraft flew the initial two missions 8,700 feet over the immediate ground zero area. They began the first mission at 1205 hours on 5 July and the second at 1615 hours on 6 July, about seven hours after the detonation. During these two flights, the aircrews also took preshot photographs of the ground zero areas for two Operation DOMINIC II shots, SMALL BOY and JOHNIE BOY. On 7 and 9 July, beginning at 1125 and 1020 hours, respectively, the aircraft flew two additional sorties to photograph the extensive upwind and crosswind base surge deposition area (47).

Project 2.03, Seismic Effects from a High Yield Nuclear Cratering Experiment in Desert Alluvium, was conducted by the U.S. Coast and Geodetic Survey, with assistance from LRL, Field Command DASA, and the Air Force Technical Applications Center. The objective was to obtain data for improving empirical scaling formulas for earth particle motion predictions. The project was designed to determine the magnitude and distal attenuation of the peak earth particle velocities, accelerations, and displacements and to compare the results with those obtained from studies of natural earthquake phenomena and underground detonations (26).

Project personnel obtained data from 11 Project 1.4 and six Project 8.1 stations. The Project 1.4 stations ranged from one to 27 kilometers from ground zero. Eight of these stations were in concrete bunkers and installations constructed for purposes other than seismographic studies. The other three stations were in seismographic shelters located out of the debris fallout range. The Project 8.1 stations were mobile and were located offsite, 150 to 1,700 kilometers from ground zero. Three of the stations were northeast of ground zero at approximate distances of 150, 200, and 250 kilometers. Of the remaining stations, one was at Tryon, Oklahoma, and the other two were near Suffield, Alberta, Canada (26). Projects 1.4 and 8.1 were VELA UNIFORM studies, and they are discussed in section 3.3.2.

Project 62.90, Some Radiochemical and Physical Measurements of Debris from an Underground Nuclear Explosion, was conducted by the U.S. Naval Radiological Defense Laboratory. The objectives were to collect fallout samples in order to determine mass per unit area, mass and activity distribution as a function of particle size, ionization decay rate and gamma spectra, and radiochemical composition of the fallout. Additional objectives were to perform leaching and exchange studies of radioactive debris and to measure the release of gaseous iodine fission products (21).

On 4 and 5 July, project personnel placed basic collectors at 20 stations ranging 750 to 5,850 meters from ground zero. At 0600 hours on 6 July, they placed an iodine gas sampler at a station about 3,000 meters from ground zero and started the motor. At 1700 hours on 8 July, participants recovered collectors from stations 1,650 to 5,850 meters from ground zero. At 1400 hours on 10 July, personnel retrieved collectors from stations 1,500 to 5,200 meters from ground zero (21).

3.3.2 VELA UNIFORM Projects

Department of Defense personnel participated in several VELA UNIFORM projects at SEDAN. The origin and purpose of the VELA UNIFORM program are discussed in chapter 2.

Project 1.4, Strong Motion Seismic Measurements, was conducted by the Defense Atomic Support Agency and the Coast and Geodetic Survey. From 1000 to 2300 hours on 5 July, project personnel made final adjustments to seismic instruments at stations one to 27 kilometers from ground zero. These stations, also used for Project 62.90, were in Areas 2, 4, 8, 9, 10, 12, and 15 of the NTS. To make the adjustments, personnel divided into three parties, each of two men. The same parties made final adjustments to the instruments on shot-day, up to three hours before the detonation. After the detonation, these parties remained at the forward checkpoint until the announcement of recovery hour, when they proceeded into the shot area to collect data (37).

Project 8.1, Intermediate Range Seismic Measurements, was conducted by the Air Force Technical Applications Center and the Coast and Geodetic Survey. The objective was to collect data to aid in improving methods of detecting and identifying underground nuclear explosions. Data obtained from stations 150 to 1,700 kilometers from ground zero were also used for Project 2.03 (37).

Project 8.4, Long Range Seismic Measurements, was conducted by the Air Force Technical Applications Center and the Coast and Geodetic Survey. Its objective was to gather seismic data from various offsite locations (37).

Department of Defense personnel also participated in Project 9.2 [support photography] and 9.3 [support photography]. The objectives of these two projects were to provide photographs for participating agencies and for public information purposes (37).

Seven DASA photo unit personnel operated a station in the shot area from 0700 to 1100 hours on shot-day. They took still and motion pictures of the detonation. From 15 minutes before to 45 minutes after the detonation, two additional personnel photographed the ground zero area from an H-21 helicopter circling upwind from ground zero. Another DASA photo unit participant joined an EG&G group at the Control Point. When the area was opened for recovery activities, this participant went to the ground zero area to take photographs (37).

3.3.3 Air Force Special Weapons Center Activities

Specific information on AFSWC activities at Project SEDAN is limited, primarily because SEDAN was conducted within the period of Operation DOMINIC II and participants in SEDAN were also involved in DOMINIC II. Documentation does not always distinguish between the activities conducted at SEDAN and those conducted at DOMINIC II. It is known, however, that AFSWC and other Air Force personnel conducted cloud-sampling, cloud-tracking, and support missions during SEDAN.

Cloud Sampling

Five B-57 aircraft, each with a crew of two, conducted cloud-sampling missions at Project SEDAN. The aircraft staged from Indian Springs AFB (37). The first B-57 (serial number 243)

sampled the SEDAN cloud four minutes after the detonation. This aircraft was sandblasted by suspended particulate, causing some damage to its skin and frosting its windscreen. After completing its mission, the aircraft returned to Indian Springs AFB, landing at 1020.

All crew members aboard the five cloud-sampling aircraft wore film badges. The highest film badge reading was 1.445 rem (40). Three film badges were taped inside the five aircraft, but the readings from these badges are not known. In addition, the outsides of the aircraft were monitored. The highest radiation intensity found on these aircraft was 8.5 R/h, recorded on the left wing of the first sampler (serial number 243) (38).

Cloud Tracking

The Offsite Radiological Safety Organization used two Air Force aircraft and crews for cloud tracking at SEDAN. One U3A flew a high-altitude and the other a low-altitude mission. A USPHS radiological safety team, probably of two personnel, accompanied the crew of each U3A, estimated at four personnel. At 0951, one of the aircraft left Indian Springs AFB for the NTS, where it was to orbit over Yucca Lake until cleared by Air Control to fly over the shot area. At 1040, this aircraft passed over the cloud at 21,500 feet, registering a reading of 0.001 R/h. The second U3A, which both tracked and penetrated the cloud, flew from Indian Springs AFB after the detonation. The aircraft made its initial cloud penetration at about 1500 hours. At 1700, it flew a west-to-east pass through the cloud to obtain an intensity profile. This aircraft ended its mission at 1729 hours, after the leading edge of the cloud had been located 24 kilometers south of Ely, Nevada (29; 39).

A WB-50 aircraft was to perform cloud tracking if the cloud rose to an altitude above the range of the U3A aircraft. This aircraft flew from Indian Springs AFB at 0930 but apparently was not needed for the mission (39).

Support

In addition to one H-21 helicopter providing support to Projects 9.2 and 9.3, four other helicopters participated in support activities. Two of these helicopters remained at the Control Point 1 helicopter pad, prepared to perform rescue operations in the forward area if needed. The other two helicopters were on standby to airlift experimental animals, handlers, and samples that were part of a USPHS project (39).

3.4 RADIATION PROTECTION AT PROJECT SEDAN

To minimize the exposures of PLOWSHARE personnel to ionizing radiation, the Atomic Energy Commission directed the Project Manager to implement radiological safety procedures. In addition, the AEC recommended an individual exposure limit of 3 rem of gamma and neutron radiation per quarter calendar year and not more than 5 rem annually. The SEDAN radiological safety program operated within these exposure guidelines (6).

3.4.1 Organization of the Radiological Safety Program

The Project Manager had overall responsibility for the radiological safety of participants in Project SEDAN. He was advised by the Technical Staff and assisted by the Technical Support Group. Working with the Technical Support Group, the Radiological Safety Division of REECo provided all onsite radiological support. The Onsite Radiological Safety Officer headed this division. The USPHS provided offsite radiological safety support. The Offsite Radiological Safety Officer supervised these activities (29; 40).

3.4.2 Radiation Protection Activities

The radiological safety program was designed to minimize the radiation exposures of participating personnel and observers, to prevent the spread of radioactive contamination to uncontrolled areas, and to assist in security and control of personnel access into radiation areas. In fulfilling its responsibilities, the REECo Radiological Safety Division did the following (40):

- Issued anticontamination clothing and equipment to personnel entering radiation areas
- Maintained exposure records to determine the accumulated exposure of each participant to gamma radiation
- Provided radiation detection instruments
- Issued, exchanged, processed, and evaluated film badge dosimeters
- Took air samples and monitored radiation areas and controlled access into these areas
- Plotted isointensity contour maps of radiation areas and provided radiation information to personnel entering radiation areas
- Decontaminated personnel, vehicles, and equipment.

Radiological safety personnel were stationed at the Test Director's Forward Control Point. This building served as the base operations station for the radiological monitoring teams. In addition, the building was used as a check station to ensure that personnel entering the test area had proper identification badges and authorization papers. The Test Director's Forward Control Point also functioned as a decontamination facility for personnel and vehicles leaving the test area. Another radiological safety section at Indian Springs AFB provided monitoring and decontamination services for the cloud-sampling program (40).

Protective Equipment and Personnel Dosimetry

Radiological safety personnel procured, issued, maintained, repaired, and stored protective equipment and supplies for personnel entering the SEDAN test area. This equipment included film badges, radiac instruments, environmental sampling equipment, and anticontamination clothing. With the exception of AFSWC participants, NTSO personnel received this equipment and clothing as they passed through the Test Director's Forward Control Point. AFSWC personnel received the equipment and clothing at the Indian Springs AFB radiological safety facility (40).

From 6 July through 13 August 1962, 378 personnel entered the test area. Each individual received a film badge and a self-reading pocket dosimeter. The pocket dosimeters were read when the individuals left the test area, and exposures were written down and used as a supplemental daily record to the film badge records. Two personnel, one from the Naval Radiological Defense Laboratory and the other from the Naval Mobile Construction Battalion-ELEVEN, exceeded the 3 rem limit. The maximum personnel exposure was 5.790 rem, and the average exposure was 0.883 rem (40). In addition to the aggregate exposure information in the "Onsite Radiological Safety Report," table 3-1 presents the gamma exposure data available from film badge records for DOD participants at SEDAN. Table 3-2 presents gamma exposure information available from film badge records for scientific personnel, contractors, and affiliates who took part in the PLOWSHARE Program. The documentation used for table 3-2 did not identify the participants according to specific PLOWSHARE event (7; 25; 41; 46).

Table 3-1: DISTRIBUTION OF GAMMA RADIATION EXPOSURES FOR DOD PERSONNEL AND AFFILIATES AT PROJECT SEDAN, PLOWSHARE PROGRAM

Units	Personnel Identified by Name	Personnel Identified by Name and by Film Badge	Average Gamma Exposure (rem)	Gamma Exposure (rem)				
				<0.1	0.1-1.0	1.0-3.0	3.0-5.0	5.0+
Army								
Unknown	3	1	1.295	0	0	1	0	0
Total (Army)	3	1	1.295	0	0	1	0	0
Navy								
Armed Forces Special Weapons Project (sic)	2	0	–					
Construction Battalion Center, Port Hueneme, CA	1	1	0.120	0	1	0	0	0
Director, Weapons Effects Tests	1	0						
Naval Administrative Unit, Sandia Base	7	6	0.044	4	1	0	0	0
Naval Mobile Construction Battalion ELEVEN	21	21	1.066	3	6	11	1	0
Naval Radiological Defense Laboratory	45	35	1.187	1	17	16	0	1
University of California Radiation Laboratory	4	0						
Unit Unknown	1	0						
Total (Navy)	82	62	1.033	8	25	27	1	1
Marine Corps								
Naval Radiological Defense Laboratory	1	1	0.330	0	1	0	0	0
Total (Marine Corps)	1	1	0.330	0	1	0	0	0

[1] "Sic" indicates that the table entry for the organization appears as it was listed in source documentation.

Table 3-1: DISTRIBUTION OF GAMMA RADIATION EXPOSURES FOR DOD PERSONNEL AND AFFILIATES AT PROJECT SEDAN, PLOWSHARE PROGRAM (CONTINUED)

Units	Personnel Identified by Name	Personnel Identified by Name and by Film Badge	Average Gamma Exposure (rem)	Gamma Exposure (rem)				
				<0.1	0.1-1.0	1.0-3.0	3.0-5.0	5.0 -
Air Force								
Air Force Flight Test Center, Headquarters	8	5	0.060	4	1	0	0	0
Air Force Flight Test Center, Headquarters	1	1	0.075	1	0	0	0	0
Unknown at This Time	4	4	0	4	0	0	0	0
1129th U.S. Air Force Special Activities Squadron	1	0						
1136th U.S. Air Force Special Activities Squadron	1	1	0.200	0	1	0	0	0
Total (Air Force)	13	11	0.048	9	2	0	0	0
Total (SEDAN)	99	75	0.883	17	28	28	1	1

Table 3-2: DISTRIBUTION OF GAMMA RADIATION EXPOSURES FOR SCIENTIFIC PERSONNEL, CONTRACTORS, AND AFFILIATES, PLOWSHARE PROGRAM*

Units	Personnel Identified by Name	Personnel Identified by Name and by Film Badge	Average Gamma Exposure (rem)	Gamma Exposure (rem)				
				<0.1	0.1-1.0	1.0-3.0	3.0-6.0	6.0+
Armour Research Foundation	9	9	0	9	0	0	0	0
Bendix Aircraft Corporation	85	85	0	85	0	0	0	0
Chance Vought	6	6	0	6	0	0	0	0
DNA Clarksville Base	16	16	0	16	0	0	0	0
DNA Lake Meade Base	30	30	0	30	0	0	0	0
DNA Manzano Base	7	7	0	7	0	0	0	0
DNA Headquarters, Washington, DC	20	20	0	20	0	0	0	0
FCDNA Civilians, Kirtland AFB	11	11	0.007	11	0	0	0	0
JCDNA NTS Detachment	12	12	0.002	12	0	0	0	0
Marquardt Aircraft	31	31	0	31	0	0	0	0
Martin	7	7	0	7	0	0	0	0
Office of Test Information	1	1	0	1	0	0	0	0
Office of the Secretary of Defense	47	47	0	47	0	0	0	0
Stanford Research Institute	13	13	0.003	13	0	0	0	0
Unit Unknown	306	306	0	306	0	0	0	0
Universities	24	24	0	24	0	0	0	0
Total	632	632	0	632	0	0	0	0

*Information is not available on personnel participation according to specific PLOWSHARE event.

Monitoring

Onsite monitoring activities of the Radiological Safety Division included (37; 40):

- Performing initial surveys and resurveys of the test area
- Marking and establishing radiation areas within isointensity lines
- Establishing and operating monitoring checkpoints
- Serving as monitors for personnel who were required to enter radiation areas.

At 1100 hours, two hours after the detonation, four two-person monitoring teams in radio-equipped vehicles left the Test Director's Forward Control Point to conduct the initial ground survey of the shot area. Radiation intensities before this time, as recorded by remote monitoring stations, were too high to permit entry into this area. The survey teams proceeded along predesignated routes into the shot area taking radiation readings as they progressed. They radioed the readings to radiological safety personnel at the base station, where isointensity maps were prepared. The maps were then made available to project personnel who entered the shot area to recover equipment and data.

The teams completed the initial survey at 1200 hours. Figure 3-9 presents a copy of the radiation isointensity map resulting from this survey. Resurveys were performed five hours after the detonation and on various days up to 33 days after the detonation. Figures 3-10 and 3-11 show copies of radiation isointensity maps resulting from surveys conducted five hours and two days after the detonation. Radiological surveys were also conducted at specific locations in addition to Area 10, including Frenchman Flat, Papoose Lake, Control Point Building 1, and Area 7 (40).

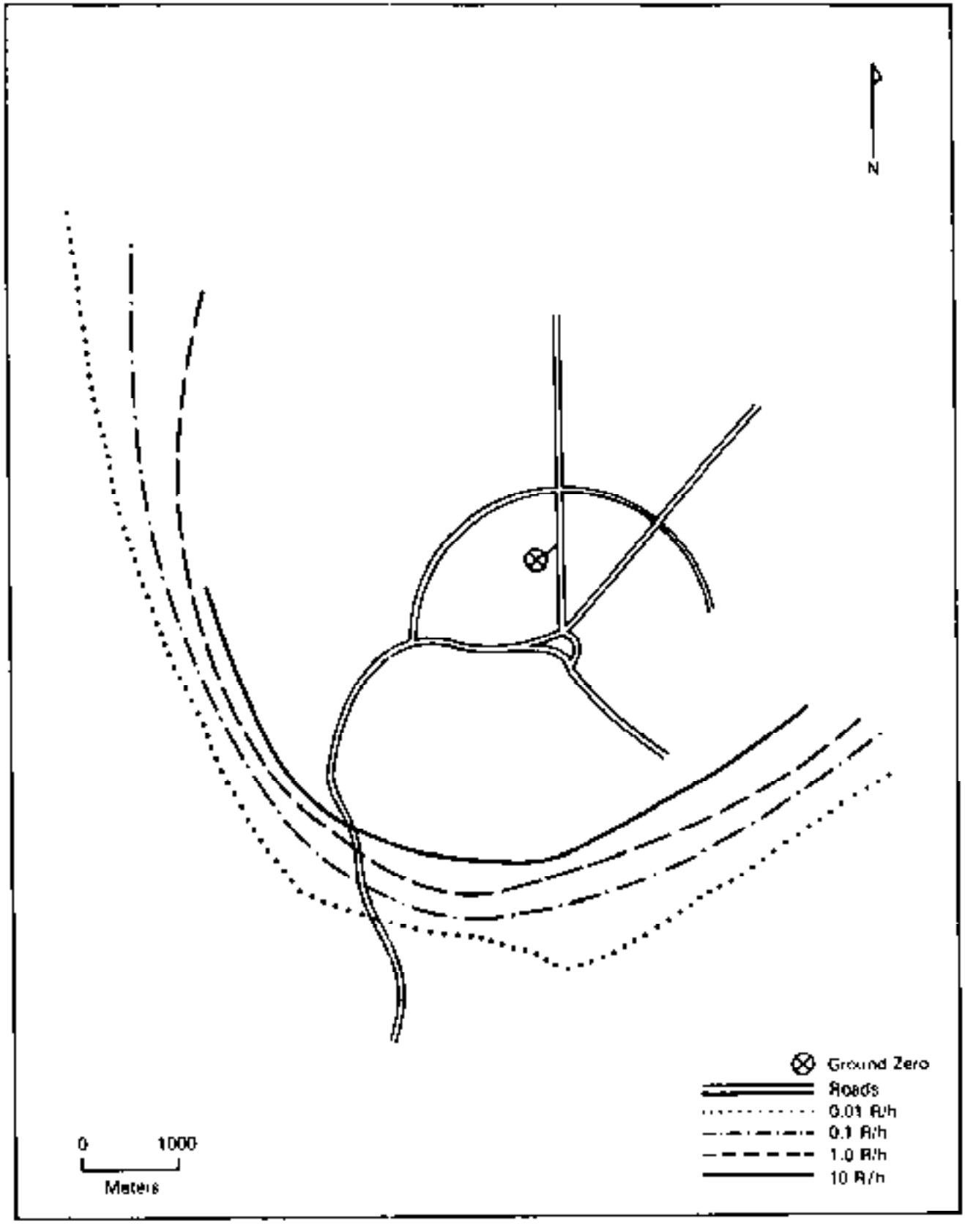

Figure 3-9: **INITIAL SURVEY FOR PROJECT SEDAN, MID-TIME 1130 HOURS, 6 JULY 1962**

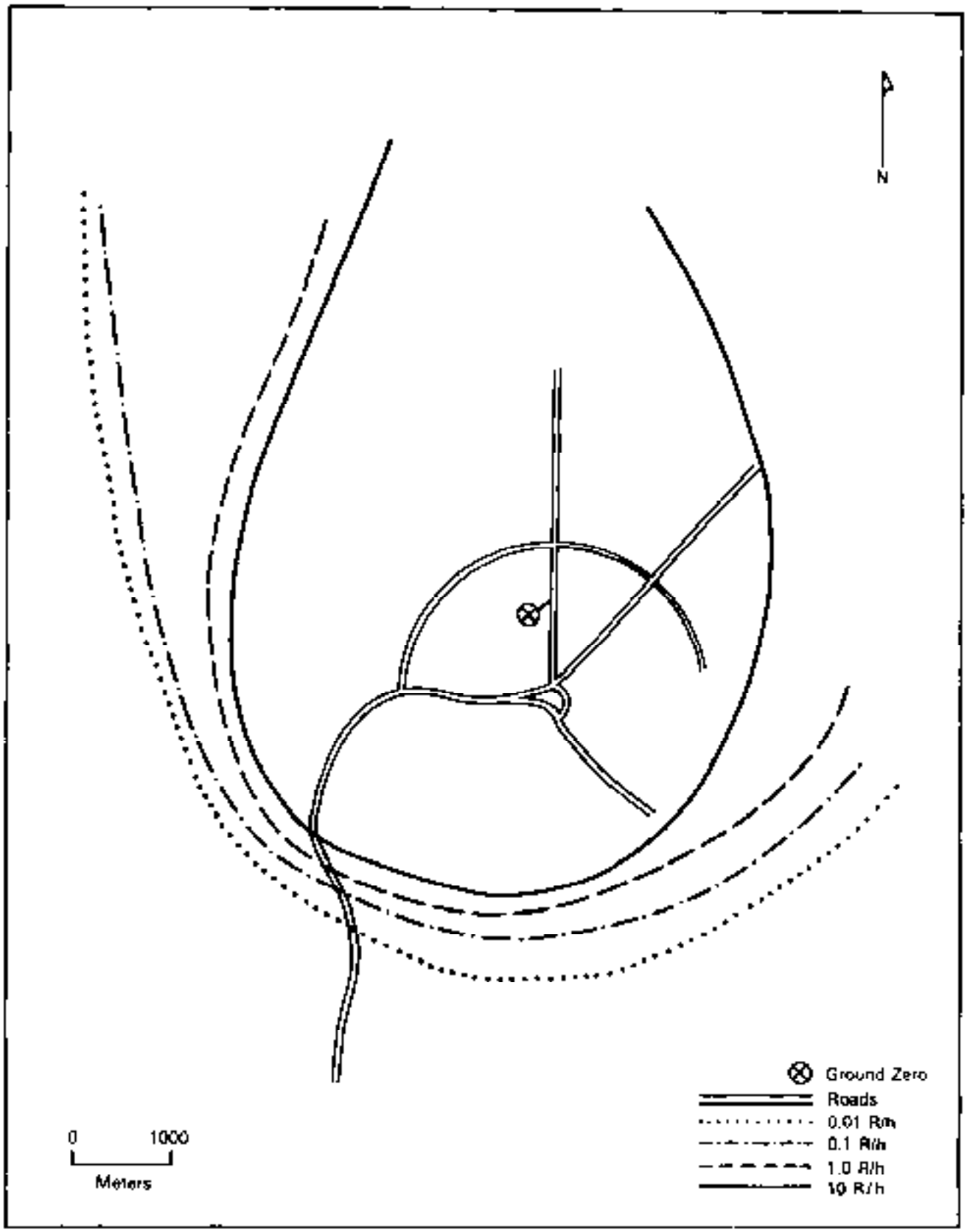

Figure 3-10: RESURVEY FOR PROJECT SEDAN, MID-TIME 1525 HOURS, 6 JULY 1962

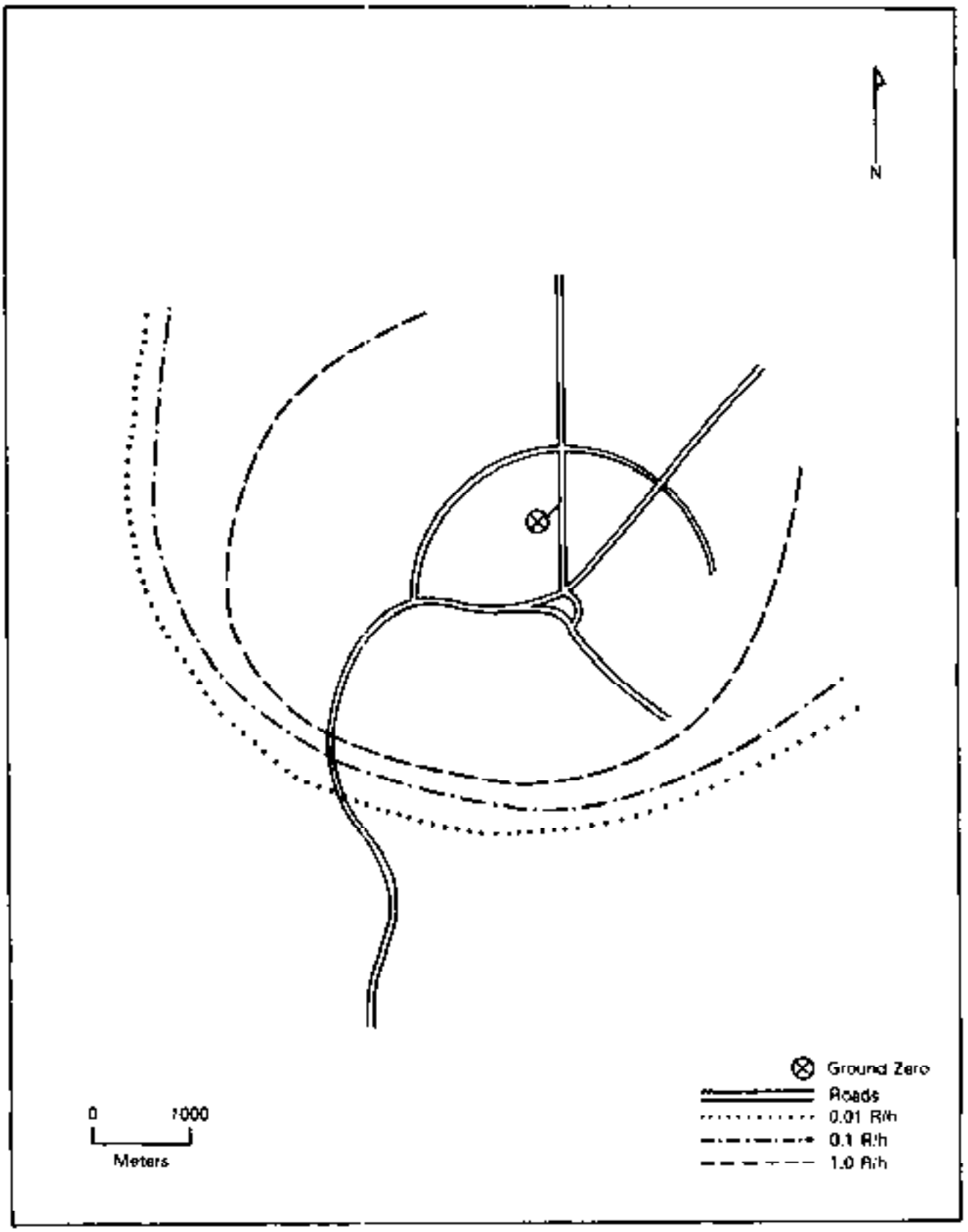

Figure 3-11: RESURVEY FOR PROJECT SEDAN, MID-TIME 0800 HOURS, 8 JULY 1962

Offsite monitoring, provided by USPHS personnel, was also conducted during the SEDAN event. Before the detonation, 18 two-person monitoring teams in radio-equipped vehicles went to selected offsite areas within about 350 kilometers of ground zero. These teams were then in position to conduct ground surveys as the SEDAN cloud drifted over their locations. The teams monitored along some highways and in populated areas in the path of the cloud. The highest gamma intensity they encountered on shot-day in unpopulated areas was 1.96 R/h, recorded about 62 kilometers north of ground zero. The highest gamma intensity encountered by teams in a populated area on shot-day was 0.324 R/h, recorded in Diablo, Nevada. The next highest intensity on shot-day was 0.032 R/h at Penoyer, Nevada (29).

Offsite monitoring teams resurveyed the towns and other populated areas each day for four days after the detonation. The highest gamma intensity recorded was 0.011 R/h in Diablo the day after the detonation (29).

Decontamination

Radiological safety personnel operated a decontamination facility from the Test Director's Forward Control Point. At this station, they monitored personnel, vehicles, and equipment leaving the test area. Decontamination was required if radioactivity exceeded the NTS limits of:

- Personnel: 0.007 R/h (beta and gamma) or 1,000 counts per minute (alpha) on anticontamination clothing and shoes

  0.001 R/h (gamma) or 200 counts per minute (alpha) on surface of skin or underclothing

- Vehicles and Equipment: 0.007 R/h (gamma) on outer surfaces

  0.007 R/h (beta and gamma) or 10,000 counts per minute (alpha) on inner surfaces.

The first step in decontaminating personnel returning from the radiation area was to clean them of surface contamination by vacuuming the dust and dirt from their garments. Returning personnel then turned in their respirators, film badges, and pocket dosimeters. Radiological safety personnel next monitored each individual. If the radioactivity reading exceeded the limit, the person was required to remove contaminated clothing and, if the reading was still too high, take a shower. Radiological safety personnel monitored the individual again after the shower. If the radiation reading was less than 0.001 R/h on the surface of the skin, the individual received fresh clothing and was released.

Vehicles returning from radiation areas were parked in designated areas adjacent to the Control Point. Members of the Radiological Safety Division monitored the vehicles. If they recorded readings of 0.007 R/h or greater, the vehicles had to be decontaminated. Radiological safety personnel first vacuumed all surfaces, including running boards, floorboards, and the undersides of tenders. They then resurveyed the vehicles and, if the vehicles were still contaminated, sprayed and washed them with a liquid detergent and rinsed them with water. When measured gamma radiation intensities were less than 0.007 R/h, radiological safety personnel returned the vehicles to service.

Radiological safety personnel also operated a decontamination facility at Indian Springs AFB. After completing their missions, AFSWC aircraft returned to the base. There, the aircraft and crews were monitored for radioactivity and decontaminated as necessary (40).

To allow natural decay of radiation intensities, decontamination crews waited until 1700 hours on shot-day to begin decontaminating the five cloud-sampling aircraft. These crews, wearing anticontamination clothing, film badges, and pocket

dosimeters, used a mixture of citric acid, sodium borate, soap, and water to decontaminate the aircraft, including the pilot areas, the engines, and the sample pods. To decontaminate engines, the crews sprayed the running engines with a two-inch stream of water from a fire hose (38).

In addition to decontaminating personnel and vehicles, a major decontamination activity during SEDAN was cleaning about 11 kilometers of the highway leading to Groom Pass. This highway had become contaminated with fallout debris from the cloud. By 11 July, the maximum radiation levels had decayed to about 1.2 R/h. Radiological safety personnel washed the contaminated material from the road with water from high-pressure hoses. They used several tanker trucks and fire trucks for this operation. After washing, the highway was resurveyed, and the highest radiation level was found to be 0.15 R/h. At 1100 hours on 11 July, the highway was reopened for traffic (40).

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ATTN: Director

Veterans Administration - RO
Fargo, ND
ATTN: Director

Veterans Administration - RO
Cleveland, OH
ATTN: Director

Veterans Administration - RO
Huntington, WV
ATTN: Director

OTHER GOVERNMENT AGENCIES (Continued)

Veterans Administration - RO
Portland, OR
ATTN: Director

Veterans Administration - RO
Pittsburgh, PA
ATTN: Director

Veterans Administration - RO
Philadelphia, PA
ATTN: Director

Veterans Administration - RO
RPC San Francisco
ATTN: Director

Veterans Administration - RO
San Juan, Puerto Rico
ATTN: Director

Veterans Administration - RO
Columbia, SC
ATTN: Director

Veterans Administration - RO
Sioux Falls, SD
ATTN: Director

Veterans Administration - RO
Houston, TX
ATTN: Director

Veterans Administration - RO
Waco, TX
ATTN: Director

Veterans Administration - RO
Salt Lake City, UT
ATTN: Director

Veterans Administration - RO
White River Junction, VT
ATTN: Director

Veterans Administration - RO
Roanoke, VA
ATTN: Director

Veterans Administration - RO
Cheyenne, WY
ATTN: Director

Veterans Administration - RO
San Diego, CA
ATTN: Director

Veterans Administration - RO
Boise, ID
ATTN: Director

Veterans Administration - RO
Detroit, MI
ATTN: Director

OTHER GOVERNMENT AGENCIES (Continued)

Veterans administration - RO
Nashville, TN
ATTN: Director

The White House
ATTN: Domestic Policy Staff

DEPARTMENT OF DEFENSE CONTRACTORS

Advanced Research & Applications Corp
ATTN: M. Lee

CH2CDR
ATTN: A. Nelson
Copy ATTN: Health & Environment Div

Kaman Tempo
ATTN: C. Martin
ATTN: DASIAC

Kaman Tempo
ATTN: R. Miller

Kaman Tempo
Copy ATTN: C. Jones

National Academy of Sciences
ATTN: C. Robinette
ATTN: Medical Follow-up Agency
ATTN: National Materials Advisory Board

Pacific-Sierra Research Corp
ATTN: H. Brode, Chairman SAGE

R & D Associates
ATTN: R. Heas

Science Applications, Inc
ATTN: Tech Library

Science Applications, Inc
Copy ATTN: L. Hewitney

OTHER

Adams State College
ATTN: Govt Publication Lib

Akron Public Library
ATTN: Govt Publication Librarian

Alabama St Dept of Archives & History
ATTN: Military Records Division

University of Alabama
ATTN: Reference Dept/Documents

University of Alaska
ATTN: Director of Libraries

University of Alaska
ATTN: Govt Publication Librarian

OTHER (Continued)

Albany Public Library
ATTN: Librarian

Alexander City State Jr College
ATTN: Librarian

Allegheny College
ATTN: Librarian

Allen County Public Library
ATTN: Librarian

Altoona Area Public Library
ATTN: Librarian

American Statistics Index
ATTN: Cathy Carney

Anaheim Public Library
ATTN: Librarian

Andrews Library, College of Wooster
ATTN: Government Documents

Angelo State University Library
ATTN: Librarian

Angelo Jacobson Public
ATTN: Librarian

Anoka County Library
ATTN: Librarian

Appalachian State University
ATTN: Library Documents

Arizona State University Library
ATTN: Librarian

University of Arizona
ATTN: Gov Doc Dept, C. Bower

Arkansas College Library
ATTN: Library

Arkansas Library Comm
ATTN: Library

Arkansas State University
ATTN: Library

University of Arkansas
ATTN: Government Documents Div

Austin College
Arthur Jenkins Library
ATTN: Librarian

Atlanta Public Library
ATTN: Ivan Allen Dept

Atlanta University Center
ATTN: Librarian

OTHER (Continued)

Auburn Univ at Montgomery Lib
ATTN: Librarian

B. Davis Schwartz Mem Lib
ATTN: Librarian

Bangor Public Library
ATTN: Librarian

Bates College Library
ATTN: Librarian

Baylor University Library
ATTN: Docs Dept

Beloit College Libraries
ATTN: Serials Docs Dept

Bemidji State College
ATTN: Library

Benjamin F. Kennedy Library
State University College
ATTN: Government Documents

Bierce Library, Akron University
ATTN: Government Documents

Boston Public Library
ATTN: Documents Department

Bowdoin College
ATTN: Librarian

Bowling Green State Univ
ATTN: Govt Docs Services

Bradley University
ATTN: Govt Publication Librarian

Brandeis University Lib
ATTN: Documents Section

Brigham Young University
ATTN: Librarian

Brigham Young University
ATTN: Documents Collection

Brookhaven National Laboratory
ATTN: Technical Library

Brooklyn College
ATTN: Documents Division

Broward County Library Sys
ATTN: Librarian

Brown University
ATTN: Librarian

Bucknell University
ATTN: Reference Dept

OTHER (Continued)

Buffalo & Erie Co Pub Lib
ATTN: Librarian

Burlington Library
ATTN: Librarian

California at Fresno State Univ Lib
ATTN: Library

California at San Diego University
ATTN: Documents Department

California at Stanislaus St Clg Lib
ATTN: Library

California St Polytechnic Univ Lib
ATTN: Librarian

California St Univ at Northridge
ATTN: Gov Doc

California State Library
ATTN: Librarian

California State Univ at Long Beach Lib
ATTN: Librarian

California State University
ATTN: Librarian

California State University
ATTN: Librarian

California Univ Library
ATTN: Govt Publications Dept

California Univ Library
ATTN: Librarian

California University Library
ATTN: Govt Documents Dept

California University Library
ATTN: Documents Sec

California University
ATTN: Government Documents Dept

Calvin College Library
ATTN: Librarian

Calvin T. Ryan Library
Kearney State College
ATTN: Govt Documents Dept

Carleton College Library
ATTN: Librarian

Carnegie Library of Pittsburgh
ATTN: Librarian

Carnegie Mellon University
ATTN: Director of Libraries

OTHER (Continued)

Carson Regional Library
ATTN: Gov Publications Unit

Case Western Reserve University
ATTN: Librarian

University of Central Florida
ATTN: Library Docs Dept

Central Michigan University
ATTN: Library Documents Section

Central Missouri State Univ
ATTN: Government Documents

Central State University
ATTN: Library Documents Dept

Central Washington University
ATTN: Library Docs Section

Central Wyoming College Library
ATTN: Librarian

Charleston County Library
ATTN: Librarian

Charlotte & Mecklenburg County Pub Lib
ATTN: L. Correll

Chattanooga Hamilton Co
ATTN: Librarian

Chesapeake Pub Lib System
ATTN: Librarian

Chicago Public Library
ATTN: Governments Publications Dept

State University of Chicago
ATTN: Librarian

Chicago University Library
ATTN: Director of Libraries
ATTN: Documents Processing

Cincinnati University Library
ATTN: Librarian

Claremont Colleges Libs
ATTN: Doc Collection

Clemson University
ATTN: Director of Libraries

Cleveland Public Library
ATTN: Documents Collection

Cleveland State Univ Lib
ATTN: Librarian

Coe Library
ATTN: Documents Division

OTHER (Continued)

Colgate Univ Library
ATTN: Reference Library

Colorado State Univ Libs
ATTN: Librarian

Colorado University Libraries
ATTN: Director of Libraries

Columbia University Library
ATTN: Documents Service Center

Columbus & Franklin Cty Public Lib
ATTN: Gov Doc Div

Compton Library
ATTN: Librarian

Connecticut State Library
ATTN: Librarian

University of Connecticut
ATTN: Govt of Connecticut

Connecticut University
ATTN: Director of Libraries

Cornell University Lib
ATTN: Librarian

Corpus Christi State University Lib
ATTN: Librarian

Culver City Library
ATTN: Librarian

Curry College Library
ATTN: Librarian

Dallas County Public Library
ATTN: Librarian

Dallas Public Library
ATTN: Librarian

Dalton Jr College Library
ATTN: Librarian

Dartmouth College
ATTN: Librarian

Davenport Public Library
ATTN: Librarian

Davidson College
ATTN: Librarian

Dayton & Montgomery City Pub Lib
ATTN: Librarian

University of Dayton
ATTN: Librarian

OTHER (Continued)

Decatur Public Library
ATTN: Librarian

Dekalb Community College
ATTN: Librarian

Delaware Area University
ATTN: Librarian

University of Delaware
ATTN: Librarian

Delta College Library
ATTN: Librarian

Delta State University
ATTN: Librarian

Denison Univ Library
ATTN: Librarian

Denver Public Library
ATTN: Documents Div

Dept of Lib & Archives
ATTN: Librarian

Detroit Public Library
ATTN: Librarian

Dickinson State College
ATTN: Librarian

Drake Memorial Learning Resource Ctr
ATTN: Librarian

Drake University
ATTN: Cowles Library

Drew University
ATTN: Librarian

Duke University
ATTN: Public Docs Dept

Duluth Public Library
ATTN: Documents Section

Earlham College
ATTN: Librarian

East Carolina University
ATTN: Library Docs Dept

East Central University
ATTN: Librarian

East Islip Public Library
ATTN: Librarian

East Orange Public Lib
ATTN: Librarian

East Tennessee State Univ Sherrod Lib
ATTN: Documents Dept

OTHER (Continued)

East Texas State University
ATTN: Library

Eastern Branch
ATTN: Librarian

Eastern Illinois University
ATTN: Librarian

Eastern Kentucky University
ATTN: Librarian

Eastern Michigan University Lib
ATTN: Documents Libn

Eastern Montana College Library
ATTN: Documents Dept

Eastern New Mexico Univ
ATTN: Librarian

Eastern Oregon College Library
ATTN: Librarian

Eastern Washington Univ
ATTN: Librarian

El Paso Public Library
ATTN: Documents & Genealogy Dept

Elko County Library
ATTN: Librarian

Elmira College
ATTN: Librarian

Elon College Library
ATTN: Librarian

Enoch Pratt Free Library
ATTN: Documents Office

Emory University
ATTN: Librarian

Evansville & Vanderburgh County Pub Lib
ATTN: Librarian

Everett Public Library
ATTN: Librarian

Fairleigh Dickinson Univ
ATTN: Depository Dept

Florida A & M Univ
ATTN: Librarian

Florida Atlantic Univ Lib
ATTN: Div of Public Documents

Florida Institute of Tech Lib
ATTN: Federal Documents Dept

Florida Intl Univ Library
ATTN: Docs Section

OTHER (Continued)

Florida State Library
ATTN: Documents Section

Florida State University
ATTN: Librarian

Florida University Libraries
ATTN: Documents Dept

Fond Du Lac Public Lib
ATTN: Librarian

Fort Hays State University
ATTN: Librarian

Fort Worth Public Library
ATTN: Librarian

Free Pub Lib of Elizabeth
ATTN: Librarian

Free Public Library
ATTN: Librarian

Freeport Public Library
ATTN: Librarian

Fresno County Free Library
ATTN: Librarian

Gadsden Public Library
ATTN: Librarian

Gaston Public Library
ATTN: Librarian

Gardner Webb College
ATTN: Documents Libra

Gary Public Library
ATTN: Librarian

Georgetown Univ Library
ATTN: Govt Docs Rm

Georgia Inst of Tech
ATTN: Librarian

Georgia Southern College
ATTN: Librarian

Georgia Southwestern College
ATTN: Director of Libraries

Georgia State Univ Lib
ATTN: Librarian

University of Georgia
ATTN: Dir of Libraries

Glassboro State College
ATTN: Librarian

Glenson Library
ATTN: Librarian

OTHER (Continued)

Government Publications Library-N
ATTN: Director of Libraries

Graceland College
ATTN: Librarian

Grand Forks Public City County Library
ATTN: Librarian

Grand Rapids Public Library
ATTN: Director of Libraries

Greenville County Library
ATTN: Librarian

Guam Rfc Memorial University Lib
ATTN: Fed Depository Collection

University of Guam
ATTN: Librarian

Gustavus Adolphus College
ATTN: Library

Harding-Simmons University Library
ATTN: Librarian

Hartford Public Library
ATTN: Librarian

Harvard College Library
ATTN: Director of Libraries

Harvard College Library
ATTN: Librarian

University of Hawaii
ATTN: Government Doc. Collection

Hawaii State Library
ATTN: Federal Documents Dept

University of Hawaii at Hilo
ATTN: Director of Libraries

University of Hawaii
ATTN: Librarian

Hayden Burns Library
ATTN: Librarian

Henry Ford Comm College Lib
ATTN: Librarian

Herbert H. Lehman College
ATTN: Library Documents Division

Hofstra Univ Library
ATTN: Documents Dept

Hollins College
ATTN: Librarian

Hoover Institution
ATTN: J. Bingham

OTHER (Continued)

Hopkinsville Comm College
ATTN: Librarian

University of Houston, Library
ATTN: Documents Div

Houston Public Library
ATTN: Librarian

Hoyt Public Library
ATTN: Librarian

Humboldt State College Library
ATTN: Documents Dept

Huntington Park Library
ATTN: Librarian

Hutchinson Public Library
ATTN: Librarian

Idaho Public Lib & Info Center
ATTN: Librarian

Idaho State Library
ATTN: Librarian

Idaho State University Library
ATTN: Documents Dept

University of Idaho
ATTN: Documents Sect
ATTN: Dir of Libraries

University of Illinois, Library
ATTN: Documents Section

Illinois State Library
ATTN: Government Documents Branch

Illinois Univ at Urbana Champaign
ATTN: R. Watson, Documents Library

Illinois Valley Comm Coll
ATTN: Library

Indiana State Library
ATTN: Serial Section

Indiana State University
ATTN: Documents Librarian

Indiana University Library
ATTN: Documents Department

Indianapolis Marion Cty Pub Library
ATTN: Social Science Div

Iowa State University Library
ATTN: Govt Documents Dept

Iowa University Library
ATTN: Government Documents Dept

OTHER (Continued)

Butler University, Irwin Library
ATTN: Librarian

Isaac Delgado College
ATTN: Librarian

James Madison University
ATTN: Librarian

Jefferson County Public Lib
ATTN: Librarian

Jersey City State College
ATTN: Librarian

Johns Hopkins University
ATTN: Documents Library

John J. Wright Library, La Roche College
ATTN: Librarian

Johnson Free Public Lib
ATTN: Librarian

Kahului Library
ATTN: Librarian

Kalamazoo Public Library
ATTN: Librarian

Kansas City Public Library
ATTN: Documents Div

Kansas State Library
ATTN: Librarian

Kansas State Univ Library
ATTN: Documents Dept

University of Kansas
ATTN: Director of Libraries

Kent State University Library
ATTN: Documents Div

Kentucky Dept of Library & Archives
ATTN: Documents Section

University of Kentucky
ATTN: Governments Publication Dept
ATTN: Director of Libraries

Kenyon College Library
ATTN: Librarian

Lake Forest College
ATTN: Librarian

Lake Sumter Comm Coll Lib
ATTN: Librarian

Lakeland Public Library
ATTN: Librarian

OTHER (Continued)

Lancaster Regional Library
ATTN: Librarian

Lawrence University
ATTN: Documents Dept

Lee Library, Brigham Young University
ATTN: Documents & Map Section

Library & Statutory Distribution & Svc
Sec ATTN: Librarian

Little Rock Public Library
ATTN: Librarian

Long Beach Publ Library
ATTN: Librarian

Los Angeles Public Library
ATTN: Serials Div U.S. Documents

Louisiana State University
ATTN: Government Doc Dept
ATTN: Director of Libraries

Louisville Free Pub Lib
ATTN: Librarian

Louisville Univ Library
ATTN: Librarian

Lyndon B. Johnson Sch of Pub Affairs Lib
ATTN: Librarian

Maine Maritime Academy
ATTN: Librarian

Maine University at Orono
ATTN: Librarian

University of Maine
ATTN: Librarian

Manchester City Library
ATTN: Librarian

Mankato State College
ATTN: Govt Publications

Mantor Library
Univ of Maine at Farmington
ATTN: Director of Libraries

Marathon County Public Library
ATTN: Librarian

Marshall Brooks Library
ATTN: Librarian

University of Maryland
ATTN: McKeldin Libr Docs Div

University of Maryland
ATTN: Librarian

OTHER (Continued)

University of Massachusetts
ATTN: Government Docs College

McHenry State Univ
ATTN: Librarian

Memphis Shelby County Pub Lib & Info Ctr
ATTN: Librarian

Memphis State University
ATTN: Librarian

Mercer University
ATTN: Librarian

Mesa County Public Library
ATTN: Librarian

University of Miami, Library
ATTN: Government Publications

Miami Public Library
ATTN: Documents Division

Miami Univ Library
ATTN: Documents Dept

Michel Orradre Library
University of Santa Clara
ATTN: Documents Div

Michigan State Library
ATTN: Librarian

Michigan State University Library
ATTN: Librarian

Michigan Tech University
ATTN: Library Documents Dept

University of Michigan
ATTN: Acq Sec Documents Unit

Middlebury College Library
ATTN: Librarian

Millersville State Coll
ATTN: Librarian

Milne Library
State University of New York
ATTN: Docs Libr

Milwaukee Pub Lib
ATTN: Librarian

Minneapolis Public Lib
ATTN: Librarian

Minnesota Div of Emergency Svcs
ATTN: Librarian

Minot State College
ATTN: Librarian

Mississippi State University
ATTN: Librarian

OTHER (Continued)

University of Mississippi
ATTN: Director of Libraries

Missouri Univ at Kansas City Lib
ATTN: Librarian

Missouri University Library
ATTN: Government Documents

M.I.T. Libraries
ATTN: Librarian

Mobile Public Library
ATTN: Governmental Info Division

Mohave Library
ATTN: Librarian

Montana State Library
ATTN: Librarian

Montana State University, Library
ATTN: Librarian

University of Montana
ATTN: Documents Div

Moorhead State College
ATTN: Library

Mt Prospect Public Lib
ATTN: Librarian

Murray State Univ Lib
ATTN: Library

Nashville Library System
ATTN: Librarian

Natrona County Public Library
ATTN: Librarian

Nebraska Library Comm
ATTN: Librarian

Univ of Nebraska at Omaha
ATTN: Librarian

Nebraska Western College Library
ATTN: Librarian

Nebraska Univers Ty Lib
ATTN: Acquisitions Dept

Univ of Nevada at Reno
ATTN: Governments Pub Dept

Univ of Nevada at Las Vegas
ATTN: Director of Libraries

New Hampshire University Lib
ATTN: Librarian

New Hanover County Public Library
ATTN: Librarian

Nebraska University
ATTN: Director of Libraries

OTHER (Continued)

New Mexico State Library
ATTN: Librarian

New Mexico State University
ATTN: Lib Documents Div

University of New Mexico
ATTN: Director of Libraries

University of New Orleans Library
ATTN: Govt Documents Div

New Orleans Public Lib
ATTN: Library

New York Public Library
ATTN: Librarian

New York State Library
ATTN: Doc Control, Cultural Ed Ctr

New York State Univ at Stony Brook
ATTN: Main Lib Doc Sect

New York State Univ Col at Cortland
ATTN: Librarian

State Univ of New York
ATTN: Library Documents Sec

State Univ of New York
ATTN: Librarian

New York State University
ATTN: Documents Center

Stony Brook University of New York
ATTN: Documents Dept

New York University Library
ATTN: Documents Dept

Newark Free Library
ATTN: Librarian

Newark Public Library
ATTN: Librarian

Niagara Falls Pub Lib
ATTN: Librarian

Nicholls State Univ Library
ATTN: Doc Div

Nicolet M. Flores Memorial Lib
ATTN: Librarian

Norfolk Public Library
ATTN: R. Parker

North Carolina Agri & Tech State Univ
ATTN: Librarian

Univ of North Carolina at Charlotte
ATTN: Atkins Library Documents Dept

Univ of North Carolina at Greensboro, Library
ATTN: Librarian

OTHER (Continued)

North Carolina Central University
ATTN: Librarian

North Carolina State University
ATTN: Librarian

North Carolina University at Wilmington
ATTN: Librarian

University of North Carolina
ATTN: BA SS Division Documents

North Dakota State University Lib
ATTN: Govt Librarian

University of North Dakota
ATTN: Librarian

North Georgia College
ATTN: Librarian

North Texas State University Library
ATTN: Librarian

Northeast Missouri State University
ATTN: Librarian

Northeastern Illinois University
ATTN: Library

Northeastern Oklahoma State Univ
ATTN: Librarian

Northeastern University
ATTN: Dodge Library

Northern Arizona University Lib
ATTN: Government Documents Dept

Northern Illinois University
ATTN: Librarian

Northern Iowa University
ATTN: Library

Northern Michigan Univ
ATTN: Documents

Northern Montana College Library
ATTN: Librarian

Northwestern Michigan College
ATTN: Librarian

Northwestern State Univ
ATTN: Librarian

Northwestern State Univ Library
ATTN: Librarian

Northwestern University Library
ATTN: Govt Publications Dept

Norwalk Public Library
ATTN: Librarian

OTHER (Continued)

University of Notre Dame
ATTN: Document Center

Oakland Comm College
ATTN: Librarian

Oakland Public Library
ATTN: Librarian

Oberlin College Library
ATTN: Librarian

Ocean County College
ATTN: Librarian

Ohio State Library
ATTN: Librarian

Ohio State University
ATTN: Libraries Documents Division

Ohio University Library
ATTN: Govt Dept

Oklahoma City University Library
ATTN: Librarian

Oklahoma City University Library
ATTN: Librarian

Oklahoma Dept of Libraries
ATTN: U.S. Govt Documents

University of Oklahoma
ATTN: Documents Div

Old Dominion University
ATTN: Doc Dept Univ Library

Olivet College Library
ATTN: Librarian

Omaha Public Clark Branch
ATTN: Librarian

Oregon State Library
ATTN: Librarian

University of Oregon
ATTN: Documents Section

Ouachita Baptist University
ATTN: Librarian

Pan American University Library
ATTN: Librarian

Passaic Public Library
ATTN: Librarian

Paul Clapper Library
ATTN: Documents Dept

Pennsylvania State Library
ATTN: Government Publications Section

DTHEA (Continued)

Pennsylvania State University
ATTN: Library Document Sec

University of Pennsylvania
ATTN: Director of Libraries

Penrose Library
University of Denver
ATTN: Penrose Library

Peoria Public Library
ATTN: Business, Science & Tech Dept

Free Library of Philadelphia
ATTN: Govt Publications Dept

Phillipsburg Free Public Library
ATTN: Library

Phoenix Public Library
ATTN: Librarian

University of Pittsburg
ATTN: Documents Office G-8

Plainfield Public Library
ATTN: Librarian

Popular Creek Public Lib District
ATTN: Librarian

Association of Portland Lib
ATTN: Librarian

Portland Public Library
ATTN: Librarian

Portland State University Library
ATTN: Librarian

Prescott Memorial Lib
Louisiana Tech Univ
ATTN: Librarian

Princeton University Library
ATTN: Documents Division

Providence College
ATTN: Physics Dept

Providence Public Library
ATTN: Librarian

Cincinnati & Hamilton County Public Library
ATTN: Librarian

Public Library of Nashville and Davidson County
ATTN: Library

University of Puerto Rico
ATTN: Doc & Maps Room

Purdue University Library
ATTN: Librarian

DTHEP (Continued)

Quinebaug Valley Community Col
ATTN: Librarian

Ralph Brown Draughon Lib
Auburn University
ATTN: Microforms & Documents Dept

Rapid City Public Library
ATTN: Librarian

Reading Public Library
ATTN: Librarian

Reed College Library
ATTN: Librarian

Reese Library
Augusta College
ATTN: Librarian

University of Rhode Island Library
ATTN: Govt Publications Office

University of Rhode Island
ATTN: Director of Libraries

Rice University
ATTN: Director of Libraries

Richard W. Norton Mem Lib
Louisiana College
ATTN: Librarian

Richland County Pub Lib
ATTN: Librarian

University of Richmond
ATTN: Library

Riverside Public Library
ATTN: Librarian

University of Rochester Library
ATTN: Documents Section

Rutgers University, Camden Library
ATTN: Librarian

Rutgers State University
ATTN: Librarian

Rutgers University
ATTN: Government Documents Dept

Rutgers University Law Library
ATTN: Federal Documents Dept

Salem College Library
ATTN: Librarian

Sanford University
ATTN: Librarian

San Antonio Public Library
ATTN: Bus Science & Tech Dept

OTHER (Continued)

San Diego County Library
ATTN: G. Jones, Acquisitions

San Diego Public Library
ATTN: Librarian

San Diego State University Library
ATTN: Govt Pubs Dept

San Francisco Public Library
ATTN: Govt Documents Dept

San Francisco State College
ATTN: Govt Pub Collection

San Jose State College Library
ATTN: Documents Dept

San Luis Obispo City County Library
ATTN: Librarian

Savannah Pub & Effingham Libry Reg Lib
ATTN: Librarian

Scottsbluff Public Library
ATTN: Librarian

Scranton Public Library
ATTN: Librarian

Seattle Public Library
ATTN: Ref Doc Asst

Selby Public Library
ATTN: Librarian

Shawnee Library System
ATTN: Librarian

Shreve Memorial Library
ATTN: Librarian

Silas Bronson Public Library
ATTN: Librarian

Samuel Schwab Mem Lib
Columbus College
ATTN: Librarian

Sioux City Public Library
ATTN: Librarian

Skidmore College
ATTN: Librarian

Slippery Rock State College Library
ATTN: Librarian

South Carolina State Library
ATTN: Librarian

University of South Carolina
ATTN: Librarian

OTHER (Continued)

University of South Carolina
ATTN: Government Documents

South Dakota Sch of Mines & Tech
ATTN: Librarian

South Dakota State Library
ATTN: Federal Documents Department

University of South Dakota
ATTN: Documents Librarian

South Florida University Library
ATTN: Librarian

Southdale-Hennepin Area Library
ATTN: Government Documents

Southeast Missouri State University
ATTN: Librarian

Southeastern Massachusetts University Library
ATTN: Documents Sec

University of Southern Alabama
ATTN: Librarian

Southern California University Library
ATTN: Documents Dept

Southern Connecticut State College
ATTN: Library

Southern Illinois University
ATTN: Librarian

Southern Illinois University
ATTN: Documents Ctr

Southern Methodist University
ATTN: Librarian

University of Southern Mississippi
ATTN: Library

Southern Oregon College
ATTN: Library

Southern University in New Orleans, Library
ATTN: Librarian

Southern Utah State College Library
ATTN: Documents Department

Southwest Missouri State College
ATTN: Library

Southwestern University of Louisiana, Libraries
ATTN: Librarian

Southwestern University School of Law Library
ATTN: Librarian

OTHER (Continued)

Spokane Public Library
ATTN: Reference Dept

Springfield City Library
ATTN: Documents Section

St. Bonaventure University
ATTN: Librarian

St. Joseph Public Library
ATTN: Librarian

St. Lawrence University
ATTN: Librarian

St. Louis Public Library
ATTN: Librarian

St. Paul Public Library
ATTN: Librarian

Stanford University Library
ATTN: Govt Documents Dept

State Historical Soc Lib
ATTN: Docs Serials Section

State Library of Massachusetts
ATTN: Librarian

State University of New York
ATTN: Librarian

Stetson Univ
ATTN: Librarian

University of Steubenville
ATTN: Librarian

Stockton & San Joaquin Public Lib
ATTN: Librarian

Stockton State College Library
ATTN: Librarian

Superior Public Library
ATTN: Librarian

Swarthmore College Lib
ATTN: Reference Dept

Syracuse University Library
ATTN: Documents Div

Tacoma Public Library
ATTN: Librarian

Tampa, Hillsborough County Public Lib
ATTN: Librarian

Temple University
ATTN: Librarian

Tennessee Technological University
ATTN: Librarian

OTHER (Continued)

University of Tennessee
ATTN: Dir of Libraries

Terteling Library
College of Idaho
ATTN: Librarian

Texas A & M University Library
ATTN: Librarian

University of Texas at Arlington
ATTN: Library Documents

University of Texas at San Antonio
ATTN: Library

Texas Christian University
ATTN: Librarian

Texas State Library
ATTN: U.S. Documents Sect

Texas Tech University Library
ATTN: Govt Docs Dept

Texas University at Austin
ATTN: Documents Coll

Texas University at El Paso
ATTN: Documents and Maps Lib

University of Toledo Library
ATTN: Librarian

Toledo Public Library
ATTN: Social Science Dept

Torrance Civic Center Library
ATTN: Librarian

Traverse City Public Library
ATTN: Librarian

Trenton Free Public Library
ATTN: Librarian

Trinity College Library
ATTN: Librarian

Trinity University Library
ATTN: Documents Collection

Tufts University Library
ATTN: Documents Dept

Tulane University
ATTN: Documents Dept

University of Tulsa
ATTN: Librarian

UCLA Research Library
ATTN: Public Affairs Svc/US Docs

OTHER (Continued)

Uniformed Svcs Univ of the Hlth Sci
ATTN: LRC Library

University Libraries
ATTN: Dir of Libraries

Upper Iowa College
ATTN: Documents Collection

Utah State University
ATTN: Librarian

University of Utah
ATTN: Special Collections

University of Utah
ATTN: Dept of Pharmacology
ATTN: Director of Libraries

Valencia Library
ATTN: Librarian

Vanderbilt University Library
ATTN: Govt Docs Sect

University of Vermont
ATTN: Director of Libraries

Virginia Commonwealth University
ATTN: Librarian

Virginia Military Institute
ATTN: Librarian

Virginia Polytechnic Inst Lib
ATTN: Docs Dept

Virginia State Library
ATTN: Serials Section

University of Virginia
ATTN: Public Documents

Volusia County Public Libraries
ATTN: Librarian

Washington State Library
ATTN: Documents Section

Washington State University
ATTN: Lib Documents Section

Washington University Libraries
ATTN: Dir of Libraries

University of Washington
ATTN: Documents Div

Wayne State University Library
ATTN: Librarian

Wayne State University Law Library
ATTN: Documents Dept

Weber State College Library
ATTN: Librarian

Wagner College
ATTN: Librarian

OTHER (Continued)

Wesleyan University
ATTN: Documents Librarian

West Chester State Coll
ATTN: Documents Dept

West Covina Library
ATTN: Librarian

University of West Florida
ATTN: Librarian

West Hills Community Coll
ATTN: Library

West Texas State University
ATTN: Library

West Virginia Coll of Grad Studies Lib
ATTN: Librarian

University of West Virginia
ATTN: Dir of Libraries

Westerly Public Library
ATTN: Librarian

Western Carolina University
ATTN: Librarian

Western Illinois University Lib
ATTN: Librarian

Western Washington Univ
ATTN: Librarian

Western Wyoming Community College Lib
ATTN: Librarian

Westmoreland City Comm Coll
ATTN: Learning Resource Ctr

Whitman College
ATTN: Librarian

Wichita State Univ Library
ATTN: Librarian

William & Mary College
ATTN: Docs Dept

William Allen White Library
Emporia Kansas State College
ATTN: Govt Documents Div

William College Library
ATTN: Librarian

Williamsburg Public Library
ATTN: Librarian

Winthrop College
ATTN: Documents Dept

University of Wisconsin at Whitewater
ATTN: Government Documents Library

OTHER (Continued)

Wisconsin Milwaukee University
ATTN: Librarian

Wisconsin Oshkosh University
ATTN: Librarian

Wisconsin Platteville University
ATTN: Librarian

Wisconsin University at Stevens Point
ATTN: Docs Section

University of Wisconsin
ATTN: Govt Pubs Dept

University of Wisconsin
ATTN: Acquisitions Dept

Worcester Public Library
ATTN: Librarian

OTHER (Continued)

Yale University
ATTN: Director of Libraries

Yeshiva University
ATTN: Librarian

Yuma City County Library
ATTN: Librarian

Wright State Univ Library
ATTN: Govts Documents Dept

Wyoming State Library
ATTN: Librarian

University of Wyoming
ATTN: Documents Div