TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

RECORD OF ISSUE/REVISIONS

ISSUE AUTHORIZATION DATE	EFFECTIVE DATE	REV. NO.	DESCRIPTION
Draft	10/17/2003	00-A	Technical Basis Document for the Nevada Test Site – Site Description. Initiated by Eugene Rollins.
Draft	12/18/2003	00-B	Incorporates comments from internal and NIOSH review. Initiated by Eugene Rollins.
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02/02/2004	02/02/2004	00	First approved issue with the restriction which states, “Nevada Test Site incidents are to be included in future revisions of the Nevada Test Site Technical Basis Documents”. Initiated by Eugene Rollins.

ACRONYMS AND ABBREVIATIONS

AEC	Atomic Energy Commission
Am	americium
BEEF	Big Explosives Experimental Facility
BREN	Bare Reactor Experiment Nevada
Ci	curie
CP	Control Point
Cs	cesium
DAF	Device Assembly Facility
DNA	Defense Nuclear Agency
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DTRA	Defense Threat Reduction Agency
DWSA	Defense Special Weapons Agency
EIS	environmental impact statement
E-MAD	Engine Maintenance Assembly and Disassembly
EPA	U.S. Environmental Protection Agency
ERDA	Energy Research and Development Administration
ft	foot; feet
g	gram
GMX	Gadgets, Mechanics, and Explosives (former division of Los Alamos National Laboratory)
Ha	hectare
HE	high explosive
HLOS	horizontal line of sight
I	iodine
in	inch
JASPER	Joint Actinide Shock Physics Experimental Research
km	kilometer
Kr	krypton
kt	kiloton
lb	pound
LOS	line of sight
m	meter
MAD	Maintenance, Assembly, and Disassembly
µCi	microcurie
MDC	Minimum Detectable Concentration
mi	mile
mL	milliliter

NAFR	Nellis Air Force Range
NEAF	Nuclear Explosive Assembly Facility
NNSA	National Nuclear Security Administration
NRDS	Nuclear Rocket Development Station
NSO	Nevada Site Office
NTS	Nevada Test Site
NUWAX	Nuclear Weapons Accident Exercise
ORAU	Oak Ridge Associated Universities
Pu	plutonium
RCRA	Resource Conservation and Recovery Act
RER	Radiological Emergency Response
RMAD	Reactor Machine Assembly and Disassembly
RWMS	Radioactive Waste Management Site
SNM	Special Nuclear Material
Sr	strontium
TBD	technical basis document
TED	track etch dosimeter
TLD	thermoluminescent dosimeter
TNT	trinitrotoluene
WEF	Waste Examination Facility
WIPP	Waste Isolation Pilot Plant
Xe	xenon

2.1 INTRODUCTION

The Nevada Test Site (NTS) in southern Nevada has served as the Nation's primary continental test site for the development of nuclear explosives. The NTS currently encompasses approximately 3,500 km^2 (1,375 square miles); it is surrounded on the east, west, and north by the Nellis Air Force Range (NAFR) complex, which provides a 24- to 100-km (15- to 64-mile) buffer zone between the NTS border and public lands. The U.S. Bureau of Land Management administers Federal lands on the southern and southwestern borders of the NTS. Las Vegas, the major metropolitan center closest to the NTS, is approximately 105 km (65 miles) southeast of the site. Residential locations within 48 km (30 miles) of the NTS boundary are Indian Springs (1990 population of 1,164) in Clark County and Pahrump (1990 population of 7,424) and Beatty (1990 population of 1,623) in Nye County. Other surrounding cities with sparse population within 48 km of the NTS are Rachel, Scotty's Junction, Rhyolite, Amargosa Valley, Johnnie, and Cactus Springs, Nevada; and, Furnace Creek Ranch and Death Valley Junction, California.

This part of the Nevada Test Site technical basis document (TBD) describes the site in relation to possible sources of radioactive contamination deriving from site activities (Section 2.2) and site processes (Section 2.3).

2.2 SITE ACTIVITIES AND FACILITIES

The U.S. Department of Energy (DOE), National Nuclear Security Administration, Nevada Site Office (NNSA/NSO) owns the NTS, which is divided into the following seven zone categories, as described in DOE (1996a):

1. Nuclear Test Zone. Land area reserved for underground hydrodynamic tests, dynamic experiments, and underground nuclear weapons and weapons effects tests. The stockpile stewardship emplacement hole inventory is in this zone. Part of the mission of the Stockpile Stewardship Program is to reserve land and infrastructure for next-generation nuclear weapons simulators pending programmatic decisions.

2. Nuclear and High Explosive Test Zone. Area designated for additional underground and above-ground high-explosive tests or experiments.

3. Research, Test, and Experiment Zone. Area designated for small-scale research, development projects, pilot projects, and outdoor tests and experiments for the development, quality assurance, or reliability of materials and equipment under controlled conditions.

4. Radioactive Waste Management Zone. Area designated for the shallow land burial of low-level and mixed wastes.

5. Critical Assembly Zone. Area used for conducting nuclear explosive operations, which generally include assembly, disassembly or modification, staging, repair, retrofit, and surveillance. This zone could also be used for weapons storage.

6. Spill Test Facility Impact Zone. A downwind geographic area that would confine impacts of the largest planned tests of materials released at the Spill Test Facility.

7. Reserved Zone. Controlled-access area that provides a buffer between non-defense-related research, development, and testing activities. The Reserved Zone includes areas and facilities that provide widespread flexible support for diverse short-term non-defense-related

research, testing, and experimentation. In addition, this zone is used for short-duration exercises and training, such as Nuclear Emergency Support Team and Federal Radiological Monitoring and Assessment Center training, both part of DOE, and U.S. Department of Defense (DOD) land navigation exercises and training.

Each numbered area on the NTS is associated with one or more of these zones. Figure 2-1 shows the numbered areas, principal facilities, and testing areas. The following sections describe these areas and indicate where activities occurred that produced radioactive effluents on the NTS. Note that there is no Area 21 or 24. *Nevada Test Site Contaminated Land Areas Report* (DOE 2000a) provides information regarding past contamination, the cause of the contamination, and current practices used to control the contaminated areas such as the use of postings and fences.

DOE was created in 1977. The past activities described in this document were, for the most part, under the authority of DOE or its predecessor agencies, the Atomic Energy Commission (AEC) and the Energy Research Development Administration (ERDA). In addition, DOD and the Defense Nuclear Agency (DNA) supported nuclear weapons testing on the NTS. DNA, whose lineage derives from the Manhattan Project, evolved from the Armed Forces Special Weapons Project in 1947 to the Defense Atomic Support Agency in 1959 to DNA in 1971. In 1996, DNA became the Defense Special Weapons Agency.

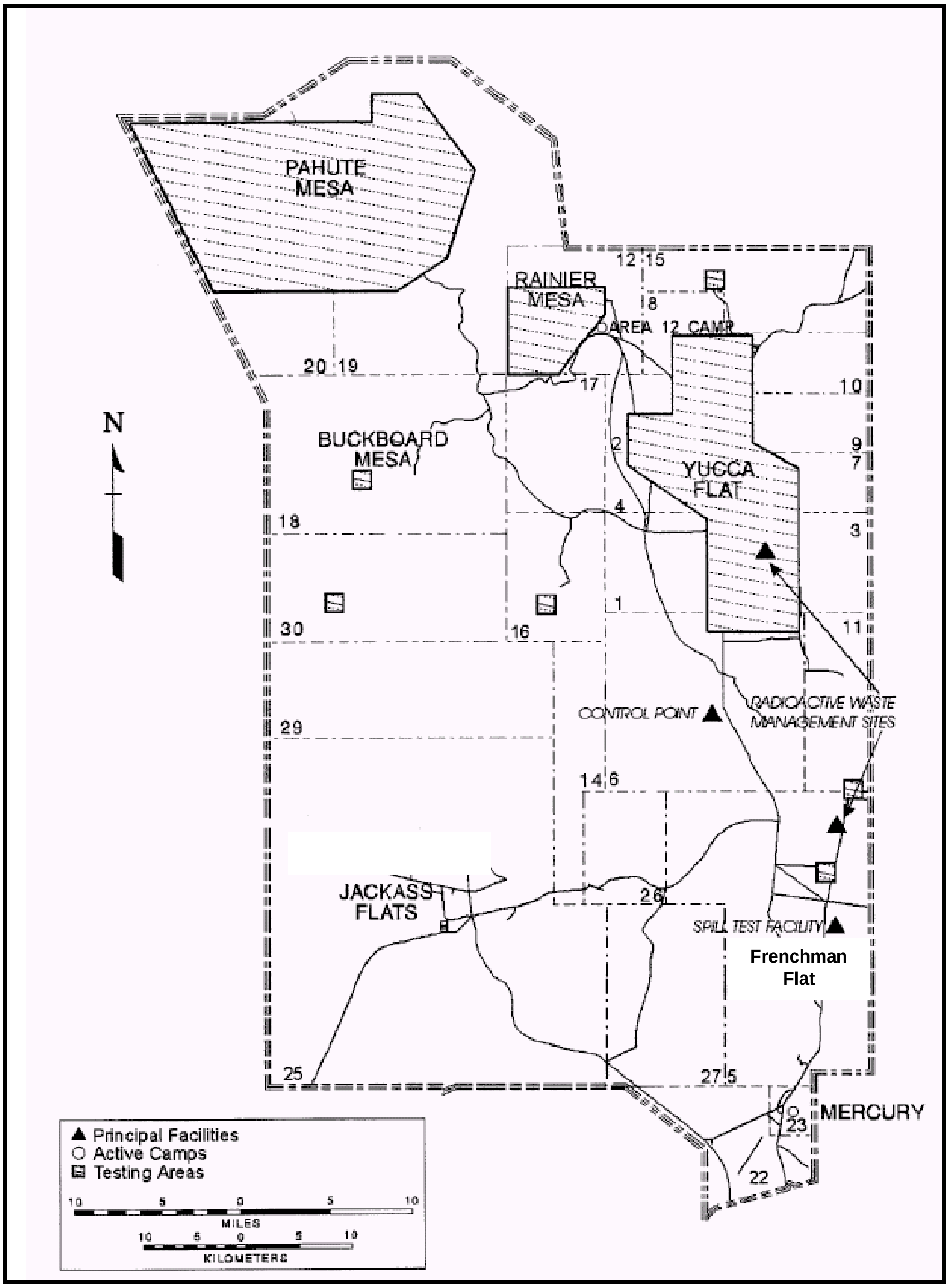
2.2.1 Area 1 Nuclear Test Zone

Area 1 was the site of five atmospheric nuclear tests between 1952 and 1955, and of three underground nuclear tests, one in 1971 and two in 1990 (DOE 2000b). In 1955, as part of the Nation's Civil Defense Program, various types of homes and buildings were constructed to test the effects of a nuclear blast and blast overpressures on typical urban structures. A few of these "Survival Town" structures still stand. Area 1 is the location of two four-story reinforced concrete structures built for structural response investigations. These structures have allowed study of structural response characteristics that are applicable to high-rise buildings.

In addition, Area 1 contains the "U1a" mined underground complex, at a depth of 305 meters (1,000 feet), which is available for dynamic experiments (including subcritical experiments involving special nuclear material) and high explosives tests that cannot be conducted atmospherically because they might disperse hazardous materials. The experiments are integrated systems tests of mockup nuclear packages calling for explosion of the conventional high explosive (HE) portion and measurement of the resulting motions and reactions of materials and components. These tests will obtain diagnostic information on the behavior of a nuclear weapons primary assembly using actual stockpile material and will evaluate the effects of aging on nuclear weapons in the Nation's arsenal. (See Section 2.2.4 for more on large-scale hydrodynamic tests.)

2.2.2 Area 2 Nuclear Test Zone

This area in the Nuclear Test Zone occupies approximately 52 km^2 (20 square miles) in the northern half of the Yucca Flat basin. The eastern portion of Area 2 was the site of seven atmospheric nuclear tests between 1952 and 1957. A series of underground nuclear tests in Area 2 began in late 1962 and continued through 1990. A number of the 137 underground tests were simultaneous detonations of multiple devices in the same emplacement hole; other underground tests involved the firing of two or more devices in separate emplacement holes.



Source: DOE 1997a

Figure 2-1. NTS areas, principal facilities, and testing area.

NTS has moved most of the structures in a former construction base camp (Butler buildings, Quonset huts, trailers, etc.) to Area 6. Remaining facilities are being moved to other locations or scrapped.

2.2.3 Area 3 Nuclear Test Zone and Radioactive Waste Management Site

This portion of the Nuclear Test Zone occupies 83 km^2 (32 square miles) near the center of the Yucca Flat weapons test basin. It was the site of 14 atmospheric tests between 1952 and 1958. A total of 252 underground nuclear tests occurred in Area 3 from 1958 through 1992 (DOE 2000b). This was the largest number of tests in any NTS underground test area. A number of these tests consisted of simultaneous device detonations, and nearly all of the simultaneous tests consisted of single devices in separate emplacement holes. Between mid-1957 and late 1958, nine underground nuclear tests in Area 3 occurred in unstemmed holes to minimize, but not eliminate, releases of radioactivity to the atmosphere. Area 3 contains numerous posted areas.

Numerous circular subsidence craters are scattered throughout Area 3. Such craters are formed by the collapse of deep underground spherical cavities formed by nuclear explosions. The earth collapses as the gases inside the shot cavity cool and outward pressures decline. The collapse progresses upward from the cavity to the ground surface, which results in the formation of a subsidence crater. The Bilby test, detonated in the fall of 1963, was a test of approximately 249 kilotons. It was one of the largest detonations ever conducted in the Yucca Flat basin, and it was the first underground test to be felt by a large number of Las Vegas residents. Bilby, which was fired 732 meters (2,400 feet) underground in volcanic rock, resulted in one of the largest subsidence craters at the test site, measuring 1,800 feet (549 meters) in diameter and 24 meters (80 feet) deep. This crater is on a public tour route. The crater bottom contains a capped borehole.

NTS disposes of bulk low-level waste in seven Area 3 subsidence craters that, collectively, comprise the Area 3 Radioactive Waste Management Site (RWMS). This activity began in the mid-1960s when the removal of scrap tower steel, vehicles, and other large objects that had been subjected to atmospheric testing began. From 1979 to 1990, large amounts of contaminated soil and other debris from the NTS were added to the craters.

There are four stockpile stewardship emplacement holes in Area 3.

2.2.4 Area 4 Nuclear Test Zone

This area in the Nuclear Test Zone occupies 41 km^2 (16 square miles) near the center of the Yucca Flat basin. Area 4 was the site of five atmospheric nuclear tests between 1952 and 1957. From the mid-1970s through 1991, there were 35 underground nuclear tests in Area 4, mainly in the northeast corner. Two of these tests involved the simultaneous detonation of multiple devices in the same emplacement hole.

The Big Explosives Experimental Facility (BEEF) in Area 4 has been designed as an operational complex for testing large conventional non-nuclear high-explosive charges weighing as much as several thousand or more kilograms. In essence, BEEF consists of several earth-covered, steel-reinforced, concrete structures. NNSA/NSO has assumed that, during the next decade, it would conduct about 100 tests at this facility, using larger high-explosive (HE) charges.

There are four stockpile stewardship emplacement holes in Area 4.

2.2.5 Area 5 Radioactive Waste Management Site and Spill Test Zones

This area, which is in the Reserved Zone, occupies about 246 km^2 (95 square miles) in the southeastern portion of the site. It includes the Area 5 Radioactive Waste Management Site, the Hazardous Waste Storage Unit, the Spill Test Facility, the TRU Pad Cover Building, and the Waste Examination Facility (WEF). The WEF houses a large multilevel glovebox used to examine legacy and national laboratory waste, separate and segregated Resource Conservation and Recovery Act (RCRA) material and repack transuranic (TRU) waste for shipment to the Waste Isolation Pilot Plant (WIPP). The original and repacked contains are stored in the TRU Pad cover building. Operations in WEF have the potential for internal exposure if a breach in the glovebox barrier occurs.

From 1951 through early 1962, there were 14 atmospheric tests at Frenchman Flat, several of which were weapons effects tests. Among the remains of the structures tested in Frenchman Flat are simulated motel complexes, metal frames that supported a variety of roofing materials, a window test structure, cylindrical liquid storage vessels, reinforced concrete domes and aluminum domes, bridge pedestals, and a bank vault, all of which are of considerable historic interest. In addition, between 1965 and 1968 there were five underground nuclear weapons tests at Frenchman Flat.

Twenty-four experiments occurred between 1954 and 1956 in the Gadgets, Mechanics, and Explosives (GMX) project site in Area 5, in which small quantities of plutonium materials were subjected to HE detonations. The purpose of these early GMX experiments was to determine if a nuclear chain reaction could occur after the accidental triggering of conventional HE materials in an assembled weapon. Five underground nuclear weapons tests occurred at Frenchman Flat between 1965 and 1971. However, the presence of a carbonate aquifer makes this area less suitable for underground testing than other locations on the Test Site.

A simulated test corresponding to the accidental explosion of HE material in an underground bunker, commonly known as a Gravel Gertie, occurred in Area 5 in the 1950s and again in late 1982. This structure satisfied tests for containment of the explosion and associated radioactive material. Similar designs have been used at the Device Assembly Facility (DAF – see Section 2.2.6) and at the Pantex Plant, near Amarillo, Texas. Pantex is where DOE has historically fulfilled its responsibilities for the assembly and disassembly of the Nation's nuclear weapons stockpile.

Area 5 is the permanent home for the Hazardous Material Spill Center.. By Congressional mandate, use of the Spill Center is available to private and public sector test sponsors (i.e., chemical processors and oil companies) on a user-fee basis. The Spill Center (the only facility of its kind in the world) was completed in April 1986 as a place to conduct safety research associated with the handling, shipping, and storage of liquefied gaseous fuels and other hazardous fluids. The facility comprises a complex of fuel tanks, spill pads, meteorological and camera towers, assorted equipment arrays, control buildings, and a large-scale wind tunnel.

One of the primary DOE Nevada NNSA/NSO missions has been to provide an ongoing waste management program that covers all wastes generated on the NTS as well as wastes from other defense-related facilities. Opened in 1961, the Area 5 RWMS is a 296-hectare (732-acre), low-level radioactive waste storage and disposal facility. The developed area at the RWMS consists of 22 landfill cells (pits and trenches) and 13 greater confinement disposal boreholes. DOE has disposed of mixed waste, including transuranic mixed waste, at the Test Site in the past, and transuranic wastes are currently stored in Area 5 pending their ultimate disposal at WIPP near Carlsbad, New Mexico.

The Hazardous Waste Storage Site in Area 5 is a RCRA State-approved, NTS-wide accumulation point for the collection of nonradioactive hazardous materials such as paint residues, miscellaneous chemicals, unused or surplus fuels, etc. Periodically, hazardous wastes generated at the Test Site are sent to licensed offsite commercial facilities for recycling, incineration, or disposal.

2.2.6 Area 6 Nuclear Test Zone

This area occupies a 212-km^2 (82-square-mile) parcel of land between Yucca Flat and Frenchman Flat, straddling Frenchman Mountain. Between 1968 and mid-1990, four underground nuclear tests occurred at this location, one of which involved the simultaneous detonation of multiple devices in separate emplacement holes, one in Area 6 and the other in Area 3.

The Control Point (CP) complex serves all NTS user organizations as a centralized point of coordination for administrative, scientific and technical matters. The CP also serves as the NNSA/NSO command center, air operations center, and timing and firing center. Support facilities include a communications building, several radiological sciences and technical laboratories. Also in this area is the Los Alamos National Laboratory (LANL) "Mouse House," which houses the LANL radiation control facilities in support of U1a activities.

The Area 6 Construction Facilities provide craft and logistical support to activities in the forward areas of the NTS. This complex replaces older construction base camps in Areas 2 and 3. The elements comprising the Yucca Lake facilities include a variety of equipment storage facilities, a heavy-duty maintenance and equipment repair facility, and decontamination facilities. Laundry facilities were also operated here. The decontamination facility was where large pieces of equipment contaminated during nuclear testing were decontaminated. Contaminated liquid waste from decontamination operations discharged through floor drains to large tanks. The yard below these facilities may be contaminated. Contaminated radioactive waste was also stored in a tent structure adjacent to the decontamination building. A 3,353-m (11,000-ft) airstrip and nearby weather station are on the dry Yucca Lake bed.

The DAF is approximately 3 miles (4.8 km) south of the CP complex and will serve as a modern, safe, and secure facility for assembling and disassembling nuclear test devices and nuclear weapons. The DAF, with five Gravel Gerties and thick bay walls and ceilings, contains about 9,300 m^2 (100,000 ft^2) of interior floor space in a fenced compound of approximately 8.9 hectares (22 acres). It replaces and consolidates facilities elsewhere on the Test Site. The DAF has been designed to limit explosive overpressures and to contain radioactive materials in the event of an accident. Construction began in 1988 and ended in 1990, when equipment installation and related interior work began. The DAF is an operational facility, which includes glovebox and downdraft table equipment to support receipt of material from JASPER. Lawrence Livermore National Laboratory (LLNL) and LANL jointly operate the DAF.

The Hydrocarbon Contaminated Soils Disposal Site is a State-of-Nevada-approved Class III landfill used for the disposal of all non-RCRA-regulated hydrocarbon-contaminated soils and materials generated on the NTS.

There are two stockpile stewardship emplacement holes in Area 6.

2.2.7 Area 7 Nuclear Test Zone

This area in the Nuclear Test Zone occupies 52 km^2 (20 square miles) in the northeast quadrant of the Yucca Flat weapons test basin. Thirty atmospheric tests occurred in this area. From late 1964 through the fall of 1991, 62 underground nuclear tests occurred in Area 7, all consisting of a single nuclear device in a drilled emplacement hole.

There are three stockpile stewardship emplacement holes in Area 7.

2.2.8 Area 8 Nuclear Test Zone

This area in the Nuclear Test Zone occupies 34 km^2 (13 square miles) in the northeast quadrant of the Yucca Flat weapons test basin. Area 8 was the site of four atmospheric nuclear tests in 1958. From mid-1966 through late 1988, 10 underground nuclear tests occurred at this location. Two of the underground tests involved the simultaneous firing of multiple devices in the same emplacement hole.

French- and German-type underground shelter structures were tested in Area 8 in 1957. In 1964, the University of Florida used these shelters for shelter habitability studies. The Baneberry test, which vented to the atmosphere, occurred here in 1970. Section 2.3.5 provides a description of the Baneberry test and other tests that resulted in radioactive releases to the environment.

The area is geographically complex due to the combination of tests, wide-spread debris, steep slopes, and wastes. This has promoted erosion and widespread contamination migration.

2.2.9 Area 9 Nuclear Test Zone

This area in the Nuclear Test Zone occupies 52 km^2 (20 square miles) in the northeast quadrant of the Yucca Flat weapons test basin. Fifteen atmospheric tests occurred in this area between 1951 and 1958. Area 9 was used extensively for underground nuclear testing; 100 such tests occurred from late 1961 to mid-1992. Of the dozen underground tests involving the simultaneous detonation of multiple devices, most involved the use of separate emplacement holes (two or more holes, each with a single device).

The Area 9 sanitary landfill is in a subsidence crater formed as the result of a subsurface nuclear detonation in the early 1960s. In October 1995, the landfill underwent partial closure as a Class II landfill and reopened as a Class III construction and demolition debris landfill.

There is one stockpile stewardship emplacement hole in Area 9.

2.2.10 Area 10 Nuclear Test Zone

This area in the Nuclear Test Zone occupies 54 km^2 (21 square miles) in the northeast quadrant of the Yucca Flat weapons test basin. Area 10 was the location for the Nation's first nuclear missile system test, an air-to-air rocket detonated in mid-1957. This was the only nuclear rocket test ever conducted at the NTS. Two of the earliest shallow nuclear cratering experiments at the NTS were detonated in 1951 and 1955 at this location. Resuming with the deeply buried SEDAN cratering experiment in mid-1962 and extending through early 1991, a number of underground nuclear tests occurred in Area 10. Counting both the cratering and contained underground tests, there were 57 nuclear tests. No atmospheric tests were conducted in Area 10. A number of the underground tests were simultaneous detonations of multiple devices in the same emplacement hole, while others involved the firing of multiple devices, but with each device in a separate emplacement hole.

Area 10 is the site of SEDAN Crater, which was formed by a thermonuclear device detonated in July 1962. It left a large throw-out crater with a diameter of 390 m (1,280 ft) and a depth of 98 m (320 ft). SEDAN was the first in a series of 23 PLOWSHARE tests conducted at the NTS to develop peaceful uses of nuclear explosives. The SCOOTER Crater, also in Area 10, is the result of a 500-ton conventional high-explosive experiment in 1960. The area includes underground bunkers and mud pits.

2.2.11 Area 11 Nuclear Test and Reserved Zone

This area, which is divided between the Nuclear Test and Reserved Zones, occupies 67 km^2 (26 square miles) along the eastern border of the NTS. Four atmospheric plutonium-dispersal safety tests occurred in the northern portion of Area 11 in 1954 and 1956 in what is now known as Plutonium Valley. One of these safety tests went partially critical, creating some fission products that contribute to the surface contamination. An enriched uranium safety shot cross-contaminated with plutonium took place in Area 11a. Experiments 11b, c, and d were ground-zero detonations. A small underground waste dump is inside the contaminated area boundary. Large metal debris has resulted in a Radiation Area near 11c. Because of the radioactive residue that remains, DOE used Area 11 for realistic training drills in radiological monitoring and sampling operations. Training was discontinued by the current contractor because of concern for plutonium intakes. Although no full-scale atmospheric tests occurred in Area 11, five underground nuclear weapons tests occurred at this location between the spring of 1966 and early 1971. A 1950-vintage experimental jet was located in Plutonium Valley and was later used by the Accident Response Group for training. Contamination was spread throughout the interior. This aircraft was recently removed for decontamination and transported to an Air Force base.

A number of technical facilities that remain in Area 11 are essentially no longer in use; NNSA/NSO is maintaining some of these in varying states of readiness in case there is a future requirement or need for such facilities. An explosive ordnance disposal facility in the southern portion of Area 11 functions as a RCRA-permitted treatment unit. This site consists of a detonation pit surrounded by an earthen pad, approximately 8 m (25 ft) by 31 m (100 ft) and support equipment including a bunker, electrical shot box, and electrical wiring.

2.2.12 Area 12 Nuclear or High Explosive Test Zone

This area, which is in the Nuclear or High Explosive Test Zone, occupies 104 km^2 (40 square miles) at the northern boundary of the NTS, known as Rainier Mesa. No atmospheric nuclear tests have occurred at this location; however, Area 12 was the site of the AEC's first fully contained underground nuclear detonation, the Rainier test, on September 19, 1957, in a horizontal tunnel about 487 m (1,600 ft) into the mesa and 274 m (900 ft) beneath the top of the mesa. In the past several decades, a number of tunnels have been mined into Rainier Mesa, in which most of the DOD horizontal line-of-sight exposure experiments have occurred. The N-, P-, and T-tunnel complexes, in particular, were developed extensively during the 1970s and 1980s. The tunnel experiments usually involve complex construction of large-diameter (up to 9 m [27 ft]), line-of-sight pipes and special closure mechanisms, blast and gas seal doors, stemming plugs, and the like. The G-tunnel complex was established for nuclear testing purposes but, since 1971, has been used only as an underground research facility. Of the 61 underground nuclear tests performed in Area 12 between late 1957 and the fall of 1992, two were detonated in vertical stemmed holes, and the 59 others were detonated in mined tunnels. Several tests in tunnels resulted in containment failures and the release of radioactive material (see Section 2.3.5). Several of the tunnels are contaminated

In addition to its use for nuclear testing purposes, N-tunnel was the location of a Nonproliferation Experiment involving 1,300,000 kg (2,900,000 lb) of conventional explosives, detonated on September 22, 1993. Observers from the United Nations' Geneva Conference on Disarmament were present. The acquired information and data are being used to develop verification requirements to support both Nonproliferation-Treaty-related activities and the Comprehensive Test Ban Treaty.

DOD operates a high-explosives research and development tunnel in Area 12. This reusable test bed supports programs involving the detonation of conventional or prototype high explosives and munitions. The inactive and mothballed Area 12 base camp was used in the past to support operations in the northern reaches of the Test Site. In addition to housing and feeding facilities, other support structures include a major maintenance building, craft and repair shops, a first aid facility, and a supply depot.

2.2.13 Area 13 Nellis Air Force Range Complex

Officially, there is no Area 13 within the NTS boundary; however, there is a land plot on the NAFR Complex, known as NAFR Complex Area 13, which is off the northeast corner of the NTS. This was the location for a plutonium-dispersal safety experiment in early 1957.

2.2.14 Area 14 Reserved Zone

This Reserved Zone area occupies 67 km^2 (26 square miles) in the south-central portion of the NTS. Because this area is relatively isolated from major NTS operational and support facilities, no atmospheric or underground nuclear tests have occurred in Area 14.

2.2.15 Area 15 Reserved Zone

This Reserved Zone area occupies 96 km^2 (37 square miles) at the northeast corner of the NTS. No atmospheric tests occurred at this location; however, between early 1962 and mid-1966, three underground nuclear tests occurred.

There are two major complexes in Area 15, the HARDHAT/PILEDRIVER site and the U.S. Environmental Protection Agency (EPA) Farm Complex, both of which are closed. The purpose of the HARDHAT/PILEDRIVER tests was to investigate the simulated effects of a nuclear surface detonation on a deeply buried, superhard command and control center in a granite rock formation.

From 1978 to 1983, the Spent Fuel Test Complex was in a separately mined drift at the HARDHAT/PILEDRIVER site. The purpose of this study was to learn more about how granite would react to heat and radiation from spent nuclear fuel. In the test, spent fuel was sealed in protective canisters and lowered underground. An underground emplacement vehicle put the canisters in lined test holes. All equipment used to handle the canisters was operated by remote control. The canisters were stored in the Climax granite stock for 3 years, then removed and repackaged at the Engine Maintenance Assembly and Disassembly (E-MAD) facility in Area 25 prior to shipment to the Idaho National Engineering and Environmental Laboratory.

As part of the DOE long-range safety program, the U. S. Public Health Service, later the EPA, developed and operated an experimental 30-acre dairy farm in Area 15 between 1965 and 1981. Researchers studied the passage of airborne radionuclides through the soil-forage-cow's milk food chain. In addition, cows were fed plutonium-loaded capsules to study the metabolism of the material. The facilities included irrigated cropland, an irrigation reservoir, and typical structures for a Grade A dairy farm. These facilities were also used for autopsy studies of animals that grazed on the NTS.

2.2.16 Area 16 Nuclear or High Explosive Test Zone

This area, which is in the Nuclear or High Explosive Test Zone, occupies 73 km^2 (28 square miles) in the west-central portion of the NTS. No atmospheric tests have occurred at this location. Area 16 was established in 1961 for exclusive DOD use in support of a nuclear effects experiment that required a tunnel location in an isolated area away from other active weapons test areas. From mid-1962 through mid-1971, six underground nuclear weapons effects tests occurred (all in the same tunnel complex) at this location. Several tests breached the tunnel containment systems. Radioactive materials include TRU and fission products. At present, DOD uses this area for high-explosives research and development in support of programs involving the detonation of conventional or prototype explosives and munitions.

2.2.17 Area 17 Reserved Zone

This area, which is in the Reserved Zone, occupies 80 km^2 (31 square miles) in the north-central portion of the NTS. It has been primarily a buffer between other testing activities. No atmospheric tests or experimental activities of programmatic consequence have occurred in Area 17.

2.2.18 Area 18 Reserved Zone

This area, which is in the Reserved Zone, occupies 231 km^2 (89 square miles) in the northwest quadrant of the NTS. The inactive Pahute airstrip is in the east-central portion of the area.

Area 18 was the site of four nuclear weapons effects tests in early to mid-1962. Two of these tests were atmospheric (slightly aboveground) and the other two were cratering experiments. SULKY, a PLOWSHARE test, in late 1964 was the first nuclear cratering test conducted by the United States after ratification of the Limited Test Ban Treaty. DANNY BOY and JOHNNIE BOY resulted in Trinity glass debris. LITTLE FELLER I and II resulted in TRU and fission product soil contamination and were also very low-yield effects tests. The SULKY device was placed fairly deep for its yield and, as a consequence, did not produce a crater, although it did produce a mound of broken rock. In addition, in 1964 this area was used for Project DUGOUT, a PLOWSHARE-sponsored test utilizing chemical high explosives to investigate the potential use of nuclear explosives for ditch digging in dense hard rock. The resulting crater was 87 m (285 ft) long, 41 m (135 ft) wide, and 11 m (35 ft) deep.

The Pahute Control Point, now abandoned, is in the northeast corner of the area; it was used until 1971 as the diagnostic and microwave communications monitoring center for nuclear test events on Buckboard and Pahute Mesas (Areas 18, 19, and 20). The deactivated Pahute Air Strip, in the east-central portion of Area 18, was used primarily for shipments of supplies and equipment related to Pahute Mesa high-yield underground nuclear test operations.

2.2.19 Area 19 Nuclear Test Zone

This area in the Nuclear Test Zone occupies 388 km^2 (150 square miles) of the Pahute Mesa in the northwest corner of the NTS. Area 19 was developed for high-yield underground nuclear tests, and no atmospheric nuclear tests occurred there. The geology of Pahute Mesa makes it possible to test devices at much greater depths than in Yucca Flat (down to more than 1,370 m [4,500 ft]). The greater depth and isolation allowed much higher yield tests with minimal levels of ground motion felt in Las Vegas, more than 160 km (100 miles) away. From the mid-1960s through 1992, 36 underground nuclear tests occurred. This area contains underground radioactive material areas because of tests and post-shot drilling pads. Soil activity is from fission products.

There are five stockpile stewardship emplacement holes in Area 19.

2.2.20 Area 20 Nuclear Test Zone

This area in the Nuclear Test Zone occupies 259 km^2 (100 square miles) in the extreme northwest corner of the NTS. Area 20, like Area 19, was developed in the mid-1960s as a suitable location for high-yield underground nuclear tests; there were no atmospheric nuclear tests there. A total of 49 tests occurred. Three underground nuclear tests in the megaton and greater yield range occurred on Pahute Mesa between 1966 and 1976. These tests were the well-publicized BOXCAR, BENHAM, and HANDLEY tests. From the mid-1960s through 1992, 46 contained underground nuclear tests occurred in Area 20. All of these tests consisted of the detonation of single nuclear devices in drilled emplacement holes. Area 20 boundaries were expanded after SCHOONER to incorporate an extensive fission product plume and throw-out debris.

One nuclear test detection experiment and three PLOWSHARE tests occurred on Pahute Mesa. The PLOWSHARE tests included the nuclear cratering experiments PALANQUIN, CABRIOLET, and SCHOONER. PALANQUIN, detonated in the spring of 1965, was the first nuclear test on Pahute Mesa. The PALANQUIN AND CABRIOLET tests were low-yield tests. TRU and fission products are present, as is Trinity glass.

There are two stockpile stewardship emplacement holes in Area 20.

2.2.21 Area 21

There is no Area 21 on the NTS.

2.2.22 Area 22 Reserved Zone

Area 22, in the southeastern corner, serves as the main entrance to the NTS, with vehicular access from Las Vegas by U. S. Highway 95. The area between Highway 95 and the Mercury town site was annexed to the NTS in 1964. Area 22 was home for Camp Desert Rock during the early days of atmospheric testing. The camp opened in September 1951 as a Sixth Army installation for housing troops taking part in military exercises at NTS; at that time, it was primarily a trailer and tent camp around a nucleus of semipermanent structures and an airstrip. During the 1955 test series, the camp housed approximately 9,000 men from the military services, some of whom saw a single shot and departed for their home duty stations, while others stayed through the entire test series. Camp Desert Rock was not used by the military services after 1958, and many of the structures were moved to other parts of the NTS. Essentially all of the remaining facilities except the airstrip were dismantled and destroyed as scrap or salvaged.

The AEC resurfaced and enlarged the Desert Rock airstrip in 1969, extending the runway to a length of 2,155 m (7,500 ft). Although this airstrip primarily serves the NTS, it is an emergency landing site for all pilots. At present, the airport is technically not open and provides no services, although it is available for pilots if necessary

2.2.23 Area 23 Reserved Zone

This area, which is in the Reserved Zone, occupies 13 km^2 (5 square miles) in the southeastern portion of the NTS and is the location of the Site's largest operational support complex. Mercury, which was established in 1951, is the main administrative and industrial support center. Permanent structures and services include housing and cafeteria services, laboratory, maintenance, communication and support facilities, computer facilities, warehouses, storage yards, motor pools, and administrative offices. Mercury also houses the health physics, medical and fire departments and NNSA. Mercury is approximately 8 km (5 miles) from U.S. Highway 95.

The Area 23 Sanitary Landfill serving all NTS organizations is a Class II landfill just west of Mercury. The landfill is an open, rectangular pit with steep, nearly vertical sides. Because of its Class II designation, the landfill is open to receive all types of nonhazardous solid waste. The current capacity of the landfill is approximately 4,500,000 m^3 (6,000,000 cubic yards). A RCRA-compliant closed Hazardous Waste site is next to the landfill. NNSA/NSO conducts periodic monitoring in accordance with State regulations at this location.

2.2.24 Area 24

There is no Area 24 on the NTS.

2.2.25 Area 25 Yucca Mountain Project, Reserved, and Research and Experiment Zones

Area 25, the largest area on the NTS, occupies about 578 km^2 (223 square miles) in the southwestern corner of the Site and includes an entrance gate to the Site. Area 25 has its own direct U. S. Highway 95 access approximately 3 km (2 miles) north of the Town of Lathrop Wells. Other than several small and isolated hills of volcanic rock in the west-central portion of Area 25, the interior valley floor encompasses what is commonly known as Jackass Flats. Roughly in the center of Area 25, Jackass Flats was selected for a series of ground tests of reactors, rocket engines, and stages as part of a program to develop nuclear reactors for use in the Nation's space program.

In the early 1960s, the AEC and the National Aeronautics and Space Administration negotiated an interagency agreement to establish and manage a test area at the NTS called the Nuclear Rocket Development Station (NRDS). The NRDS facilities, inactive since 1973 and added to the NTS in 1974, are in various stages of disrepair. They consist of three widely separated reactor test cells or stands, two Maintenance, Assembly, and Disassembly (MAD) facility buildings, a Control Point complex, an Administrative Area complex, and a radioactive materials storage area. A standard-gauge railroad system connects the test stands and the MAD buildings. The railroad transported nuclear reactors and engine systems back and forth from the rocket and engine assembly buildings to the test cells and engine test stand. The NRDS operated two shallow-land burial radioactive waste disposal units and an equipment decontamination facility was operated near the MAD facility.

During the late 1970s and early 1980s, the E-MAD building was used for high-level radioactive materials handling studies. It contained the world's largest hot cells, which were used to disassemble, examine, and package nuclear reactors. These hot cells are highly contaminated. Thirteen "hot" spent fuel assemblies were brought to E-MAD and encapsulated in stainless-steel canisters with welded lid closures. Eleven of the canisters were transported to Area 15 in support of the underground "Spent Fuel-Climax" project. The other two canisters were used in above-ground, concrete-shielded, storage studies, and shallow, dry-well, storage studies. When the studies were completed in 1983, the canisters were removed from their temporary storage holes and returned to E-MAD. E-MAD Test Cell A and Test Cell C have not been remediated. In 1986, all 13 of the spent fuel assemblies were repackaged and shipped to the Idaho National Engineering and Environmental Laboratory. Due to the destruction of two nuclear reactors and transport of radioactive material, the area is extensively contaminated with enriched uranium, niobium, cobalt, and cesium. Several highly radioactive burial areas, such as Reactor Machine Assembly and Disassembly (RMAD) Trolley Dump and leach fields also exist. Due to the nature of historic operations and subsequent clean-ups, the potential for significant internal and external radiation exposure exist.

The former NRDS Administrative Area complex in Area 25, along with much of the land area to the north and west of Lathrop Wells Road, has been rededicated as a Yucca Mountain support site. Scientists are studying Yucca Mountain, which is just off the western boundary of Area 25 and 160 km (100 miles) northwest of Las Vegas, to determine if it is suitable for safely storing 70,000 metric tons (77,000 tons) of spent nuclear fuel and high-level radioactive waste for 10,000 years. About 90 percent of the waste would be from commercial nuclear power reactors and the rest would be wastes from defense nuclear reactors.

The 465-meter (1,530-foot) BREN Tower in Area 25 received its name from a 1962 experiment known as the Bare Reactor Experiment in Nevada. It was used to determine approximate exposures experienced by survivors of the Hiroshima and Nagasaki bombings. An unshielded reactor on an outside elevator was raised and lowered to determine changes in dose by distance and shielding measurements on target Japanese-type housing.

The BREN Tower is a versatile facility used intermittently by a number of organizations to conduct sonic boom research, meteorological studies, and free fall/gravity drop tests. Recently, the tower was used in support of the BRILLIANT PEBBLES program, and in studies to develop technology and measurement techniques for advanced infrared imaging from space satellites. BRILLIANT PEBBLES was a relatively small, computer-operated, rocket-powered, laser-equipped missile designed to detect, track, and intercept ballistic missiles.

The Rock Valley Study Area, south of Jackass Flats Road on the southern boundary of Area 25, was selected in 1960 for studies of radiation on a desert ecosystem. Three study plots were fenced in the early 1960s, and in 1964 a ^{137}Cs shielded source was installed on a 50-foot tower in the center of one of the plots. The cesium source was removed in the fall of 1982. The other two areas were used as control areas. Many research projects have been conducted at the Rock Valley facility in the past three decades by a number of government-sponsored scientists, as well as students and others conducting environmental research.

The DOD used portions of Area 25 during the 1980s in conjunction with MX (Peacekeeper) missile siting studies and canister ejection certification tests; all of these facilities have been removed. At present, Area 25 is used by the U.S. Army's Ballistic Research Laboratory for depleted uranium ballistics testing. Two types of tests, open-air tests and X-tunnel tests, which include hazard classification and system tests, are conducted.

DOE established a so-called Treatability Test Facility in Area 25 several years ago for bench-scale testing of physical processes for decontamination of plutonium- and uranium-contaminated soils. At present, Area 25 is under consideration as a site for a utility-scale research and demonstration solar project planned for the NTS. As noted in the Final NTS environmental impact statement (EIS; DOE 1996a), depending on the technology or technologies being pursued for application at the Test Site, the solar project could affect an area as large as 971 hectares (2,400 acres).

The military uses portions of the Area 25 Reserved Zone for land navigation and training exercises.

2.2.26 Area 26 Reserved Zone

This area, which is in the Reserved Zone, occupies 57 km^2 (22 square miles) in the south-central portion of the NTS. The area contains the Horn Silver Mine and a leach field from Building 2201. Radionuclides in the soil are a mixture of fission products and uranium. No nuclear explosive tests occurred at this location. However, the southern portions of the area were used for nuclear-powered ramjet engine tests; the facilities associated with Project Pluto are still there. Although the tests were successful, this program was terminated. The residual test facilities include a control point, test bunker, compressor house and air storage facilities, and a disassembly building. In recent years, these facilities were used as mock reactor facilities to provide Radiological Emergency Response (RER) training for civilian and Federal emergency teams. Joint Nuclear Weapons Accident Exercises (NUWAX) were conducted in this and other NTS areas. The NUWAX Spreader was used to disperse radionuclides onto the soil for training exercises.

2.2.27 Area 27 Critical Assembly Zone

This area, which is in the Critical Assembly Zone, occupies 130 km^2 (50 square miles) in the south-central portion of the NTS. Area 27 principal facilities include five assembly bays, four storage magazines, two combination assembly bay/storage magazines, and three radiography buildings. The critical assembly facilities are an alternative to the Device Assembly Facility. In addition, the operational Joint Actinide Shock Physics Experimental Research (JASPER) Facility is in Area 27..Area 27 is controlled by LLNL.

Area 27 was used in the past for the Super Kukla Reactor Facility. As in Area 26, no nuclear explosive tests occurred in this area.

2.2.28 Area 28

Area 28 is no longer in existence. The Area 28 designation applied to a portion of the NTS that has been absorbed into Areas 25 and 27.

2.2.29 Area 29 Reserved Zone

This area, which is in the Reserved Zone, occupies 161 km^2 (62 square miles) on the west-central border of the NTS. A communications repeater station for the NTS is in the Shoshone Mountains.

Area 29 is composed of rugged terrain that includes Mid-Valley, Fortymile Canyon, and Shoshone Mountain. Because of its mountainous terrain and relative inaccessibility, limited use has been made of this area. Historically, Area 29 has served as a buffer zone between activities in Area 25 and weapons testing activities elsewhere on the NTS.

2.2.30 Area 30 Reserved Zone

This area in the Reserved Zone occupies 150 km^2 (58 square miles) on the western edge of the NTS. Area 30 has fairly rugged terrain and includes the northern reaches of Fortymile Canyon. In the past, Area 30 had limited use in support of nuclear testing programs. In the spring of 1968, it was the site of Project BUGGY, the first nuclear row-charge experiment in the PLOWSHARE Program. BUGGY was designed to develop nuclear excavation technology for digging canals or mountain passes. Five small devices were spaced 46 m (150 ft) apart at a depth of 41 m (135 ft) and detonated simultaneously in early 1968. The result was a trench 255 m (835 ft) long, 77 m (254 ft) wide, and 206 m (675 ft) deep. The BOSSY test resulted in large quantities of vitrified glass. This site is relatively inaccessible.

2.2.31 Other Areas and Facilities

The Industrial Sites Project includes areas on the NTS and the Tonopah Test Range that supported testing operations. More than 1,500 historic structures or industrial sites have been identified, verified, and inventoried for characterization, closure, or restoration. Of these, nearly 750 sites have been formally closed. The remaining sites have been grouped according to source of contamination, location, and other technical characteristics.

The deactivation and decommissioning process is included in the Industrial Sites Project. This process supports the cleanup of the six remaining surplus facilities transferred from the NNSA/NSO Defense Programs to the DOE Office of Environmental Restoration. These include the Pluto Facility;

Super Kukla Facility; RMAD Facility, E-MAD Facility; Test Cell A; and Test Cell C (DOE 2002b). Other than RMAD, no cleanup has occurred or is currently planned at these other facilities.

The Nellis Air Force Range complex includes the Nellis Air Force Range and the Tonopah Test Range. The more-than-12,000-km^2 (4,700-square-mile) Nellis Air Force Range buffers the NTS on its north, east, and west boundaries. The Tonopah Test Range, which covers about 1600 km^2 (620 square miles), is inside the NAFR boundaries. According to DOE (1994), one atmospheric nuclear test (Small Boy in 1962) and five experiments (in which nuclear devices were subjected to conventional explosives to determine if the devices could attain criticality under accident conditions) occurred on the NAFR complex. The nuclear explosive energies for the five experiments were reported as zero, although plutonium was dispersed into the air and onto the ground in each test.

In addition to these six events, nuclear tests occurred on the NTS in which atmospheric plumes caused contamination to spread beyond the Site boundary. The plume of SCHOONER in 1968 appeared prominently on the 1994 aerial radiation survey (EG&G 1994).

The Tonopah Test Range is approximately 40 km (25 miles) southeast of Tonopah (1990 population 3,616) in Nye County, Nevada. This site was used for Defense- and Work for Others-related research, design, and testing activities, including the three CLEAN SLATE tests. The two other tests were DOUBLE TRACKS, about 23 km (14 miles) east of Goldfield, Nevada, just outside the southwest corner of the Tonopah Test Range, and Project 57 No. 1, which was in a 4-square-mile region referred to as Area 13 in some documents. Cleanup activities at the CLEAN SLATE and DOUBLE TRACK sites were completed in 1998. Several intakes occurred during the work that were thought to be ingestions. Area 13 is just outside the northeast corner of the NTS.

In Area 5 and the NAFR property east of Area 5, HAMILTON, PRISCILLA, and SMALLBOY tests resulted in contaminated land areas. HAMILTON was a plutonium safety experiment. The PRISCILLA site was used for multiple high-altitude atmospheric fission tests. Soil activation was noticed. SMALLBOY was a low-yield weapon-effect test. An extensive ^{241}Am plume was detected northeast of the area.

2.3 SITE OPERATIONS AND PROCESSES

This section briefly describes the operations and historic nuclear weapons tests that could have resulted in occupational radiation exposure to employees on the NTS site.

Timeline. The sources of radionuclides on the NTS include current and past activities. The Site was the primary location for the testing of nuclear explosives in the Continental United States between 1951 and 1992. Historic testing above or at ground surface included (1) atmospheric testing in the 1950s and 1960s, (2) earth-cratering experiments, and (3) open-air nuclear reactor and rocket testing. Since 1961, testing of nuclear explosive devices has occurred mainly in drilled vertical holes or in mined tunnels.

The United States entered a unilateral testing moratorium on October 1, 1958. On September 15, 1961, testing resumed. Before the moratorium, most tests occurred in the atmosphere. Following the resumption of testing, more than 800 nuclear weapon tests occurred in the United States. No such test has occurred since September 23, 1992. *Radiological Effluents Released from U.S. Continental Tests 1961 Through 1992* (DOE 1996) provides information on radiological releases that resulted from each test. Table 2-1 summarizes the types of tests by the testing era. Table 2-2 provides a listing of radionuclides of concern for various NTS operations. Table 2-3 presents a listing of radionuclides typically deposited following atmospheric tests for various time intervals (10 days, 1 year, 20 years, and 50 years). The data presented in the table are calculated gamma radiation exposure rates from fallout and related radionuclides from the Buster-JANGLE test in 1951. The ^{233}U, ^{235}U, ^{238}U, and $^{239, 240}$Pu data were omitted primarily to keep the output unclassified. Furthermore, the natural plutonium in Nevada and Utah soils comes from worldwide fallout (DNA, 1982a)

The following categories summarize NTS operations that might have resulted in radiological releases:

- Atmospheric Weapons Testing
- Safety Tests
- Big Explosives Experimental Facility
- Deep Underground Tests
- Nuclear Reactor Development Tests
- Shallow Borehole Tests
- Crater Disposal
- Shallow Land Burial Low-level Waste
- Greater Confinement Disposal
- U1a Complex
- Containment Ponds
- Laboratories
- Well Logging
- Treatability Test Facility
- Decontamination Facility
- Radiation Instrument Calibration Facilities
- Radioactive Source Storage Areas
- JASPER
- Nuclear Explosives Assembly and Device Assembly Facility

Most of the information in the following sections related to the NTS testing program, site operations, and facilities was compiled from information in the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada,* DOE/EIS-0243 (DOE 1996a), unless otherwise noted.

2.3.1 Atmospheric Weapons Testing

U.S. aboveground nuclear weapons tests began on January 27, 1951, with the detonation of a 1-kiloton (kt) air-dropped weapon over Frenchman Flat. More than 100 atmospheric tests occurred before the signing of the Limited Test Ban Treaty in August 1963. In addition to air drops, atmospheric testing included detonations from towers at heights from 30 to 213 m (100 to 700 ft), detonations on the surface of the ground, and the use of helium-filled balloons 137 to 457 m (450 to 1,500 ft.) above the ground to loft weapons.

Depending on the proximity of the explosion to the ground surface and the size of the yield, surface disturbances from atmospheric testing varied widely. The greatest surface disturbances typically occurred when an air-dropped weapon penetrated the ground surface to a shallow depth (about 15 m [50 ft.]) before detonation. Such a test with a yield of 100 kt would result in a crater about 36 m (120 ft) deep and about 219 m (720 ft) in diameter (DOE 1996a).

Radioactivity from atmospheric tests was dispersed by three primary mechanisms: throwout, base surge, and fallout. Throwout occurred at detonation when the fireball propelled large volumes of rock and soil upward. Base surge was the settling and outward movement of the throwout. Fallout is the portion of material that did not settle, but rose and merged with weapon residues. These materials descended to earth over the next few hours or more as fallout. The extent and distribution of contamination from an atmospheric test was quite variable depending on the height of detonation, the yield and type of device, the nature of the ground surface, the mass of inert material surrounding the device, and weather conditions at the time of, and following, the test. Typical radionuclides formed during atmospheric testing included isotopes of strontium, cesium, barium, tritium, and iodine. Of these, ^{90}Sr and ^{137}Cs are of the most concern because of their longer half-lives of 28 and 29 years, respectively (DOE 1996a)

The vast majority of radioactivity released during atmospheric testing decayed quickly after each test. For example, for a 1-kt atmospheric test, the initial release after 1 minute was about 4.1×10^{10} Ci. This activity was reduced to 1.0×10^{7} Ci just 12 hours after the detonation. If the activity remaining after 12 hours was used as the basis for estimates, about 6.0×10^{10} Ci were released during atmospheric testing between 1951 and 1963 at the NTS (DOE 1996a).

Many of the fission products released during detonations were dispersed into the atmosphere, and much of the residual radioactivity has decayed in the 40 years since the last atmospheric test. Nonetheless, some of the longer-lived radionuclides remain in the soil and physical structures. The primary radionuclides that remain on the NTS from historic atmospheric testing include americium, plutonium, cobalt, cesium, strontium, and europium.

Residual contamination for atmospheric testing is present in Areas 1, 2, 3, 4, 7, 8, 9, and 10 of the NTS and on Buckboard Mesa in Area 18. All areas except Areas 22, 23, and 27 have some monitoring and restrictions as a result of these tests. The routine device for external exposure monitoring in the atmospheric test areas is the whole-body TLD (REECo 1995).

Table 2-4 summarizes the major sources of radioactivity on the NTS.

2.3.2 Safety Tests

Safety tests evaluated the safety of nuclear weapons in accident scenarios. Two series, the GMX PROJECT and PROJECT 56, occurred in NTS Areas 5 and 11, respectively. The GMX PROJECT site was used for 24 specific equation-of-state studies or experiments with fissile materials. PROJECT 56 consisted of four discrete surface safety tests. In addition, PROJECT 57 consisted of a single test (DOUBLE TRACKS) conducted in Area 13 in the northernmost part of the NAFR Complex. Preliminary characterization at the DOUBLE TRACKS test site located several pieces of highly radioactively contaminated metal, which were retrieved and placed in a drum at the site. Between 998 and 1,588 g (2.2 and 3.5 lb) of plutonium were spread during the test. Three safety tests conducted as part of the CLEAN SLATE experiments occurred on the Tonopah Test Range.

The safety tests used mixtures of plutonium and uranium dispersed by conventional explosives. Concurrent with and after these detonations, extensive studies were conducted to understand the dispersal and transport of these radionuclides in the environment, including uptake by plants and animals. These studies were documented in a benchmark series of papers by the Nevada Applied Ecology Group, a panel of scientists chartered to investigate the effects of testing at the NTS. The immediate effects of the tests included the dispersal of plutonium and uranium over wide areas. To determine the area affected by these tests, inventories were conducted and later augmented by extensive field sampling efforts conducted under the Radionuclide Inventory and Distribution Program.

These studies resulted in the definition of affected areas. The GMX PROJECT at Area 5 resulted in the contamination of about 240 acres. The PROJECT 56 tests resulted in the contamination of about 2,200 acres. On the NAFR Complex, two disturbed areas total slightly less than 1,000 acres. On the Tonopah Test Range, almost 670 acres were contaminated.

At both on- and offsite locations, the primary radionuclides are plutonium, uranium, and americium, with lesser amounts of cesium, strontium, and europium. These long-lived radionuclides remain today in the surface soils in the vicinity of the test areas and are available for transport by wind and uptake by plants and animals. Extensive research into the mobility of the radionuclides has found that wind can transport such contaminants and concentrate them in mounds around desert shrubs, and water can cause plutonium to migrate deeper into the soils with time. At present, the radionuclides are relatively immobile unless the soils are disturbed. Evidence of “wind-driven” contamination is low. Heat of initial blast, soil bonding and weathering and rockiness of native soil prevents deep migration (REECo 1995).

Table 2-5 provides an estimate of the $^{239+240}$Pu inventory at the studied sites.

2.3.3 Big Explosives Experimental Facility

The Big Explosives Experimental Facility is in north-central Area 4 of the NTS. The site contains seven underground structures previously associated with atmospheric testing; one set of unidentified stanchions that might have been associated with atmospheric testing; the BREN Tower foundations and stanchions; and the Japanese Village complex. The area also has the U-4ad drill hole and drill sump, the U-4af exclusion zone, and a white silicified volcanic core reduction flake. Most of these structures were abandoned as atmospheric testing ended. Two of the buried structures, Bunkers 4-300 and 4-480, have been modified to accommodate modern hydrodiagnostic equipment to serve as a hydrodynamic test facility for detonations of very large conventional HE charges and devices.

The structural soundness of the modified bunkers for expanded operations and the potential impacts of blast, noise, and dust uplift due to hydrodynamic tests were investigated between March 1995 and August 1995 in the five experiments of the POPOVER test series. The tests consisted of detonations of successively larger amounts of spherical charges of conventional trinitrotoluene (TNT) explosive beginning at 232 kg (512 lb) and ending with 3,538 kg (7,800 lb). The noise, acceleration, strain, overpressure, dust uplift, and area contamination were monitored to validate predictive models of shock, blast, noise, and gas product dispersion and to certify the safety of the manned operation of Bunker 4-300 during hydrodynamic tests. The bunkers met all required safety criteria.

Some detonations at the Big Explosives Experimental Facility involved radioactive materials such as depleted uranium.

2.3.4 Deep Underground Tests

Since 1963, the United States has conducted all of its nuclear weapons tests underground in accordance with the terms of the Limited Test Ban Treaty. Hence, complete containment of all nuclear weapons tests was a dominant consideration in nuclear test operations.

Various methods were used for emplacing nuclear test devices so the ensuing explosion was contained. The most common method was to place a test device at the bottom of a vertically drilled hole. Another method was to place a test device in a tunnel mined horizontally to a location sufficiently deep to provide containment.

The following paragraphs describe processes associated with nuclear weapons tests in vertical drill holes and mined tunnels. The information is from DOE (1996a).

Tests in Vertical Drill Holes. There were two types of tests in vertical drill holes: smaller-yield devices in relatively shallow holes in the Yucca Flat area (Areas 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10) and higher-yield devices in deeper holes on Pahute Mesa (Areas 18, 19, and 20). Tests at the Yucca Flat and Pahute Mesa sites had the same general requirements, but differed in the magnitude of the operations. Deeper-hole operations disturbed a larger area, required more onsite equipment, and had higher requirements for electric power and utilities. The distance from NTS facilities and infrastructure was also a factor to minimize the effects of the tests. Pahute Mesa operations were 48 to 81 km (30 to 50 miles) farther away than Yucca Flat.

The following paragraphs describe a vertical drill-hole test:

1. Site Selection and Drilling. There were two options in site selection as it applied to a specific event – selection of an existing drill hole or selection of a new drill site from the Nuclear Test Zone. The goal of siting was to optimize the various parameters to attain operational feasibility and successful containment of yields.

   A normal hole was from 1 to 3 m (39 to 120 in.) in diameter and from 213 to 762 m (600 to 2,500 ft) deep. During drilling, samples of drill cuttings were collected at 3-m (10-ft.) intervals, and rock cores were taken as required. After drilling was completed, geophysical logs were run into the hole to evaluate its condition and gain a more thorough understanding of the geology. The drill site was secured by filling the sump and installing specially designed covers over the hole.

2. Site Engineering and Construction. An area was cleared and leveled for the surface ground-zero equipment. Another area close by was cleared and leveled for the recording trailer park. Onsite construction was temporary and abandoned after the test. Concrete pads were poured around the surface at ground zero to provide a stable platform for down-hole operations and a base for the assembly towers. Equipment was moved in to place the nuclear device in the hole, record the data produced, and provide radiological and seismic monitoring of the site. A circle of radiation detectors was placed back from the surface at ground zero to detect and assess releases from the experiment. Finally, a perimeter fence was erected, and access was controlled both to and from the site.

3. Device Delivery and Assembly. For safety reasons, the nuclear device was delivered to the NTS unassembled. The device was assembled and inserted in a container in the Area 27 Assembly/Staging Facilities. The device, now encased in the container, was delivered to the event site accompanied by armored convoy. It was attached to the diagnostics canister in preparation for placement in the hole.

4. Diagnostic Assembly. A diagnostic canister was assembled off the site and transported to the test site. A typical canister might be 2 m (8 ft) in diameter and 30 m (120 ft) long and contain all the instrumentation required to receive data at the time of the explosion (real time). On arrival at the site, the diagnostic canister was installed in the assembly tower to be mated with the device.

5. Emplacement of the Experiment. The drill hole was opened and the nuclear explosive and measurement devices were moved to the hole and lowered to the detonation position, along with diagnostic materials and instrumentation cables. The assembly was placed on a set of

fracture-safe beams that spanned the opening. Any auxiliary equipment was lowered into the hole, and the area was secured.

The hole was stemmed to prevent radioactive materials from escaping during or after the experiment. Areas around instrument cables were sealed to prevent a radioactive gas path to the surface.

6. Test Execution. Security operations began 2 days before the test to ensure that all non-event-related personnel were evacuated prior to the test for security and safety. The explosive was armed. Radiation monitors were activated, and aircraft with tracking capability circled the site in case gas and debris unexpectedly vented to the surface. Weather forecasts and fallout pattern predictions were reviewed. When acceptable weather conditions and other criteria were met, the device was detonated.

   When an underground nuclear device was detonated, the energy released almost instantaneously produced extremely high temperature and pressure that vaporized the device and the surrounding rock. Within a fraction of a second after detonation, a generally spherical cavity was formed at the emplacement position. As the hot gases cooled, a lining of molten rock puddled at the cavity bottom.

   After a period of minutes to hours, as the gases in the cavity cooled, the pressure subsided and the weight of the overburden sometimes caused the cavity roof to collapse, producing a vertical, rubble-filled column known as a *rubble chimney*. The rubble chimney commonly extended to the surface, forming a subsidence crater. There are a number of subsidence craters on NTS. These craters generally are bowl-shaped depressions with diameters ranging from about 60 to 600 m (200 to 2,000 ft) and a depth ranging from a few meters to 60 m (200 ft), depending on the depth of burial and the explosive energy yield. Some deeply buried explosions of low yield formed cavities that did not collapse to the surface and, as a consequence, did not create subsidence craters.

   After the test, ground zero remained secure until it was certain that the test had been contained. A reentry crew was dispatched to the site to retrieve data and note the condition of equipment. Reentries had the potential to cause significant external and internal radiation exposures. After all was secure, normal NTS operations resumed. Ground zero was roped off, outlining an exclusion zone if there was danger of potential cratering.

7. Post-Shot Operations (drillback). After the temperature of the cavity had cooled, a post-shot hole was usually drilled to the point of the explosion to retrieve debris samples. The highly radioactive samples provided important information on the test. The post-shot hole was as small in diameter as possible and was drilled at an angle to allow the drill rig to be positioned safely away from the surface at ground zero. After drilling and sampling operations were complete, the drill rig and tools were decontaminated. Residual radiation was cleaned up at the site.

   It was possible to encounter high gas pressures in the cavity because the drillback was often performed within a day or two of the detonation. Engineering devices were used to prevent the escape of radioactive gases and particulates. However, there was the potential for exposure to gaseous and particulate fission and activation products (REECo 1995).

   The pathways for release of radioactivity and personnel exposure were twofold. The first scenario was based on a loss of containment in the drilling or coring operation. This occurred during routine drilling operations, or it could be caused by a failure of containment equipment. The radionuclides of concern for dose for this pathway were the fission products ^{85}Kr, ^{131}I, ^{133}I, ^{133m}Xe, and ^{137}Cs. The second scenario was based on particulate fission or activation products in the core samples being obtained following an underground test (REECo 1995).

Although weapons tests have not been conducted since September 1992, in an effort to maintain readiness skills, drillback operations have been occasionally conducted. Personnel involved in drillback operations typically wear a pocket dosimeter and full personal protection clothing (PPC). Those handling core samples wear extremity monitoring dosimeters (REECo 1995).

Tests in Mined Tunnels. Rainier Mesa in Area 12 was the site of the Nation's first fully contained underground nuclear detonation, called RAINIER, on September 19, 1957, in a horizontal tunnel about 488 m (1,600 ft) into the mesa and 274 m (900 ft) beneath the top of the mesa. Of the 61 underground nuclear tests in Area 12 between late 1957 and 1992, only 2 were in drilled holes; the 59 others were in mined tunnels. By the early 1990s there was only one active tunnel in use.

The tunnel tests evaluated the effects of nuclear weapons explosions, thermal radiation, blast, shock, X-rays, and gamma rays on military hardware, such as communication equipment, rocket nosecones, and satellites. The typical horizontal-line-of sight (HLOS) test was designed to minimize blast and shock effects from the experiments. The large tunnel complex mined under the mesa contained HLOS pipe, which was about 460 to 550 m (1,500 to 1,800 ft) long and tapered from as much as 9 m (30 ft) in diameter at the test chamber to several inches at the working point. Experiments were placed in the pipe test chambers. At zero time, when the nuclear device was detonated, radiation flowed instantaneously down the pipe, creating the necessary radiation environment. To prevent bomb debris and blast from reaching and damaging the experiments, three mechanisms were used to close the pipe; the first was the Fast Acting Closure, which was slammed shut by high explosives in about 1 millisecond; the other two closures followed within 30 and 300 milliseconds.

A number of tunnels have been mined into Rainier Mesa, in which most DOD HLOS exposure experiments occurred. In particular, the N-, P-, and T-Tunnel complexes were extensively developed during the past several decades. N-Tunnel was the location for a nonproliferation experiment, detonated in September 1993, which involved 1.3×10^6 kg (2.9×10^6 lb) of conventional high explosives. DOD currently operates an HE research and development tunnel in Area 12. This reusable test bed supports programs involving the detonation of conventional or prototype explosives and munitions.

<u>**Routine Tunnel Operations.**</u> Routine tunnel operations had a potential for personnel exposure to fission or activation products that remained from tests conducted previously in the tunnel complex. These radioactive materials could be carried by water, or could seep through faults and fissures to reenter the working areas. Experience has shown that the external dose levels in routine tunnel work areas were very low. The principal radionuclides of external dose concern were the fission products ^{90}Sr/^{90}Y and ^{137}Cs (REECo 1995).

<u>**Reentry and Mineback Operations.**</u> Reentry and mineback operations related to tests in mined tunnels usually took place within days or weeks of an underground test. In some instances they were conducted as much as decades after a test. These operations took place in a confined underground environment whereby personnel actually entered the test cavity. There were two exposure scenarios during reentry and minebacks. The first scenario was based on a loss of containment in the drilling or coring operation. This could occur during the routine drilling operations, or be caused by a failure of

containment equipment. The radionuclides of concern for this pathway were ^{54}Mn, ^{90}Sr, ^{90}Y, ^{103}Ru, ^{106}Rh, ^{131}I, ^{133}I, ^{127}Cs, and ^{182}Ta (REECo 1995).

The second exposure scenario was the possibility of fission or activation products entering the working areas of the tunnels by migrating through fissures in the rock; by escaping through LOS pipes when they were opened to remove experiment equipment and samples; or by personnel actually entering the cavity. The radionuclides of concern for dose for this pathway were ^{60}Co, ^{124}Sb, ^{131}I, ^{133}I, and ^{137}Cs. At present, no mineback or reentry operations are likely to be conducted at the NTS unless testing is resumed. If this occurs, personnel would wear a whole-body thermoluminescent dosimeter (TLD), pocket dosimeters, and PPC (REECo 1995).

Radioactive Releases Resulting from Nuclear Weapon Testing. The containment of underground nuclear explosions was a process that continually evolved through learning, experimentation, and experience. The record of containment illustrates the various types of releases and their relative impact. Operational releases were small releases of radioactivity resulting from the operational aspects of vertical drill hole tests. Activities that often resulted in operational releases included drilling back down to the location of the explosion to collect core samples, collecting gas samples from the explosion, and sealing the drill back holes (OTA 1989).

Late-time seeps were small releases that occurred days or weeks after a test when gases diffused through pore spaces of the overlying rock and were drawn to the surface by decreases in atmospheric pressure.

Controlled tunnel purging was an intentional release of radioactive material to recover experimental equipment and ventilate test tunnels. During a controlled tunnel purging, gases from the tunnel were filtered, mixed with air to reduce the concentration, and released over time when weather conditions were favorable for dispersion into sparsely populated areas (OTA 1989).

Successful containment was defined as no radioactivity detectable off the site and no unanticipated release of radioactivity onsite. By definition there has been containment failure on four occasions since 1970 (OTA 1989). Table 2-6 includes every instance (for both announced and unannounced tests) where radioactive material reached the atmosphere under any circumstances whatsoever from 1971 through 1988. The lower part of Table 2-6 summarizes underground tests prior to 1971 and provides a comparison with others releases of radioactive material.

Operational Releases and Tunnel Purging. Past underground tests formed pockets of radioactive contamination around each underground test site. The source term includes many short- and long-lived radionuclides. For example, for atmospheric testing of a 1-kt nuclear weapon, an initial release of 41 billion Ci decays to about 10 million Ci in just 12 hours. The quantity of radioactivity remaining from a 1-kt underground detonation 180 days after detonation is about 45,000 Ci (including 18,570 Ci of tritium). However, there is considerable uncertainty concerning these estimates. For example, the actual tritium activity after 180 days could range from 5,570 to 55,770 Ci (DOE 1996a).

With regard to tunnel tests, purging gases from the tunnel occasionally resulted in releases of radioactivity, and contaminated water drained from the tunnels to containment ponds (DOE 2002a). While the tunnel complex was being secured prior to detonation of the nuclear device, the ventilation line was disconnected at each containment plug and the penetration through the plug was sealed. Thus, it was necessary to reenter the tunnel to reestablish ventilation through the various containment plugs. If radioactive gases were present in a portion of the complex, it became necessary to purge these gases from the tunnel. The major potential for release of radioactive materials to the atmosphere existed during these purging operations. The purging resulted in release of noble gases

(^{85}Kr, ^{85m}Kr, ^{86}Kr, ^{131m}Xe, ^{133}Xe, ^{133m}Xe, and ^{135}Xe) and small quantities of ^{131}I and ^{133}I. A release during this phase of the operation was typically of the order of 100 Ci or less of noble gases, with microcurie or millicurie quantities of radionuclides. Reentry drilling produced dust that was removed from the reentry heading by the tunnel ventilation system. This dust contained fission and activation products produced by neutron activation of the HLOS pipe.. These releases were in the millicurie range (DOE 1995).

Unexpected Releases of Radioactivity. Although over 90 percent of all nuclear weapon tests occurred as predicted, sometimes something unexpected occurred. In some cases, the failure resulted in the loss of experimental equipment or required the controlled ventilation of a tunnel system. In even more rare cases (3%), the failure resulted in the unintentional release of radioactive material to the atmosphere. A look at examples shows situations where an unexpected sequence of events contributed to create an unpredictable situation. The following information was taken from OTA (1989) unless otherwise noted.

1. BLANCA (October 30, 1958, horizontal tunnel test, 22 kilotons, radioactivity detected on the site). Although BLANCA was detonated in a tunnel, it vented through the overburden into the atmosphere. Venting occurred at the edge of Rainer Mesa in Area 12. The ensuing cloud rose 580 feet above the mesa and drifted off in a westerly direction (DNA 1982b).

2. DES MOINES (June 13, 1962, horizontal tunnel test, 2.9 kilotons, radioactivity detected off the site). The test location was NTS U12j.01. Almost immediately after detonation, venting of radioactive effluents occurred at the surface, then from the vent hole, and finally through the portal. The release lasted approximately 5 minutes at a velocity of approximately 65 miles per hour. The cloud direction was northeasterly over Queen City, Nevada (unpopulated). The maximum distance radiation was detected was at Ely, Nevada, 163 miles from the detonation site. The cause of the release was attributed to stemming failure around the device (DSWA 1997).

3. BANEBERRY (December 18, 1970, vertical shaft test, 10 kilotons, radioactivity detected off the site). The test location was NTS U8d. The BANEBERRY test resulted in a prompt massive venting. Radioactive material from BANEBERRY was tracked as far as the Canadian border. The cloud direction was northeasterly and moved over Nevada, Utah, and Wyoming. Another fraction moved toward California. The exact cause of the 1970 BANEBERRY venting is unknown. The original explanation postulated the existence of an undetected water table. It assumed that the high temperatures of the explosion produced steam that vented to the surface. Later analysis, however, discredited this explanation and proposed an alternative scenario based on three geologic features of the BANEBERRY site: water-saturated clay, buried scarp of hard rock, and a nearby fault. It is thought the energy of the explosion was unable to support the containment structure; the hard scarp strongly reflected back the energy of the explosion increasing the force; and the nearby fault provided a pathway that gases could travel along.

4. CAMPHOR (June 29, 1971, horizontal tunnel test, less than 20 kilotons, radioactivity detected only on the site). The test location was NTS U2g.10. The ground shock produced by the CAMPHOR test failed to close the HLOS pipe fully. After about 10 seconds, gases leaked through and eroded the stemming plug. As gases flowed through the stemming plug, pressure increased on the closure door behind the experiment. Gases leaked around the cable passageways and eroded open a hole. Pressure was then placed on the final door, which held but leaked slightly. The releases from the Cable Building lasted for 30 minutes; the releases from the portal lasted 4 days.

5. DIAGONAL LINE (November 24, 1971, vertical shaft test, less than 20 kilotons, radioactivity detected off the site). The test location was NTS U11g . DIAGONAL LINE was conducted in the northern part of Frenchman Flat. It is speculated that carbonate material released CO2 gas that forced radioactive material to leak to the surface. The cloud direction was southwesterly toward Amargosa Desert, Nevada. DIAGONAL LINE was the last test detonated on Frenchman Flat.

6. RIOLA (September 25, 1980, vertical shaft test, less than 20 kilotons, radioactivity detected off the site). The test location was NTS U2eg. RIOLA exploded with only a small fraction of the expected yield. A surface collapse occurred and the failure of a containment plug resulted in the release of radioactive material.

7. AGRINI (March 31, 1984, vertical shaft test, less than 20 kilotons, radioactivity detected only on the site). The test location was NTS U2ev. The AGRINI test formed a deep subsidence crater 60 ft west of the emplacement hole. A small amount of radioactive material was pushed through the chimney by noncondensible gas pressure and was detected on the site.

8. MIDAS MYTH (February 15, 1984, horizontal tunnel test, less than 20 kilotons, no release of radioactive material). All of the radioactive material produced by the MIDAS MYTH test was contained within vessel 1, with no release of radioactivity to either the atmosphere or the tunnel system. Three hours after the test, however, the cavity collapsed and the chimney reached the surface, forming an unanticipated subsidence crater. Equipment trailers were damaged and personnel were injured and one person later died due to physical circumstances. There was no radiation exposure.

9. MISTY RAIN (April 6, 1985, horizontal tunnel test, less than 20 kilotons, no unintentional release of radioactive material). The test location was U12n.17. MISTY RAIN is unusual in that it is the only tunnel test since 1970 that did not have three containment vessels. During the test, an early flow of energy down the HLOS pipe prevented the complete closure of the modified auxiliary doors (MAC). The MAC doors overlapped, but stopped a couple of inches short of full closure. The tunnel and pipe seal (TAPS) door closed only 20% before the deformation from ground shock prevented it from closing. A small amount of radioactive material escaped down the pipe and then seeped into the bypass tunnel. Subsequently, the tunnel was intentionally vented so experimental equipment could be recovered.

10. MIGHTY OAK (April 10, 1986, horizontal tunnel test, less than 20 kilotons, no unintentional release of radioactive material). The test loacation was U12t.08. During the MIGHTY OAK test, the closure system near the working point was over-pressured and failed. The increased pressure and temperature from escaping gases caused both the MAC and the gas seal auxiliary closure to fail. The loss of the stemming plug near the working point left the tunnel an open pathway from the cavity. Temperatures and pressures on the closed TAPS door reached 2,000°F and 1,400 pounds per square inch. After 50 seconds, the center part (approximately 6 feet in diameter) of the TAPS door broke through. With the closures removed, the stemming column squeezed out through the tunnel. Radioactive material leaked from vessel I and vessel II and into vessel III, where it was successfully contained. About $32 million of normally recoverable and reusable equipment was lost. Controlled purging of the tunnel began 12 days after the test and continued intermittently from April 22 to May 19, when weather conditions were favorable. A total of 36,000 Ci were released to the atmosphere during the period.

2.3.5 Nuclear Reactor Development Tests

A number of activities occurred at the Nuclear Rocket Development Station in Area 25. From 1959 through 1973, the area was used for a series of open-air nuclear reactor, nuclear engine, and nuclear furnace tests and for the High Energy Neutron Reactions Experiment. Equipment and facilities remain from some of these activities, and there are some limited areas of contaminated soils. The total estimated inventory of radionuclides remaining in the soils in this area is about 1 Ci (DOE 1996a). The primary soil contaminants are enriched uranium, strontium, cesium, cobalt, and europium. Because of aging and weathering, these materials have become fairly fixed.

The goal of the nuclear rocket engine test program was to develop an operational nuclear-powered rocket for space travel, given that the crew could be adequately protected from radiation produced by the engine. Ramjet exhaust dispersed radioactive material at the core and cladding degraded during operation of the engine. In a somewhat parallel program, the development of a nuclear ramjet engine began in 1957 in Area 26. Because the ramjet was designed as an air-breathing engine, it was visualized as being restricted to relatively low altitudes. The final reactor test was of a nuclear furnace with a replaceable core in a reusable test bed designed to provide an inexpensive approach to testing advanced fuels in full-scale reactor environments. The nuclear furnace was successfully tested in 1972. Reactor-related tests ended in 1973.

Total releases by all rocket and ramjet engine tests amounted to about 834,000 Ci (DOE 1995a). As noted above the radionuclides ^{60}Co, ^{90}Sr/^{90}Y, ^{137}Cs, and ^{152}Eu are primarily of concern for dose in this area. When entering into the rocket test areas, personnel wore whole-body TLDs (REECo 1995).

2.3.6 Shallow Borehole Tests

Shallow borehole tests occurred between 1960 and 1968. Some of these tests were safety related; others were conducted as part of Project PLOWSHARE to determine if nuclear detonations could be used as a method for excavation. The shallow tests resulted in the development of some large ejection craters, most notably the SEDAN crater in the northern end of the Yucca Flat testing area. SEDAN, a 104-kt nuclear device detonated 194 m (635 ft) underground, displaced about 1.2 x 10^7 tons of earth and created a crater 390 m (1,280 ft) in diameter and 98 m (320 ft) deep. The estimated remaining inventory of surface radioactivity at the SEDAN crater is 344 Ci. The total estimate for all releases from shallow borehole tests to the surface soil horizon at the NTS is 2,000 Ci. Radionuclides include isotopes of americium, cesium, cobalt, europium, plutonium, and strontium (DOE 1996a).

2.3.7 Crater Disposal – Area 3 Radioactive Waste Management Site

DOE disposes of bulk low-level waste in seven selected Area 3 subsidence craters that, collectively, comprise the Area 3 Radioactive Waste Management Site. This activity began in the mid-1960s when DOE began removing scrap tower steel, vehicles, and other large objects that had been subjected to atmospheric testing. From 1979 to 1990, large amounts of contaminated soil and other NTS debris were added to the craters (DOE 1996a).

Today, Area 3 is used for the disposal of bulk and packaged low-level waste from on- and offsite DOE-approved generators. Current waste disposal cells at the Area 3 RWMS comprise four subsidence craters (U-3ax, U-3bl, U-3ah, and U-3at), with areas between craters U-3ax and U-3bl and between craters U-3ah and U-3at excavated to make two oval-shaped landfill units. Conventional landfill methods are used to dispose of waste in each cell; each layer of waste is covered with 1 m (3 ft) of fill before additional waste materials are added. The inactive U-3ax/bl disposal cell contains low-level mixed waste. The U-3ah/at cell is used for low-level waste disposal; mixed waste is not accepted. Three additional subsidence craters (U-3bh, U-3bg, and U-3az) have been reserved for use as low-level waste cells. As of 1996, approximately 1,250 Ci had been disposed of in the Area 3 subsidence craters (DOE 1996a).

Because the low-level Area 3 RWMS is in a location where the surrounding surface soil has been contaminated by past nuclear tests, the resuspension of this soil by wind or vehicular activity results in the detection of above-background levels of plutonium in air samples collected inside and outside the perimeter fence (DOE 2002a).

Personnel working inside the Radioactive Waste Management Site wear a whole-body TLD and pocket dosimetry. Extremity monitoring and multiple dosimetry are required for some waste handling work (REECo 1995).

2.3.8 Shallow Land Burial – Area 5 Low-Level Radioactive Waste Management Site

The Area 5 RWMS uses pits and trenches for shallow land burial of standard-packaged low-level waste.

The category of low-level waste includes material that is "classified" because of its physical shape or specific composition. Classification creates a need for the use of separate disposal units that are controlled with additional security measures.

In 1961, the Area 5 RWMS was established for the disposal of low-level waste, low-level mixed waste, and classified low-level waste from both on- and offsite generators. The waste area at the Area 5 site consists of 23 landfill cells (pits and trenches), 13 greater confinement disposal boreholes, as discussed below, and the transuranic waste storage pad (DOE 2002b).

Approximately 500,000 Ci of low-level waste had been disposed of in Area 5 pits and trenches by 1996. High-specific-activity wastes were disposed of in the greater confinement disposal units.

The Area 5 RWMS is a diffuse source of radiological effluents. However, the only emission detected by the various types of samplers surrounding the site in 2001 and attributed to site operations was HTO in atmospheric moisture. Table 2-7 lists the estimated number of curies emitted from the source for 2001 (DOE 2002a).

Personnel working inside the site wear whole-body TLD, a track-etch dosimeter (TED), and a pocket dosimeter. Extremity monitoring is required for some waste-handling work (REECo 1995).

2.3.9 Greater Confinement Disposal – Area 5 Radioactive Waste Management Site

NTS adopted greater confinement burial (21 to 40 m [70 to 120 ft.] deep) for wastes that are not appropriate for near-surface disposal due to their radioactive exposure levels. Material was disposed of from 1984 to 1989. Specifically, these waste types include certain high-specific-activity, low-level waste (for example, fuel rod claddings and sealed sources), transuranic waste, and some classified material. The developed waste area in the Area 5 RWMS includes 13 greater confinement disposal boreholes.

As of 1996, approximately 9.3×10^6 Ci of high-specific-activity waste, primarily tritium, had been disposed of in greater confinement disposal units in Area 5 (DOE 1996a).

2.3.10 U1a Complex

The U1a Complex is a mined underground complex in Area 1 that is available for dynamic experiments (including subcritical experiments involving special nuclear material) and hydrodynamic tests that cannot be conducted above ground because they might contain hazardous materials. Initial work on the U1a Complex began in the late 1960s with the mining of the U1a shaft to a depth of 305 m (1,000 ft.) for a nuclear test, but the shaft was not used. Further work took place in the 1980s and early 1990s to develop a complex that could be used to perform experiments likely to remain subcritical. The complex includes a drilled hole (U1g) and connecting mined tunnels. The LEDOUX nuclear test with a yield of less than 20 kts was conducted in 1990 in a drift in this tunnel complex. The dynamic KISMET experiment, involving high explosives, tritium, depleted uranium, and other materials, was conducted in the Complex in March 1995. Both LEDOUX and KISMET were contained to prevent radiological releases to the rest of the Complex and the surface environment.

Surface facilities are west of the Mercury Highway in Yucca Flat. Site development includes a 3-acre recording trailer park by the U1g hole and a 17-acre pad that contains the construction support buildings at the U1a shaft location. Newer construction includes U1h. Down-hole support equipment includes data gathering, emergency refuge chambers, distribution conduits for air and utilities, and a freight and passenger landing at the hoist.

2.3.11 Containment Ponds

The containment ponds were constructed to catch contaminated runoff from the tunnel complexes. All active containment ponds are fenced and posted with radiological warning signs to prevent human access.

Water contaminated with radionuclides seeped from the tunnels in Area 12 and was collected in the containment ponds, resulting in water evaporation and seepage into the soil. The tunnels have been sealed, but water continues to seep from E Tunnel. The only radiological contaminant that produces a measurable air emission from evaporation of the water is ^{3}H (as HTO). In 2001, an estimated 14 Ci of HTO were discharged to the ponds (DOE 2002a). Table 2-4 lists the 1996 estimate.

2.3.12 Laboratories

Radiological analyses were conducted in laboratories in Building 652 in Mercury and Building CP-95A, Building CP-50, and the Device Assembly Facility in Area 6. Because these facilities process environmental samples, very little radioactivity passes through them. However, there is potential for discharges of some radionuclides to the atmosphere from the hood ventilation system during sample processing, particularly of spiked samples, or from loss of radioactive standards in liquid or gaseous form. In the past, evaporation and spills from samples containing HTO, radioiodines, or noble gases were estimated conservatively by assuming all such materials were released, although they were not. In 2001, only actual emissions were reported; 5.6 Ci of tritium gas were used periodically during the year at Area 6 CP-50 to calibrate analytical equipment (DOE 2002a).

Following the closure of the Analytical Services Laboratory in Building 650, all the standards, check sources, and tracer solutions were stored until proper disposal of all items. Contamination can still be found in the fumehoods. An inventory of standards, check sources, and tracer materials indicates that three of them are volatile and could become a source of air emissions (DOE 2002a):

$^{3}H – 3.0 \times 10^{-4}$ Ci
$^{85}Kr – 8.7 \times 10^{-2}$ Ci
$^{129}I – 5.4 \times 10^{-7}$ Ci

Table 2-4 lists the 1996 estimate.

The Los Alamos National Laboratory (Building 701 at Mercury) maintained standards of radioactivity containing ^{133}Xe, ^{131}I, and ^{3}H. Due to the test moratorium that began in 1992, the need for standards was reduced (DOE 2002a).

Radiograph Operations. Sealed radioactive sources are used for radiography at the NTS. The potential for external exposure is most likely to occur when the source is removed from the shield for radiography. The radionuclide currently used for radiography at the NTS is ^{192}Ir, although ^{60}Co can be used. Radiographers are required to wear a whole-body TLD, a pocket dosimeter, and an electronic alarming dosimeter (REECo 1995).

Radiochemistry and Counting Laboratories. Sealed and uncontained radioactive sources are used for radiochemistry and sample counting operations at the NTS. These low-level radioactive sources used as tracers and for instrument calibration present very little external dose potential. Laboratory personnel wear whole-body monitoring TLDs (REECO 1995).

2.3.13 Contaminated Surface Soils

Surface soils in certain areas on and off the NTS were contaminated with plutonium, americium, and/or tritium from nuclear device safety, atmospheric, or cratering tests. Vehicular activity is forbidden in these areas. There is no evidence of significant wind dispersal after initial deposition. Rain and surface sheeting have caused migration in some areas. These areas could become sources of exposures to americium and plutonium if the contaminated soils were to be resuspended during windy conditions, surface cleanup, construction, vehicular travel, or similar activities.

Areas 1-12 and 15-20 on the NTS, Area 13 on NAFR, and the CLEAN SLATE sites on the NAFR at the Tonopah Test Range contain diffuse sources of radionuclide effluents. Due to occasional high winds, some contaminated soil becomes airborne. Results from air samples in these areas indicate the routine detection of ^{241}Am and $^{239+240}Pu$, but only in concentrations slightly above the Minimum Detectable Concentration (MDC). The other predominant isotopes found in NTS soil samples are ^{137}Cs and ^{238}Pu.

An investigation of contaminated surface soils during the Nevada Applied Ecology Group studies, and updated by the Desert Research Institute in 1991, developed the inventories of americium and plutonium listed in Table 2-8. These areas could become sources of exposure to americium and plutonium if the contaminated soils were resuspended.`

2.3.14 Well Logging Operations

Sealed radioactive sources are a potential source of external exposure during well logging operations at the NTS. Well logging is used to characterize drill holes and water movement. The radionuclides 60Co, 131I, 137Cs, 226Ra, 228Th, 241Am, and 252F are used for well logging, and are of concern for dose. Well loggers routinely wear a whole-body TLD and pocket dosimetry when working with sources and may wear extremity dosimeters. They also wear a TED when working with neutron sources (REECo 1995).

2.3.15 Treatability Test Facility

The Treatability Test Facility is a pilot project to bench-test technologies to be used for decontamination of soils containing transuranic materials. Techniques used to separate the radionuclides from the soil include both gravimetric separation and separation based on other properties of the material. The concentrations of radionuclides in the soil are unlikely to exceed a few picocuries per gram of soil. Thus, external exposure to personnel is not likely to represent any unusual exposure control requirements (REECo 1995).

2.3.16 Decontamination Facility

Equipment, materials, PPC, and devices used in nuclear weapons testing operations can become contaminated with radioactive material. These items are decontaminated on location or are transported to the decontamination facility in Area 6 where the contamination is removed from the material or equipment. The decontamination methods include washing with high-pressure water, submersion in chemical dip tanks, and use of other nonhazardous material solvents. Many different radionuclides might be present at the decontamination facility because items for decontamination can come from support of any of the operations at the NTS. However, decontamination of material is normally delayed until decay of short-lived radionuclides occurs (REECo 1995).

2.3.17 Radiation Instrument Calibration Facilities

Sealed radioactive sources are used to calibrate instruments needed to detect radioactive materials. The sources are controlled and leak-tested as required by the DOE Radiological Control Manual. The potential for external exposure comes from the use of the sources during calibration and testing operations. In general, the sources are remotely operated, and personnel are removed from the calibration range during source exposure periods. The radionuclides 60Co, 90Sr, 90Y, 137Cs, 226Ra, 227,228Th, 241Am, and PuBe (neutron) could contribute to the external dose at these facilities. The routine method of monitoring the external radiation exposure at the instrument calibration facilities is with the whole-body TLD and pocket dosimeter. Neutron monitoring TEDs are required for personnel using neutron sources (REECo 1995).

2.3.18 Radioactive Source Storage Areas

Sealed radioactive sources, in addition to the radiography, well logging, and instrument calibration sources are stored in a few specified building at the NTS. These sources belong to other organizations, and are stored at the NTS for future use. Because only a few are currently in use, the potential for external exposure is of very short duration during source inventory (REECo 1995).

2.3.19 Joint Actinide Shock Physics Experimental Research Facility

The construction and startup phase for the hydrogen gas gun in Building 5100 in Area 27 ended in June 2000. Equation-of-state experiments with the two-stage light gas gun use special nuclear materials and other actinide materials as target material (DOE 2002a).

2.3.20 Nuclear Explosive Assembly and Device Assembly Facility

The Nuclear Explosive Assembly Facility (NEAF) was built for the assembly of nuclear weapon components. The DAF was completed in 1992 and was being built for future assembly or disassembly of nuclear weapon components. The potential external exposure at these facilities is high because significant quantities of radionuclides of concern for external exposure could be present.

The NEAF is in operation and personnel are required to wear whole-body monitoring TLDs, TEDs, and extremity dosimeters where appropriate. When DAF becomes operational, personnel will be required to wear whole-body monitoring TLDs, TEDs, and extremity dosimeters as appropriate for the specific work being performed (REECo 1995).

Table 2-1. Nuclear weapon test timeline.

Testing era	Number of tests	Type of tests
Post-World War II to 1951[a]	5	Atmospheric
1951-1958 Atmospheric Testing Period	97	Atmospheric
	2	Cratering (near-surface)
	20	Underground
1958-1961 Voluntary Moratorium		
1961-1992 Underground Testing Period	6[b]	Surface
	1	Tower (atmospheric)
	7[c]	Cratering (near-surface)
	799[d]	Underground (vertical shafts or tunnels)

Source: DOE (2000a).
1963 Limited Test Ban Treaty on Atmospheric Testing
1992 U.S. Cessation of Nuclear Weapon Testing

a. Excludes Trinity, July 5, 1945. First nuclear test conducted near Alamogordo, New Mexico, that produced a yield of 21 kt.
b. Little Feller II, Little Feller I, Clean Slate I, Double Tracks, Clean Slate II, Clean Slate III
c. Five of the 7 cratering tests were for peaceful purposes as part of the PLOWSHARE Program; DANNY BOY, SEDAN, Johnnie Boy, PALANQUIN, CABRIOLET, Buggy, Schooner
d. Total of underground tests at NTS from 1951 to 1992 was 828.

Table 2-2. Radionuclides of concern for various NTS activities.

Radionuclides of concern	Drillback Core Sample	Reentry and Mineback Operations Areas 1 & 2	Routine Operations Areas 1 & 2	Decontamination Facility Area 6	Treatability Test Facility Area 25	Atmospheric Weapon Test Areas Areas 3 & 11	Atmospheric Weapons Test Areas All areas except 22, 23, & 27	Low-Level Waste Site Area 3	Low-Level Waste Site Area 5	Radiation Instrument Calibration	Radiograph Operations	Well Logging Operations	Nuclear Explosive Assembly Area 27	Device Assembly Area 6	Nuclear Rocket Development Area 25	Radioactive Source Storage	Radiochemistry and Counting Laboratories
Ac-227								X	X								
Am-241					X		X	X	X	X		X				X	
Am-243								X	X								X
Ba-133					X		X		X							X	X
Ba-140								X	X								
Ce-139	X[g]																X
Ce-141	X[e]			X[i]				X	X								
Ce-143	X[b]																
Ce-144	X[a]			X[i]	X			X	X								X
Cf-252												X				X	
Cm-244																	X
Co-57				X[i]					X							X	X
Co-60		X		X[j]	X		X	X	X	X	X	X			X	X	X
Cs-134					X		X	X	X								
Cs-137	X[h]	X	X		X		X	X	X	X		X			X	X	X
Eu-152					X		X		X						X	X	X
Eu-154					X		X		X							X	
Eu-155					X		X		X								
Fe-59				X[i]													
Hg-203																	X
I-131	X[d]	X										X					
I-133	X[b]	X															
I-135	X[b]																
Ir-192									X		X					X	
Lu-174					X		X										
Mn-54		X		X[i]				X	X							X	
Mo-99	X[b]								X								
Na-22									X							X	
Na-24																	X
Ni-63																X	
Np-237									X								
Pm-147	X[g]			X[i]	X												
Pu-238					X		X	X	X								
Pu-239					X		X	X	X							X	X
Pu-240					X		X	X	X							X	
Pu-241								X	X								
Pu-242									X								X
PuBe										X						X	
Ra-226									X	X		X				X	
Rh-100					X												
Rh-101					X												
Rh-102m					X		X										
Rh-106		X					X										
Ru-103	X[C]	X		X[i]				X	X								
Ru-106	X[a]	X		X[i]				X	X								
Sb-124		X		X[i]					X								
Sb-125				X[j]	X		X		X								
Sn-113																	
Sr-85								X	X								X
Sr-89	X[c]																
Sr-90		X															
Sr-113																	X
Sr-90/Y-90	X[f]		X	X[j]	X			X		X					X	X	X
Ta-182		X							X								
Te-132	X[d]																
Th-228								X	X			X				X	
Th-230								X	X								
Th-232								X	X								
Th-228, -230										X							
U-233								X	X								
U-234								X	X								
U-235								X	X							X	

Table 2-2. Radionuclides of concern for various NTS activities.

Radionuclides of concern	Drillback Core Sample	Reentry and Mineback Operations	Routine Operations	Decontamination Facility	Treatability Test Facility	Atmospheric Weapon Test Areas	Atmospheric Weapons Test Areas	Low-Level Waste Site	Low-Level Waste Site	Radiation Instrument Calibration	Radiograph Operations	Well Logging Operations	Nuclear Explosive Assembly	Device Assembly	Nuclear Rocket Development	Radioactive Source Storage	Radiochemistry and Counting Laboratories
		Areas 1 & 2	**Areas 1 & 2**	**Area 6**	**Area 25**	**Areas 3 & 11**	**All areas except 22, 23, & 27**	**Area 3**	**Area 5**				**Area 27**	**Area 6**	**Area 25**		
U-238								X	X								
Y-88																	X
Y-90		X															
Y-91	X[c]																
Yb-169									X								
Zr-95/Nb-95	X[a]			X[i]	X			X	X								
Zr-97	X[b]																

Source: REECo 1995

a. Time Post Test 1, 10, 100, and 365 days.
b. Time Post Test 1 day.
c. Time Post Test 10 and 100 days.
d. Time Post Test 1 and 10 days.
e. Time Post Test 10 days.
f. Time Post Test 100, 365, and 10,000 days.
g. Time Post Test 365 days.
h. Time Post Test 10,000 days.
i. Within first year.
j. Within first year and after first year.

Table 2-3. Radionuclides typically deposited following atmospheric tests for various time intervals.

Radionuclide	**Period**				
mCi/m²	**10 Days**	**1 Year**	**10 Year**	**20 Year**	**50 Year**
Be-7	2.61E-07	3.46E-07	7.96E-28		
Na-24	1.02E-06				
Mn-54	1.96E-05	1.05E-05	5.69E-09	1.34E-12	1.75E-23
Fe-55	3.57E-05				
Fe-59	2.56E-05	1.89E-06	1.95E-28		
Co-57	3.56E-05	1.62E-05	3.62E-09	3.16E-13	
Co-58	7.68E-02	2.55E-03	3.40E-17	1.30E-32	
Co-60	1.51E-04	1.71E-04	5.20E-05	1.39E-05	2.67E-07
Cu-64	5.29E-06				
Cu-67	7.09E-06				
W-181					
W-185		1.64E-08	1.09E-21		
W-187					
W-188					
Au-198					
Au-199					
Pb-203					
U-237	6.5E-02				
U-240	5.47E-06				
Np-237					
Np-239	1.54E+00				
Np-240m	5.52E-06				
Am-241	7.05E-09	1.11E-06	1.13E-06	1.13E-06	1.11E-06
Cm-242	1.75E-07	3.00E-06	2.55E-12	7.43E-17	6.83E-17
Ge-77	4.45E-09				
As-77	1.50E-04				
Se-77m	4.50E-07				
As-78					
Br-82	3.33E-06				
Br-83	7.74E-30				
Kr-83m	3.40E-29				
Kr-85m	3.18E-16				
Kr-85	9.24E-05	5.37E-05	3.01E-05	1.59E-05	2.32E-06
Kr-87					
Kr-88	4.99E-25				
Rb-88	5.56E-25				
Sr-89	7.87E-02	4.28E-04	4.01E-23	2.91E-44	
Sr-90	6.10E-04	3.57E-04	2.87E-04	2.24E-04	1.07E-04
Y-90	5.67E-04	3.57E-04	2.87E-04	2.24E-04	1.07E-04
Sr-91	5.40E-07				
Y-91m	3.50E-07				
Y-91	9.84E-02	9.89E-04	1.48E-20	2.98E-39*	
Sr-92	1.30E-25				
Y-92	6.70E-19				
Y-93	1.45E-06				
Zr-95	1.13E-01	2.31E-03	1.39E-18	1.70E-35	
Nb-95m	1.97E-03	4.89E-05	2.95E-20	3.61E-37	
Nb-95	2.11E-02				
Zr-97	6.14E-01				

Table 2-3 (cont.). Radionuclides typically deposited following atmospheric tests for various time intervals.

Radionuclide	**Period**				
mCi/m²	**10 Days**	**1 Year**	**10 Year**	**20 Year**	**50 Year**
Nb-97m	5.89E-04				
Nb-97	6.19E-04	4.97E-03	3.01E-18	3.69E-35	
Mo-99	2.55E-01				
Tc-99m	2.43E-01				
Ru-103	1.28/E-01	4.51E-04	4.69E-29		
Rh-103m	1.28E-01	4.52E-04	4.69E-29		
Ru-105	1.03E15				
Ru-105m	1.03E-15				
Rh-105m	2.63E-02				
Ru-106	7.73E-03	1.01E-02	2.04E-05	2.06E-08	2.12E-17
Rh-106	7.73E-03	1.01E-02	2.04E-05	2.06E-08	2.12E-17
Pd-109	2.39E-06				
Ag-109m	2.40E-06				
Pd-111m	5.45E-14				
Pd-111	4.40E-14				
Ag-111m	5.76E-14				
Ag-111	9.54E-03				
Pd-112	5.15E-05				
Ag-112	6.10E-05				
Ag-113	7.23E-15				
Cd-115m	8.97E-05				
Cd-115	1.27E-03				
In-115m	1.38E-03				
Cd-117	5.40E-31				
In-117m	2.76E-30				
In-117	1.86E-30				
Sn-121	1.39E-04				
Sn-123	3.34E-04	9.79E-05	1.19E-12	1.91E-21	7.91E-48
Sn-125	4.57E-03				
Sb-125	1.04E-04	2.48E-04	2.46E-05	1.89E-06	8.56E-10
Sb-126	1.02E-03				
Sn-127	9.86E-35				
Sb-127	2.40E-02				
Te-125m		1.01E-04	1.02E-05	7.81E-07	3.54E-10
Te-127m	8.98E-04	1.68E-04	1.40E-13	1.15E-23	6.43E-54
Te-127	2.17E-02	1.66E-04	1.39E-13	1.14e-23	6.37E-54
Sb-128	7.23E-09				
Sb-129	1.56E-16				
Te-129m	6.84E-03				
Te-129	4.37E-03				
I-130	2.91E-08				
Te-130m	1.85E-03				
Te-131	3.37e-04				
I-131	2.80E-01				
Xe-131m	1.47E-03				
Te-132	2.38E-01				
I-132	2.45E-01				
I-133	3.84E-03				
Xe-133m	7.41E-03				

Table 2-3 (cont.). Radionuclides typically deposited following atmospheric tests for various time intervals.

Radionuclide	**Period**				
mCi/m^2	**10 Days**	**1 Year**	**10 Year**	**20 Year**	**50 Year**
Xe-133	5.71E-01				
I-135	4.7E-10				
Xe135m	1.47E-10				
Xe-135	1.10E-06				
Cs-136	3.15E-03				
Cs-137	7.76E-04	8.99E-04	7.30E-04	5.77E-04	2.90E-04
Ba-137m	7.24E-04	8.43E-04	6.84E-04	5.41E-04	2.71E-04
Ba-139					
Ba-140	3.65E-01				
La-140	4.09E-01				
La-141	1.50E-17				
Ce-141	2.04E-01	9.67E-06	2.82E-35		
La-142					
Ce-143	3.39E-02				
Pr-143	3.49E-01				
Ce-144	2.15E-02	7.87E-03	2.59E-06	3.48E-10	8.51E-22
Pr-144	2.15E-02	7.87E-03	2.59E-06	3.48E-10	8.51E-22
Pr-145	1.69E-11				
Nd-147	1.45E-01				
Pm-147	1.45E-03	2.60E-03	2.41E-04	1.71E-05	6.12E-09
Nd-149	1.60E-39				
Pm-149	3.36E-02				
Pm-150	4.41E-28				
Pm-151	3.03E-03				
Sm-153	1.02E-02				
Sm-156	1.10E-08				
Eu-155	6.33E-04	5.49E-04	1.48E-04	3.46e-05	4.38E-07
Eu-156	9.98E-03				
Eu-157	5.19E-06				
Gd-159	9.39E-06				
Tb-161	7.18E-04				

Source: DNA (1982b).

Table 2-4. Radioactivity on the NTS, January 1996.

Source of radioactivity	Type of area	Environmental media	Major known elements or waste	Depth range	Approximate activity (curies)
Atmospheric tests[a]	Above-ground nuclear proving area	Surface soils and test structures	Americium Cesium Cobalt Plutonium Europium Strontium	At surface	20
Safety tests[a]	Above-ground experimental areas	Surface soils	Americium Cesium Cobalt Plutonium Strontium	Less than 0.9m (3ft)	35
Big Explosives Experimental Facility[a]	Bunkers	Underground	Depleted uranium	N/A	N/A
Deep underground tests[a]	Underground nuclear testing areas	Soils, alluvium, and consolidated rock	Tritium Fission and activation products	Typically less than 640 m (2,100 ft); but may be deeper	Greater than 300 million
Nuclear reactor tests[a]	Nuclear rocket motor, reactor, and furnace testing area	Surface soils	Cesium Strontium	Less then 3 m (10 ft)	1
Shallow borehole tests[a]	Underground nuclear testing area	Soils and alluvium	Americium Cesium Cobalt Europium Plutonium Strontium	Less than 61 m (200 ft)	2,000 at land surface; depth unknown
Shallow land burial of low-level waste[a]	Waste disposal landfills	Soils and alluvium	Dry-packaged low-level and mixed-wastes	Less than 9 m (30 ft)	500,000 at time of disposal; no decay
Crater disposal[a]	Subsidence crater with sidewalls, cover, and drainage	Soils and alluvium	Bulk contaminated soils and equipment	Less than 30 m (100 ft)	1,250 at time of disposal; no decay
Greater containment disposal[a]	Monitored underground waste disposal borehole	Soils and alluvium	Tritium Americium	Less than 30 m (100 ft)	9.3 million at time of disposal; no decay
U1a Complex[a]	Mined underground complex	Underground	SNM Tritium Depleted uranium	To 350 m (1,000 ft.)	N/A
Containment ponds[b]	Surface	Water, air, and soil	Tritium	N/A	130
Laboratories[b]	Surface	Air and soil	Tritium	At surface	500 uCi
Joint actinide research (JASPER)[b]	Surface	Air and soil	SNM Actinides	N/A	N/A
Contaminated surface soils[b]	Surface	Soil	Americium Plutonium	0 to 5 cm	Assumed to be included in above totals

N/A – Not available.
a. DOE (1996a).
b. DOE (1997a).

Table 2-5. Estimated $^{239+240}$Pu in surface soil (0 to 5 cm).

NTS Site	Area (km^2)	Estimated activity (curies)	95% confidence interval (curies)	$^{239+240}$Pu air concentration annual avg. (± 2σ) in 10^8 μCi/mL
Project 56 (Area 11)[a]	4.83	36.00	28-44	23 ± 9
GMX (Area 5)[a]	0.125	1.50	1.1-1.9	5 ± 5
LITTLE FELLER II (Area 18)[d]	0.375	32.00[c]	22-41	--
PALANQUIN (Area 20)[b]	3.895	13.00	6-21	1.6 ± 1.2
SEDAN (Area 10)[b]	28.264	111.20	--	12 ± 13
T2 series (Area 2)[d]	30.100	26.70	--	8 ± 16
Various tests (Area 9)		89.00	--	245 ± 216
Area 13[a]	4.02	46.00	28-64	--
CLEAN SLATE & DOUBLE TRACKS[a]	2.60	61.80	--	--

Source: DOE (1997b).

a. Safety test of nuclear devices.
b. PLOWSHARE tests (PALAQUIN and CABRIOLET sites in Area 20 combined).
c. Inventory consists of $^{239+240}$Pu + ^{241}Am.
d. Weapons effects tests.

Table 2-6. Releases from underground tests (normalized to 12 hours after event.[a]

All releases 1971-1988	Ci released
Containment failures:	
CAMPHOR, 1971b	360
DIAGNONAL LINE, 1971	6,800
RIOLA, 1980	3,100
AGRINI, 1984	690
Late-time seeps:	
KAPPELL, 1984	12
TIERRA, 1984	600
LABQUARK, 1986	20
BODIE, 1986c	52
Controlled tunnel purgings:	
HYBIA FAIR, 1974	500
HYBIA GOLD, 1977	0.005
MINERS IRON, 1980	0.3
HURON LANDING, 1982	280
MINI JADE, 1983	1
MILL YARD, 1985	5.9
DAIMOND BEACH, 1985	1.1
MISTY RAIN, 1985	63
MIGHTY OAK, 1987	38,000
MISSION GHOST, 1987c	3
Operation releases:	
108 test from 1980-1988	5,500
Total since BANEBERRY:	54,000
Major pre-1971 releases:	
PLATTE, 1962	1,900,000
EEL, 1962	1,900,000
DES MOINES, 1962	11,000,000
BANEBERRY, 1970	6,700,000
28 others from 1958-1970	3,800,000
Total:	25,300,000
Other releases for reference:	
NTS atmospheric testing, 1951-1963	12,000,000,000
1-kiloton aboveground explosion	10,000,000
Chernobyl (estimate)	81,000,000

Source: OTA (1989)

a. R+12 values apply only to containment failures; others are at time of release.
b. The Camphor failure includes 140Ci from tunnel purging.
c. Bodie and Mission Ghost also had drill-back releases.

Table 2-7. Estimated number of curies emitted from the source for 2001.

Event	Activity in Curies
Radioactive Waste Management Site No. 4	6.5
Sedan Crater	13
E Tunnel Pond	11
Schooner	400

Source: DOE (2002a).

Table 2-8. Inventory of contaminated soil, Curies.

Area	Area (mi^2)	^{241}Am	^{238}Pu	^{239,240}Pu	^{60}Co	^{137}Cs	^{90}Sr	^{152}Eu	^{154}Eu	^{155}Eu
1	26.5	4.2	6.5	24	1.1	8.8	15	15	0.1	0.5
2	19.7	2.9	8.6	22	1.2	24	46	14	0	0.4
3	32.3	4.6	3.1	37	1	12	33	18	0.1	0.5
4	16	6.6	13	40	1.6	12	13	9.1	0	0.2
5	2.9	0.6	0.1	4.8	0.6	0.4	0.9	10	0.2	0
6	32.3	1.7	3.3	8.4	0.2	2.8	3.5	0	0	0
7	19.3	2.2	0.6	16	1	5.2	9.2	22	0.2	0.3
8	13.9	17	8	110	5.7	42	25	4.4	0	0.6
9	20	4.2	2.2	89	0.7	8.7	13	23	0.2	0.3
10	20	19	19	110	9.7	84	55	2.2	0.3	5
11	4	3.3	0.5	29	0	0.5	0.3	0	0	0
12	39.6	5.7	8.5	39	1.2	20	17	0	0	0
15	35.3	8	7.8	63	0.3	19	22	0	0	0
16	14.3	0.7	1.5	3.7	0.1	2.9	3.7	0	0	0
17	31.4	2.8	4.5	18	1	15	19	0	0	0
18	27.3	19	5.6	100	0.7	10	17	1.1	0.1	0.8
19	148.3	21	32	140	1.1	36	31	0	0	0
20	6.2	23	30	41	7.9	5.5	4.3	13	1.6	4.8
25	0.9	0	0	0	0	0.2	0.1	0.4	0	0
26	0.2	0	0	0	0	0	0	0	0	0
30	.0.3	3.2	4.5	14	0.8	1.5	1.3	0.7	0.1	0.2

Source: McArthur (1991).

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GLOSSARY

Gravel Gertie

A round room with 2-foot-thick concrete walls and a staging area with two staging bays connected to the round room. Tests were conducted in the Gravel Gertie with high explosives and uranium devices to measure fallout.

greater confinement boreholes

From 1984 to 1989, DOE conducted intermediate-depth disposal operations at the NTS. These operations emplaced high-specific-activity, low-level radioactive wastes and limited quantities of classified transuranic wastes in greater confinement boreholes. The boreholes are about 3 m (10 ft.) in diameter and 36 m (120 ft.) deep. The bottom 15 m (50 ft.) of each borehole was used for waste emplacement and the upper 21 m (70 ft.) was backfilled with native alluvium.

Trinity glass debris

Vitrified material created during tests that contains radioactive material. In general, there is no removable radioactive contamination, but the material can represent an external hazard. At NTS this material usually looks like a black rough piece of charcoal, or perhaps like the outcrop of a lava flow and is not “glassy” in appearance.