Chapter 2

History of the Nevada Test Site and Nuclear Testing Background

Contents: The Nevada Test Site (NTS) and the types of nuclear tests conducted there from 1951 to date are described, and resulting off-site contamination, especially with respect to ^{131}I, is discussed.

2.1. NEVADA TEST SITE LOCATION AND SIZE

The Nevada Test Site (NTS) is located in Nye County in southern Nevada; the southernmost point of the NTS is about 65 miles (105 kilometers) northwest of Las Vegas. The site contains 1,350 square miles (3,500 square kilometers) of federally owned land with restricted access, and varies from 28-35 miles (45-56 kilometers) in width (east-west) and from 40-55 miles (64-88 kilometers) in length (north-south).

The Nevada Test Site is bordered on three sides by 4,120 square miles (10,700 square kilometers) of land comprising the Nellis Air Force Range, another federally owned, restricted area *(Figure 2.1)*. This restricted area provides a buffer zone to the north and east between the test area and land that is open to the public, and varies in width from 15-65 miles (24-105 kilometers). A northwestern portion of the Nellis Air Force Range is occupied by the Tonopah Test Range, an area of 624 square miles (1,620 square kilometers), which is operated for the U.S. Department of Energy (DOE) by the Sandia Laboratories primarily for airdrop tests of ballistic shapes. The combination of the Tonopah Test Range, the Nellis Air Force Range, and the Nevada Test Site is one of the largest unpopulated land areas in the United States, comprising some 5,470 square miles (14,200 square kilometers).

Figure 2.1. Location of the Nevada Test Site.

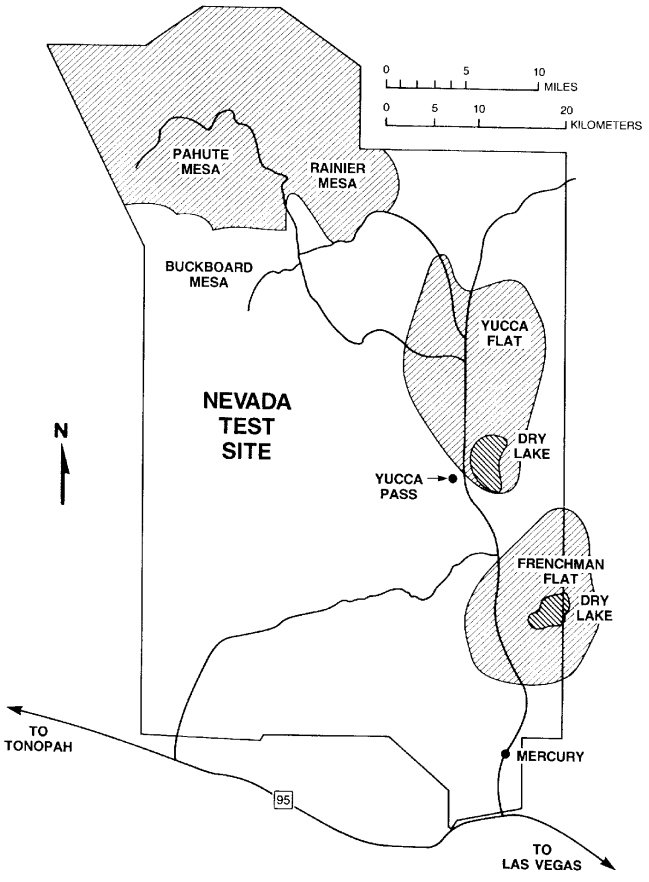


Figure 2.2 Details of the Nevada Test Site. Areas used for nuclear testing are shaded.

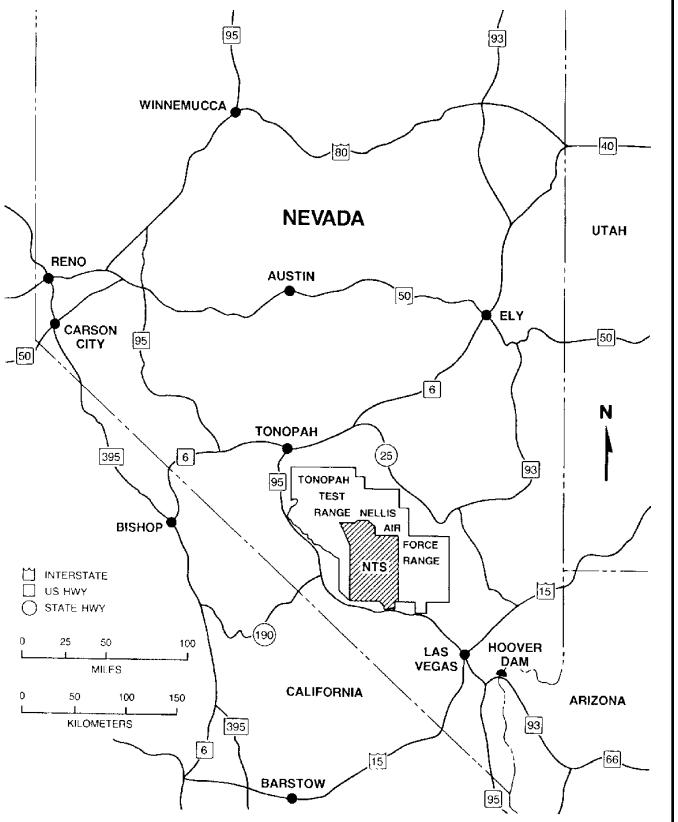


Figure 2.2 shows the general layout of the Nevada Test Site, and identifies some of the areas within the site referred to in this report.

2.2. HISTORICAL BACKGROUND OF THE NEVADA TEST SITE

From the end of World War II until 1951, five U.S. nuclear weapons tests were conducted at distant islands in the Pacific Ocean: two at Bikini atoll and three at Enewetak atoll (U.S. Department of Energy 1994). Testing at those sites required an extensive logistic effort and an inordinate amount of time. When the decision to accelerate the development of nuclear weapons was made in the late 1940s in response to the national defense policy, it became apparent that weapons development lead times would be reduced and considerably less expense incurred if nuclear weapons, especially the lower yield weapons, could be tested safely within the continental boundaries (Anders et al. 1983). Accordingly, a number of sites throughout the continental United States, including Alaska, were considered on the basis of low population density, safety, favorable year-round weather conditions, security, available labor sources, reasonable accessibility including transportation routes, and favorable geology. After review of known information about fallout, thermal, and blast effects, it was determined that an area within what is now the Nellis Air Force Range could be used for relatively low-yield nuclear detonations. Although the NTS originally was selected to meet criteria for atmospheric tests, it subsequently also was used for underground tests.

Public Land Order 805 dated February 19, 1952, identified 680 square miles (1,800 square kilometers) for nuclear testing purposes from an area used by the Air Force as a bombing and gunnery range; this area now comprises approximately the eastern half of the present Nevada Test Site. The predominant geological features of this area are the closed drainage basins of Frenchman Flat and Yucca Flat where the early atmospheric tests were conducted. The main Control Point has remained on the crest of Yucca Pass between these two basins (*Figure 2.2*). Additional land was added to the site in 1958, 1961, 1964, and 1967, thereby enlarging the site to its present size of about 1,350 square miles (3,500 square kilometers).

2.3. NUCLEAR TESTING PROGRAM AT THE NEVADA TEST SITE

Nuclear testing at the NTS has been conducted in two distinct eras (Friesen 1985): the atmospheric testing era (January 1951 through October 1958) and the underground testing era (1961 to the present). On October 31, 1958, the United States and the Soviet Union entered into voluntary test moratoria which lasted until the U.S.S.R. resumed testing on September 1, 1961. The United States responded with renewed testing on September 15, 1961. A few surface, near surface, and cratering tests were conducted from 1961 to 1968, but all other nuclear weapons tests have been carried out underground since 1961. The United States and the Soviet Union signed the Limited Test Ban Treaty on August 5, 1963, which effectively banned these countries from testing nuclear weapons in the atmosphere, in outer space and underwater. Six of the eight cratering tests conducted between 1962 and 1968 were part of a peaceful applications program.

2.3.1. Atmospheric Testing Era (1951-1958)

The United States conducted 119 nuclear tests at the NTS from the start of testing in January 1951 through October 1958 (U.S. Department of Energy 1988; U.S. Department of Energy 1994). Most of those nuclear tests were carried out in the atmosphere. Some tests were positioned for firing by airdrop, but metal towers were used for many Nevada tests at heights ranging from 100 to 700 feet (30-200 meters) above the ground surface. In 1957 and 1958, helium-filled balloons, tethered to precise heights and locations 340 to 1,500 feet (105 to 500 meters) above ground, provided a simpler, quicker, and less expensive method for the testing of many experimental devices. The tests of the atmospheric era took place in Yucca and Frenchman Flats *(Figure 2.2). Table 2.1* gives the characteristics of the 119 nuclear tests that were conducted at the NTS during the atmospheric testing era (1951-1958); they consist of 97 nuclear tests conducted in the atmosphere, of two cratering tests, detonated at depths less than 100 feet (30 meters), and of 20 underground tests. In *Table 2.1,* "type" refers to the type of deployment of the nuclear device at time of detonation (Friesen 1985):

Table 2.1. List of nuclear detonations at the Nevada Test Site during the atmospheric testing era (1951-1958) (Hicks 1981; U.S. Weather Bureau 1964; U.S. Department of Energy 1988).

Test Series	Date (mo/d/y)	Time (GMT) [a]	Yield (kt)	Type	Height Above Ground (m)	Atmospheric release of ^{131}I (kCi)
RANGER:						
ABLE	01/27/51	1945	1	Airdrop	320	140
BAKER	01/28/51	1952	8	Airdrop	330	1300
EASY	02/01/51	1947	1	Airdrop	330	100
BAKER-2	02/02/51	1940	8	Airdrop	335	1300
FOX	02/06/51	1947	22	Airdrop	340	3200
BUSTER-JANGLE:						
ABLE [b]	10/22/51	1400	<0.1	Tower	100	N.D.
BAKER	10/28/51	1520	3.5	Airdrop	340	600
CHARLIE	10/30/51	1500	14	Airdrop	345	2000
DOG	11/01/51	1530	21	Airdrop	430	3100
EASY	11/05/51	1630	31	Airdrop	400	4500
SUGAR	11/19/51	1700	1.2	Surface	1	170
UNCLE	11/29/51	2000	1.2	Crater	-5	170
TUMBLER-SNAPPER:						
ABLE	04/01/52	1700	1	Airdrop	240	140
BAKER	04/15/52	1730	1	Airdrop	320	140
CHARLIE	04/22/52	1730	31	Airdrop	1050	4600
DOG	05/01/52	1630	19	Airdrop	320	2900
EASY	05/07/52	1215	12	Tower	90	1800
FOX	05/25/52	1200	11	Tower	90	1600
GEORGE	06/01/52	1155	15	Tower	90	2200
HOW	06/05/52	1155	14	Tower	90	2100

[a] GMT = Greenwich Mean Time; Greenwich Mean Time is eight hours ahead of Pacific Time.
[b] Activity detected on-site only.
N.D. = not detectable.

Table 2.1. cont'd

Test Series	Date (mo/d/y)	Time (GMT) [a]	Yield (kt)	Type	Height Above Ground (m)	Atmospheric release of ^{131}I (kCi)
UPSHOT-KNOTHOLE:						
ANNIE	03/17/53	1320	16	Tower	90	2400
NANCY	03/24/53	1310	24	Tower	90	3600
RUTH	03/31/53	1300	0.2	Tower	90	28
DIXIE	04/06/53	1530	11	Airdrop	1835	1700
RAY	04/11/53	1245	0.2	Tower	30	28
BADGER	04/18/53	1235	23	Tower	90	3500
SIMON	04/25/53	1230	43	Tower	90	6300
ENCORE	05/08/53	1530	27	Airdrop	740	3900
HARRY	05/19/53	1205	32	Tower	90	4800
GRABLE [b]	05/25/53	1530	15	Airburst	160	2100
CLIMAX	06/04/53	1115	61	Airdrop	400	8500
TEAPOT:						
WASP	02/18/55	2000	1	Airdrop	230	160
MOTH	02/22/55	1945	2	Tower	90	320
TESLA	03/01/55	1330	7	Tower	90	1200
TURK	03/07/55	1320	43	Tower	150	6400
HORNET	03/12/55	1320	4	Tower	90	620
BEE	03/22/55	1305	8	Tower	150	1200
ESS	03/23/55	2030	1	Crater	-20	140
APPLE-I	03/29/55	1255	14	Tower	150	2000
WASP PRIME	03/29/55	1800	3	Airdrop	225	450
HA	04/06/55	1800	3	Airdrop	11160	450
POST	04/09/55	1230	2	Tower	90	340
MET	04/15/55	1915	22	Tower	120	3100
APPLE-II	05/05/55	1210	29	Tower	150	4100
ZUCCHINI	05/15/55	1200	28	Tower	150	4000

[a] GMT = Greenwich Mean Time, Greenwich Mean Time is eight hours ahead of Pacific Time.
[b] Fired from 280-mm gun.

Table 2.1. cont'd

Test Series	Date (mo/d/y)	Time (GMT) [a]	Yield (kt)	Type	Height Above Ground (m)	Atmospheric release of ^{131}I (kCi)
PROJECT 56:						
No. 1 [b]	11/01/56	2210	0	Surface	0	N.D.
No. 2 [b]	11/03/56	2115	0	Surface	0	N.D.
No. 3 [b]	11/05/56	1955	No Yld.	Surface	0	N.D.
No. 4 [b]	01/18/56	2130	Slight	Surface	0	N.D.
PLUMBBOB:						
BOLTZMANN	05/28/57	1155	12	Tower	150	1900
FRANKLIN	06/02/57	1155	0.14	Tower	90	19
LASSEN [c]	06/05/57	1145	0.0005	Balloon	150	0.1
WILSON	06/18/57	1145	10	Balloon	150	1500
PRISCILLA	06/24/57	1330	37	Balloon	210	5300
COULOMB-A	07/01/57	N.A.	0	Surface	0	N.D.
HOOD	07/05/57	1140	74	Balloon	460	11000
DIABLO	07/15/57	1130	17	Tower	150	2500
JOHN [d]	07/19/57	1400	About 2	Rocket	6100	6100
KEPLER	07/24/57	1150	10	Tower	150	1700
OWENS	07/25/57	1330	10	Balloon	150	1700
PASCAL-A	07/26/57	800	Slight	Shaft	N.A.	10
STOKES	08/07/57	1225	19	Balloon	460	2800
SATURN	08/10/57	N.A.	0	Tunnel	N.A.	N.D.
SHASTA	08/18/57	1200	17	Tower	150	2500
DOPPLER	08/23/57	1240	11	Balloon	460	1700

[a] GMT = Greenwich Mean Time; Greenwich Mean Time is eight hours ahead of Pacific Time.
[b] Safety experiment.
[c] Activity detected on-site only.
[d] Air-to-air missile.
N.D. = not detectable.
N.A. = not available.

Table 2.1. cont'd

Test Series	Date (mo/d/y)	Time (GMT) [a]	Yield (kt)	Type	Height Above Ground (m)	Atmospheric release of ^{131}I (kCi)
PLUMBBOB (cont'd):						
PASCAL-B	08/27/57	N.A.	N.A.	Shaft	N.A.	N.D.
FRANKLIN P.	08/30/57	1240	4.7	Balloon	230	690
SMOKY	08/31/57	1230	44	Tower	210	6400
GALILEO	09/02/57	1240	11	Tower	150	1900
WHEELER	09/06/57	1245	0.2	Balloon	150	27
COULOMB-B	09/06/57	2005	0.3	Surface	N.A.	42
LAPLACE	09/08/57	1300	1	Balloon	230	140
FIZEAU	09/14/57	1645	11	Tower	150	1700
NEWTON	09/16/57	1250	12	Balloon	460	2100
RAINER [b]	09/19/57	1700	1.7	Tunnel	-240	0
WHITNEY	09/23/57	1230	19	Tower	150	2900
CHARLESTON	09/28/57	1300	12	Balloon	460	1800
MORGAN	10/07/57	1300	8	Balloon	460	1200
PROJECT 58:						
PASCAL-C [c]	12/06/57	2015	Slight	Shaft	N.A.	N.D.
COULOMB-C [c]	12/09/57	2000	0.5	Surface	N.A.	69
PROJECT 58 A:						
VENUS [c]	02/22/58	N.A.	<0.001	Tunnel	N.A.	N.D.
URANUS [c]	03/14/58	N.A.	<0.001	Tunnel	N.A.	N.D.
HARDTACK-PHASE II:						
OTERO [c]	09/12/58	2000	0.038	Shaft	-150	6
BERNALILLO [c]	09/17/58	1930	0.015	Shaft	-140	N.D.
EDDY	09/19/58	1400	0.083	Balloon	150	12
LUNA [c]	09/21/58	1900	0.0015	Shaft	-150	N.D.

[a] GMT = Greenwich Mean Time; Greenwich Mean Time is eight hours ahead of Pacific Time.
[b] Contained underground.
[c] Safety Experiment.
N.D. = not detectable.
N.A. = not available.

Table 2.1. cont'd

Test Series	Date (mo/d/y)	Time (GMT) [a]	Yield (kt)	Type	Height Above Ground (m)	Atmospheric release of ^{131}I (kCi)
HARDTACK-PHASE II (cont'd):						
MERCURY [b]	09/23/58	N.A.	Slight	Tunnel	N.A.	N.D.
VALENCIA [b]	09/26/58	2000	0.002	Shaft	-150	N.D.
MARS [b]	09/28/58	0	0.013	Tunnel	N.A.	N.D.
MORA	09/29/58	1405	2	Balloon	460	340
HIDALGO	10/05/58	1410	0.077	Balloon	100	11
COLFAX [b]	10/05/58	1615	0.0055	Shaft	-110	N.D.
TAMALPAIS	10/08/58	2200	0.072	Tunnel	-100	N.D.
OLIVY	10/10/58	1430	0.079	Tower	30	11
LEA	10/13/58	1320	1.4	Balloon	460	240
NEPTUNE	10/14/58	1800	0.115	Tunnel	-30	N.D.
HAMILTON	10/15/58	1600	0.0012	Tower	15	0.2
LOGAN	10/16/58	600	5	Tunnel	-250	N.D.
DONA ANA	10/16/58	1420	0.037	Balloon	140	6
VESTA	10/17/58	2300	0.024	Surface	0	4
RIO ARRIBA	10/18/58	1425	0.09	Tower	22	120
SAN JUAN [b]	10/20/58	N.A.	0	Shaft	N.A.	N.D.
SOCORRO	10/22/58	1330	6	Balloon	440	1000
WRANGELL	10/22/58	1650	0.115	Balloon	460	17
RUSHMORE	10/22/58	2340	0.188	Balloon	150	17
OBERON [b]	10/22/58	N.A.	0	Tower	N.A.	N.D.
CATRON	10/24/58	1500	0.021	Tower	22	4
JUNO	10/24/58	1601	0.0017	Surface	0	N.D.
CERES	10/26/58	400	0.0007	Tower	10	N.D.
SANFORD	10/26/58	1020	4.9	Balloon	460	750
DE BACA	10/26/58	1600	2.2	Balloon	460	380
CHAVEZ	10/27/58	1430	0.0006	Tower	15	0.1
EVANS	10/29/58	0	0.055	Tunnel	-260	N.D.
HUMBOLDT	10/29/58	1445	0.0078	Tower	10	1
MAZAMA	10/29/58	N.A.	0	Tower	N.A.	N.D.
SANTA FE	10/30/58	300	1.3	Balloon	460	220
TITANIA	10/30/58	2004	0.0002	Tower	10	0.03
BLANCA	10/30/58	1500	22	Tunnel	-250	0.51
GANYMEDE [b]	10/30/58	N.A.	0	Surface	N.A.	N.D.

[a] GMT = Greenwich Mean Time; Greenwich Mean Time is eight hours ahead of Pacific Time.
[b] Safety Experiment.
N.D. = not detectable.
N.A. = not available.

airburst: fired from a cannon,
airdrop: dropped from an aircraft,
balloon: suspended from a tethered balloon,
rocket: launched by rocket,
tower: mounted at top of a metal or wooden tower,
surface: placed on or close to the earth's surface,
crater: placed shallow enough underground to produce a throw-out of the earth when exploded,
shaft: exploded at the end of a drilled or mined vertical hole,
tunnel: exploded at the end of a long horizontal hole mined into a mountain or mesa in a way that places the burst point deep within the earth.

The yields presented in *Table 2.1* are a measure of the total energy released during the explosion; they are expressed in terms of the equivalent mass of TNT required to produce the same energy release. The unit commonly used for the yield is the kiloton (kt). Depending on the type of weapon, the yield may include a fusion component in addition to the fission component. It is believed that all the nuclear weapons tested at the NTS during the atmospheric era were only of the fission type, and therefore that their yields were the same as their fission yields.

The yields of the 119 nuclear tests detonated in the atmospheric era ranged from 0 to 74 kt, with 41 tests with yields greater than, or equal to, 10 kt, 23 tests with yields between 1 and 10 kt, and 55 tests with yields less than or equal to 1 kt. The arithmetic average yield was 8.6 kt. Among the tests with yields lower than 1 kt are included all safety experiments, in which atomic bombs were destroyed by conventional explosives in order to determine the spread of the fissionnable material so that the consequences of transportation accidents involving warheads could be evaluated. The yields of the safety experiments that were reported as "slight," "not available," or "no yield" were taken to be equal to zero.

2.3.2. Underground Testing Era (1961 to 1992)

In 1962, before the onset of the Limited Test Ban Treaty, the United States conducted, in addition to its underground tests, two small surface tests, one tower test and two cratering tests as part of the nuclear weapons testing program. Six nuclear cratering tests were conducted from 1962 through 1968 as part of the peaceful applications (Plowshare) program. The overwhelming majority of the 809 tests that took place at the NTS from 1961 through September 1992 were conducted underground either in shafts or in tunnels that were designed for containment of the

Table 2.2. List of atmospheric and cratering events at the Nevada Test Site from 1961 through September 1992 (Hardy et al. 1964; Hicks 1981; Schoengold et al. 1990; U.S. Department of Energy 1994).

Test	Date (mo/d/y)	Time (GMT)[a]	Yield (kt)	Type	Height (m)	Cloud Height (km MSL)	Atmospheric release of ^{131}I (kCi)
DANNY BOY	03/05/62	1815	0.43	Crater	-30	N.A.	73
SEDAN[b,c]	07/06/62	1700	104	Crater	-200	3.7	880
LITTLE FELLER 2	07/07/62	1900	<20	Surface		2.4	N.A.
JOHNNY BOY	07/11/62	1645	0.5	Crater	-1	3.4	70
SMALL BOY	07/14/62	1830	<20	Tower		4.6	270
LITTLE FELLER 1	07/17/62	1700	<20	Surface		3	3
SULKY[c]	12/18/64	1935	0.092	Crater	-30	N.A.	13
PALANQUIN[c]	04/14/65	1314	4.3	Crater	-85	N.A.	910
CABRIOLET[c]	01/26/68	1600	2.3	Crater	-20	N.A.	6
BUGGY[c]	03/12/68	1704	5.4	Crater	-40	N.A.	40
SCHOONER[c]	12/08/68	1600	30	Crater	-100	N.A.	15

[a] GMT = Greenwich Mean Time; Greenwich Mean Time is eight hours ahead of Pacific Time.
[b] Less than 30 kt fission yield.
[c] Tests conducted as a part of the "Plowshare" program.
N.A.= not available

Table 2.3. List of underground events at the Nevada Test Site during the underground testing era (from 1961 through September 1992) that resulted in the detection of radioactive materials off-site[a] (Hardy et al. 1964; Hicks 1981; U.S. Department of Energy 1988; Schoengold et al. 1990).

Test	Date (mo/d/y)	Time (GMT)[b]	Yield (kt)	Type	Atmospheric release of ^{131}I (kCi)
ANTLER	09/15/61	1600	2.6	Tunnel	0.0042
FEATHER	12/22/61	1730	Low	Tunnel	0.00114
PAMPAS	03/01/62	2010	Low	Shaft	0.000012
PLATTE	04/14/62	1900	1.85	Tunnel	0.0114
EEL	05/19/62	1700	Low	Shaft	0.0114
DES MOINES	06/13/62	2200	Low	Tunnel	33
BANDICOOT	10/19/62	1900	Low	Shaft	9
YUBA	06/05/63	1800	Low	Tunnel	0.000022
EAGLE	12/12/63	1702	Low	Shaft	0.00228
OCONTO	01/12/64	N.A.	less than 20	Shaft	0.001
PIKE	03/13/64	1702	less than 20	Shaft	0.36
ALVA	08/19/64	1700	less than 20	Shaft	0.000037
DRILL	12/05/64	2215	3.4	Shaft	0.0122
PARROT	12/16/64	2100	1.3	Shaft	0.0046
ALPACA	02/12/65	1610	less than 20	Shaft	0.000024
TEE	05/07/65	1647	less than 20	Shaft	0.0016
DILUTED WATERS	06/16/65	1730	less than 20	Shaft	0.0177
RED HOT	03/05/66	1915	less than 20	Tunnel	0.2
FENTON	04/23/66	N.A.	less than 20	Shaft	N.A.
PIN STRIPE	04/25/66	1938	less than 20	Shaft	0.2
DOUBLE PLAY	06/15/66	1800	less than 20	Tunnel	0.12
DERRINGER	09/12/66	1630	less than 20	Shaft	0.00024
NASH	01/19/67	1745	20 to 200	Shaft	0.0138
MIDI MIST	06/26/67	1700	less than 20	Tunnel	0.00026
UMBER	06/29/67	1225	less than 20	Shaft	0.00052
DOOR MIST	08/31/67	1730	less than 20	Tunnel	0.008
HUPMOBILE	01/18/68	1730	10	Shaft	0.12
TYG	12/12/68	N.A.	less than 20	Shaft	Undetected
POD	10/29/69	2100	20 to 200	Shaft	0.000078
SCUTTLE	11/13/69	1515	less than 20	Shaft	0.000004
SNUBBER	04/21/70	1530	less than 20	Shaft	0.0055
MINT LEAF	05/05/70	1630	less than 20	Tunnel	0.08
BANEBERRY	12/18/70	1630	10	Shaft	80
DIAGONAL LINE	11/24/71	2015	less than 20	Shaft	0.00136
RIOLA	09/25/80	826	less than 20	Shaft	0.00058
MISTY RAIN	04/06/85	N.A.	less than 20	Tunnel	Undetected
GLENCOE	03/22/86	N.A.	20 to 150	Shaft	0.000000009
MIGHTY OAK	04/10/86	N.A.	less than 20	Tunnel	0.0024

[a] There were in addition more than 500 underground events that did not result in detection off-site.
[b] GMT = Greenwich Mean Time; Greenwich Mean Time is eight hours ahead of Pacific Time.
N.A. = not available.

radioactive debris (U.S. Department of Energy 1993; U.S. Department of Energy 1994). Most underground tests were conducted under Yucca Flat but a few underground and cratering tests took place under Buckboard, Pahute, and Rainier Mesas in the northern part of the Nevada Test Site *(Figure 2.2)*.

Table 2.2 presents the characteristics of the 11 atmospheric and cratering tests conducted since 1961 while *Table 2.3* gives the characteristics of the 38 underground events detonated through September 1992 that have released volatile radioactive materials (particulate or gaseous), which resulted in detection off-site (Hicks 1981; Schoengold et al. 1990; U.S. Department of Energy 1994).

The remainder of the 809 tests that took place at the NTS between 1961 and 1992 were either completely contained underground or resulted in releases of radioactive materials that were only detected onsite. *Table 2.4* presents the characteristics of the 299 events that resulted in releases of radioactive materials that were detected onsite only (Schoengold et al. 1990; U.S. Department of Energy 1993; U.S. Department of Energy 1994). When quantified, those releases are extremely small in comparison to those from atmospheric and cratering tests.

All United States nuclear tests have been publicly announced; the total number of nuclear weapons tests that were conducted at the Nevada Test Site up to September 1992 is 928—100 which were atmospheric, and the other 828 underground (U.S. Department of Energy 1993; 1994).

On October 2, 1992, the United States entered into another unilateral moratorium on nuclear weapons testing announced by President Bush. President Clinton extended this moratorium in July 1993, and again in March 1994 until September 1995 (U.S. Department of Energy 1994).

2.4. NUCLEAR TESTING BY THE U.S. AT SITES OTHER THAN THE NEVADA TEST SITE

Although the scope of this report is limited to the estimation of the radiation exposures resulting from nuclear tests that took place at the NTS, other sites also were used by the U.S. to conduct nuclear tests.

The first test of a nuclear weapon was in the atmosphere on July 16, 1945, in a remote part of New Mexico on what was

Figure 2.3. Location and number of nuclear tests conducted from July 1945 to September 1992 in the continental U.S.

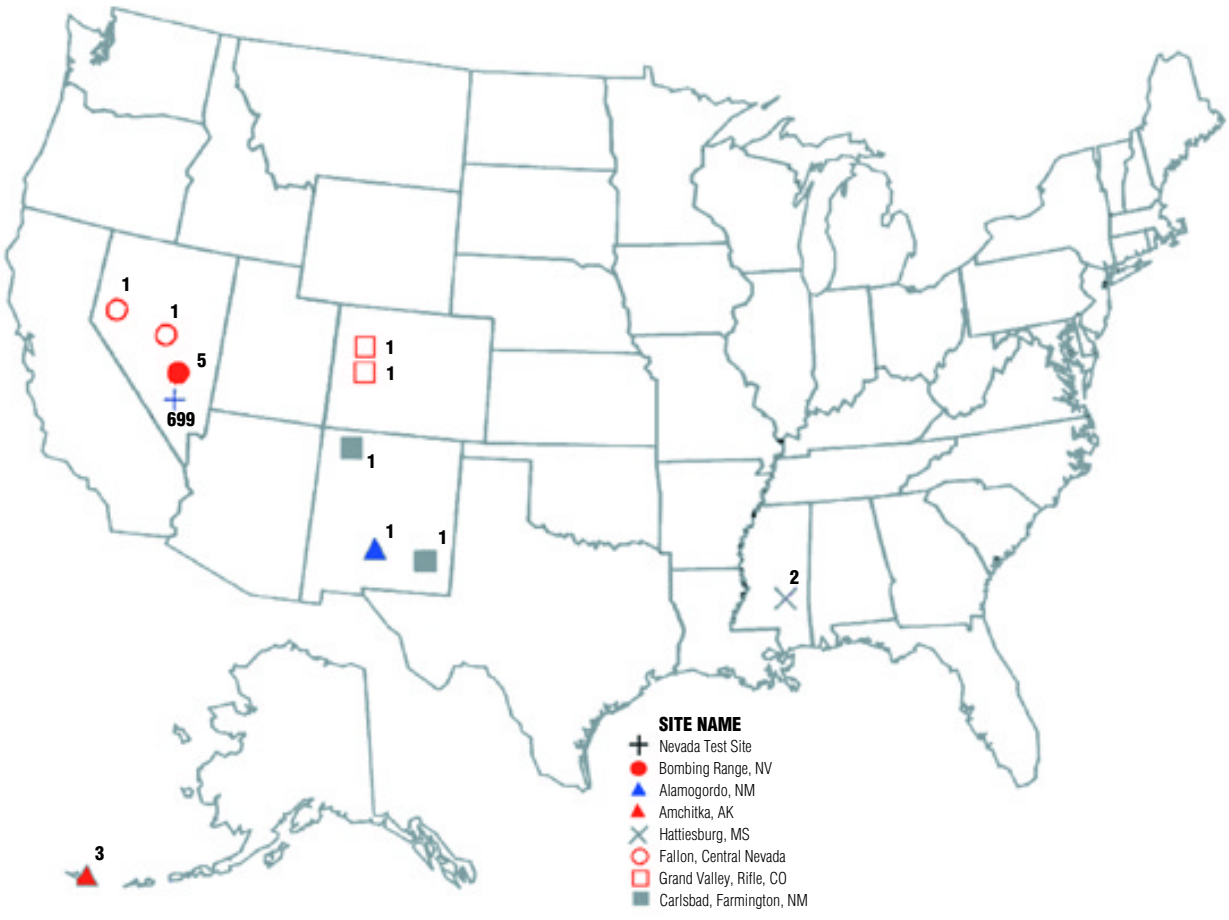


Table 2.4. List of nuclear detonations at the Nevada Test Site during the underground testing era (from 1961 through September 1992) that resulted in the detection of radioactive materials onsite but not offsite (Schoengold et al. 1990; U.S. Department of Energy 1993; U.S. Department of Energy 1994). The release of ^{131}I, when available, is presented in the last column. When the release of ^{131}I is not available, the reported amount for the release of all radioactive materials is provided for most of the tests. Footnotes are at the end of the Table.

Test	Date (mo/d/y)	Purpose	Yield (kt)	Type	Release of ^{131}I or of all radioactive materials (Ci)
SHREW	09/16/61	Weapons related	<20	Shaft	^{131}I not detected
BOOMER	10/01/61	Weapons related	<20	Shaft	^{131}I not detected
CHENA	10/10/61	Weapons related	<20	Tunnel	^{131}I not detected
MINK	10/29/61	Weapons related	<20	Shaft	All: 500
FISHER	12/03/61	Weapons related	13.4	Shaft	^{131}I not detected
MAD	12/13/61	Weapons related	0.5	Shaft	^{131}I not detected
RINGTAIL	12/17/61	Weapons related	<20	Shaft	^{131}I not detected
STOAT	01/09/62	Weapons related	5.1	Shaft	^{131}I not detected
DORMOUSE	01/30/62	Weapons related	<20	Shaft	^{131}I not detected
STILLWATER	02/08/62	Weapons related	3.07	Shaft	^{131}I not detected
ARMADILLO	02/09/62	Weapons related	7.1	Shaft	^{131}I not detected
HARD HAT	02/15/62	Weapons effects	5.7	Shaft	^{131}I not detected
CHINCHILLA	02/19/62	Weapons related	1.9	Shaft	^{131}I not detected
CODSAW	02/19/62	Weapons related	<20	Shaft	All: <1,000
CIMARRON	02/23/62	Weapons related	11.9	Shaft	^{131}I not detected
PLATYPUS	02/24/62	Weapons related	<20	Shaft	^{131}I not detected
ERMINE	03/06/62	Weapons related	<20	Shaft	^{131}I not detected
BRAZOS	03/08/62	Weapons related	8.4	Shaft	^{131}I not detected
HOGNOSE	03/15/62	Weapons related	<20	Shaft	^{131}I not detected
HOOSIC	03/28/62	Weapons related	3.4	Shaft	^{131}I not detected
CHINCHILLA II	03/31/62	Weapons related	<20	Shaft	^{131}I not detected
DORMOUSE PRIME	04/05/62	Weapons related	10.6	Shaft	^{131}I not detected
PASSAIC	04/06/62	Weapons related	<20	Shaft	^{131}I not detected
HUDSON	04/12/62	Weapons related	<20	Shaft	^{131}I not detected
DEAD	04/21/62	Weapons related	<20	Shaft	^{131}I not detected
BLACK	04/27/62	Weapons related	<20	Shaft	^{131}I not detected
PACA	05/07/62	Weapons related	<20	Shaft	^{131}I not detected
ARIKAREE	05/10/62	Weapons related	<20	Shaft	^{131}I not detected
AARDVARK	05/12/62	Weapons related	40	Shaft	^{131}I not detected
WHITE	05/25/62	Weapons related	<20	Shaft	^{131}I not detected
PACKRAT	06/06/62	Weapons related	<20	Shaft	^{131}I not detected
DAMAN I	06/21/62	Weapons related	<20	Shaft	^{131}I not detected
HAYMAKER	06/27/62	Weapons related	67	Shaft	^{131}I not reported[a]
MARSHMALLOW	06/28/62	Weapons effects	<20	Tunnel	^{131}I not detected
SACRAMENTO	06/30/62	Weapons related	<20	Shaft	All: <1,000
LITTLE FELLER II	07/07/62	Weapons effects	<20	Surface	^{131}I not detected
MERRIMAC	07/13/62	Weapons related	20-200	Shaft	^{131}I not detected
WICHITA	07/27/62	Weapons related	<20	Shaft	All: 760
BOBAC	08/24/62	Weapons related	<20	Shaft	^{131}I not detected
YORK	08/24/62	Weapons related	<20	Shaft	^{131}I not detected

Table 2.4. cont'd

Test	Date (mo/d/y)	Purpose	Yield (kt)	Type	Release of ^{131}I or of all radioactive materials (Ci)
RARITAN	09/06/62	Weapons related	<20	Shaft	^{131}I not detected
HYRAX	09/14/62	Weapons related	<20	Shaft	^{131}I not detected
ALLEGHENY	09/29/62	Weapons related	<20	Shaft	^{131}I not detected
MISSISSIPPI	10/05/62	Weapons related	115	Shaft	^{131}I not detected
ROANOKE	10/12/62	Weapons related	<20	Shaft	^{131}I not detected
WOLVERINE	10/12/62	Weapons related	<20	Shaft	^{131}I not detected
SANTEE	10/27/62	Weapons related	<20	Shaft	^{131}I not detected
ST.LAWRENCE	11/09/62	Weapons related	<20	Shaft	^{131}I not detected
ANACOSTIA	11/27/62	Plowshare	<20	Shaft	^{131}I not detected
TAUNTON	12/04/62	Weapons related	<20	Shaft	^{131}I not detected
MADISON	12/12/62	Weapons related	<20	Shaft	^{131}I not detected
NUNBAT	12/12/62	Weapons related	<20	Shaft	^{131}I not detected
MANATEE	12/14/62	Weapons related	<20	Shaft	^{131}I not detected
CASSELMAN	02/08/63	Weapons related	<20	Shaft	^{131}I not detected
KAWEAH	02/21/63	Plowshare	<20	Shaft	^{131}I not detected
CARMEL	02/21/63	Weapons related	<20	Shaft	^{131}I not detected
TOYAH	03/15/63	Weapons related	<20	Shaft	^{131}I not detected
CUMBERLAND	04/11/63	Weapons related	<20	Shaft	^{131}I not detected
KOOTANAI	04/24/63	Weapons related	<20	Shaft	^{131}I not reportedb
PAISANO	04/24/63	Weapons related	<20	Shaft	^{131}I not detected
STONES	05/22/63	Weapons related	20-200	Shaft	All: 5,800
PLEASANT	05/29/63	Weapons related	<20	Shaft	All: 20,000
APSHAPA	06/06/63	Weapons related	<20	Shaft	^{131}I not detected
KENNEBEC	06/25/63	Weapons related	<20	Shaft	^{131}I:<30
PEKAN	08/12/63	Weapons related	<20	Shaft	^{131}I: 10
KOHOCTON	08/23/63	Weapons related	<20	Shaft	All: 3,000
AHTANUM	09/13/63	Weapons related	<20	Shaft	^{131}I not detected
BILBY	09/13/63	Weapons related	249	Shaft	Trace
CARP	09/27/63	Weapons related	low	Shaft	All: 570
GRUNION	10/11/63	Weapons related	<20	Shaft	^{131}I: 0.043
TORNILLO	10/11/63	Plowshare	<20	Shaft	^{131}I not detected
CLEARWATER	10/16/63	Weapons related	20-200	Shaft	^{131}I: 0.023
ANCHOVY	11/14/63	Weapons related	low	Shaft	^{131}I: 2.5
MUSTANG	11/15/63	Weapons related	<20	Shaft	Trace
GREYS	11/22/63	Weapons related	20-200	Shaft	All: 460
SARDINE	12/04/63	Weapons related	<20	Shaft	^{131}I:<0.09
EAGLE	12/12/63	Weapons related	<20	Shaft	^{131}I:<0.1
TUNA	12/20/63	Weapons related	low	Shaft	All: 0.12
FORE	01/16/64	Weapons related	20-200	Shaft	^{131}I not detected
CLUB	01/30/64	Weapons related	<20	Shaft	All: 1.2
SOLENDON	02/12/64	Weapons related	<20	Shaft	All: 9.6
BUNKER	02/13/64	Weapons related	<20	Shaft	All: 1.4
KLICKITAT	02/20/64	Plowshare	20-200	Shaft	^{131}I:<0.02
HANDICAP	03/12/64	Weapons related	<20	Shaft	All: 300

Table 2.4. cont'd

Test	Date (mo/d/y)	Purpose	Yield (kt)	Type	Release of ^{131}I or of all radioactive materials (Ci)
HOOK	04/14/64	Weapons related	<20	Shaft	^{131}I not detected
STURGEON	04/15/64	Weapons related	<20	Shaft	^{131}I: 0.01
BOGEY	04/17/64	Weapons related	<20	Shaft	All: 6.9
TURF	04/24/64	Weapons related	20-200	Shaft	^{131}I:<2
PIPEFISH	04/29/64	Weapons related	<20	Shaft	^{131}I not detected
DRIVER	05/07/64	Weapons related	<20	Shaft	All: 37
BACKSWING	05/14/64	Weapons related	<20	Shaft	^{131}I:<37
ACE	06/11/64	Plowshare	<20	Shaft	^{131}I:<9.3
FADE	06/25/64	Weapons related	<20	Shaft	^{131}I:<35
DUB	06/30/64	Plowshare	<20	Shaft	^{131}I:<5
BYE	07/16/64	Weapons related	20-200	Shaft	^{131}I:<1
CORMORANT	07/17/64	Joint US-UK	<20	Shaft	^{131}I: 0.014
LINKS	07/23/64	Weapons related	<20	Shaft	All: <6.7
CANVASBACK	08/22/64	Weapons related	<20	Shaft	^{131}I: 0.2
PAR	10/09/64	Plowshare	38	Shaft	^{131}I not detected
BARBEL	10/16/64	Weapons related	<20	Shaft	^{131}I: 0.41
FOREST	10/31/64	Weapons related	<20	Shaft	^{131}I: 0.002
HANDCAR	11/05/64	Plowshare	12	Shaft	^{131}I not detected
CREPE	12/05/64	Weapons related	20-200	Shaft	^{131}I not detected
MUDPACK	12/16/64	Weapons related	2.7	Shaft	^{131}I:<1
WOOL	01/14/65	Weapons related	<20	Shaft	^{131}I not detected
TERN	01/29/65	Weapons related	<20	Shaft	All: 170
CASHMERE	02/04/65	Weapons related	<20	Shaft	^{131}I not detected
MERLIN	02/16/65	Weapons related	10.1	Shaft	^{131}I not detected
WISHBONE	02/18/65	Weapons effects	<20	Shaft	^{131}I: 1.3
SEERSUCKER	02/19/65	Weapons related	<20	Shaft	All: 1.3
WAGTAIL	03/03/65	Weapons related	20-200	Shaft	^{131}I: 0.03
CUP	03/26/65	Weapons related	20-200	Shaft	^{131}I: 1
KESTREL	04/05/65	Weapons related	<20	Shaft	^{131}I: 0.029
GUM DROP	04/21/65	Weapons effects	<20	Tunnel	^{131}I not detected
CHENILLE	04/22/65	Weapons related	<20	Shaft	All: 0.93
TWEED	05/21/65	Weapons related	<20	Shaft	^{131}I: 0.02
TINY TOT	06/17/65	Weapons effects	<20	Tunnel	^{131}I:<7
PONGEE	07/22/65	Weapons related	<20	Shaft	All: 6.4
BRONZE	07/23/65	Weapons related	20-200	Shaft	^{131}I: 0.23
CENTAUR	08/27/65	Weapons related	<20	Shaft	^{131}I: 0.0022
SCREAMER	09/01/65	Weapons effects	<20	Shaft	All: 63,000
ELKHART	09/17/65	Weapons related	<20	Shaft	^{131}I not detected
SEPIA	11/12/65	Weapons related	<20	Shaft	^{131}I: 0.0011
KERMET	11/23/65	Weapons related	<20	Shaft	All: <5.5
CORDUROY	12/03/65	Weapons related	20-200	Shaft	^{131}I not detected
EMERSON	12/16/65	Weapons related	<20	Shaft	^{131}I not detected
MAXWELL	01/13/66	Weapons related	<20	Shaft	^{131}I not detected
REO	01/22/66	Weapons related	<20	Shaft	All: 10

Table 2.4. cont'd

Test	Date (mo/d/y)	Purpose	Yield (kt)	Type	Release of ^{131}I or of all radioactive materials (Ci)
PLAID II	02/03/66	Weapons related	<20	Shaft	^{131}I:<1
REX	02/24/66	Weapons related	19	Shaft	^{131}I not detected
FINFOOT	03/07/66	Weapons related	<20	Shaft	^{131}I not detected
CLYMER	03/12/66	Weapons related	<20	Shaft	^{131}I not detected
TEMPLAR	03/24/66	Plowshare	<20	Shaft	^{131}I not detected
STUTZ	04/06/66	Weapons related	<20	Shaft	^{131}I not detected
DURYEA	04/14/66	Weapons related	70	Shaft	^{131}I not detected
TRAVELLER	05/04/66	Weapons related	<20	Shaft	^{131}I not detected
TAPESTRY	05/12/66	Weapons related	<20	Shaft	^{131}I not detected
DUMONT	05/19/66	Weapons related	20-200	Shaft	^{131}I not detected
PILE DRIVER	06/02/66	Weapons effects	62	Tunnel	^{131}I not detected
KANKAKEE	06/15/66	Weapons related	20-200	Shaft	^{131}I not detected
VULCAN	06/25/66	Plowshare	25	Shaft	^{131}I not detected
SAXON	07/28/66	Plowshare	<20	Shaft	^{131}I not detected
ROVENA	08/10/66	Weapons related	<20	Shaft	^{131}I not detected
NEWARK	09/29/66	Weapons related	<20	Shaft	^{131}I not detected
SIMMS	11/05/66	Plowshare	<20	Shaft	^{131}I: 0.009
AJAX	11/11/66	Weapons related	<20	Shaft	^{131}I not detected
CERISE	11/18/66	Weapons related	<20	Shaft	^{131}I not detected
VIGIL	11/22/66	Weapons related	<20	Shaft	All: 0.0014
SIDECAR	12/13/66	Weapons related	<20	Shaft	All: 0.041
NEW POINT	12/13/66	Weapons effects	<20	Shaft	^{131}I not detected
RIVET II	01/26/66	Weapons related	<20	Shaft	All: 0.058
RIVET III	03/02/67	Weapons related	<20	Shaft	Trace
MUSHROOM	03/03/66	Weapons related	<20	Shaft	All: 0.38
HEILMAN	04/06/66	Weapons related	<20	Shaft	All: 0.031
COMMODORE	05/20/67	Weapons related	250	Shaft	Trace
KNICKERBOCKER	05/26/67	Weapons related	76	Shaft	^{131}I not detected
SWITCH	06/22/67	Plowshare	<20	Shaft	Trace
STANLEY	07/27/67	Weapons related	20-200	Shaft	^{131}I not detected
WASHER	08/10/67	Weapons related	<20	Shaft	^{131}I not detected
YARD	09/07/67	Weapons related	20-200	Shaft	^{131}I not detected
MARVEL	09/21/67	Plowshare	2.2	Shaft	^{131}I:<27
LANPHER	10/18/67	Weapons related	20-200	Shaft	^{131}I not detected
COGNAC	10/25/67	Weapons related	<20	Shaft	All: 0.064
SAZERAC	10/25/67	Weapons related	<20	Shaft	^{131}I: 0.0049
STACCATO	01/19/68	Weapons related	20-200	Shaft	^{131}I not detected
BRUSH	01/24/68	Weapons related	<20	Shaft	All: 0.00002
KNOX	02/21/68	Weapons related	20-200	Shaft	^{131}I not detected
RUSSET	03/05/68	Weapons related	<20	Shaft	All: 29
MILK SHAKE	03/25/68	Weapons related	<20	Shaft	^{131}I not detected
NOOR	04/10/68	Weapons related	20-200	Shaft	^{131}I not detected
SHUFFLE	04/18/68	Weapons related	20-200	Shaft	^{131}I not detected
SCROLL	04/23/68	Vela Uniform	<20	Shaft	All: 18,000

Table 2.4. cont'd

Test	Date (mo/d/y)	Purpose	Yield (kt)	Type	Release of ^{131}I or of all radioactive materials (Ci)
ADZE	05/28/68	Weapons related	<20	Shaft	All: 0.007
TUB	06/06/68	Weapons related	<20	Shaft	^{131}I not detected
FUNNEL	06/25/68	Weapons related	<20	Shaft	All: 0.00002
SEVILLA	06/25/68	Weapons related	<20	Shaft	All: 0.004
TANYA	07/30/68	Weapons related	20-200	Shaft	^{131}I not detected
IMP	08/09/68	Weapons related	<20	Shaft	All: 4,200
DIANA MOON	08/27/68	Weapons related	<20	Shaft	^{131}I: 0.1
NOGGIN	09/06/68	Weapons related	20-200	Shaft	^{131}I not detected
STODDARD	09/17/68	Plowshare	20-200	Shaft	^{131}I not detected
HULA	10/29/68	Weapons related	<20	Shaft	All: 0.06
TINDERBOX	11/22/68	Weapons related	<20	Shaft	^{131}I not detected
SCISSORS	12/12/68	Weapons related	<20	Shaft	All: 0.00013
PACKARD	01/15/69	Weapons related	10	Shaft	^{131}I not detected
BARSAC	03/20/69	Weapons related	<20	Shaft	^{131}I:<41
COFFER	03/21/69	Weapons related	<100	Shaft	^{131}I not detected
BLENTON	04/30/69	Weapons related	20-200	Shaft	^{131}I not detected
IPECAC	05/27/69	Weapons related	20-200	Shaft	Trace
TAPPER	06/12/69	Weapons related	<20	Shaft	^{131}I not detected
HUTCH	07/16/69	Weapons related	20-200	Shaft	^{131}I not detected
SPIDER	08/14/69	Weapons related	<20	Shaft	^{131}I not detected
PLIERS	08/27/69	Weapons related	<20	Shaft	^{131}I not detected
MINUTE STEAK	09/12/69	Weapons effects	<20	Shaft	^{131}I: 0.05
KYACK	09/20/69	Weapons related	20-200	Shaft	All: 510
SEAWEED	10/01/69	Weapons related	20-200	Shaft	All: 0.00000005
PIPKIN	10/08/69	Weapons related	200-1000	Shaft	^{131}I not detected
SEAWEED B	10/16/69	Weapons related	20-200	Shaft	All: 0.0000002
TUN	12/10/69	Weapons related	20-200	Shaft	All: 72
TERRINE	12/18/69	Weapons related	20-200	Shaft	^{131}I not detected
YANNIGAN	02/26/70	Weapons related	20-200	Shaft	^{131}I not detected
CYATHUS	03/06/70	Weapons related	8.7	Shaft	^{131}I:<1
HOD	05/01/70	Weapons related	<20	Shaft	^{131}I not detected
DIAMOND DUST	05/12/70	Vela Uniform	<20	Tunnel	^{131}I not detected
MANZANAS	05/21/70	Weapons related	<20	Shaft	^{131}I not detected
FLASK	05/26/70	Plowshare	105	Shaft	^{131}I not detected
HUDSON MOON	05/26/70	Weapons effects	<20	Tunnel	^{131}I:<49
PITON A	05/28/70	Weapons related	<20	Shaft	All: 25,000
ARNICA	06/26/70	Weapons related	20-200	Shaft	^{131}I not detected
SCREE	10/13/70	Weapons related	<20	Shaft	All: 11
TRUCHAS	10/28/70	Weapons related	<20	Shaft	All: 3
CREAM	12/16/70	Weapons related	<20	Shaft	^{131}I not detected
CARPETBAG	12/17/70	Weapons related	220	Shaft	^{131}I not detected
HAREBELL	06/24/71	Weapons related	20-200	Shaft	^{131}I not detected
CAMPHOR	06/29/71	Weapons effects	<20	Tunnel	^{131}I not reported[c]
MINAITA	07/08/71	Plowshare	83	Shaft	Trace

Table 2.4. cont'd

Test	Date (mo/d/y)	Purpose	Yield (kt)	Type	Release of ^{131}I or of all radioactive materials (Ci)
ZINNIA	05/17/72	Weapons related	<20	Shaft	^{131}I not detected
MIERA	03/08/73	Weapons related	20-200	Shaft	^{131}I not detected
ANGUS	04/25/73	Weapons related	20-200	Shaft	^{131}I: 0.0013
STARWORT	04/26/73	Weapons related	90	Shaft	^{131}I not detected
PORTULACA	06/28/73	Weapons related	20-200	Shaft	^{131}I not detected
BERNAL	11/28/73	Weapons related	<20	Shaft	^{131}I not detected
FALLON	05/23/74	Joint US-UK	20-200	Shaft	^{131}I not detected
ESCABOSA	07/10/74	Weapons related	20-200	Shaft	^{131}I not detected
PUYE	08/14/74	Weapons related	<20	Shaft	^{131}I: 0.000002
HYBLA FAIR	10/28/74	Weapons effects	<20	Tunnel	^{131}I not detected
CABRILLO	03/07/75	Weapons related	20-200	Shaft	^{131}I not detected
ESROM	02/04/76	Weapons related	20-200	Shaft	^{131}I not detected
BILLET	07/27/76	Weapons related	20-150	Shaft	^{131}I not detected
BANON	08/26/76	Joint US-UK	20-150	Shaft	^{131}I not detected
MARSILLY	04/05/77	Weapons effects	20-150	Shaft	^{131}I not detected
COULOMMIERS	09/27/77	Weapons related	20-150	Shaft	^{131}I not detected
BOBSTAY	10/26/77	Weapons related	<20	Shaft	^{131}I: 0.000003
HYBLA GOLD	11/01/77	Weapons effects	<20	Tunnel	^{131}I not detected
FARALLONES	12/14/77	Weapons related	20-150	Shaft	^{131}I not detected
CAMPOS	02/13/78	Weapons related	<20	Shaft	^{131}I: 0.000026
REBLOCHON	02/23/78	Weapons related	20-150	Shaft	^{131}I not detected
QUARGEL	11/18/78	Joint US-UK	20-150	Shaft	^{131}I not detected
KLOSTER	02/15/79	Weapons related	20-150	Shaft	^{131}I not detected
PEPATO	06/11/79	Weapons related	20-150	Shaft	^{131}I not detected
FAJY	06/28/79	Weapons related	20-150	Shaft	^{131}I not detected
TARKO	02/28/80	Weapons related	<20	Shaft	^{131}I not detected
NORBO	03/08/80	Weapons related	<20	Shaft	^{131}I not detected
FLORA	05/22/80	Weapons related	<20	Shaft	^{131}I: 1
VERDELLO	07/31/80	Weapons related	<20	Shaft	^{131}I: 0.007
MINERS IRON	10/31/80	Weapons effects	<20	Tunnel	^{131}I not detected
VIDE	04/30/81	Weapons related	<20	Shaft	^{131}I not detected
NIZA	07/10/81	Weapons related	<20	Shaft	^{131}I not detected
HAVARTI	08/05/81	Weapons related	<20	Shaft	^{131}I not detected
ISLAY	08/27/81	Weapons related	<20	Shaft	^{131}I not detected
TREBBIANO	09/04/81	Weapons related	<20	Shaft	^{131}I: 0.05
CABOC	12/16/81	Weapons related	<20	Shaft	^{131}I not detected
MOLBO	02/12/82	Weapons related	20-150	Shaft	^{131}I not detected
GIBNE	04/25/82	Joint US-UK	20-150	Shaft	^{131}I not detected
BOUSCHET	05/07/82	Weapons realted	20-150	Shaft	^{131}I:<0.0001
MONTEREY	07/29/82	Weapons related	20-150	Shaft	^{131}I not detected
FRISCO	09/23/82	Weapons related	20-150	Shaft	^{131}I not detected
HURON LANDING/ DIAMOND ACE	09/23/82	Weapons effects	<20	Tunnel	^{131}I not detected
MANTECA	12/10/82	Weapons related	20-150	Shaft	^{131}I not detected

Table 2.4. cont'd

Test	Date (mo/d/y)	Time (GMT)[b]	Yield (kt)	Type	Release of ^{131}I or of all radioactive materials (Ci)
CHEEDAM	02/17/83	Weapons related	<20	Shaft	^{131}I not detected
TURQUOISE	04/14/83	Weapons related	<150	Shaft	^{131}I: 0.000003
ARMADA	04/22/83	Joint US-UK	<150	Shaft	^{131}I not detected
CROWDIE	05/05/83	Weapons related	<20	Shaft	^{131}I not detected
MINI JADE	05/26/83	Weapons effects	<20	Tunnel	^{131}I not detected
DANABLU	06/09/83	Weapons related	<20	Shaft	^{131}I not detected
LABAN	08/03/83	Weapons related	<20	Shaft	^{131}I: 0.000011
ROMANO	12/16/83	Weapons related	20-150	Shaft	^{131}I not detected
GORBEA	01/31/84	Weapons related	20-150	Shaft	^{131}I not detected
AGRINI	03/31/84	Weapons related	<20	Shaft	^{131}I not detected
CAPROCK	05/31/84	Weapons related	20-150	Shaft	^{131}I not detected
KAPPELI	07/25/84	Weapons related	20-150	Shaft	^{131}I not detected
BRETON	09/13/84	Weapons related	20-150	Shaft	^{131}I not detected
TIERRA	12/15/84	Weapons related	20-150	Shaft	^{131}I not detected
VAUGHN	03/15/85	Weapons related	20-150	Shaft	^{131}I: 0.006
MISTY RAIN	04/06/85	Weapons effects	<20	Tunnel	^{131}I not detected
SALUT	06/12/85	Weapons related	20-150	Shaft	^{131}I not detected
VILLE	06/12/85	Weapons related	<20	Shaft	^{131}I not detected
MARIBO	06/26/85	Weapons related	<20	Shaft	^{131}I not detected
SERENA	07/25/85	Weapons related	20-150	Shaft	^{131}I not detected
DIAMOND BEECH	10/09/85	Weapons effects	<20	Tunnel	^{131}I not detected
MILL YARD	10/09/85	Weapons effects	<20	Tunnel	^{131}I not detected
GLENCOE	03/22/86	Weapons related	20-150	Shaft	^{131}I: 0.000009
JEFFERSON	04/22/86	Weapons related	20-150	Shaft	^{131}I not detected
PANAMINT	05/21/86	Weapons related	<20	Shaft	^{131}I: 0.001
CYBAR	07/17/86	Weapons related	20-150	Shaft	^{131}I not detected
CORNUCOPIA	07/24/86	Weapons related	<20	Shaft	^{131}I not detected
LABQUARK	09/30/86	Weapons related	20-150	Shaft	^{131}I not detected
BELMONT	10/16/86	Weapons related	20-150	Shaft	^{131}I not detected
GASCON	11/14/86	Weapons related	20-150	Shaft	^{131}I not detected
BODIE	12/13/86	Weapons related	20-150	Shaft	^{131}I not detected
HAZEBROOK	02/03/87	Weapons related	<20	Shaft	^{131}I not detected
HARDEN	04/30/87	Weapons related	20-150	Shaft	^{131}I not detected
MISSION GHOST	06/20/87	Weapons effects	<20	Tunnel	^{131}I not detected
PANCHUELA	06/30/87	Weapons related	<20	Shaft	^{131}I<0.3
LOCKMEY	09/24/87	Weapons related	20-150	Shaft	^{131}I: 0.001
BORATE	10/23/87	Weapons related	20-150	Shaft	^{131}I not detected
SCHELLBOURNE	05/13/88	Weapons related	<150	Shaft	^{131}I: 0.000035
BULLFROG	08/30/88	Weapons related	<150	Shaft	^{131}I not detected
BARNWELL	12/08/89	Joint US-UK	20-150	Shaft	^{131}I not reportedd

[a] The event produced detectable offsite ^{131}I contamination in milk with a maximum measured concentration of 180 pCi L^{-1} at Austin NVon 30 June. The Department of Energy has nevertheless classified this event as an onsite only release. The release of ^{131}I has not been reported.

[b] The total release of radioactive materials is estimated to be 400 Ci and to consist of xenons and iodines. The fraction of activity due to ^{131}I has not been reported.

[c] A controlled release of radioactive materials of 140 Ci has been estimated. The fraction of activity due to ^{131}I has not been reported.

[d] Information on the release of ^{131}I has not been found.

then the Alamogordo Bombing Range, and is now the White Sands Missile Range. Following this test, nuclear bombs were dropped on Hiroshima and Nagasaki, Japan, in August 1945. These bombs leveled both cities and ended the war in the Pacific. After the war, at various times between June 1946 and November 1962, five underwater and 101 atmospheric tests took place in the Pacific (mainly in the Marshall Islands, Christmas Island, and Johnston Atoll), and three atmospheric tests were conducted over the South Atlantic Ocean. Since July 1962, all nuclear tests conducted by the United States have been underground and most of them have been at the NTS. Five tests were conducted on the Nellis Air Force Bombing Range in the vicinity of the NTS; one in central Nevada; one in northwestern Nevada; three in New Mexico; two in Colorado; two in Mississippi; and three on Amchitka, one of the Aleutian islands off the coast of Alaska (U.S. Department of Energy 1993;1994).

The number and type of tests that were conducted by the U.S. through September 1992 are listed in *Table 2.5* for each location. *Figure 2.3* shows the location and the number of tests that took place in the continental U.S. (U.S. Department of Energy 1994).

2.5. PRODUCTION AND CHARACTERISTICS OF ^{131}I IN FALLOUT

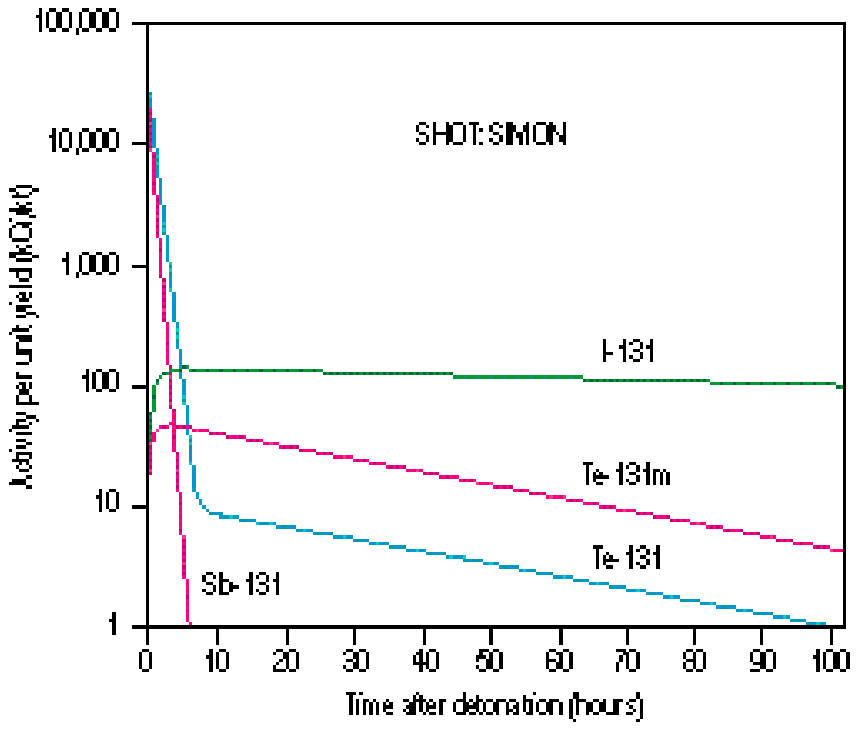
The production of ^{131}I in a nuclear test, its dispersion in the atmosphere and its deposition on the ground are discussed in the following section.

2.5.1. Production of ^{131}I

The detonation of a nuclear device creates hundreds of different kinds of radioactive atoms, or radionuclides. As these radioactive atoms decay, the number of original radionuclides drops while new decay products form. Over a period of time, most of the atoms become stable (non-radioactive), leaving a residue consisting of relatively few radionuclides. The term "half-life" is used to characterize the rate of decay of each radionuclide, i.e., the time it takes for that radionuclide to decay to one half of its initial activity. Radionuclides that decay rapidly have a short half-life, while those that decay more slowly have a longer half-life. For example, the isotope of caesium with a mass number of 137 (^{137}Cs) takes 30.2 years to decay to half of its initial activity, but ^{131}I decays to one half of its initial activity in about eight days.

Most of the activity of ^{131}I resulting from the fission process arises from the decay of short-lived precursors with half-lives ranging from 0.29 second to 30 hours. *Table 2.6* presents the radioactive precursors and decay products of ^{131}I, along with their radioactive half-lives and an example of their fractional independent yields; the latter represent the relative numbers of atoms with a mass number of 131 that are created during the nuclear explosion, expressed as a fraction of the fission-chain yield.[1] The fractional independent yields and the fission-chain yield vary slightly from one test to another; *Table 2.6* presents the values derived from measurements related to the shot Simon, detonated 25 April 1953 (Hicks 1981).

Figure 2.4. Activity of radionuclides of the 131 chain.



[1] The fission-chain yield is the total number of fissions creating atoms with the same mass number (in this case, 131) and is expressed as the percentage of the total number of fissions produced in the explosion.

Table 2.5. United States nuclear tests from July 1945 through September 1992 (Friesen 1985; U.S. Department of Energy 1993; 1994).

	Aboveground	Underground		Underwater	Total
		Cratering	Non-cratering		
Continental U.S.:					
NTS(through 1958)	97	2	20	0	119
NTS(since 1961)	3	8	798[a]	0	809
Other	6	0	11	0	17
Pacific:					
Johnston Island	12	0	0	0	12
Enewetak	41	0	0	2	43
Bikini	22	0	0	1	23
Christmas Island	24	0	0	0	24
Other	2	0	0	2	4
South Atlantic					
	3	0	0	0	3
Total	210	10	829	5	1054

[a] Including 24 tests conducted jointly with the United Kingdom

[b] Totals do not include two combat uses of nuclear weapons, which are not considered "tests". The first combat detonation was a 15-kt weapon airdropped on August 6, 1945, at Hiroshima, Japan, The second was a 21-kt weapon airdropped on August 9, 1945 at Nagasaki, Japan.

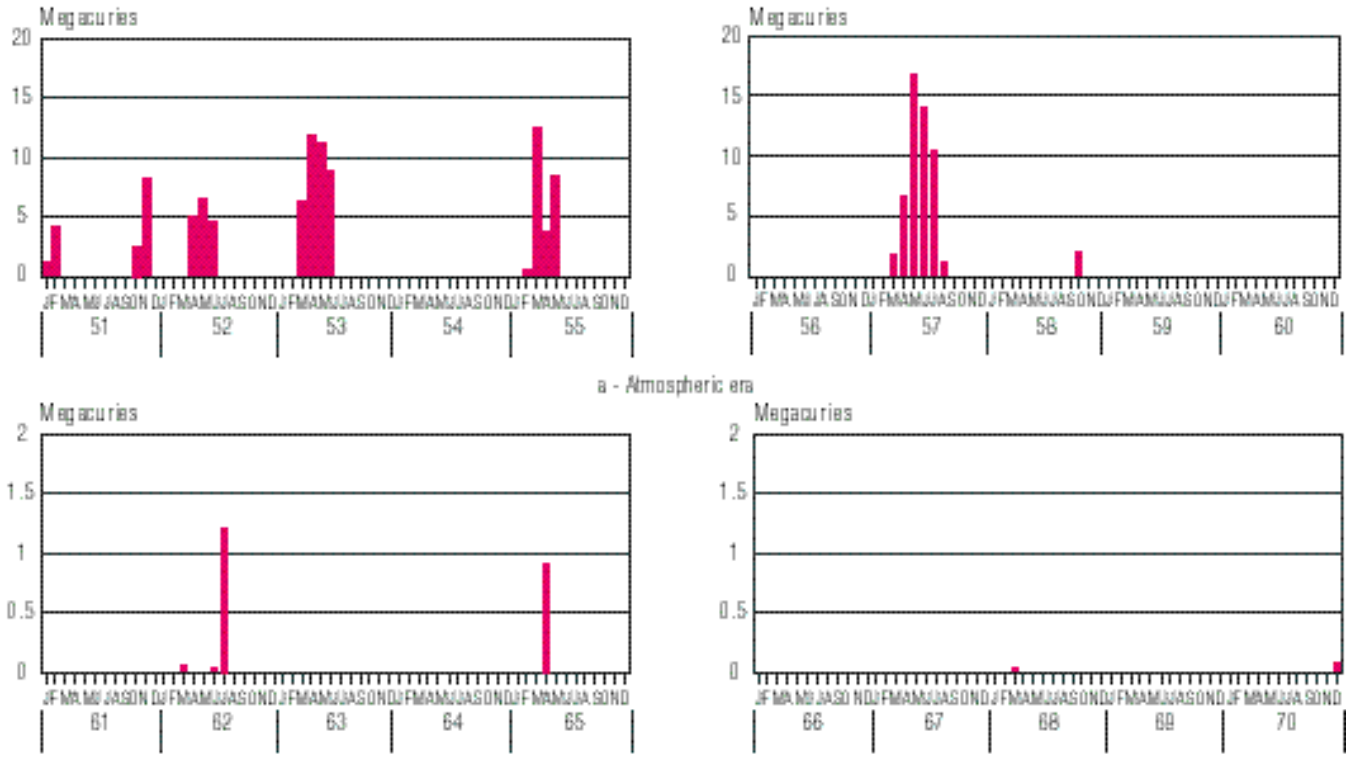
The variation of the activity of important radionuclides of the mass-131 decay chain with time after detonation was calculated using the parameter values given in *Table 2.6.* The results, presented in *Figure 2.4,* are related to the shot Simon but would be very similar for most of the tests conducted at the NTS. The activity of ^{131}I increases rapidly during the first few hours after detonation and then remains relatively constant for several days. About 150,000 curies (Ci) of ^{131}I are produced per kt of energy released. The actual amounts of ^{131}I released into the atmosphere in each nuclear test were calculated on the basis of measurements, as indicated in **Appendix 1.** The total activity of ^{131}I released into the atmosphere by the Nevada atmospheric bomb tests is estimated to be 150 MCi. *Figure 2.5* illustrates the distribution with time of the monthly releases of ^{131}I into the atmosphere. Most of the ^{131}I releases took place in the 1950s, with peaks above 10 MCi in a month in 1953, 1955, and1957. The highest monthly releases in the 1960s were in the neighborhood of 1 MCi. The last substantial monthly release of the monthly releases between 1971 and 1990 (not shown in *Figure 2.5*) are all below 0.0001 MCi.

It is worth noting that there is no practical possibility at the present time to detect the amounts of ^{131}I that were released into the environment in the 1950s. Because of its radioactive half-life of 8.04 days, ^{131}I decays to 2 x 10^{-14} of its initial value after one year, and to 2 x 10^{-479} of its initial value after 35 years. The amounts of ^{131}I still present in the environment are therefore infinitesimally small. Theoretically, ^{127}I and ^{129}I, other isotopes of iodine that are created by the fission process, could be used as tracers for ^{131}I (Holland 1963). Stable ^{127}I, as the endpoint of a low-yield fission product decay chain is produced in such small quantities when compared to the natural inventory that it cannot be used as a tracer for ^{131}I. The radioactive ^{129}I has a half-life of 16 million years, so that its activity at the present time is practically the same as it was 35 years ago. Unfortunately, the production of ^{129}I resulting from nuclear tests at the NTS constitutes a small fraction of the total activity of ^{129}I that has been released into the environment as a result of nuclear tests at other sites and of the reprocessing of nuclear fuel. In measurements of ^{129}I/^{127}I ratios in human thyroid tissues from Utah that had been stored in paraffin blocks since the 1940s and 1950s, Wrenn et al. (1992) found no statistical difference between the mean values of ^{129}I/^{127}I ratios prior to and after the start of atmospheric testing at the NTS in 1951.

2.5.2. Characteristics and Dispersion of the Radioactive Cloud

Nuclear tests (also called bursts, shots or events) releasing radioactivity into the air are categorized by the position of the detonation point relative to the earth's surface. This categorization arises from the direct and secondary explosion phenomenology as the explosion interacts with its environment. Whether or not the fireball created by the shot touches the

Figure 2.5. Chronology of atmospheric releases of I-131 resulting from nuclear tests at the NTS.



ground is the separating criterion between types. The typical air shot, of which the high-altitude shot is a special case, explodes at a height where the fireball is in its entirety above the surface of the earth so there is little or no interaction with the surface.

The important difference between an air shot and those involving the surface or sub-surface is that the resulting radioactive cloud from the latter two is very heavily loaded with ground debris. This debris includes the material initially vaporized or melted and the material drawn up into the cloud by the subsequent strong updraft.

The stabilization height, defined as the maximum height reached by the radioactive cloud, depends on the thermal buoyancy generated by the weapons' energy release into the atmosphere and by the ambient atmospheric conditions, primarily the stability of the atmosphere and its moisture content. The greater the heat generated by the explosion and released into the atmosphere, the greater is the thermal buoyancy and the higher the cloud ascends. The cloud from an airburst rises higher than a similar-sized surface or sub-surface event which loses heat in its ground interaction and has reduced thermal buoyancy.

The radioactive cloud that is formed after an atmospheric detonation near the ground surface usually is in the shape of a mushroom with a stem extending from the mushroom cloud base to the ground, and, if of sufficient energy, can penetrate to the highest layers of the troposphere, and occasionally reach into the stratosphere. As an example, *Figure 2.6* shows a schematic depiction of the mushroom cloud and stem resulting from the test Simon, which took place on 25 April 1953 (List 1954). The top of the radioactive cloud reached an altitude of 13.7 km. Eighty percent of the ^{131}I activity contained in the radioactive cloud was estimated to be between 9.5 km and 13.7 km; 10% was between ground level and 9.5 km, and the remaining 10% was deposited as local fallout.

As the radioactive cloud reaches its stabilization height, ambient meteorological conditions begin to exert their influence on its movement. Winds aloft begin to move the cloud downwind while atmospheric vertical motions and dispersion cause vertical and lateral cloud movement. As exemplified in *Figure 2.7* in the case of the test Simon, wind speeds and directions usually vary with altitude. These variations result in a substantial spread of the ^{131}I present in the radioactive cloud over large territories. *Figure 2.7* presents the paths of the trajectories followed by the portions of the radioactive cloud located at four altitudes after the test Simon. The entire radioactive cloud, which spread between those trajectories, covered about half of the continental United States. The meteorological model that

Figure 2.6. Schematic depiction of the mushroom cloud and stem resulting from the test Simon, detonated 25 April 1953.

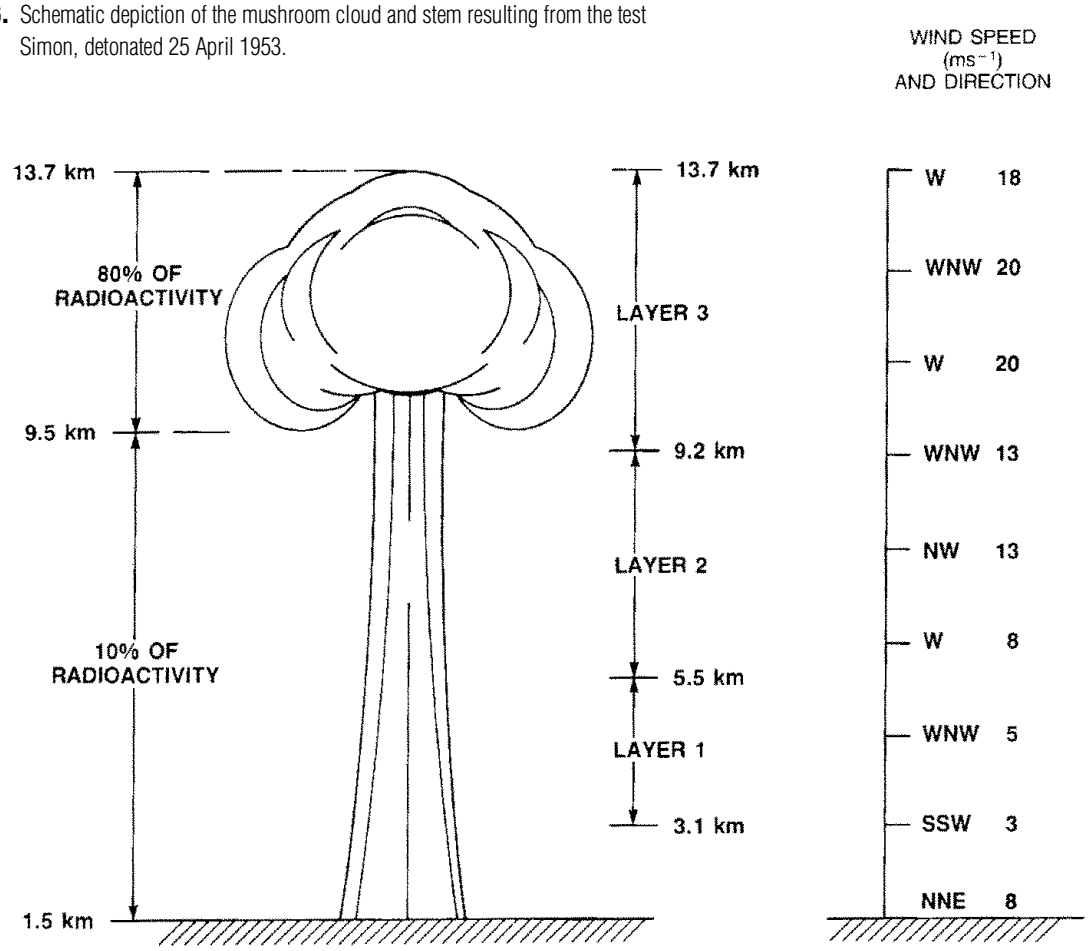


Table 2.6. Nuclear characteristics of the radionuclides of the 131 decay chain.

Name of radionuclide		Radioactive half-life (Lederer 1978)	Fractional independent fission yields (a) (Crouch 1977, Hicks 1981)
Indium-131	(In-131)	0.29 s	0.01
Tin-131	(Sn-131)	63 s	0.27
Antimony-131	(Sb-131)	23.03 min	0.47
Tellurium-131 isomer	(Te-131m)	30 n	0.00002
Tellurium-131	(Te-131)	25 min	0.23
Iodine-131	(I-131)	8.04 d	0.02
Xenon-131 isomer	(Xe-131m)	11.77 d	—
Xenon-131	(Xe-131)	stable	—
Fission-chain yield (a): 3.72%			

(a)Based on measurements related to the shot Simon detonated 25 April 1953; the values vary slightly from shot to shot

was used in this report to estimate the dispersion of the radioactive cloud is described in detail in **Appendix 1**.

2.5.3. Characteristics of ^{131}I in Fallout

A nuclear detonation creates a fireball of extremely high temperature that vaporizes everything in the immediate area. In an atmospheric detonation, as the fireball rises rapidly and begins to cool, some of the vaporized radioactive fission products condense from the gaseous state into droplets. Some of the more volatile elements such as iodine collect on the solid particles (soil and other materials) that have been drawn up into the cloud. In the absence of precipitation, large particles fall back to the earth's surface within a few hours (close-in, or local, fallout), smaller particles are deposited within a few days or weeks (intermediate, or tropospheric, fallout) while very small particles may be carried to high altitudes (in the stratosphere) and fall back to earth over a period of months to years (world-wide or global, fallout). When precipitation occurs, however, particles of any size are scavenged by rain as a result of (a) incorporation of particles in the raindrops as they are formed in the cloud, or (b) attachment of the particles to the raindrops as they fall to the ground.

The chemical and physical form of the ^{131}I is an important factor in estimating the amount of ^{131}I deposited on the ground. Limited measurements, unrelated to weapons testing at Nevada Test Site (NTS), show that ^{131}I from weapons tests is partitioned among three physico-chemical forms: gaseous organic, gaseous inorganic, and particulate (Perkins 1963; Perkins et al. 1965; Voilleque 1979). From measurements taken after a

Figure 2.7. Paths of the trajectories followed by portions of the radioactive cloud at the altitudes of 3.1, 5.5, 9.2, and 12.2 km above mean sea level (MSL) resulting from the test Simon detonated 25 April 1953. The closed dots represent the locations of the trajectories at 00:00 GMT, while the numbers near the closed dots are the day of the month. The open dots represent the locations of the trajectories at 06:00, 12:00 and 18:00 GMT.

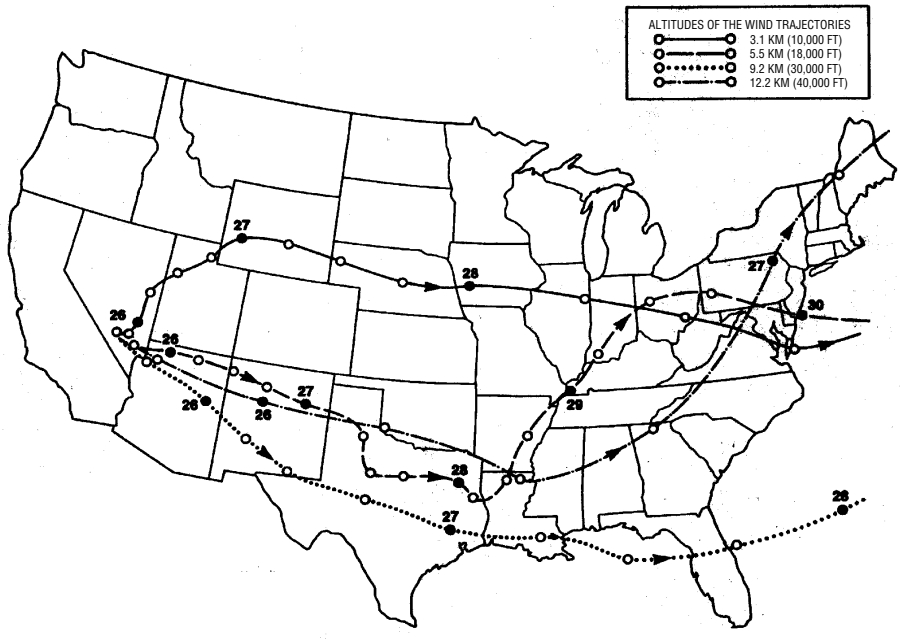
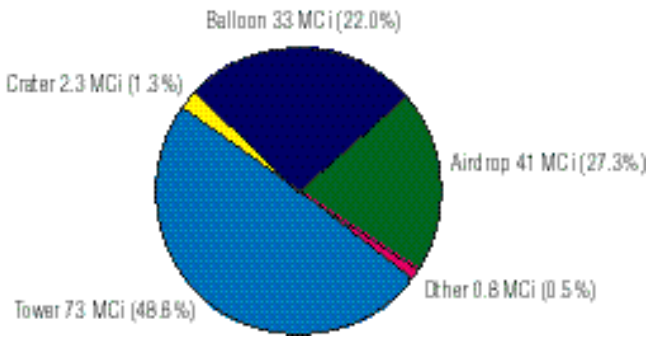


Figure 2.8. Distribution and activity releases of I-131 (MCi) into atmosphere according to type of test.



Chinese nuclear weapons test, the partitioning between these three forms was shown to vary with the time elapsed following the detonation (Voilleque 1979). At the request of the NCI, Voilleque (1986) reviewed the literature and estimated that more than half the ^{131}I from NTS fallout would be associated with particle diameters of less than about 20 m, with the remainder of the ^{131}I presumably in organic and inorganic gaseous forms. Because the behaviour of particles with respect to deposition processes is intermediate between those of gaseous organic and gaseous inorganic iodine, it is assumed for the purpose of the calculations that all of the ^{131}I was associated with particles. It is shown in **Appendix 7** that this assumption does not lead to a substantial bias in the estimates of ^{131}I deposition.

The pattern of local and intermediate fallout from a given nuclear test had unique characteristics determined by the meteorological conditions (e.g., wind speed and direction at all altitudes, atmospheric stability, precipitation) and by the characteristics of the initial radioactive cloud (e.g., physical dimensions, range of particle sizes, distribution of activity within the cloud). In general, tower and surface shots resulted in substantial local and intermediate fallout whereas very little close-in fallout was associated with airdrops or balloon events. *Figure 2.8* shows that about half of the total activity of ^{131}I released into the atmosphere as the result of the Nevada atmospheric bomb tests was due to tower shots, while the other half was contributed by airdrop and balloon events.

2.6. SUMMARY

- The Nevada Test Site (NTS), located in Nye county in southern Nevada, consists of 3,500 square kilometers of federally owned land with restricted access.

- Detonation of a nuclear device creates hundreds of radionuclides, among which are ^{131}I and its precursors, and is accompanied by a tremendous release of energy. The characteristics of the radioactive cloud produced by the explosion depend essentially on the energy released (yield) and on the location of the device in relation to the earth's surface. Above-ground nuclear tests of substantial yield result in radioactive clouds which extend vertically over 10 kilometers and carry radioactive debris that may fall back to earth over a period of months to possibly years.

- Low-yield nuclear tests have been conducted at the NTS since 1951. From January 1951 through October 1958, 119 tests were conducted, most of them above ground. Nuclear testing was interrupted between November 1958 and September 1961, but more than 800 tests were conducted from 1961 until September 1992; the overwhelming majority of those shots were detonated underground, under conditions that were designed for containment of radioactive debris. On October 2, 1992, the United States entered into another unilateral moratorium on nuclear weapons testing announced by President Bush. President Clinton extended this moratorium in July 1993, and again in March 1994 until September 1995 (U.S. Department of Energy 1994).

- The total activity of ^{131}I released into the atmosphere is estimated to have amounted to 150 MCi; most of this activity was released in the 1950s, with peaks in 1953 and in 1957.

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