Preliminary Studies/Background

Book 1

CERCLA Preliminary Assessment of DOE's Nevada Operations Office Nuclear Weapons Testing Areas Vol. II, April 1988

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CERCLA PRELIMINARY ASSESSMENT OF DOE'S NEVADA OPERATIONS OFFICE NUCLEAR WEAPONS TESTING AREAS

Prepared by

Water Resources Center
Desert Research Institute
University of Nevada System

VOL. II

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CONTENTS

VOLUME I

SECTION 3.1

COVER SHEET

NAME OF SITE: Tonopah Test Range, Nevada

LOCATION: The Tonopah Test Range (TTR) is located in south central Nevada between longitudes 116°24′ and 116°55′W, and between latitudes 37°33′ and 37°53′N.

DISPOSITION: The TTR is operated by the Sandia National Laboratory (SNL) for the DOE. The DOE was permitted the use of this area through a Memorandum of Understanding (MOU) by the Department of Air Force in November, 1956. TTR has restricted access.

PRELIMINARY ASSESSMENT REPORT
TONOPAH TEST RANGE (TTR)

INTRODUCTION

TTR is located in south central Nevada. The site, approximately 26 by 24, is surrounded on the east, west, and south sides by the Nellis Air Force Range (NAFR) (Figure 3.1.1). The area to the north of TTR is controlled by the Bureau of Land Management (BLM). Tonopah, the nearest town by road, is located 35 miles to the northwest while Las Vegas is located 140 miles to the southeast. Due west is Goldfield, the geographically nearest town to TTR (26 miles), however, access is not allowed on the dirt road that connects the two areas.

OVERALL FACILITY DESCRIPTION

In 1963 parts of TTR were used for a series of safety shots called operation Roller Coaster*. These safety shots distributed plutonium and other transuranics over parts of the test range.

Prior to the MOU between the Department of Air Force and the ERDA (now DOE), TTR was used as a bombing range. Since 1969 Sandia National Laboratory (SNL) has been operating the TTR for DOE.

SNL's principal responsibility is research and development of nuclear ordnance: the arming, fusing, and firing systems used in U.S. nuclear bombs and warheads. Components in these systems developed by Sandia include power supplies and timing mechanisms, radars, switches, and other parts and circuitry which make up the intricate actuating and control systems of those bombs and warheads. In addition, SNL designs bomb casings for the weapons which would be dropped from aircraft. In the case of warheads, SNL's job is one of team-play with missile designers to assure compatibility of each device with its delivery vehicle.[15]

The TTR is located in south central Nevada within the Basin and Range physiographic province. The boundaries of the TTR encompass several basins or portions of basins and several mountains. The majority of the facilities and test

* One of the safety shots of operation Roller Coaster was conducted on the Nellis Air Force Range, just beyond the TTR boundary. For the purpose of this investigation it will be considered part of TTR.

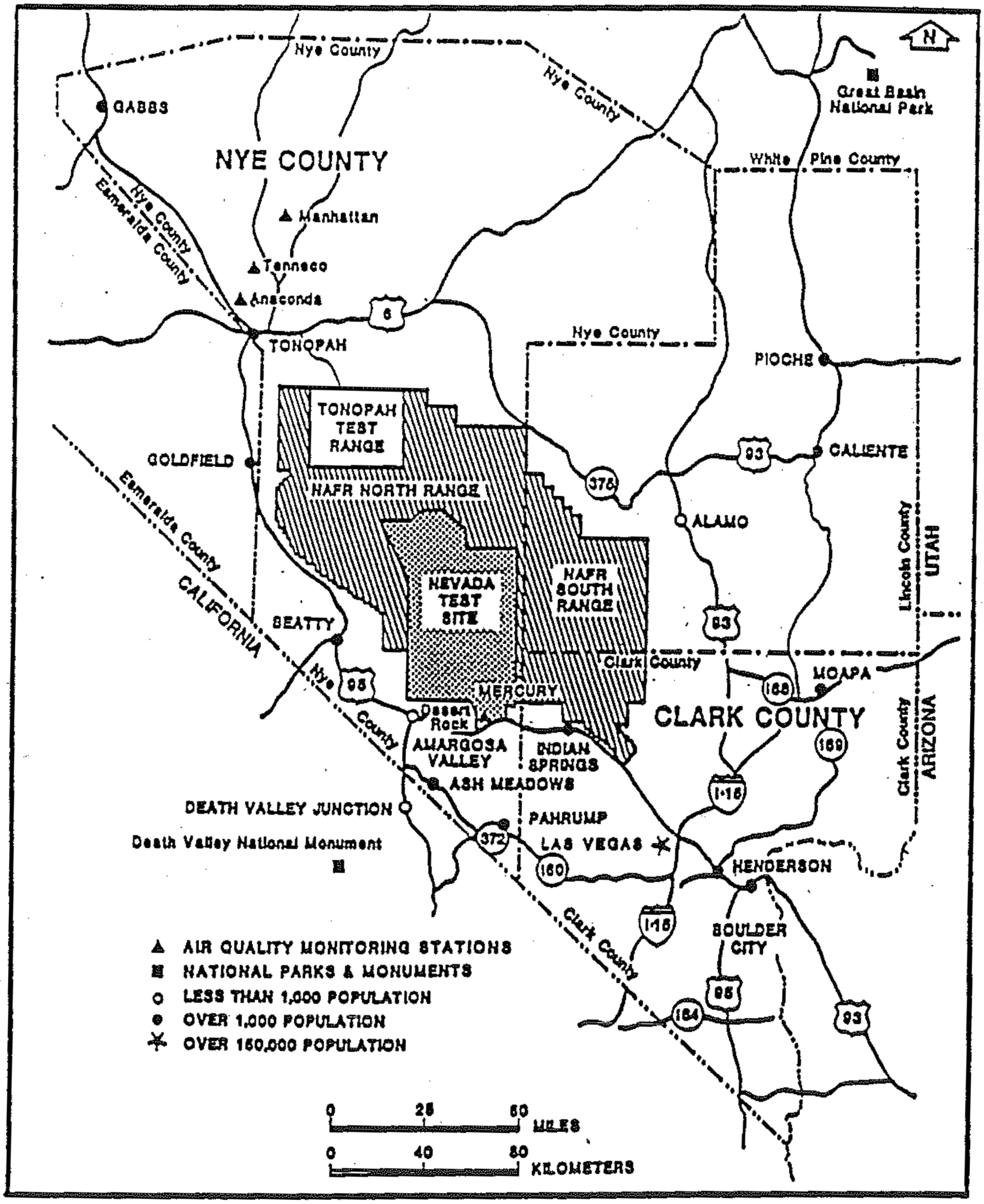

FIGURE 3.1.1. Location Map of the Tonopah Test Range.

areas are located in Cactus Flat (Figure 3.1.2), however, one of the safety shots of operation Roller Coaster did occur in Stonewall Flat, the basin adjacent to Cactus Flat.

The northeastern side of Cactus Flat is bordered by the Kawich Range which has a maximum elevation of 9,404 ft. To the south and southeast several low-lying hills separate Cactus Flat from Gold Flat. The northeastern portion has a low-lying topographic divide separating it from Stone Cabin Basin. The Cactus Range, which has a maximum elevation of 7,482 ft, separated Cactus Flat and Stonewall Flat. Cactus Flat, which lies at 5,500 ft, has several playa lakes which occur along the long axis of the central portion of the valley. Stonewall Flat (4,650 ft) has one playa which is not located within the boundaries of TTR.

The facilities at the TTR consist of two main areas of development, areas 3 and 9, and many isolated sites which contain targets, contravallutions, radars, telescopes, or telemetry stations (Figure 3.1.3). Area 3 is the Control Point Area. Its facilities include housing administration, an airstrip, a control tower, operation control facilities, telemetry playback equipment, and maintenance shops. Area 9 is the center for rocket and gun firings.[15]

ENVIRONMENTAL SETTING

As previously mentioned, TTR is surrounded on 3 sides by the Nellis Air Force Range. This area is used for the training of aircrews and operational evaluations of weapon system capability.[15] Access to this area and to the TTR is restricted. North of the TTR the land is managed by the BLM. It is open range which is used for cattle grazing.

The nearest national park or monument to the TTR is Death Valley National Monument. It is located 50 miles to the southwest of the Cactus Range.

Table 3.1.1 shows a list of endangered, threatened, or sensitive plants that are known to occur at the TTR.[10] This list includes species protected under the Nevada Revised Statutes as well as those designated by the Northern Nevada Native Plant Society.

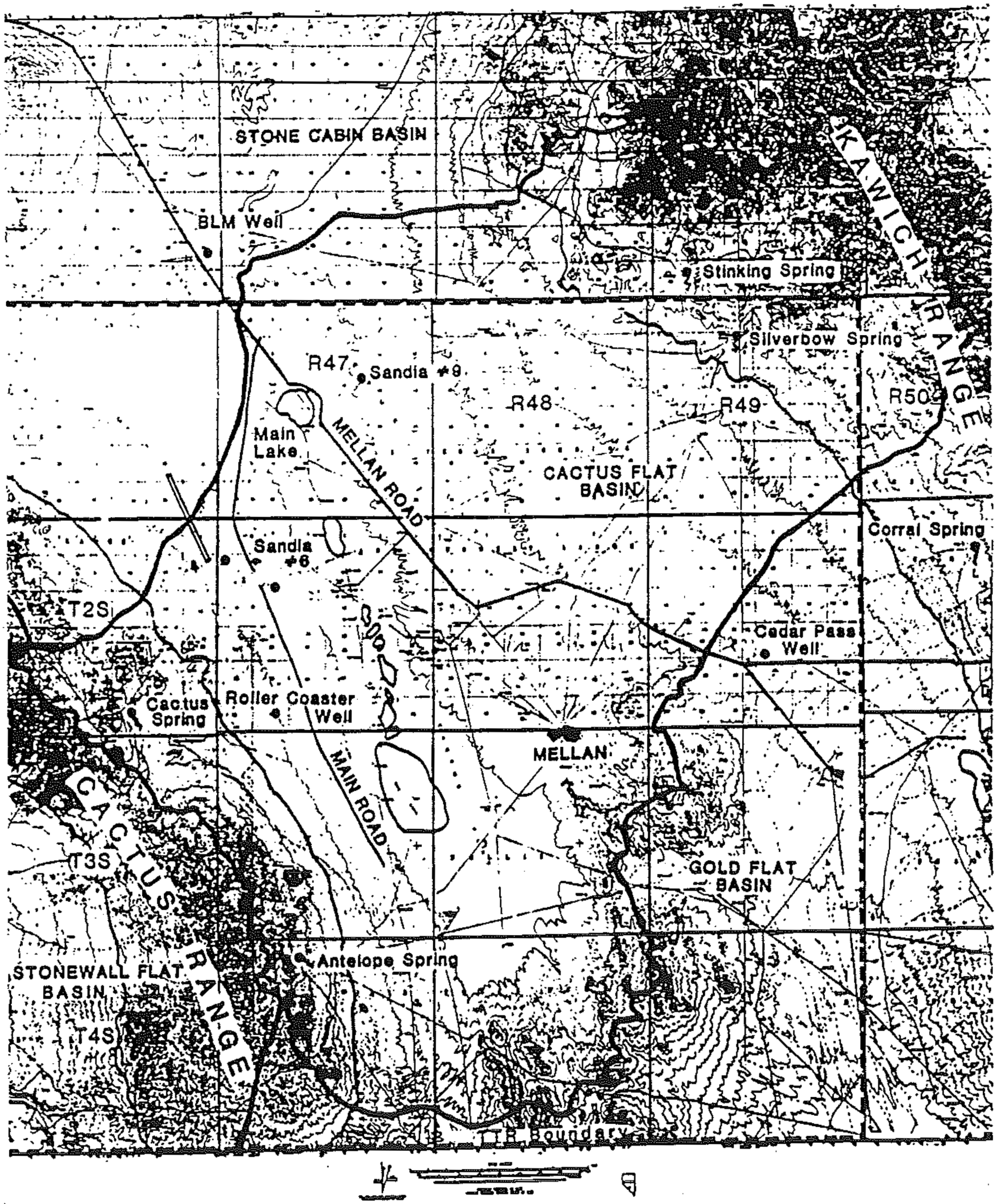

FIGURE 3.1.2. Physiographic Map of Cactus Flat.

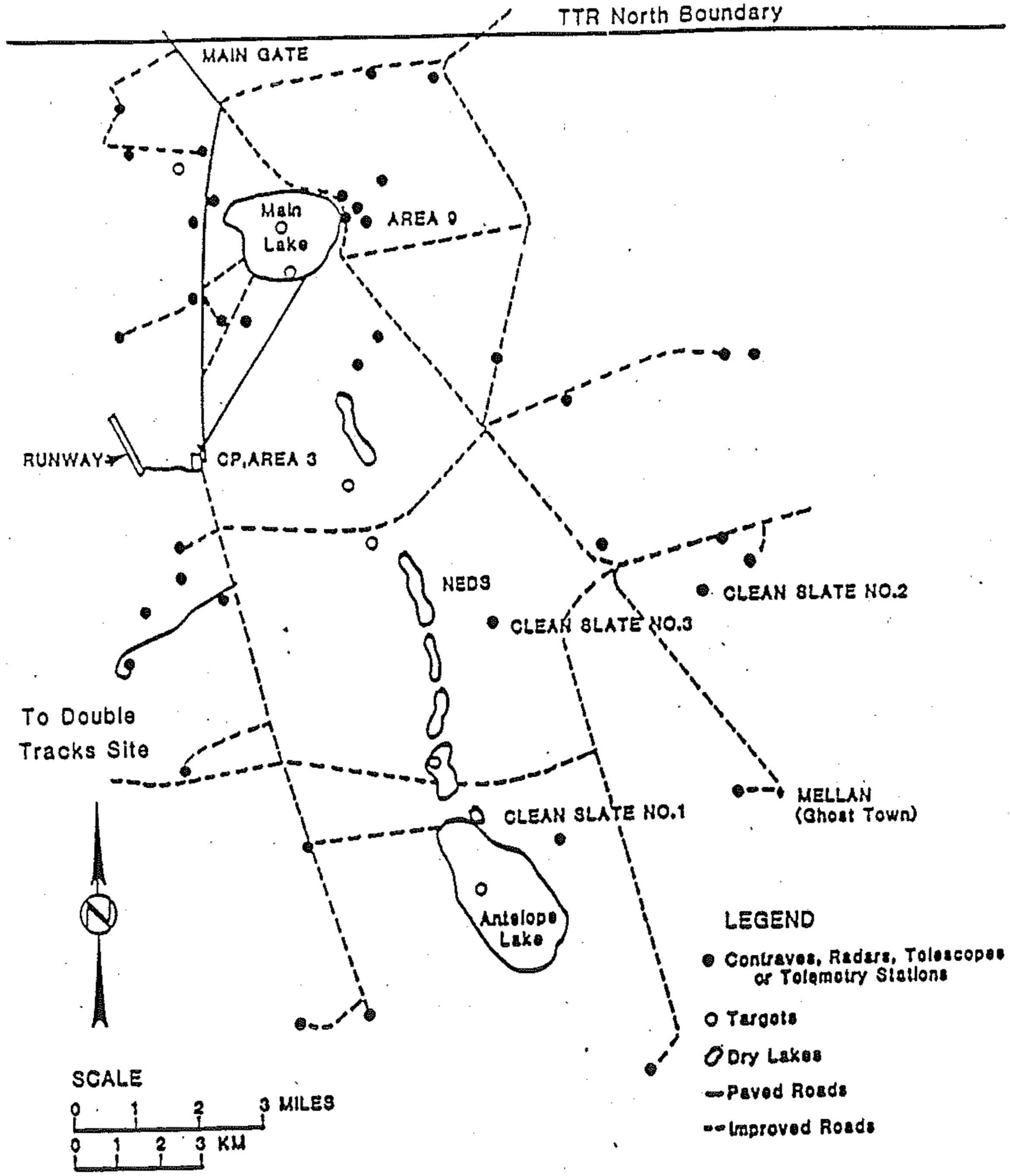

FIGURE 3.1.3. Facility Map of TTR.

TABLE 3.1.1. ENDANGERED, THREATENED OR SENSITIVE PLANT TAXA KNOWN TO OCCUR ON THE TONOPAH TEST RANGE.

Species	Federal[1] Status	Nevada[2] Status	NNNPS[3] Status
Asclepias eastwoodiana	2C	—	W
Coryphantha vivipara var. rosea	3C	E	Dc
Gilia nyensis	3C	—	OR
Opuntia pulchella	3C	E	Dc
Phacelia mustelina	3C	—	OR
Sclerocactus polyancistrus	3C	E	Dc

[1] Federal status codes include:

- 2C Candidate 2 - USFWS need more information before listing is possible.
- 3C Non-candidate - Taxa are considered to be more widespread than originally thought, and (or) have no identifiable threat.

[2] Nevada status codes include:

- E Protected by Nevada Revised Statute 527.270 as a critically endangered plant, or by NRS 527.060 under the Cacti and Yucca Law.
- — Indicates that no status has been given.

[3] NNNPS (Northern Nevada Native Plant Society) status codes include:

- W Watch - Taxa of uncertain abundance and distribution, and (or) for those whose threats cannot be defined to a reasonable degree.
- OR Other Rare - Taxa of limited distribution, but not under any presently known threat.
- Dc Deletion - Category c deletion indicates that taxa are more widespread than originally thought, and (or) have no identifiable threat.
- RFT Recommended Federal Threatened - Taxa have been recommended for threatened status.

HYDROGEOLOGIC SUMMARY

Since the Roller Coaster test was conducted in two separate valleys, two separate ground-water systems are of importance. However, because these are restricted areas and for all practical purposes undeveloped, little is known about the aquifers. Typically, the valleys or more properly grabens of the Basin and Range Province contain thousands of feet of alluvial material eroded from adjacent mountain ranges. The particle size and distribution varies widely throughout these grabens.

In Cactus Flat, well logs indicate the sediments are composed of gravels, sands, silts, and clays. Continuous confining layer are not present, so the aquifers that are used for water production are phreatic.[5] The depth to ground water in Cactus Flat ranges from 90 to 150 ft,[15] depending on the surface elevation of the well.

Less is known of the Stonewall Flat ground-water system. Desert Well, the only well in Stonewall Flat, has no recorded well log. The stratigraphy would be expected to be similar to that of Cactus Flat. The depth to water at Desert Well was reported to be 110 ft.[12]

Regional ground-water discharge from both of these systems is believed to be toward Sarcobatus Flat, but data are insufficient to confirm this hypothesis.[13]

The precipitation pattern in Nevada is principally related to topography. Stations at higher elevations generally receive more precipitation than those at lower elevations. On the valley floors, where precipitation is small, little precipitation infiltrates into the ground-water reservoirs. The greater precipitation in the mountains provides most of the recharge. Water reaches the ground-water reservoirs by seepage loss from streams on the alluvial apron and by underflow from the consolidated rocks.

A climatology study was conducted at the TTR from 1961 to 1967.[14] The meteorologic station was located 1 mile southwest of Main Lake. Table 3.1.2 shows the monthly averages for this period at Cactus Flat.

Monthly average precipitation records for Tonopah (elevation 6,093 ft) and Tonopah Airport (elevation 5,426 ft) are also available. These records are shown in Table 3.1.3. Table 3.1.4 is a 46-year record of average annual precipitation at Tonopah.[13]

HUMAN RECEPTORS

With the exception of the employees at the TTR, there are no inhabitants within 4 miles of this site. The nearest town is Goldfield, which is 26 miles to the west. The 1970 population was 300. The closest town by road is Tonopah; it had a 1970 population of 1,716. Both of these communities are expected to be somewhat larger at this time.

Several wells have been drilled in Cactus Flat for the purpose of supplying potable water. They will be discussed in detail under site specific descriptions.

TABLE 3.1.2. PRECIPITATION, 7-YEAR AVERAGES (1961-1967).

	Total Precipitation (inches)	Total Snow, sleet (inches)	Number of Days			
			Precipitation 0.01 inch or more	Snow, sleet 1.0 inch or more	Thunderstorms	Fog
January	0.19	2	1	1	0	1
February	0.24	3	2	1	0	1
March	0.19	3	4	2	1	1
April	0.40	4	5	2	1	1
May	0.56	3	4	1	1	1
June	0.54	0	4	0	2	0
July	0.30	0	3	0	1	0
August	1.06	0	5	0	1	0
September	0.61	0	2	0	1	0
October	0.11	1	1	0	0	0
November	0.40	2	4	1	0	1
December	0.23	1	2	1	0	1
Year	4.92	19	37	9	8	7

TABLE 3.1.3. AVERAGE MONTHLY AND ANNUAL PRECIPITATION, IN INCHES, AT TONOPAH, NEVADA FOR THE PERIOD 1941 TO 1953 AND FOR TONOPAH AIRPORT FOR 1951 TO 1961.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Tonopah	0.32	0.37	0.69	0.76	0.39	0.27	0.43	0.31	0.24	0.59	0.57	0.49	5.46
Tonopah Airport	0.23	0.16	0.15	0.23	0.51	0.08	0.51	0.55	0.34	0.28	0.25	0.14	3.44

TABLE 3.1.4. ANNUAL PRECIPITATION, IN INCHES, AT TONOPAH, NEVADA FOR THE PERIOD 1907 TO 1953.

Date	Precipitation	Date	Precipitation	Date	Precipitation
1907	5.24	1923	4.99	1939	7.26
1908	5.30	1924	4.10	1940	4.56
1909	7.49	1925	5.59	1941	6.29
1910	4.22	1926	2.13	1942	2.19
1911	4.93	1927	1.92	1943	6.56
1912	4.06	1928	2.63	1944	3.49
1913	6.75	1929	3.36	1945	5.73
1914	4.46	1930	4.60	1946	10.27
1915	6.58	1931	6.53	1947	3.66
1916	6.59	1932	3.88	1948	6.11
1917	4.21	1933	2.19	1949	5.85
1918	5.37	1934	3.48	1950	5.08
1919	4.56	1935	3.40	1951	4.99
1920	4.06	1936	5.06	1952	7.89
1921	5.86	1937	4.39	1953	2.91
1922	4.89	1938	7.71		

ENVIRONMENTAL RECEPTORS

Because of the nature of the contamination from operation Roller Coaster both plants and animals are possible receptors. Tables 3.1.5 and 3.1.6 present the environmental receptors commonly found at the TTR.

HISTORY

Operation Roller Coaster is the name given to a joint Atomic Energy Commission, Department of Defense, and United Kingdom research program conducted in 1963. Operation Roller Coaster consisted of four safety-shots named Double Tracks and Clean Slate I, II, and III. These tests were designed to study plutonium dispersal from accidental non-nuclear explosions of plutonium-bearing weapons and to evaluate storage, handling, and transportation criteria for them as well.[4] At each of these tests, plutonium-bearing weapons were demolished with chemical explosives. The amount of plutonium in each of these tests was in the low kilogram range, although the exact amounts are not specified.[15]

TABLE 3.1.5. VEGETATION COMMONLY FOUND AT TTR.

		Salt Desert Shrub	Northern Desert Shrub	Pine-Juniper Woodland
Gymnospermae				
Pinaceae - Pine family				
Pinon pine	*Pinus monophylla*			X
Cupressaceae - Cypress family				
Utah juniper	*Juniperus osteosperma*			X
Angiospermae - Monocotyledonae				
Gramineae - Grass family				
Galleta	*Hilaria jamesii*	X		
Bluebunch wheatgrass	*Agropyron spp*		X	
Squirreltail	*Sitanion hystrix*		X	
Indian ricegrass	*Oryzopsis hymenoides*	X		
Nevada bluegrass	*Poa nevadensis*		X	
Agavaceae - Agave family				
Joshua tree	*Yucca brevifolis*		X	
Angiospermae - Dicotyledoneae				
Salicaceae - Willow family				
Fremont's cottonwood	*Populus fremontii*			X
Chenopodiaceae - Goosefoot family				
White sage (winter-fat)	*Eurotia lanata*	X		
Four-wing saltbush	*Atriplex canescens*	X		
Shadscale	*Atriplex confertifolia*	X		
Haletogen	*Haletogen glomeratus*	X		
Bailey's greasewood	*Sarcobatus baileyi*	X		
Greasewood	*Sarcobatus vermiculatus*	X		
Russian thistle (tumbleweed)	*Salsola kali*	X		
Compositae - Aster family				
Black sagebrush	*Artemsia nova*	X		
Bud sagebrush	*Artemisia spinescens*	X		
Big sagebrush	*Artemisia tridentata*		X	
Rubber rabbitbrush	*Chrysothamnus nauseosus*		X	
Green rabbitbrush	*Chrysothamnus viscidiflorus*	X	X	
Spiny hopsage	*Grayia spinosa*	X		

TABLE 3.1.6. FAUNA FOUND AT TTR.

		Salt Desert Shrub	Northern Desert Shrub	Pine-Juniper Woodland
<u>Mammals</u>				
Audubon cottontail	*Silvilagus audubonii*			X
Black-tailed jackrabbit	*Lepus californicus*		X	
Cliff chipmunk	*Eutamias dorsalis*		X	
Least pocket mouse	*Perognathus longimembris*	X		
Great Basin pocket mouse	*Perognathus parvus*		X	
Dark kangaroo mouse	*Microdipodops megacephalus*	X		
Ord kangaroo rat	*Dipodomys ordii*	X	X	X
Chisel-toothed kangaroo rat	*Dipodomys microps*	X	X	
Western harvest mouse	*Reinthrodontomys megalotis*		X	
Canyon mouse	*Peromyscus crinitus*			X
White-footed deer mouse	*Peromyscus maniculatus*	X	X	X
Pinon mouse	*Peromyscus truei*			X
Northern grasshopper mouse	*Onychomys leucogaster*		X	
Desert wood rat	*Neotoma lepida*			X
Coyote	*Canis latrans*	X	X	X
Kit fox	*Vulpes macrotis*	X	X	
Badger	*Taxidea taxus*	X		
Bobcat	*Lynx rufus*	X	X	X
Mule deer	*Odocoileus hemionus*			X
<u>Reptiles</u>				
Desert horned-lizard (horned toad)	*Phrynosma platyrhinos*	X		
Sagebrush lizard	*Sceloporus graciosus*		X	
Western fence lizard	*Sceloporus occidentalis*			X
Side-blotched lizard	*Uta stansburiana*	X	X	X
Whip-tailed lizard	*Cnemidophorus tigris*	X		
Gophersnake	*Pituophis catenifer*		X	
Speckled rattlesnake	*Crotalus mitchelli*	X	X	X
<u>Birds</u>				
Golden eagle	*Aquila chrysaetos*		X	
Sage grouse	*Centrocerus urophasianus*		X	
Mourning dove	*Zenaidura macroura*	X		X
Poor-will	*Phalaenoptilus nuttallii*			X
Dusky flycatcher	*Empidonax oberholseri*			X
Horned lark	*Eremophila alpestris*	X	X	
Raven	*Corvus corax*		X	
Mountain chickadee	*Parus gambeli*			X
Bushtit	*Psaltriparus minimus*			X
White-breasted nuthatch	*Sitta carolinensis*			X
Bewick's wren	*Thryomanes bewickii*			X
Sage trasher	*Oreoscoptes montanus*	X	X	
Gray vireo	*Vireo vicinor*			X
Black-throated gray warbler	*Dendroica nigrescens*			X
Vesper sparrow	*Pooecetes gramineus*	X		
Lark sparrow	*Chondestes graminacus*		X	
Black-throated sparrow	*Amphispiza bilineata*		X	
Brewer's sparrow	*Spizzela breweri*	X		

Real–time event monitoring was accomplished with air samplers tethered to balloon dirigibles and with photographic equipment.

Cleanup activities included scraping the highly contaminated ground and collecting large debris such as concrete and metal, then burying this waste near each respective ground zero (GZ). The areas were then fenced to restrict access.

WASTE GENERATION AND DISPOSAL

The waste generated during the tests consisted of plutonium from the weapon as well as other possible contaminants in the weapon or chemical explosives. Disposal consisted of burying the highly contaminated soils at GZ. The total quantity of waste is unknown.

OVERALL SITE AND HAZARD ASSESSMENT

The Double Tracks site was the only site with enough information to rank it with respect to the HRS scoring system. It had a score of 0.86.

Data on worker population was not correctly available on the Clean Slate site and was not scored. Data collected during the PA phase is presented, however.

SITE SPECIFIC DESCRIPTION

Name of Site - Double Tracks

Location - Double Tracks is the name given to a safety-shot conducted on the Nellis Bombing and Gunnery Range on May 15, 1963. The GZ of Double Tracks is located 5 miles to the west of TTR and 14 miles due east of the town of Goldfield (Figure 3.1.4).

HISTORY

The Double Tracks experiment consisted of demolishing one plutonium-bearing weapon with chemical explosives on a concrete pad (Figure 3.1.5).[4] Following the Double Tracks test, decontamination efforts were limited to blading the immediate shot area back into the GZ.[1] The GZ area was fenced at a radius sufficient to enclose the GZ compacted area contaminated by throw out and jetting. Signs were placed at strategic locations to warn people of impending dangers. Because of renewed concern about the contaminated area, in 1972 the fenced areas were moved to restrict access to a larger area.

WASTE GENERATION AND DISPOSAL

The waste generated during the test consisted of plutonium from the weapon as well as potentially other contaminants in the weapon or chemical explosives. Disposal consisted of burying the highly contaminated soils at GZ. The total quantity of waste is unknown.

KNOWN RELEASES

Following the test, but on the same day, a survey using a Eberline PAC-39 (Proportional Air Counter) was conducted downwind of GZ. The results of this survey are presented in Figure 3.1.6.[4] The 2000 counts per minute (cpm) contour represents a contamination level of 10 $\mu g/m^2$.

Subsequently, radiation surveys were performed on an annual basis by the Environmental Surveillance Branch of Reynolds Electrical & Engineering Co. Figure 3.1.7 shows the results of the survey performed in June of 1966.[6] The upper value represents the average value recorded at each site while the lower value represents the maximum value recorded.

Estimates of the amount of plutonium in the top 5 cm of soil were made on the basis of a FIDLER* survey. The results of this survey are reported in Table

* Field instrument for the detection of low energy radiation.

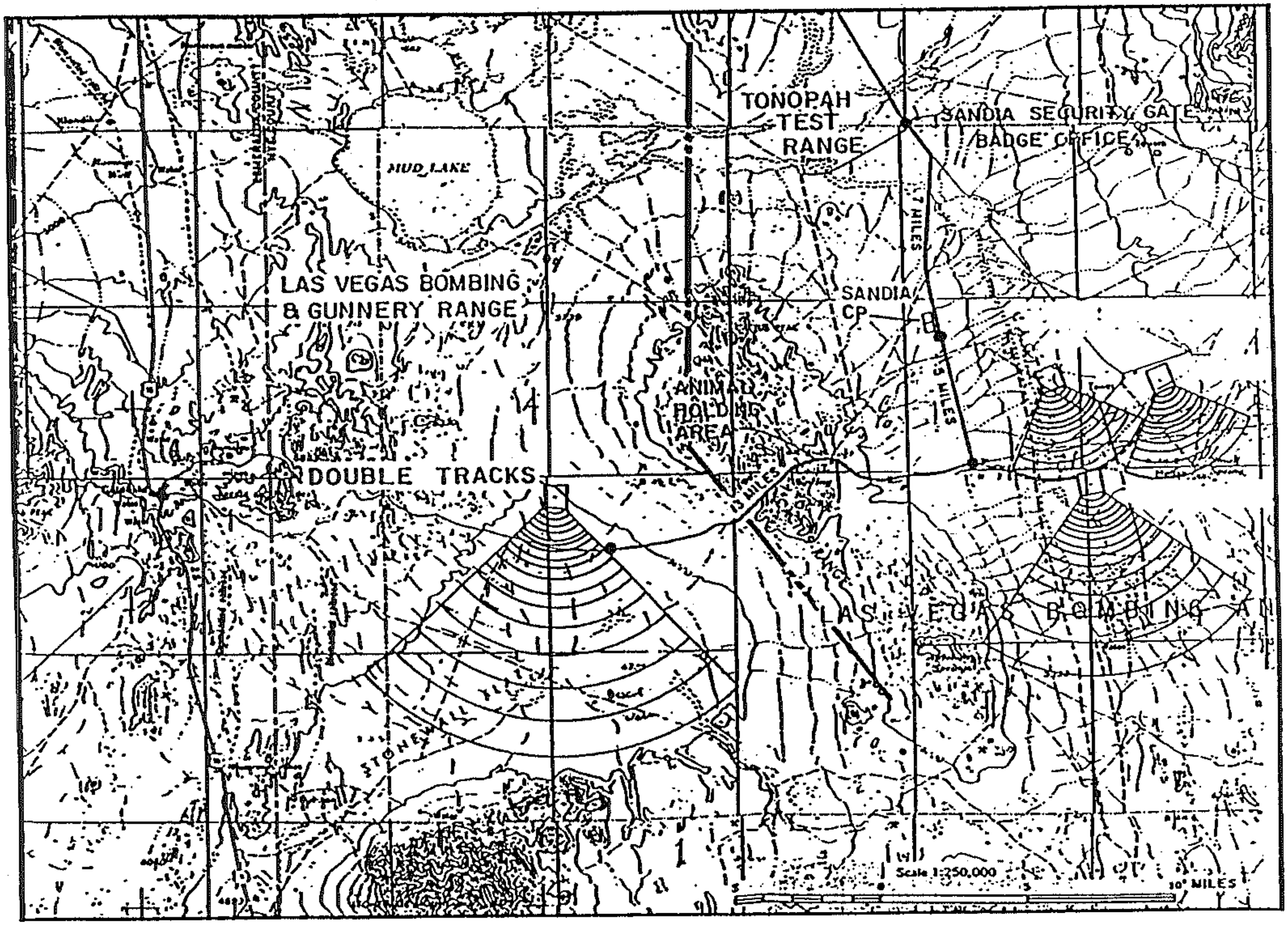

FIGURE 3.1.4. Location Map of Double Tracks Test Area.

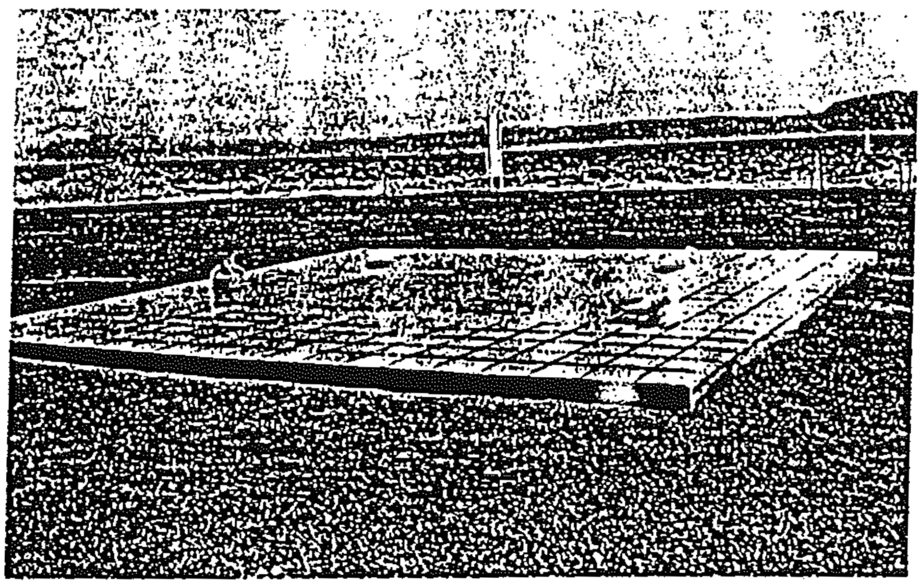

FIGURE 3.1.5. Double Tracks Ground Zero Before Event.

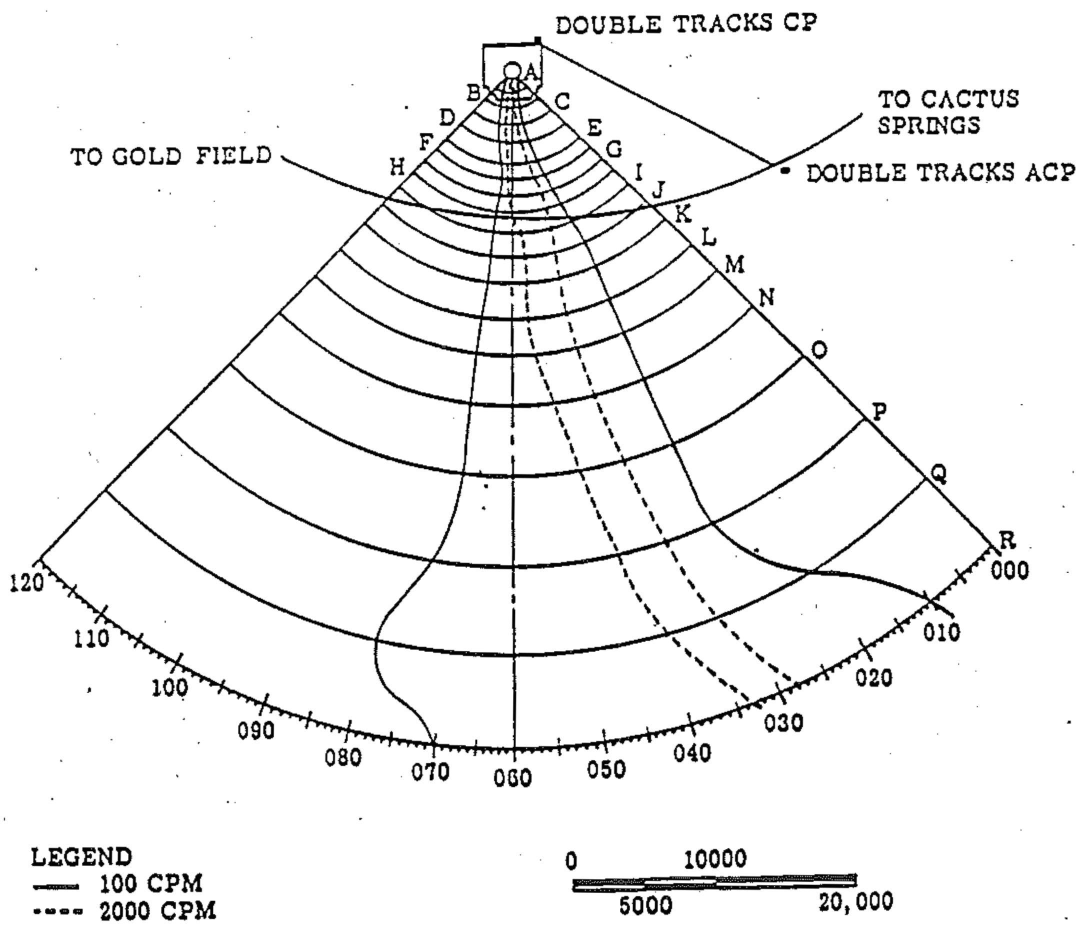

FIGURE 3.1.6. Radiation Survey of Double Tracks.

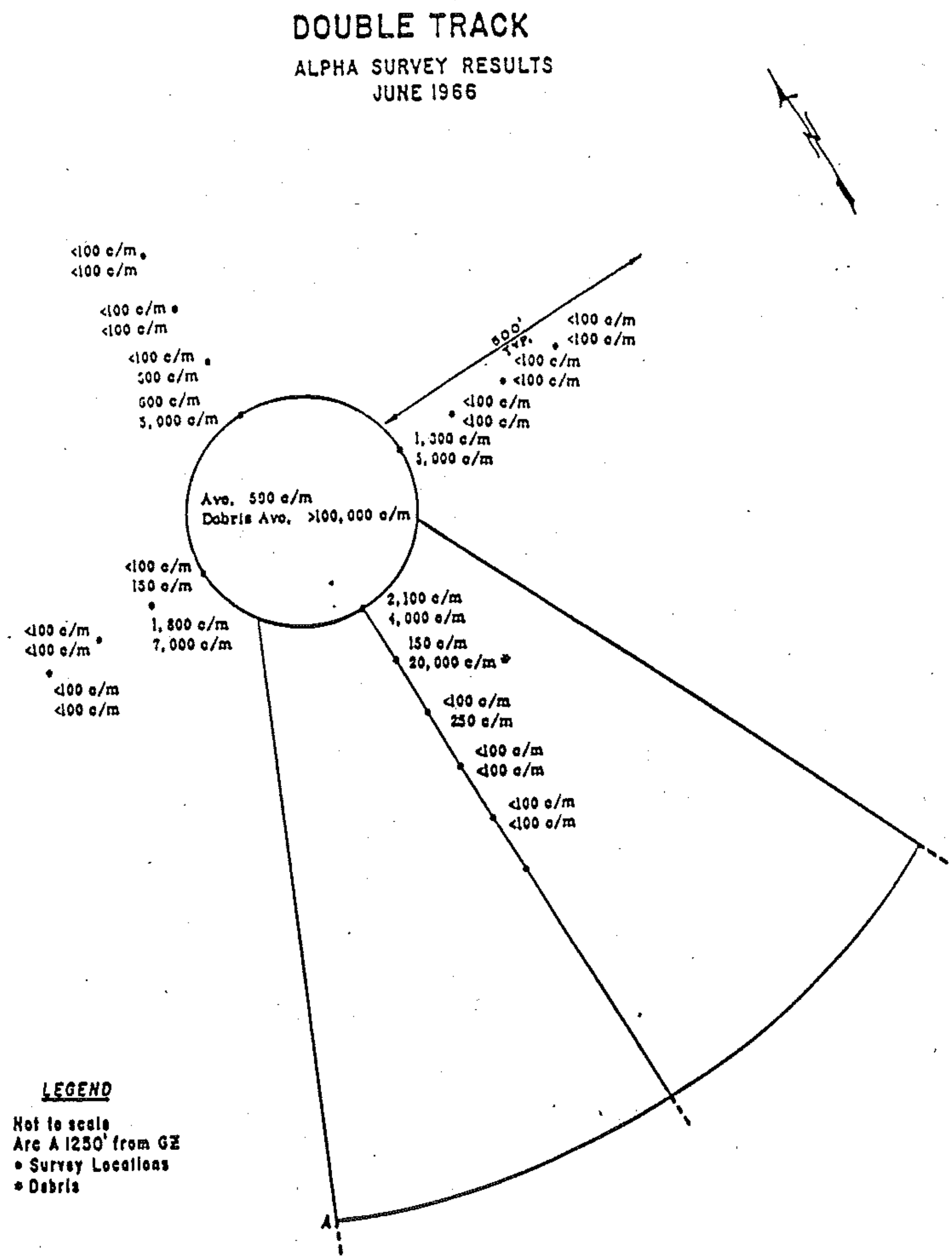

FIGURE 3.1.7. Double Tracks Alpha Survey, June 1966.

3.1.7.9 It should be emphasized that these are only statistical estimates and only include the top 5 cm of soil. The material buried near GZ as well as highly contaminated debris would not be included in these estimates.

POTENTIAL FOR DIRECT CONTACT OR FIRE/EXPLOSION HAZARD

Because of the restricted nature of this site, the potential for direct contact by humans is low. The highly contaminated GZ area is fenced with signs that warn of the potential hazard. It should be noted that the contaminants from this test were detected up to 10 miles from the GZ, and no efforts were made to decontaminate the area except in the close proximity of GZ. Several unimproved roads lead from highway 95 and Goldfield to the vicinity of this test. It is not known what security measures the Air Force uses to restrict access to this area.

Fire and explosion hazard is expected to be very low due to the dispersed nature of the contaminants. This site is located in a basin which has little vegetation. However, since this site is located on a bombing range, the potential for spreading plutonium from bombing activities does exist.

POTENTIAL FOR GROUND-WATER RELEASE

The area contaminated by the Double Tracks test is quite extensive. Much of this area is coincident with alluvial fans and ephemeral stream channels. From studies conducted on the Nevada Test Site, the potential for ground-water recharge in this type of environment is present. In fact, soil surveys conducted at the Double Tracks site shows that plutonium has migrated to a depth of 25 cm at a minimum.[7] Another potential source of ground-water contamination is the Desert Well. The well was in place during the Double Tracks test and it is located downwind within the contaminated area.

NUMBER OF WELLS WITHIN A FOUR-MILE RADIUS

Only one well is known to be present within 4 miles of the Double Tracks site. Desert Well is actually located in the area contaminated by the test. Although the status and use of this well are unknown, it is doubtful that it is presently being used for any purpose. The next closest well is probably located in Goldfield, which is 15 miles to the west.

There is no well log available for Desert Well, the only known well is this basin. Therefore, nothing is known of the hydrostratigraphy.

TABLE 3.1.7. CORRECTED ESTIMATES OF INVENTORY $^{239-240}$Pu IN SURFACE SOIL (0-5 CM DEPTH) AT FOUR SITES ON THE TONOPAH TEST RANGE.

Area	Strata	Size of Area		n	Mean ± S.E. ++ (µCi/m²)	Estimated Inventory ± S.E. (Curies)	Percent of Total Inventory	Estimated 95% C.L. on Inventory (Curies)		c+++ of Inventory Estimate
		m	Percent					Lower	Upper	
Double Track	1	176,000	98.3	23	6.7 ± 3.5	1.2 ± 0.62	33	-0.09	2.5	0.52
	2	1,600	0.9	11	350 ± 250	0.56 ± 0.40	16	-0.33	1.5	0.71
	3	800	0.4	10	190 ± 59	0.15 ± 0.047	4	0.044	0.26	0.31
	4	600	0.3	9	2,800 ± 1,000	1.7 ± 0.60	47	0.32	3.1	0.35
	Total	179,000	99.9	53		3.6 ± 0.95	100	1.7	5.5	0.26
Clean Slate 1	1	157,000	88.9	21	15 ± 7.0	2.4 ± 1.1	58	0.11	4.7	0.46
	2	10,000	5.7	13	64 ± 22	0.64 ± 0.22	15	0.16	1.1	0.34
	3	8,400	4.5	13	110 ± 35	0.92 ± 0.29	22	0.29	1.6	0.32
	4	1,700	1.0	10	120 ± 39	0.20 ± 0.066	5	0.05	0.35	0.33
	Total	177,100	100.1	57		4.2 ± 1.2	99	1.8	6.6	0.29
Clean Slate 2	1	351,000	74.7	18	4.1 ± 1.3	1.4 ± 0.46	8	0.43	2.4	0.33
	2	82,300	17.4	12	73 ± 30	6.0 ± 2.5	34	0.50	12	0.42
	3	26,200	5.5	13	270 ± 99	7.1 ± 2.6	41	1.4	13	0.37
	4	11,000	2.3	20	260 ± 65	2.9 ± 0.72	17	1.4	4.4	0.25
	Total	470,500	99.9	63		17 ± 3.7	100	9.6	24	0.22
Clean Slate 3	1	1,615,000	93.2	28	12 ± 2.2	19.4 ± 3.6	52	12	27	0.19
	2	61,000	3.5	12	58 ± 16	3.5 ± 0.98	9	1.3	5.6	0.28
	3	40,000	2.3	13	210 ± 63	8.4 ± 2.5	23	3.0	14	0.30
	4	16,000	0.9	10	370 ± 190	5.9 ± 3.0	16	-0.89+	13	0.51
	Total	1,732,000	99.9	63		37 ± 5.4	100	26	48	0.15

* These negative values result from the statistical uncertainty in the estimate of $^{239-240}$Pu.
++, +++ Reported in Romney et al. (1975), p. 64.

POTENTIAL FOR SURFACE WATER RELEASE

The Landsat-5 image of Cactus Flat indicates that several ephemeral channels from the Cactus Range, Goldfield Hills, and Stonewall Mountain cross the contaminated area. These drainages terminate in the playa in the central portion of the basin.[16] No permanent water exists in the area.

POTENTIAL FOR AIR RELEASE

Resuspension of plutonium in the environment is a function of the availability of the contaminant, the particle size, the wind characteristics, and the topography.

The concern of the resuspension potential prompted an air sampling survey that was conducted by the Environmental Surveillance group in 1966. This survey was accomplished with a cab-mounted air sampling device and several stationary air sampling devices placed downwind. The vehicle was driven around the area to induce air suspension of the material. The results of this survey are presented in Table 3.1.8. This information, combined with the results of the alpha survey of the site, indicates that there has been little resuspension of contaminated material.[8]

TABLE 3.1.8. GROSS ALPHA RADIOACTIVITY OF AIR SAMPLES COLLECTED AT TONOPAH TEST RANGE JUNE 29, 1966.

Sample Description	Gross Alpha µCi/cc	% 2 Sigma error
Hurricane High Volume Sampler (11 cm Whatman filter paper)		
4.95 m^3 in Double Tracks general area	4.82×10^{-13}	52.3
8.49 m^3 25 ft south of Double Tracks exclusion fence	2.81×10^{-13}	52.3
Hurricane High Volume Sampler (18.5 cm Whatman filter paper)		
16.13 m^3 25 ft south of Double Tracks exclusion fence	7.23×10^{-13}	18.1
9.41 m^3 Double Tracks general area	4.76×10^{-13}	32.2

THREATS TO THE FOOD CHAIN AND ENVIRONMENT

The significance of vegetation in any plutonium-contaminated area rests primarily upon its capacity to function as the carrier of plutonium and other transuranics to animals and man.

Two mechanisms are responsible for the introduction of these contaminants into vegetation. Most important is the occurrence of these contaminants becoming superficially entrapped on the vegetation. The other mechanism is the uptake of the contaminant through the roots.[11] Table 3.1.9 shows some results of a plant survey at the Double Tracks site. It should be noted that americium, which is present as an impurity and as the daughter product of plutonium, is more readily available to the plant community than plutonium. It may be that americium poses a more significant problem than plutonium.[8]

Animals may introduce these contaminants into the food chain by methods other than ingestion of contaminated vegetation. Burrowing animals that live on the contaminated site will inhale contaminated material. Also ingestion from preening activities is a strong possibility for these animals.

TABLE 3.1.9. $^{239-240}$Pu CONTENTS OF VEGETATION AND SOIL SAMPLES AND THE VEGETATION/SOIL RATIOS FOR SAMPLES FROM AGED Pu-FALLOUT AREAS.

Activity	Vegetation (nCi/g dry issue)		Soil (nCi/g)		Vegetation/Soil Ratio		
Strata	n	Mean ± S.E.[a]	n	Mean ± S.E.[a]	n	Ratio ± S.E.[b]	r[c]
TTR DOUBLE TRACKS (1963)							
1	17	0.010 ± 0.0035	24	0.12 ± 0.057	14	0.094 ± 0.088	0.67
2	9	0.072 ± 0.029	10	5.7 ± 4.0	7	0.024 ± 0.025	0.95
3	11	0.11 ± 0.036	10	2.9 ± 0.97	8	0.035 ± 0.011	0.92
4	11	0.49 ± 0.16	9	44.0 ± 15.0	8	0.011 ± 0.020	0.11

[a] Standard error of mean = $[\text{Var.}/n]^{1/2}$

[b] Ratio = $\Sigma y_i/\Sigma x_i$; and

[c] S.E. = $\{ [\sum (y_i^2/x_i) - (\sum y_i)^2/\sum x_i]/(n-1)\sum x_i \}^{1/2}$

CONCLUSION AND RECOMMENDATIONS

A preliminary HRS was conducted for the Double Tracks site and is included in Appendix 3.1.A.1. Using the existing HRS system, the Double Tracks site had a migrating score of 0.86.

The site appears to pose a threat to flora and fauna in the area. More detailed studies will be necessary to fully assess this threat. Until these studies are completed, final site status, i.e., cleanup cannot be evaluated.

SITE SPECIFIC DESCRIPTION

Name of Site - Clean Slates I, II, and III

Location - Because of their close proximity to each other, and the similarity of these tests, they will be described together. Clean Slate I was conducted on May 25, 1963. This test involved the demolition of 9 weapons of which only one contained plutonium. The other weapons contained depleted uranium.[15] These devices were demolished with chemical explosives on a concrete pad. The location of this test is shown in Figure 3.1.8.

HISTORY

Clean Slate II was conducted on May 25, 1963. This test involved the demolition of 19 weapons of which only one contained plutonium and the others contained depleted uranium.[15] These devices were placed in a bunker that had 2 ft of earth cover, then demolished with chemical explosives. The location of the Clean Slate II test is shown in Figure 3.1.8. This bunker is shown before and after the test in Figures 3.1.9 and 3.1.10.[4]

Clean Slate III was conducted on June 9, 1963. Like Clean Slate II it involved 19 devices, only one of which contained plutonium. They were placed in a bunker that had 8 ft of earth cover then demolished with chemical explosives. The location for this test is shown in Figure 3.1.8.

WASTE GENERATION AND DISPOSAL

The exact amount of plutonium involved in each of these tests is classified information, but it is reported that each test involved plutonium in the low kilogram range.[15]

The clean-up and disposal of the contaminated debris from all of these sites followed the same procedures. The debris in the vicinity of each GZ and fragments out to a range of 2,500 ft were collected and buried in a pit inside the fenced GZ area. The highly contaminated GZ area was scraped to a depth of several inches. This material was subsequently buried or mounded then covered with uncontaminated earth, compacted, and watered.

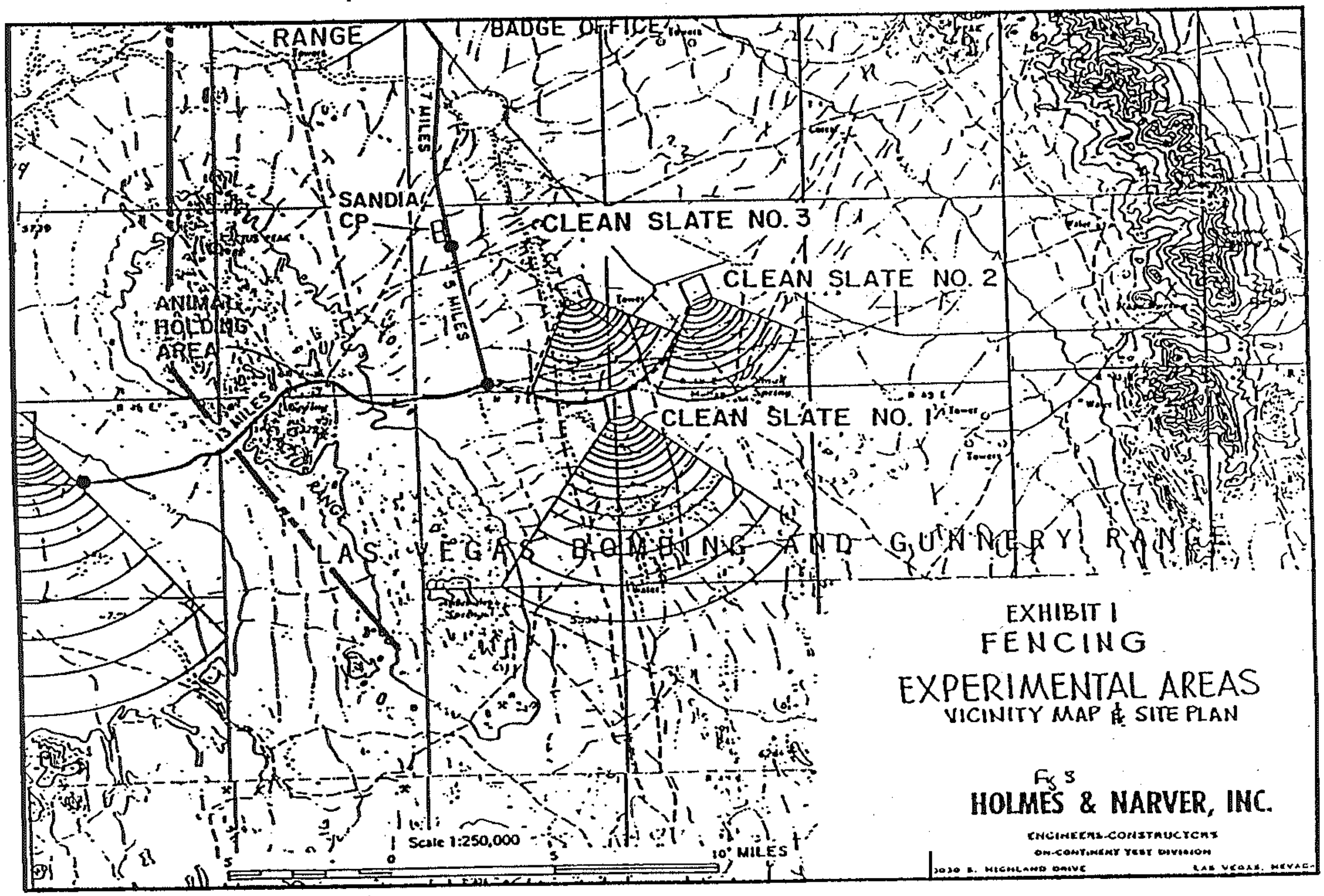

FIGURE 3.1.8. Location Map of Clean Slates I, II, and III.

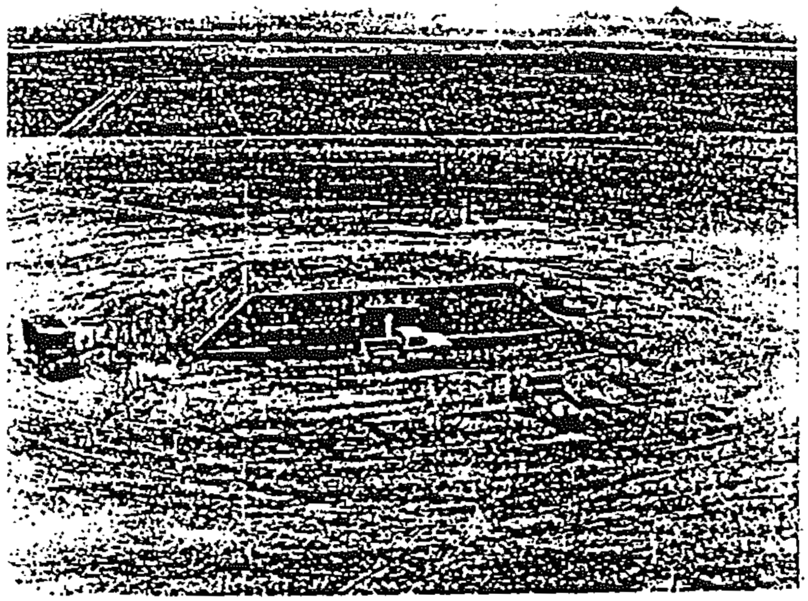

FIGURE 3.1.9. Clean Slate II Bunker before the Event. Clean Slate III was similar to this.

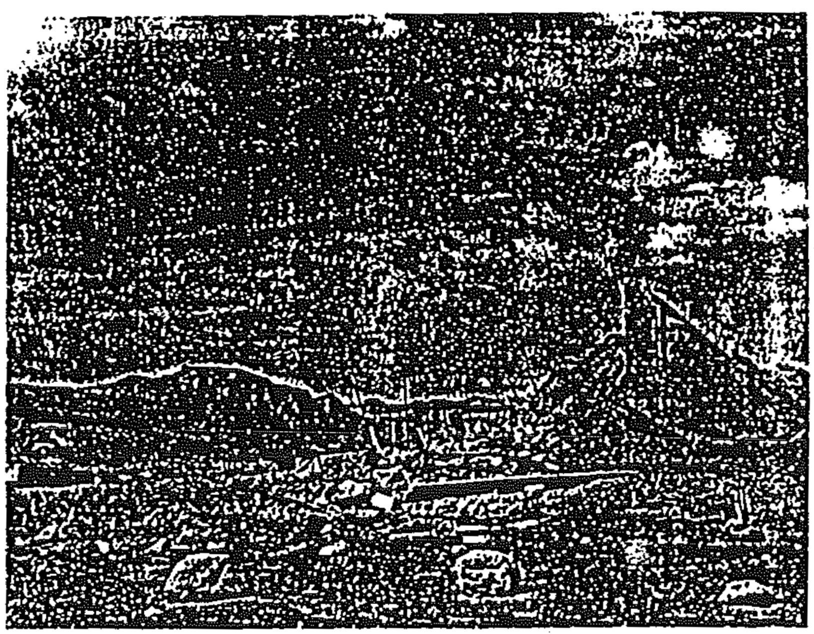

FIGURE 3.1.10. The Clean Slate II Bunker after the Event. Note the Concrete Debris and Metallic Fragments, all of which were Highly Contaminated.

KNOWN RELEASES

On the day of the test, radiation surveys were conducted at each site with a Eberline PAC-39. The results of this survey are presented in Figures 3.1.11 through 3.1.13. The area enclosed by the 2000 cpm intervals represents a minimum contamination of 10 $\mu g/m^2$.[8]

Subsequently, radiation surveys were performed on an annual basis by the Environmental Surveillance Branch of Reynolds Electrical and Engineering Co. Inc., Figures 3.1.14 through 3.1.16 show the results of the June 1966 survey. The upper value represents the average reading over a 1 m^2 area while the lower number represents the maximum reading over the same area.

Estimates of the amount of plutonium in the top 5 cm of soil were made on the basis of a FIDLER survey. The results of this survey are reported in Table 3.1.7.[9] It should be emphasized that these are only statistical estimates and only include the top 5 cm of soil. The material buried near GZ as well as highly contaminated debris would not be included in these estimates.

POTENTIAL FOR DIRECT CONTACT OR FIRE/EXPLOSION HAZARD

The potential for direct contact with the Clean Slate sites is low. As already stated, access to the TTR is restricted and within Cactus Flat security measures are adequately enforced. The highly contaminated GZ areas are fenced and well-marked. A working population of an unknown number is located within a 4-mile radius of Clean Slate III.

Fire and explosion are also not expected to be problems for these sites. Sparse vegetation and operations on Cactus Flat are not conducive to these hazards.

POTENTIAL FOR GROUND-WATER RELEASE

As with the Double Tracks site migration of contaminated material to the ground water is possible. However, the Landsat-5 image of this area indicates considerably more vegetation is present at the Clean Slate sites than was present at the Double Tracks site.[10] This vegetation should significantly reduce ground-water recharge in these locations.

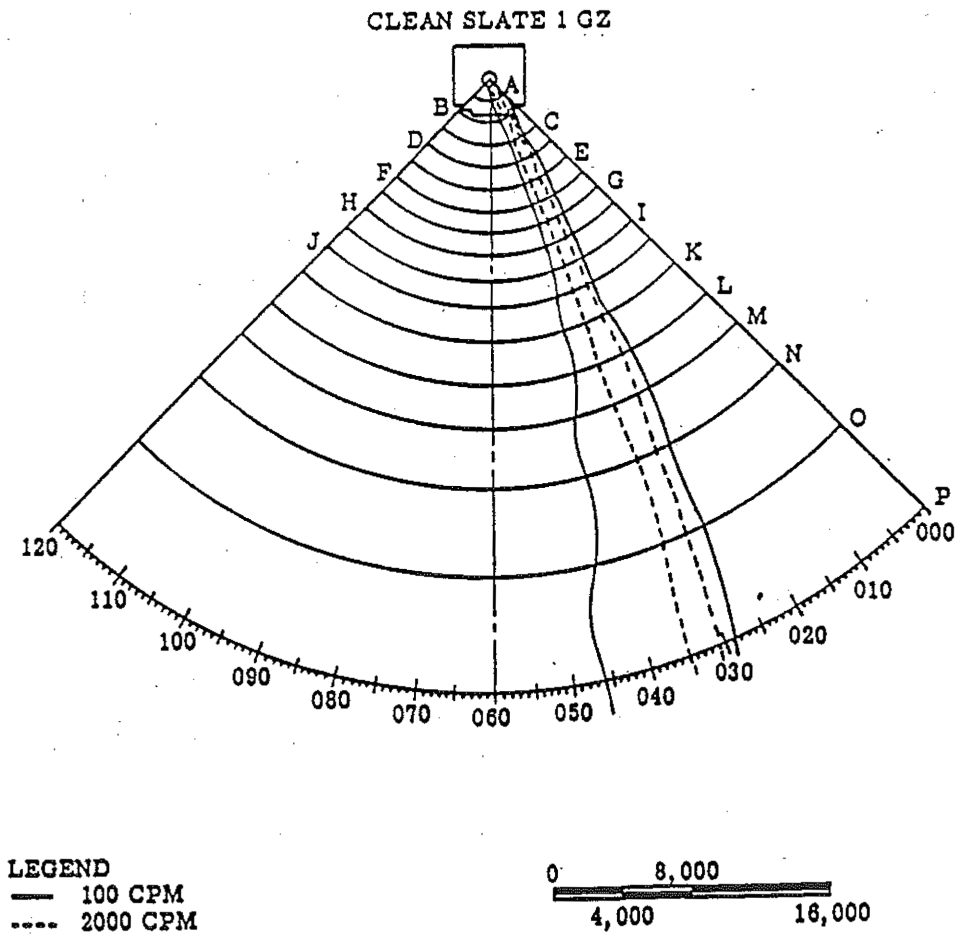

FIGURE 3.1.11. Radiation Survey of Clean Slate I.

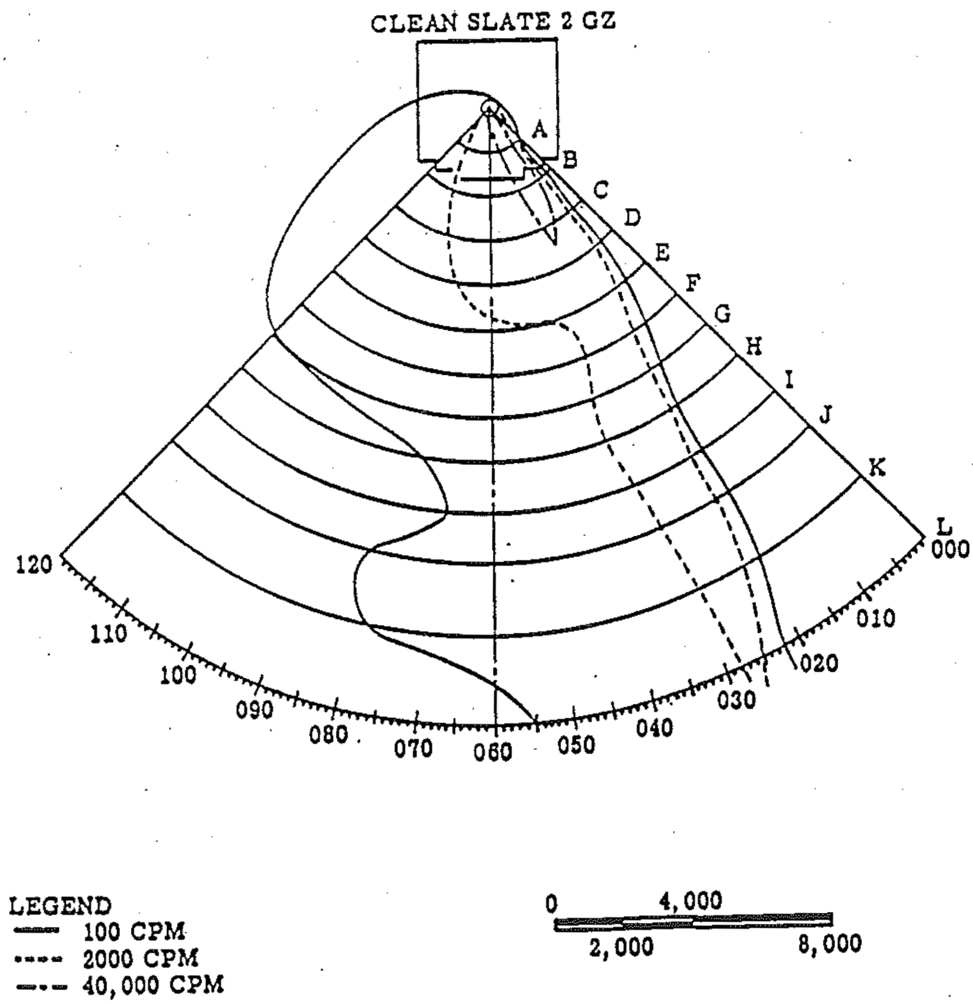

FIGURE 3.1.12. Radiation Survey of Clean Slate II.

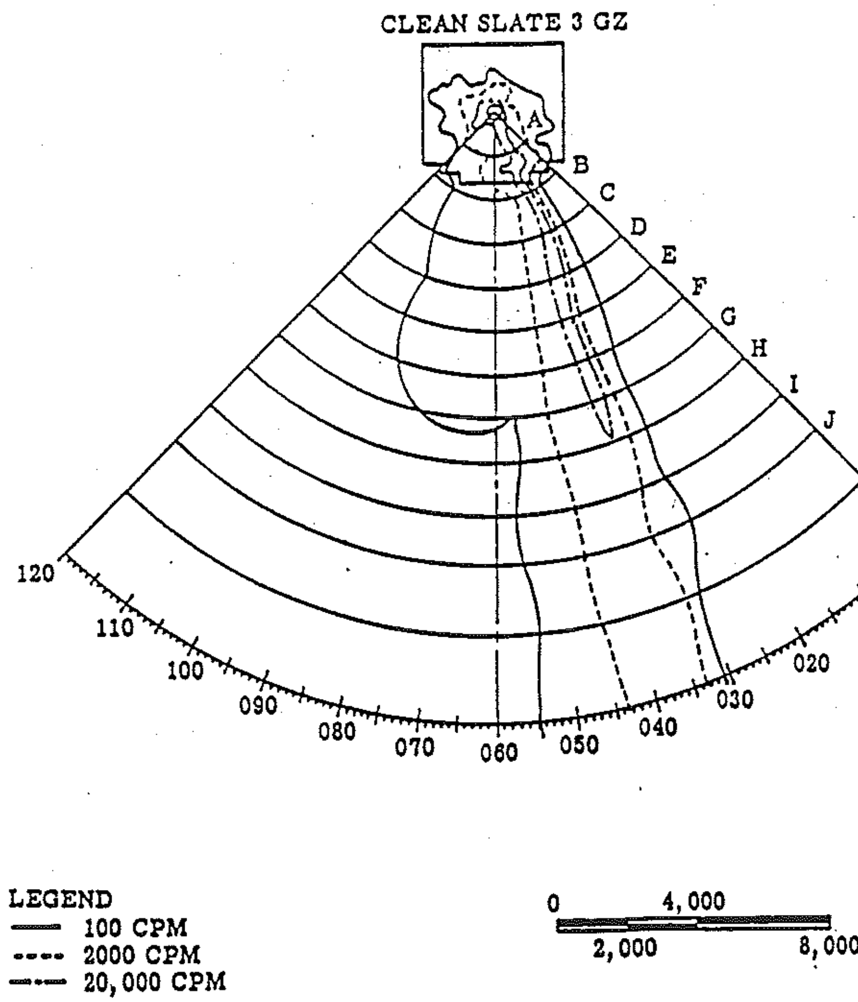

FIGURE 3.1.13. Radiation Survey of Clean Slate III.

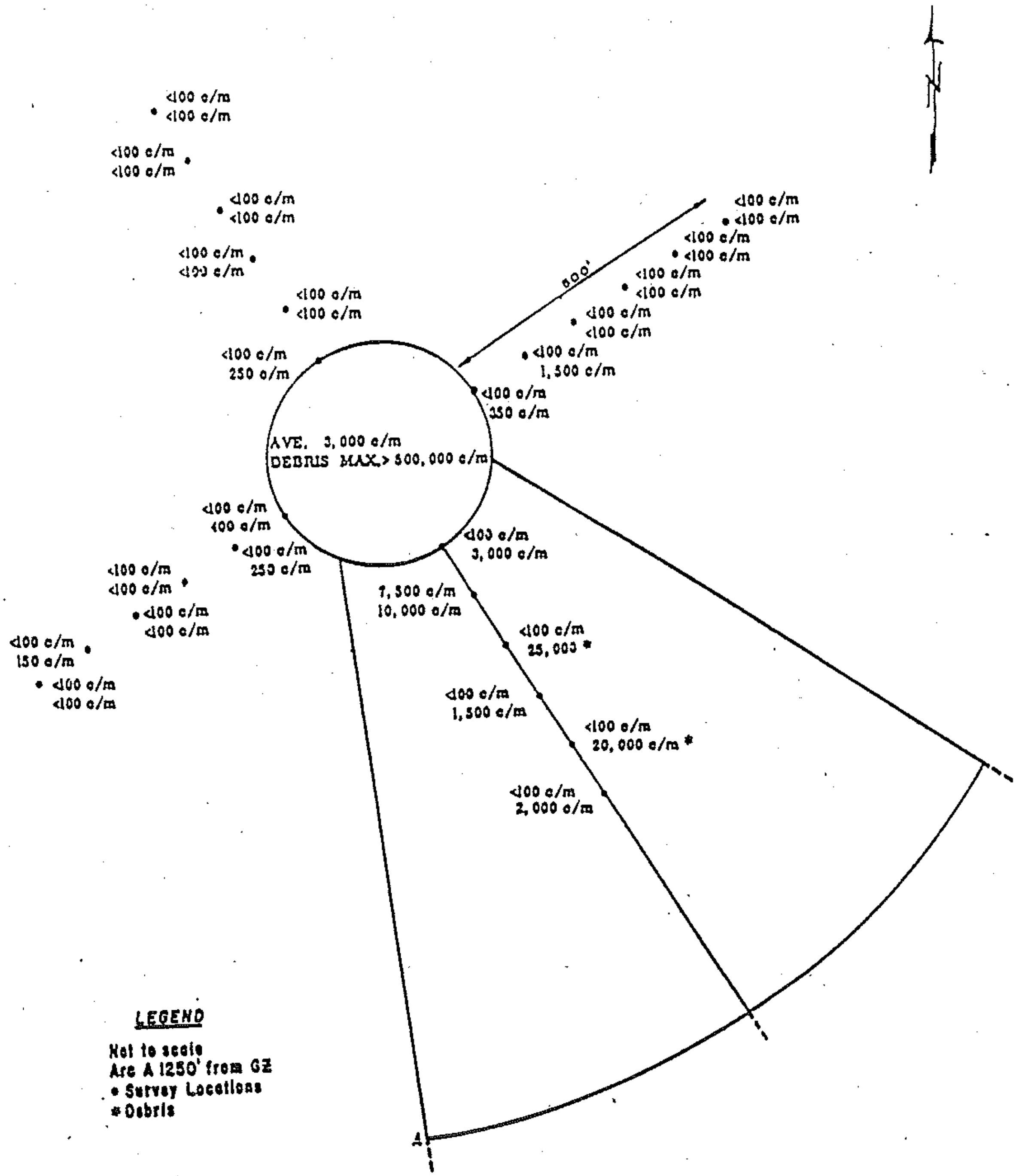

FIGURE 3.1.14. Clean Slate I Alpha Survey Results, June 1966.

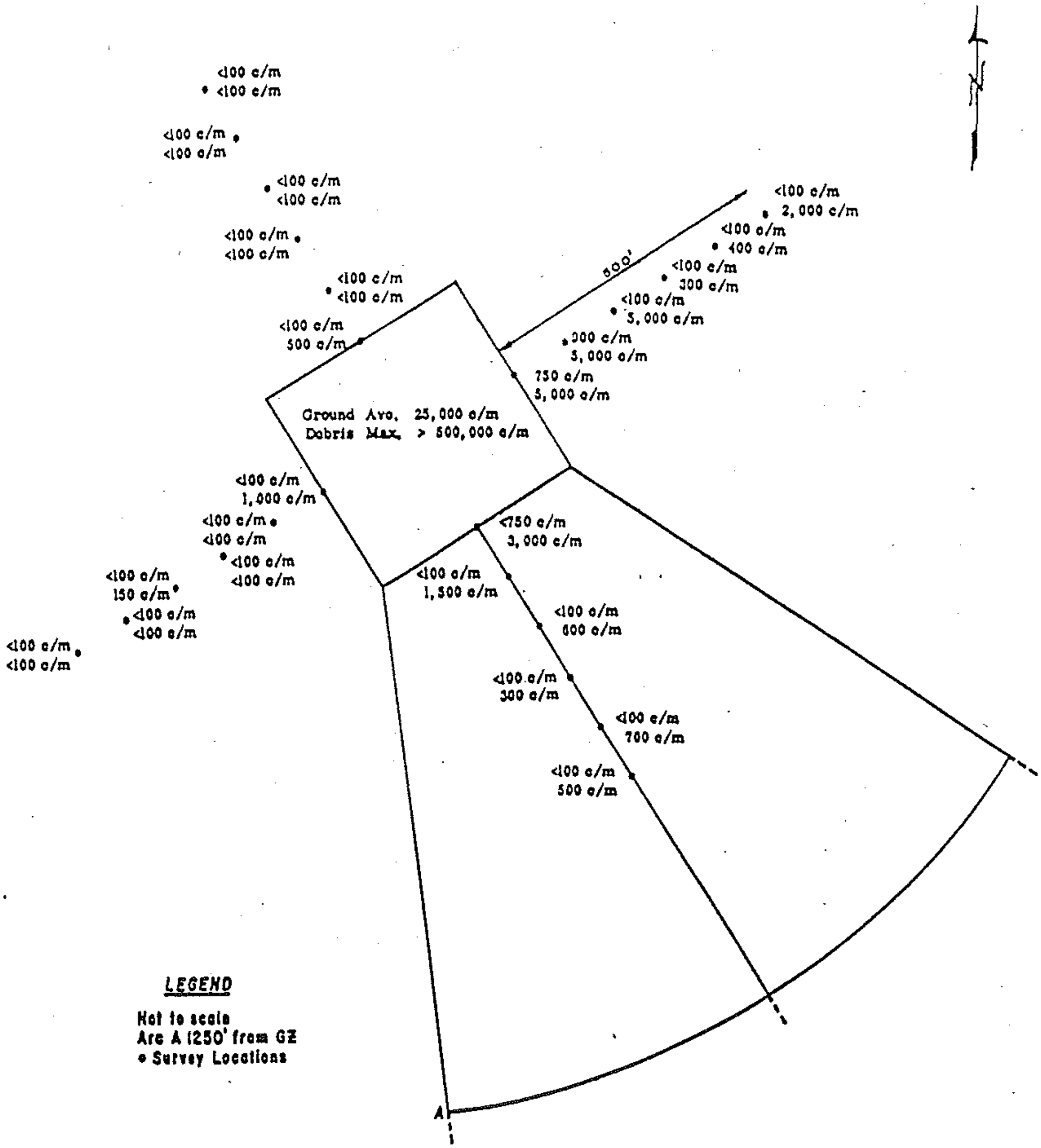

FIGURE 3.1.15. Clean Slate II Alpha Survey Results, June 1966.

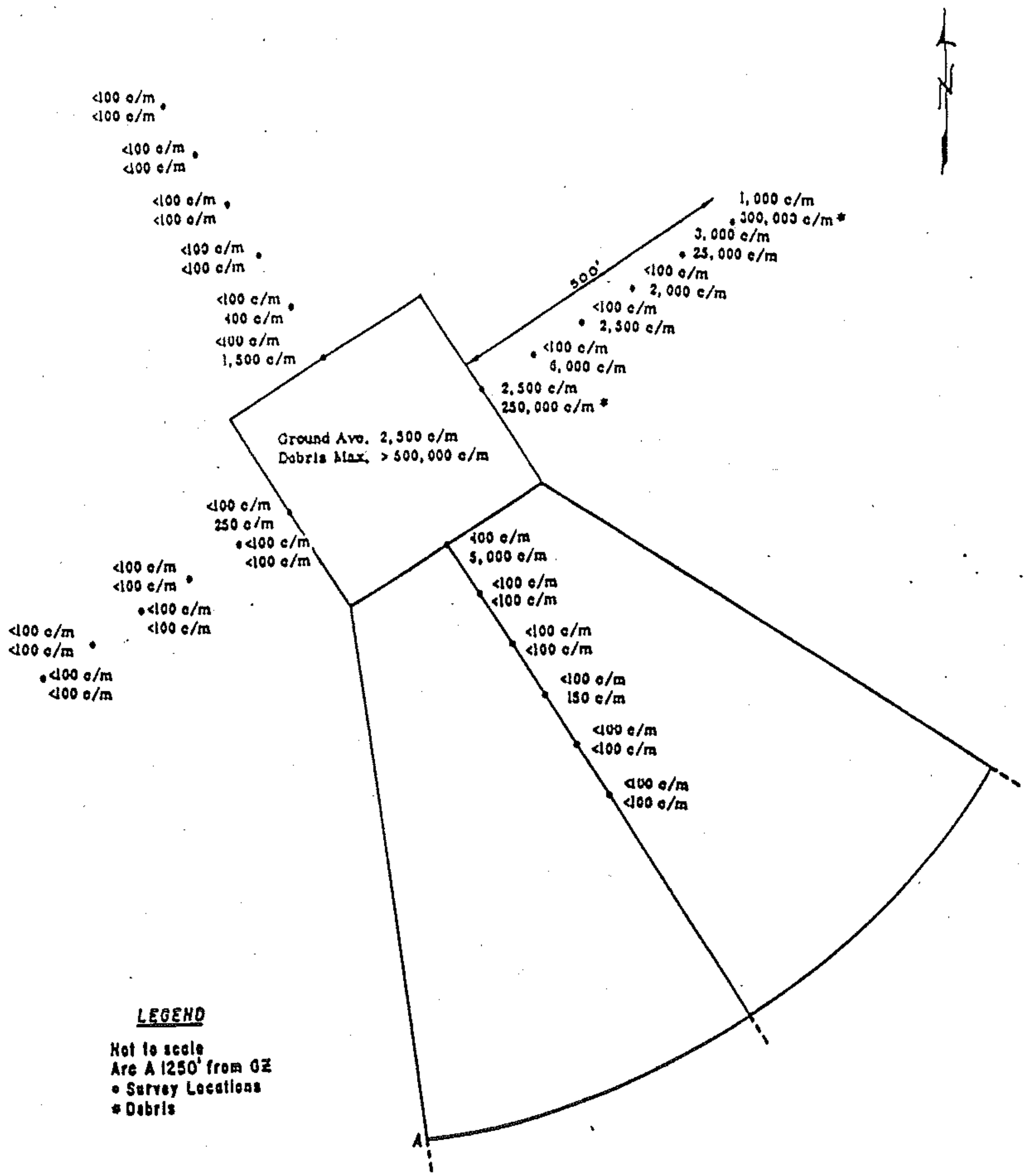

FIGURE 3.1.16. Clean Slate III Alpha Survey Results, June 1966.

NUMBER OF WELLS WITHIN A FOUR-MILE RADIUS

Two wells are located within a 4-mile radius of the Clean Slate sites. These wells are Roller Coaster Well and Sandia 6. The Roller Coaster Well was constructed for the Roller Coaster test and it is located next to the decontamination facility. Sandia 6 is the well that supplies Area 3. Since stratographic information in this area is sparse, the interconnectedness of the aquifer is not known.

POTENTIAL FOR SURFACE WATER RELEASE

Surface water runoff from the Kawich Range crosses all of the Clean Slate sites. This runoff would then terminate in the playa in the center of Cactus Flat. The playas of Cactus Flat are classified as recharge playas.[2] This indicates that they were formed from surface runoff with subsequent evaporation and infiltration. One significant ephermal channel, Breen Creek, passes through the fenced area of Clean Slate II.[18]

POTENTIAL FOR AIR RELEASES

The concern of potential resuspension led to an air sampling survey conducted by the Environmental Surveillance group in 1966. This survey was accomplished with a cab mounted sampling device and several stationary sampling devices placed downwind. The vehicle was driven around the area to induce air suspension of the material. The results of this survey are presented in Table 3.1.10.

THREATS TO FOOD CHAIN

As with the case of Double Tracks, the same mechanisms for introduction of the contaminant into the food chain are viable.

CONCLUSION AND RECOMMENDATIONS

Data was not available on worker and building status due to classification. The dispersal nature of the plutonium appears to pose a threat to the environment and therefore, steps should be taken to address the potential for further contamination for this site.

TABLE 3.1.10. GROSS ALPHA RADIOACTIVITY OF AIR SAMPLES COLLECTED AT TONOPAH TEST RANGE JUNE 29, 1966.

Sample Description	Gross Alpha µCi/cc	% 2 Sigma error
Gelman Little Giant Sampler in Truck Cab (4.7 cm membrance filter)		
8.77 m^3 in Clean Slate I general area	2.07×10^{-13}	Det. Lim*
15.85 m^3 Clean Slate II and III general area	7.36×10^{-14}	82.0
Hurricane High Volume Sampler (18.5 cm Whatman filter paper)		
25.54 m^3 downwind (NW) of Clean Slate I exclusion fence	7.43×10^{-14}	Det. Lim
25.54 m^3 downwind (NW) of Clean Slate II exclusion fence	7.05×10^{-14}	Det. Lim.
25.54 m^3 downwind (NW) of Clean Slate III exclusion fence	5.15×10^{-14}	Det. Lim.

* The detection limit is two times the value for which the relative 2-sigma counting error equals 100 percent.

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APPENDIX 3.1.A.1
HRS WORKSHEETS
DOUBLE TRACKS SITE

DOUBLE TRACKS
FIRE AND EXPLOSION WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Containment	(1) 3	1	1	3	7.1
2 Waste Characteristics					7.2
Direct Evidence	(0) 3	1	0	3	
Ignitability	(0) 1 2 3	1	0	3	
Reactivity	(0) 1 2 3	1	0	3	
Incompatibility	(0) 1 2 3	1	0	3	
Hazardous Waste Quantity	0 (1) 2 3 4 5 6 7 8	1	1	8	
Total Waste Characteristics Score			1	20	
3 Targets					7.3
Distance to Nearest Population	(0) 1 2 3 4 5	1	0	5	
Distance to Nearest Building	(0) 1 2 3	1	0	3	1
Distance to Sensitive Environment	(0) 1 2 3	1	0	3	
Land Use	(0) 1 2 3	1	0	3	
Population Within 2-Mile Radius	(0) 1 2 3 4 5	1	0	5	
Buildings Within 2-Mile Radius	(0) 1 2 3 4 5	1	0	5	1
Total Targets Score			0	24	
4 Multiply 1 x 2 x 3			0	1,440	
5 Divide line 4 by 1,440 and multiply by 100			S_{FE} = 0		

DOUBLE TRACKS
DIRECT CONTACT WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	8.1

If observed release is given a score of 45, proceed to line 4.

If observed release is given a score of 0, proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Accessibility	0 1 2 (3)	1	3	3	8.2
3 Containment	0 (15)	1	15	15	8.3
4 Waste Characteristics Toxicity	0 1 2 (3)	5	15	15	8.4
5 Targets					8.5
Population Within a 1-Mile Radius	(0) 1 2 3 4 5	4	0	20	
Distance to a Critical Habitat	(0) 1 2 3	4	0	12	
Total Targets Score			0	32	
6 If line 1 is 45, multiply 1 x 4 x 5					
If line 1 is 0, multiply 2 x 3 x 4 x 5			0	21,600	
7 Divide line 6 by 21,600 and multiply by 100		S_{DC} =	0		

DOUBLE TRACKS
GROUND WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	3.1
If observed release is given a score of 45, proceed to line 4.					
If observed release is given a score of 0, proceed to line 2.					
2 Route Characteristics					3.2
Depth to Aquifer of Concern	0 (1) 2 3	2	2	6	
Net Precipitation	(0) 1 2 3	1	0	3	
Permeability of the Unsaturated Zone	0 1 (2) 3	1	2	3	
Physical State	0 (1) 2 3	1	1	3	
Total Route Characteristics Score			5	15	
3 Containment	0 1 2 (3)	1	3	3	3.3
4 Waste Characteristics					3.4
Toxicity/Persistence	0 3 6 9 12 15 (18)	1	18	18	
Hazardous Waste Quantity	0 (1) 2 3 4 5 6 7 8	1	1	8	
Total Waste Characteristics Score			19	26	
5 Targets					3.5
Ground Water Use	0 (1) 2 3	3	3	9	
Distance to Nearest Well/Population Served	(0) 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
Total Targets Score			3	49	
6 If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			855	57,330	
7 Divide line 6 by 57,330 and multiply by 100			S_{gw} = 1.49		

DOUBLE TRACKS
SURFACE WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	4.1

If observed release is given a score of 45, proceed to line 4.

If observed release is given a score of 0, proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Route Characteristics					4.2
Facility Slope and Intervening Terrain	0 1 2 (3)	1	3	3	
1-yr. 24-hr. Rainfall	0 (1) 2 3	1	1	3	
Distance to Nearest Surface Water	0 1 2 (3)	2	6	6	
Physical State	0 (1) 2 3	1	1	3	
Total Route Characteristics Score			11	15	
3 Containment	0 1 2 (3)	1	3	3	4.3
4 Waste Characteristics					4.4
Toxicity/Persistence	0 3 6 9 12 15 (18)	1	18	18	
Hazardous Waste Quantity	0 (1) 2 3 4 5 6 7 8	1	1	8	
Total Waste Characteristics Score			19	26	
5 Targets					4.5
Surface Water Use	(0) 1 2 3	3	0	9	
Distance to a Sensitive Environment	(0) 1 2 3	2	0	6	
Population Served/ Distance to Water Intake Downstream	(0) 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
Total Targets Score			0	55	
6 If line 1 is 45, multiply 1 x 4 x 5					
If line 1 is 0, multiply 2 x 3 x 4 x 5			0	64,350	
7 Divide line 6 by 64,350 and multiply by 100		S_{SW} =	0		

DOUBLE TRACKS
AIR ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 (45)	1	45	45	5.1
Date and Location: May 15, 1963 Double Tracks site.					
Sampling Protocol:					

If line 1 is 0, the S_a = 0. Enter on line 5.

If line 1 is 45, then proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Waste Characteristics					5.2
Reactivity and Incompatibility	(0) 1 2 3	1	0	3	
Toxicity	0 1 2 (3)	3	9	9	
Hazardous Waste Quantity	0 (1) 2 3 4 5 6 7 8	1	1	8	
Total Waste Characteristics Score			10	20	
3 Targets					5.3
Population Within 4-Mile Radius	(0) 9 12 15 18 21 24 27 30	1	0	30	
Distance to Sensitive Environment	(0) 1 2 3	2	0	6	
Land Use	(0) 1 2 3	1	0	3	
Total Targets Score			0	39	
4 Multiply 1 x 2 x 3			0	35,100	
5 Divide line 4 by 35,100 and multiply by 100		S_a = 0			

HRS SCORE

$S_{gw} = 1.49$

$S_{sw} = 0$

$S_a = 0$

$$S_m = \frac{1}{1.73}\sqrt{S_{gw}^2 + S_{sw}^2 + S_a^2}$$

$$S_m = 0.86$$

Fire and Explosion $S_{FE} = 0$

Direct Contact $S_{DC} = 0$

SECTION 3.2

COVER SHEET

NAME OF SITE: Central Nevada Test Area

LOCATION: The site is located in south central Nevada, 60 miles east of Tonopah, Nevada. Most of the site was withdrawn by the AEC (now DOE) from Bureau of Land Management holdings.

DISPOSITION: The majority of the site has reverted to BLM control. Portions of the site remain under control by USAF and DOE.

PRELIMINARY ASSESSMENT REPORT
CENTRAL NEVADA TEST SITE (CNTS)

INTRODUCTION

Project Faultless has been the only nuclear test conducted at the Central Nevada Test Area (CNTA). It was executed to determine the behavior of seismic waves generated by a nuclear device detonation in Hot Creek Valley and to evaluate the potential usefulness of the site for higher-yield experiments. The event was conducted on January 19, 1968. The device, with a yield of less than 1 Mt, was detonated at a depth of 3,200 ft in drill hole UC-1, at Nevada State coordinates (central zone) N 1,414,340 ft, E 629,000 ft, Nye County, Nevada (Figure 3.2.1). The event produced an unusual collapse crater. Instead of the typical cone-shaped depression, a large area subsided as an irregular block bounded by local faults.[1]

Radioactivity from the Faultless event was contained during the event and all subsequent drillback operations. A radiological survey, made prior to demobilization and restoration, detected no radioactivity that could be attributed to the project. As a consequence, radiological cleanup was not required.[2]

OVERALL FACILITY DESCRIPTION

The CNTA is in Hot Creek Valley, a remote desert area of central Nevada. U.S. Highway 6, extending from Tonopah to Ely, borders the area on the southeast. The base camp, at an elevation of approximately 5,250 ft above sea level, is located approximately 57 miles northeast of Tonopah, a mining and ranching community of about 1,700 people, and approximately 110 miles southwest of Ely. It is also 9 miles northeast of Warm Springs.

In lieu of forming a single, large test site similar to the Nevada Test Site (NTS), the CNTA consisted of approximately 20 separate properties (land withdrawals, land easements, and special land-use permits) obtained from the BLM. Also, a contract, AT(26-1)-552, was negotiated with Nye County, Nevada for a 300 ft x 300 ft area on an aircraft parking apron at the Tonopah Airport. The area was selected because of its remoteness.[5] For this review, both above and below ground facilities are treated as one site.

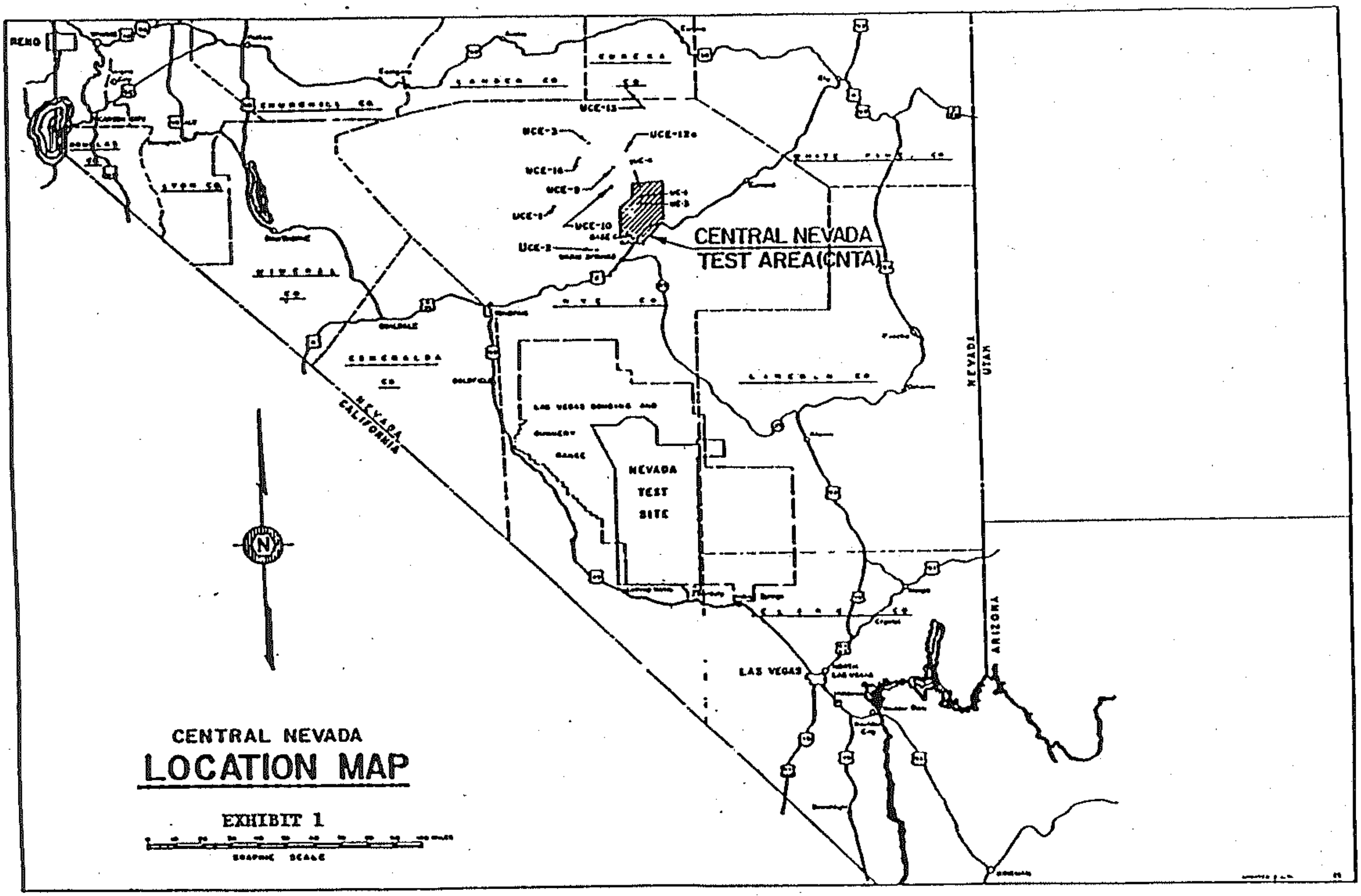

FIGURE 3.2.1. Location of Central Nevada Test Area.

ENVIRONMENTAL SETTING

The climate is generally dry and mild, with occasional severe snow and blizzard conditions and an average temperature of 40°F in winter and 85°F in summer. The average annual precipitation is 4.50 in.[5] For HRS scoring, it has been assumed that the 1 year, 24 hr precipitation event is between 1 and 2 in.

It is not believed that currently federally-listed threatened or endangered species inhabit the site. The surrounding land is used for livestock grazing.

HYDROGEOLOGIC SUMMARY

The thick alluvial fill of Hot Creek Valley displays little evidence of the structural framework or the stratigraphy of the valley; therefore, the primary source of subsurface geologic data is the several exploratory holes which were drilled in the area. The Faultless emplacement hole (UC-1) penetrated alluvium from the surface to a depth of 2,400 ft. The alluvium is underlain by tuffaceous sediments and zeolitized tuff from 2,400 to 3,275 ft, which was the total depth of the hole.

The water table in the immediate area of the Faultless site is about 500 ft below land surface. Hydrologic test holes drilled in the area indicate that ground-water potentials do not increase or decrease with depth; therefore, the flow is lateral. The recharge area for Hot Creek Valley is found in the Hot Creek Range to the west and northwest of the valley. Water moves laterally from the alluvial fans toward the central portion of the valley. Ground-water movement in the central valley and movement away from the general area of Faultless is in a southeasterly direction towards Railroad Valley (see Figure 3.2.2).[5]

HUMAN RECEPTORS

Based upon the wells and springs within the CNTA area and therefore water availability, the area within a 5-mile radius has no permanent population.[1] The nearest habitation (Hot Creek Ranch) is approximately 10 miles south and west. No ground water appears to be used within 3 miles of the detonation site. Wells and springs provide drinking water for habitations in the valley.

ENVIRONMENTAL RECEPTORS

Since no radioactivity was measured at the surface, environmental receptors in the area such as cattle and wild horses are not at risk from radioactive contami-

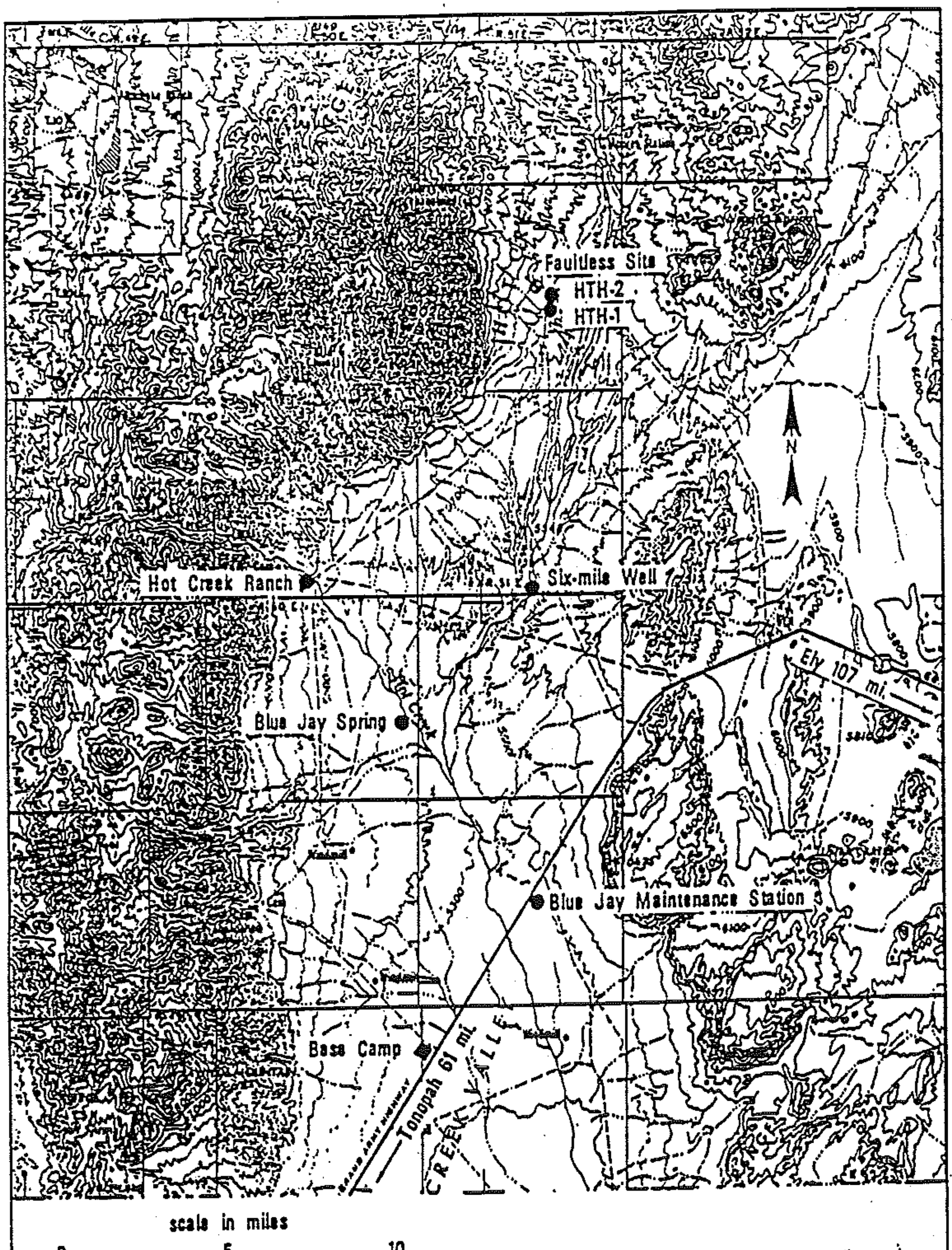

FIGURE 3.2.2. Hot Creek Valley, Including Faultless Ground Zero and the Water Sampling Point Network.

nation. Uptake of chromium by plants could possibly affect grazing animals. It is not believed, at the time of this writing, that critical habitats exist within 1 mile of the site.

HISTORY

Under the direction of the AEC Site Manager, the CNTA was operated and maintained by Holmes & Narver, Inc. (H&N) and its subcontractors. The National Environmental Research Center (NERC, formerly the U.S. Public Health Service), the Air Resources Laboratory (ARL, formerly the U.S. Weather Bureau), the U.S. Geological Survey (USGS), and the National Ocean Survey (NOS, formerly USC&GS) were among the participating Government agencies active at the CNTA. Scientific programs were jointly determined by the Lawrence Livermore Laboratory (LLL), Los Alamos Scientific Laboratory (LASL), and the AEC and were implemented by AEC prime contractors. Various contractors performed construction and support functions at the CNTA.[1]

The CNTA was developed for use as an alternative area of testing to the Nevada Test Site. Figure 3.2.3 shows the locations of the various facilities constructed to serve these purposes. A 1 $mile^2$ land withdrawal at the Faultless Site (UC-1) (see Figure 3.2.3) was formalized between the AEC and BLM on December 6, 1968, under Public Land Order No. 4338. Subsequent withdrawals were made for the UC-3 and UC-4 sites on December 2, 1969, under Public Land Order No. 4748. During this period, other permits and easements were obtained for exploratory drill sites, weather stations, and other support areas in Hot Creek Valley. The withdrawals for the UC-3 and UC-4 sites were larger than the UC-1 site by about one-half $mile^2$.

Emplacement holes were drilled on all three sites. Casing was installed and cemented at the UC-1 and UC-3 sites. The UC-4 emplacement hole remains uncased. Waste facilities included sewage lagoons, trash dumps, and mud pits for drilling operations.

On January 19, 1968, the Faultless test was conducted. The weapon had a yield of less than 1 Mt and was detonated at a depth of 3,200 ft. No radioactivity was released to the above-ground environment during or subsequent to the test. The geologic media at shot point consisted of tuffaceous sediments and zeolitized non-welded tuffs.

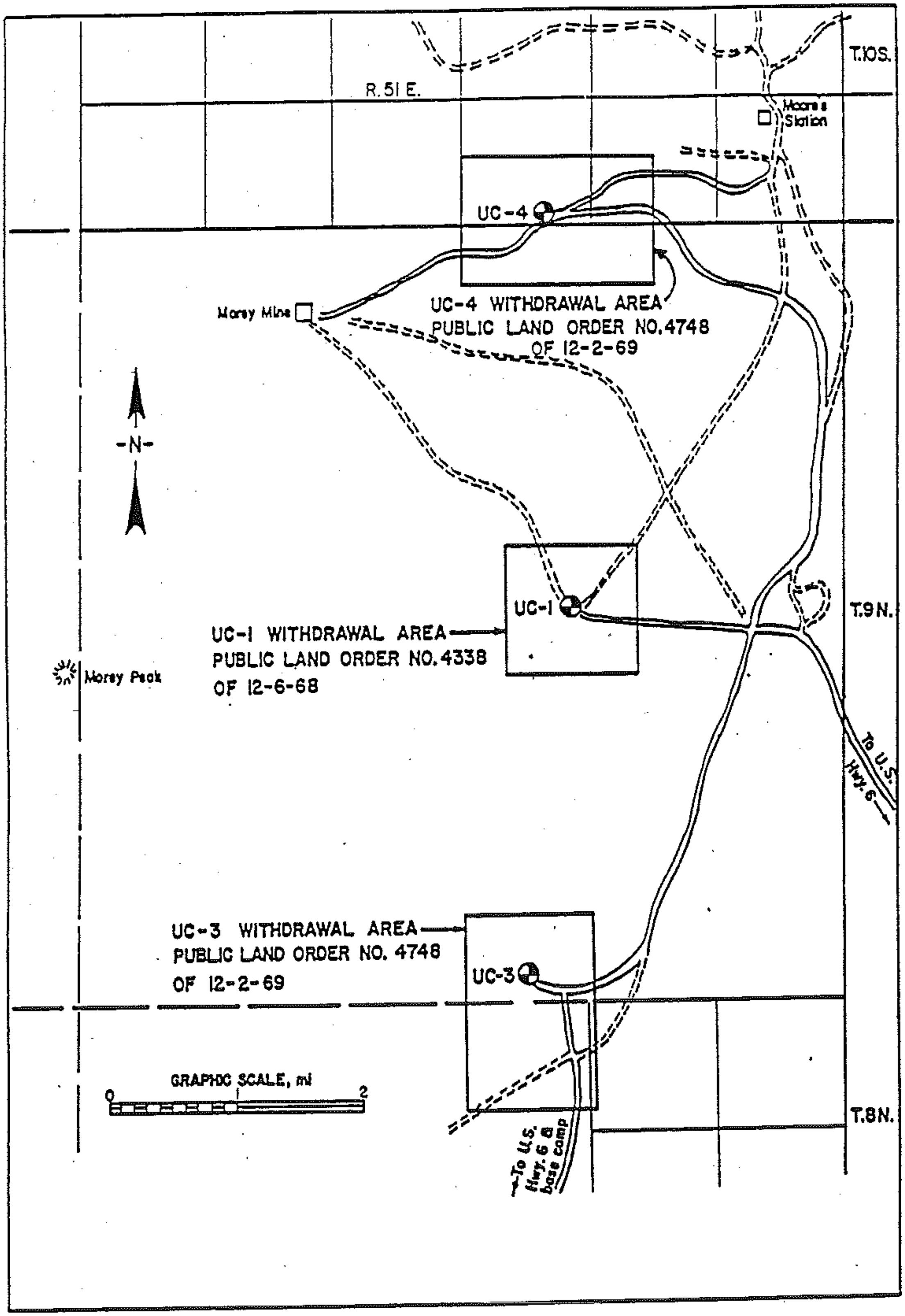

FIGURE 3.2.3. Location of CNTA Facilities and Land Withdrawals.

The Faultless event produced abundant surface fractures up to 9,000 ft and greater in length. Vertical displacements on these fractures are up to 15 ft and horizontal offsets as much as 3 ft. Some of these displacements occurred at the time of detonation, while others are suspected of occurring several hours later and seem to be related to the subsidence of the quasi-sink in the surface ground zero (SGZ) area. This sink is a graben bounded on the northwest, southeast, and south by faults. The area of subsidence is roughly 4,000 ft^2.

A hydrologic mound exists around the Faultless site which produces a gradient toward the chimney. The chimney had not filled above 2,280 ft below land surface in 1972, 4 years after the test. In 1983, the fluid level in UC-1-P-2SR was 1,088 ft below land surface and approximately 542 ft below the pre-event water level.[6]

The site was decommissioned in 1973. At that time, Nevada Operations Office retained control of some limited areas, while BLM and USAF assumed responsibility of much of the area.[1]

Numerous drill holes were plugged, but two wells, HTH-1 and HTH-2, were left open for hydrologic monitoring.[5] Well UC-1-P-2SR was also left open to monitor water levels and chemistry from above the shot cavity. A radiological survey of all surface faculties and shallow soils detected no radioactivity other than naturally occurring nuclides.[2] Sampling for non-radioactive hazardous materials indicated that chromium and an organic solvent were present in an uncovered drilling mud pit.[3]

A long-term hydrologic monitoring program is currently conducted by DOE. Six wells and springs are monitored for tritium on a yearly basis. No radioactivity above background has been found in these monitoring wells. Elevated levels of tritium have been found in UC-1-P-2SR, which is believed to be connected to the shot cavity. Figure 3.2.4 shows the monitoring locations, while Table 3.2.1 shows the results of monitoring in 1985.[3]

WASTE GENERATION AND DISPOSAL

Radioactive waste produced from the test is contained in the cavity. The estimated radioactivity (assuming a 1 Mt device) at 1 minute after shot time is estimated as 3×10^{10} Ci/kt, or 3×10^{13} Ci. The size of the cavity is 1.79×10^{8} ft^3.

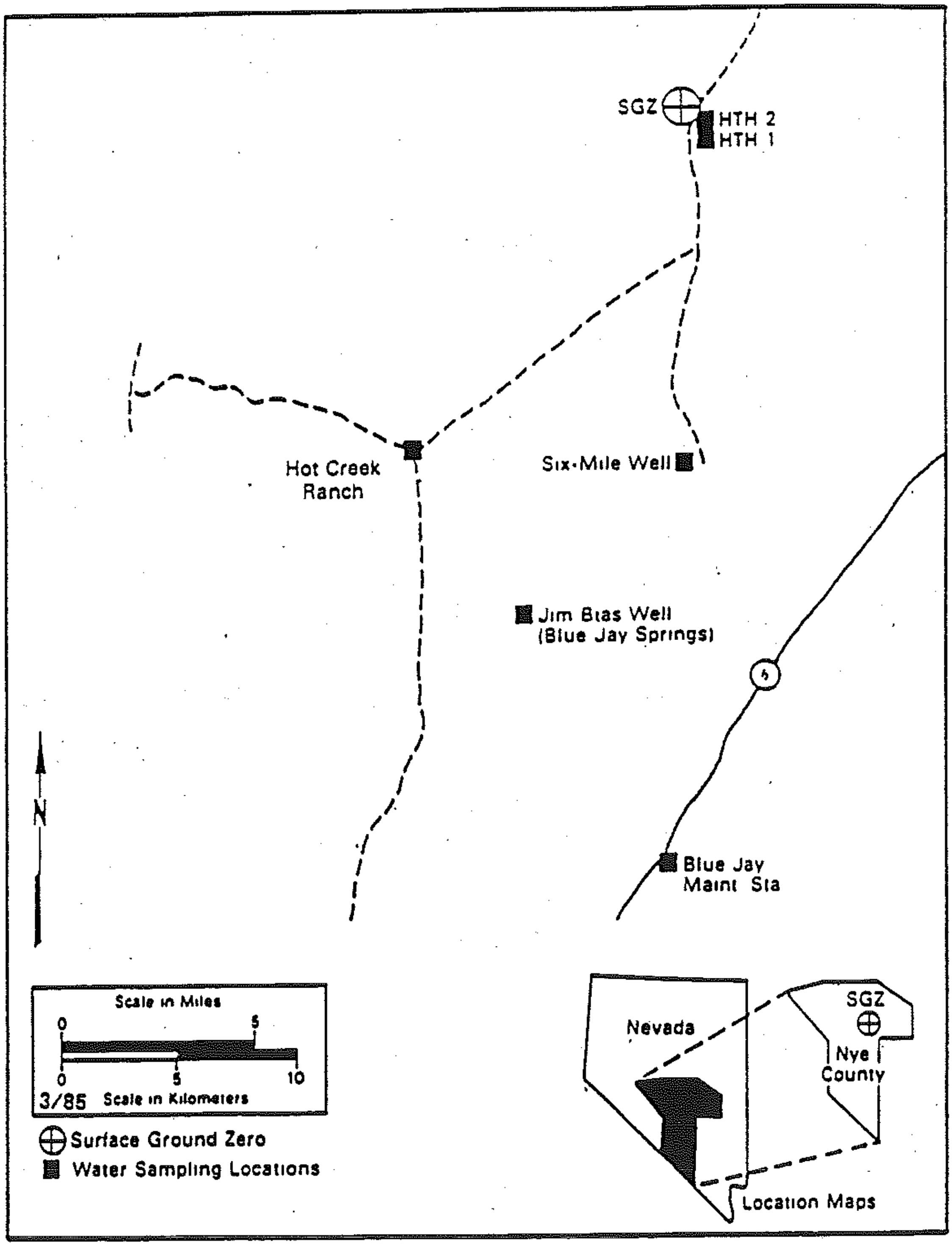

FIGURE 3.2.4. Long-Term Hydrologic Sampling Locations for CNTA.

TABLE 3.2.1. PROJECT FAULTLESS (CNTA) RESULTS OF MONITORING.

	Date of Sampling	Tritium (pCi/l)
Hot Creek Ranch Spring	07/22/85	15 ± 8
Maintenance Station	07/22/85	−4.6 ± 9.3*
Well Bias (Blue Jay Springs)	07/22/85	5.4 ± 9.2*
Well HTH-1	07/21/85	2.0 ± 9.2*
Well HTH-2	07/21/85	6.8 ± 9.0*

* Concentration was less than the minimum detectable concentration.

No surface radioactivity related to Faultless was detected in a survey completed in 1973. Non-radioactive waste generated from drilling and operations appears to be confined to the central mud pit. The following two sites (Figure 3.2.5) were investigated for hazardous materials.[3]

Site #1 - Runoff Ditch

A surface sample was collected from a runoff ditch 10 ft southwest of UC-1 and PS-2 (an emplacement well and post-shot hole).

Site #2 - Central Mud Pit

The central mud pit is located southeast of UC-1 (see Figure 3.2.5). It was used for the disposal of drilling mud. Upon inspection, the mud pit was found to be covered with a "dried oily-looking crust." Samples of "oily dirt" and "oily crust" were collected and analyzed.[3] The site is not covered or securely diked.[1]

The non-radioactive hazardous materials detected in samples collected at the CNTA are listed in Table 3.2.2. Note that the leachate from the dirt/crust samples collected at the Central Mud Pit contains concentrations of chromium, i.e., 8 mg/l, which slightly exceed the EP toxicity concentration of 40 CFR 261.24, i.e., 5 mg/l. Since only two samples were collected, both at the fringe of the mud pit, the extent of the chromium contamination cannot be determined at this time. However, there is roughly 10,000 cu ft of crusted drilling mud in the mud pit which has the "oily" appearance described earlier. The chromium is believed to be from chrome lig-

TABLE 3.2.2. NON-RADIOACTIVE HAZARDOUS SUBSTANCES DETECTED AT THE CENTRAL NEVADA TEST SITE.[3]

Site	Site Number	Chemical or Metal	EP Toxicity Detected (mg/l)	EP Toxicity Hazardous (mg/l)*	Halocarbon Detected (μg/kg)	Halocarbon Hazardous (kg)**
Runoff Ditch	1	Lead	0.3	5.0		
Central Mud Pit	2 (oily crust)	Chromium	7.9	5.0		
	2 (oily dirt)	2-Butanone			37	1000
		Chromium	8.1	5.0		

* Hazardous concentrations as listed in 40 CFR 261.24.
** Hazardous quantity as listed in 40 CFR 261.33.

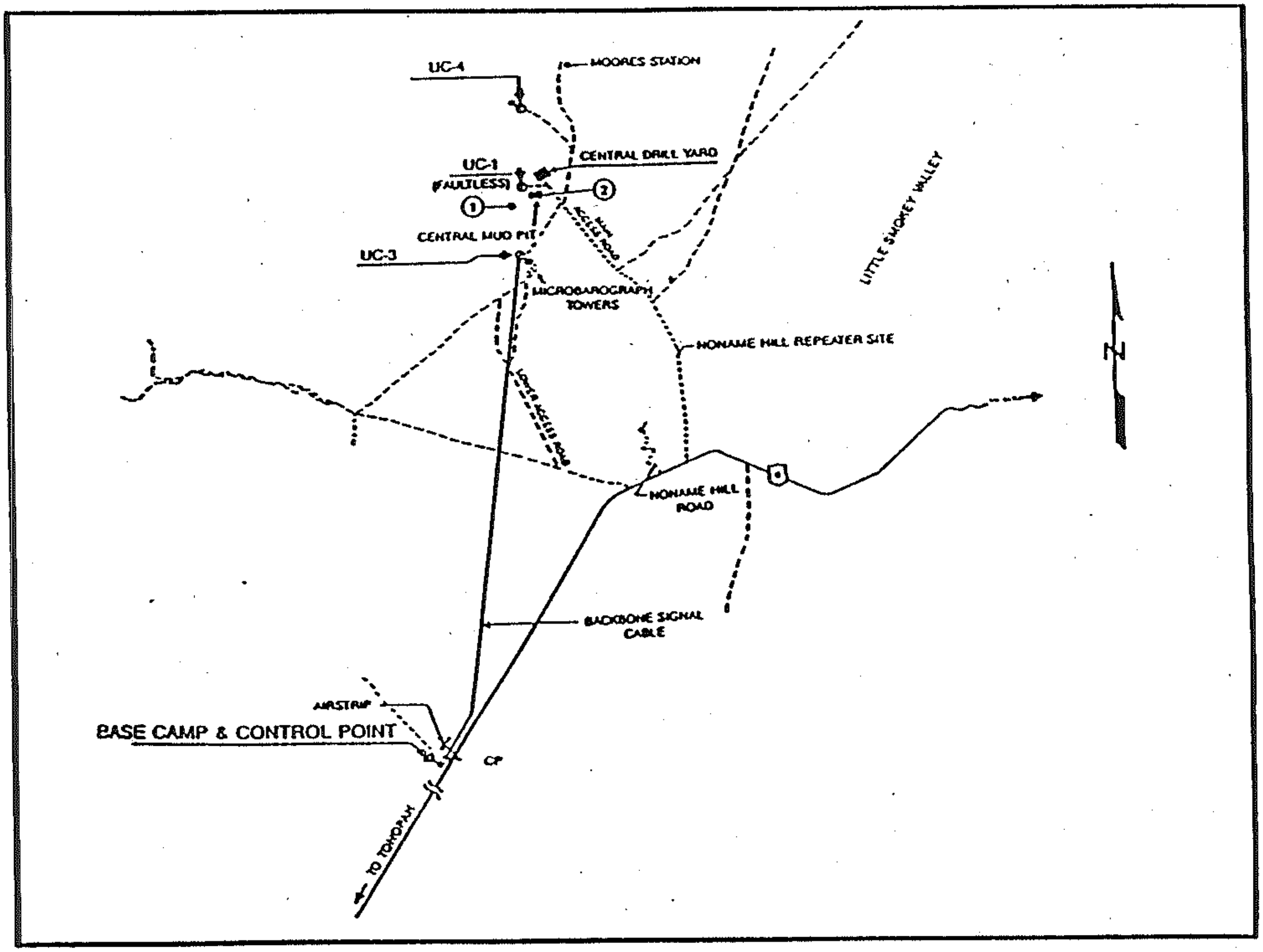

FIGURE 3.2.5. Location of Sampling Points for Surface Hazardous Waste.

nosulfonate, an organic-based drilling mud additive, actually a thinner commonly used for controlling mud viscosity and water loss.[3]

Other Sites

Mud pits were filled in at other emplacement holes (UC-4, UC-3) and well sites during the restoration activities of 1974. No samples have been collected or analyzed at these other sites.

OVERALL SITE AND HAZARD ASSESS: IENT

See Site Specific conclusions.

KNOWN RELEASES

There have been no known surface releases of radioactivity as a result of nuclear testing at the CNTA.[5] Chromium and 2-butanone were found in the unlined central mud pit. The detonation of the device contaminated the ground water within the cavity area.[6]

POTENTIAL FOR DIRECT CONTACT OR FIRE/EXPLOSION HAZARD

The potential for direct contact with radionuclides in the cavity (3,200 ft below ground) is minimal as no drilling or mining is permitted with 3,300 ft of SGZ. Well UC-1-P-2SR remains open to above the cavity to measure water levels. Direct contact of cavity water other than by authorized personnel is not likely. Direct contact with chromium in the mud is possible, but due to the remoteness of the site, improbable. The possibility of fire or explosion occurring at this site is minimal.

POTENTIAL FOR GROUND-WATER RELEASE

It has been predicted that ground water will not migrate away from the cavity-chimney complex until it has filled the available void volume and approaches the pre-event water table level, about 500 ft below land surface. After this occurs at the Faultless site, contaminated ground water could leave the chimney in a general south-southeast direction at a velocity of 0.4 ft/year. The chimney had not filled above 2,280 ft below land surface in 4 years following the event and is now filling at an exceptionally slow rate. Studies indicate that another 80 to 100 years may elapse before filling to pre–event levels is complete (when the start of a very slow southeasterly migration will occur).[5]

Prior to Faultless, Teledyne Isotopes' Palo Alto Laboratory established a 60–point water sampling network at the CNTA. It was reduced to 30 points with preshot samplings on a monthly basis. Post shot samplings indicated no increase in background radioactivity. The network was further reduced to eight points and sampled until 1971.

NV is currently sampling the following points:

Drill Hole UC–1–P–2SR (at the Faultless Site)
Drill Hole HTH–1
Drill Hole HTH–2
Hot Creek Ranch Domestic Water Supply
6–Mile Well
Blue Jay Spring
Blue Jay Maintenance Station Well

Samples are analyzed for tritium, gross alpha, and gross beta, and are given a gamma spectral scan. The monitoring programs for CNTA will continue until, based on continued negative results, a decision is made to terminate them.

Migration of chromium to the ground water from the central mud pit is possible, but unlikely due to the low permeability of mud. The depth to ground water at the central mud pit is estimated to be 500 ft.

NUMBER OF WELLS WITHIN A FOUR-MILE RADIUS

No drinking water wells are believed to be located within a 4–mile radius of Faultless.

POTENTIAL FOR SURFACE WATER RELEASES

No potential for radioactive release to surface water is plausible. The central mud pit is within 1 mile of several ephemeral streams. It is possible that flash floods could cause migration of chromium or organic mud wastes. The levels of chromium are low, however, and surface water is not used for drinking water in the area. Based upon topographic maps of the area, the average slope from the mud pit to the ephemeral streams is 2 percent.

POTENTIAL FOR AIR RELEASES

Air release of chromium from the dried mud pit is possible, however, no population lives within a 5-mile radius of the site. Since all holes into the shot cavity are sealed or locked, the release of radionuclides from the shot cavity to the atmosphere is insignificant.

THREATS TO FOOD CHAIN AND ENVIRONMENT

Uptake of chromium by plants at or near the central mud pit is possible. At the time of this writing, it was not determined if fencing around the central mud pit was sufficient to exclude animals from entering this area and consuming such plants.

CONCLUSION AND RECOMMENDATIONS

The hydrologic monitoring program has shown no migration of tritium from the shot cavity. This program will continue.

A preliminary HRS was conducted for the Central Nevada Test site and is included in Appendix 3.2.A. Since no drinking water sources are located within a 10-mile radius and the site is remote, the score is low at 3.54.

It is recommended that further samples be collected from the central mud pit and if contamination is confirmed, a closure plan will be developed. Based upon the available data, it appears that low permeable cover would be sufficient to limit migration.

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1. DOE. 1974. Summary Report: Central Nevada Test Area, Demobilization and Restoration Activities. NVO-152, 61 pp.

2. U.S. AEC. 1973. Radiation Contamination Clearance Report for Central Nevada Test Area. NVO-294-10, 19 pp.

3. DOE. 1986. Draft Phase I Installation Report, RRS-86-16, 60 pp.

4. EPA. 1987. Off Site Environmental Monitoring Report: Radiation Monitoring Around United States Nuclear Test Areas, Calendar Year 1986, EPA/600/4-87/017, 62 pp.

5. DOE. 1973. Planning Directive, Demobilization, Restoration and Monitoring Central Nevada Test Area. NVO-90, 4 pp.

6. Thordarson, W. 1987. Hydrogeology of the Faultless Site, Nye County, Nevada. Water Resources Investigation Report 86-4342.

APPENDIX 3.2.A
HRS WORKSHEETS
CENTRAL NEVADA TEST AREA

FIRE AND EXPLOSION WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
[1] Containment	(1) 3	1	1	3	7.1
[2] Waste Characteristics					7.2
Direct Evidence	(0) 3	1	0	3	
Ignitability	(0) 1 2 3	1	0	3	
Reactivity	(0) 1 2 3	1	0	3	
Incompatibility	(0) 1 2 3	1	0	3	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			8	20	
[3] Targets					7.3
Distance to Nearest Population	(0) 1 2 3 4 5	1	0	5	
Distance to Nearest Building	(0) 1 2 3	1	0	3	
Distance to Sensitive Environment	(0) 1 2 3	1	0	3	
Land Use	0 1 2 (3)	1	3	3	
Population Within 2-Mile Radius	(0) 1 2 3 4 5	1	0	5	
Buildings Within 2-Mile Radius	(0) 1 2 3 4 5	1	0	5	
Total Targets Score			3	24	
[4] Multiply 1 x 2 x 3			24	1,440	
[5] Divide line 4 by 1,440 and multiply by 100			S_{FE} = 1.67		

DIRECT CONTACT WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	8.1

If observed release is given a score of 45, proceed to line 4.

If observed release is given a score of 0, proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Accessibility	0 1 2 (3)	1	3	3	8.2
3 Containment	0 (15)	1	15	15	8.3
4 Waste Characteristics					8.4
Toxicity	0 1 2 (3)	5	15	15	
5 Targets					8.5
Population Within a 1-Mile Radius	(0) 1 2 3 4 5	4	0	20	
Distance to a Critical Habitat	(0) 1 2 3	4	0	12	
Total Targets Score			0	32	
6 If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			0	21,600	
7 Divide line 6 by 21,600 and multiply by 100			S_{DC} = 0		

GROUND WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 (45)	1	45	45	3.1

If observed release is given a score of 45, proceed to line 4.

If observed release is given a score of 0, proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Route Characteristics					3.2
Depth to Aquifer of Concern	0 1 2 3	2		6	
Net Precipitation	0 1 2 3	1		3	
Permeability of the Unsaturated Zone	0 1 2 3	1		3	
Physical State	0 1 2 3	1		3	
Total Route Characteristics Score				15	
3 Containment	0 1 2 3	1		3	3.3
4 Waste Characteristics					3.4
Toxicity/Persistence	0 3 6 9 12 15 (18)	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			26	26	
5 Targets					3.5
Ground Water Use	0 (1) 2 3	3	3	9	
Distance to Nearest Well/Population Served	(0) 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
Total Targets Score			3	49	
6 If line 1 is 45, multiply 1 x 4 x 5			3,510		
If line 1 is 0, multiply 2 x 3 x 4 x 5				57,330	
7 Divide line 6 by 57,330 and multiply by 100			S_{gw} = 6.12		

SURFACE WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi- plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	4.1
If observed release is given a score of 45, proceed to line 4.					
If observed release is given a score of 0, proceed to line 2.					
2 Route Characteristics					4.2
Facility Slope and Intervening Terrain	(0) 1 2 3	1	0	3	
1-yr. 24-hr. Rainfall	(0) 1 2 3	1	0	3	
Distance to Nearest Surface Water	0 (1) 2 3	2	2	6	
Physical State	0 (1) 2 3	1	1	3	
Total Route Characteristics Score			3	15	
3 *Containment*	0 1 2 (3)	1	3	3	4.3
4 Waste Characteristics					4.4
Toxicity/Persistence	0 3 6 9 12 15 (18)	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 (5) 6 7 8	1	5	8	
Total Waste Characteristics Score			26	26	
5 Targets					4.5
Surface Water Use	(0) 1 2 3	3	0	9	
Distance to a Sensitive Environment	(0) 1 2 3	2	0	6	
Population Served/ Distance to Water Intake Downstream	(0) 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
Total Targets Score			0	55	
6 If line 1 is 45, multiply 1 x 4 x 5					
If line 1 is 0, multiply 2 x 3 x 4 x 5			0	64,350	
7 Divide line 6 by 64,350 and multiply by 100		S_{SW} =	0		

AIR ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 45	1	0	45	5.1
Date and Location:					
Sampling Protocol:					
If line 1 is 0, the S_a = 0. Enter on line 5. If line 1 is 45, then proceed to line 2.					
2 Waste Characteristics					5.2
Reactivity and *Incompatibility*	0 1 2 3	1		3	
Toxicity	0 1 2 3	3		9	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1		8	
Total Waste Characteristics Score				20	
3 Targets					5.3
Population Within 4-Mile Radius	0 9 12 15 18 21 24 27 30	1		30	
Distance to Sensitive Environment	0 1 2 3	2		6	
Land Use	0 1 2 3	1		3	
Total Targets Score				39	
4 Multiply 1 x 2 x 3				35,100	
5 Divide line 4 by 35,100 and multiply by 100		S_a = 0			

HRS SCORE FOR
CENTRAL NEVADA TEST AREA

$S_{gw} = 6.12$

$S_{sw} = 0$

$S_a = 0$

$$S_m = \frac{1}{1.73} \sqrt{(6.12)^2 + (0)^2 + (0)^2}$$

$$S_m = 3.54$$

$S_{FE} = 1.67$

$S_{DC} = 0.0$

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SECTION 3.3

COVER SHEET

NAME OF SITE: Amchitka Island, Alaska

LOCATION: Amchitka, the southernmost island of the Rat Island Group, is located between longitudes 178°937'W and 179°29'W and between latitudes 51°21'N and 51°939'N.

DISPOSITION: Amchitka Island is currently under the control of U.S. Fish and Wildlife Service of the Department of Interior (DOI) as part of the Aleutian Islands National Wildlife Refuge. Radionuclide contamination of the island occurred on October 29, 1965, October 2, 1969, and November 6, 1971. During these periods, Amchitka was under the direct control of the Atomic Energy Commission (AEC) with the exception of the 1965 nuclear test, during which it was under the control of both the U.S. Department of Defense (DOD) and the AEC. In 1975, the AEC was disbanded and most of its activities were transferred to the Energy Research and Development Administration (ERDA). In 1979, ERDA became a part of the Department of Energy (DOE).

PRELIMINARY ASSESSMENT REPORT
AMCHITKA ISLAND, ALASKA

INTRODUCTION

Amchitka Island, Alaska, is the southernmost island of the Rat Island Group of the Aleutian Islands (Figure 3.3.1).[9] The island is about 40 miles long, from 3 to 5 miles wide, and trends in a northwesterly direction (Figure 3.3.2).[14] The other islands in the Rat Island Group include Semispochnoi, Little Sitkin, Segula, Rat Island, and three smaller islands. The entire group lies within a circle having a radius of about 40 miles.[7]

Amchitka Island was the location of three high-yield underground nuclear detonations. The nuclear tests were conducted over a long period of time for three basic purposes: seismic testing, calibration, and warhead development. These tests were Long Shot, a test of approximately 80 kt; Milrow, a test of approximately 1 Mt; and Cannikin, which had a yield of approximately 5 Mt.[18] The tests were conducted on October 29, 1965; October 2, 1969; and November 6, 1971, respectively.[9]

OVERALL FACILITY DESCRIPTION

Figures 3.3.1 and 3.3.2 give the general location and configuration of Amchitka Island. Area C on Figure 3.3.2 represents the general location in which all of the nuclear tests were conducted. This area is presented in detail in Figure 3.3.3.[14] The numbered symbols represent environmentally disturbed areas in this segment of the island. Sites 53 and 54 represent the location of the Milrow event, site 62 represents the location of the Long Shot event, and site 69 represents the area of the Cannikin event. Figures 3.3.4, 3.3.5, and 3.3.6 are simple maps of each of the event sites.[11,13,19].

ENVIRONMENTAL SETTING

Amchitka Island is currently under the control of the U.S. Fish and Wildlife Service as part of the Aleutian Islands National Wildlife Refuge. It is also the site of construction of an experimental radar station by the U.S. Navy. As such, there is a resident population of approximately 160 people in the southern half of the island (Chuck Costa, personal communication, February 17, 1988).

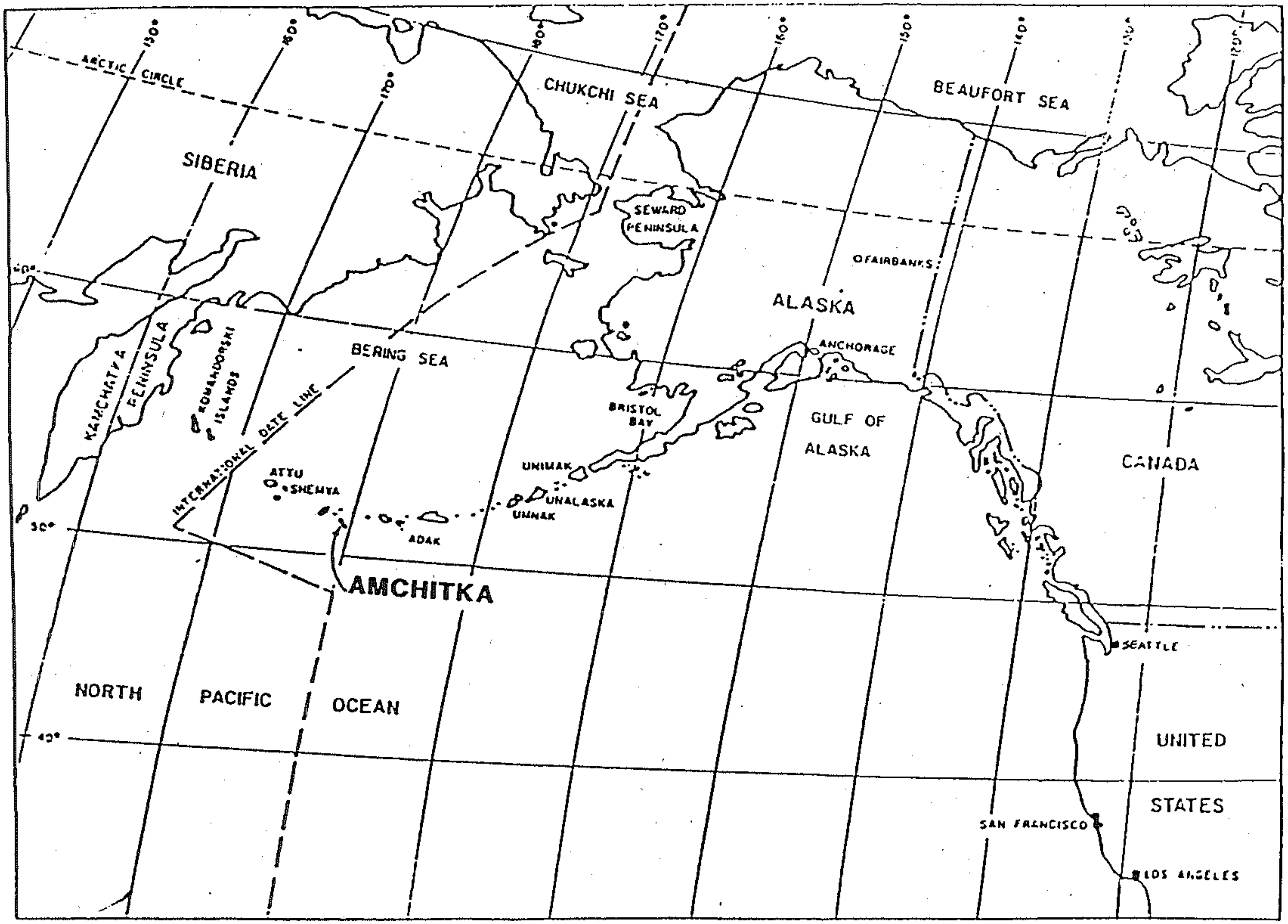


FIGURE 3.3.1. Amchitka's Position Between Asia and North America.

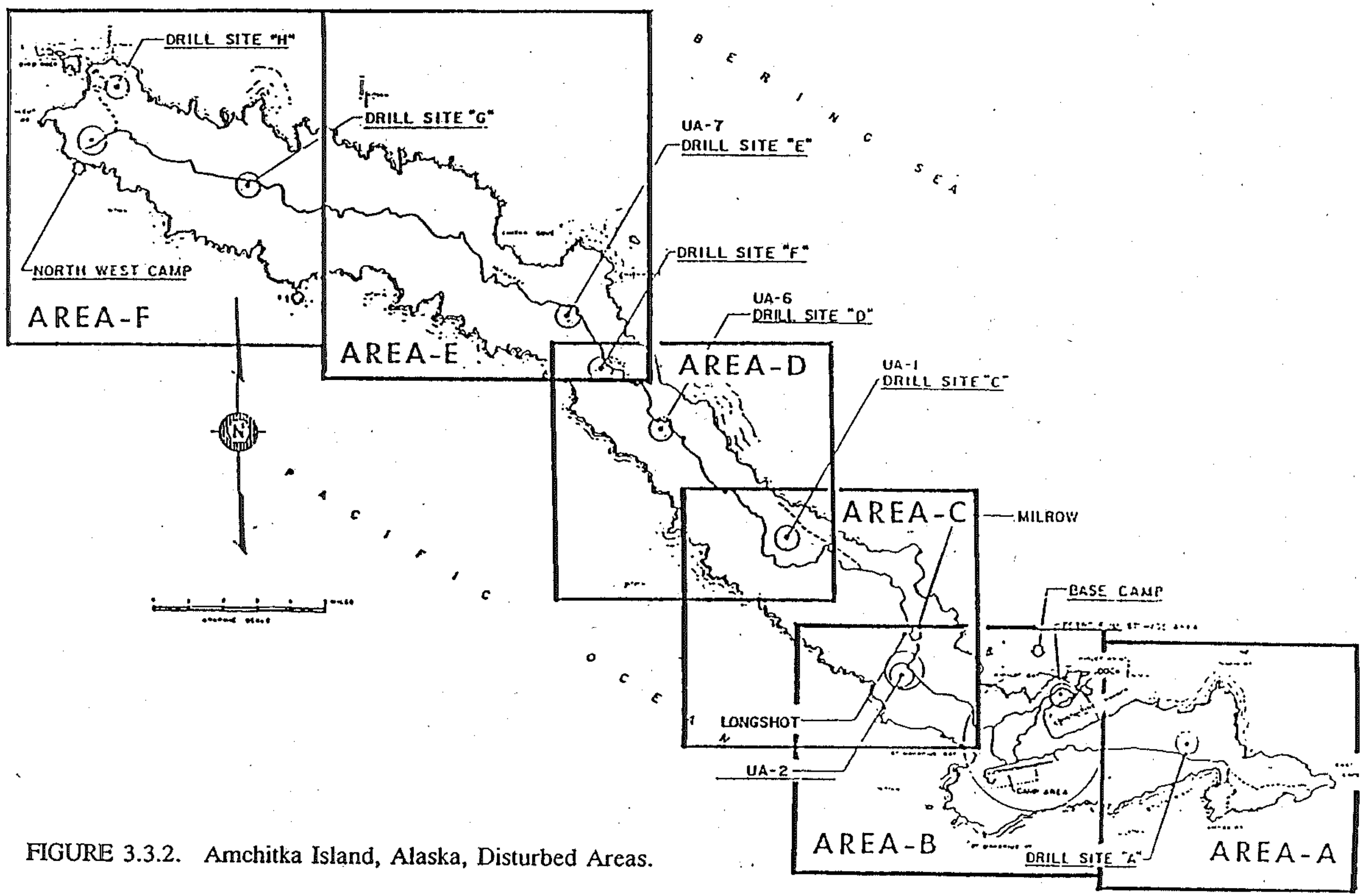


FIGURE 3.3.2. Amchitka Island, Alaska, Disturbed Areas.

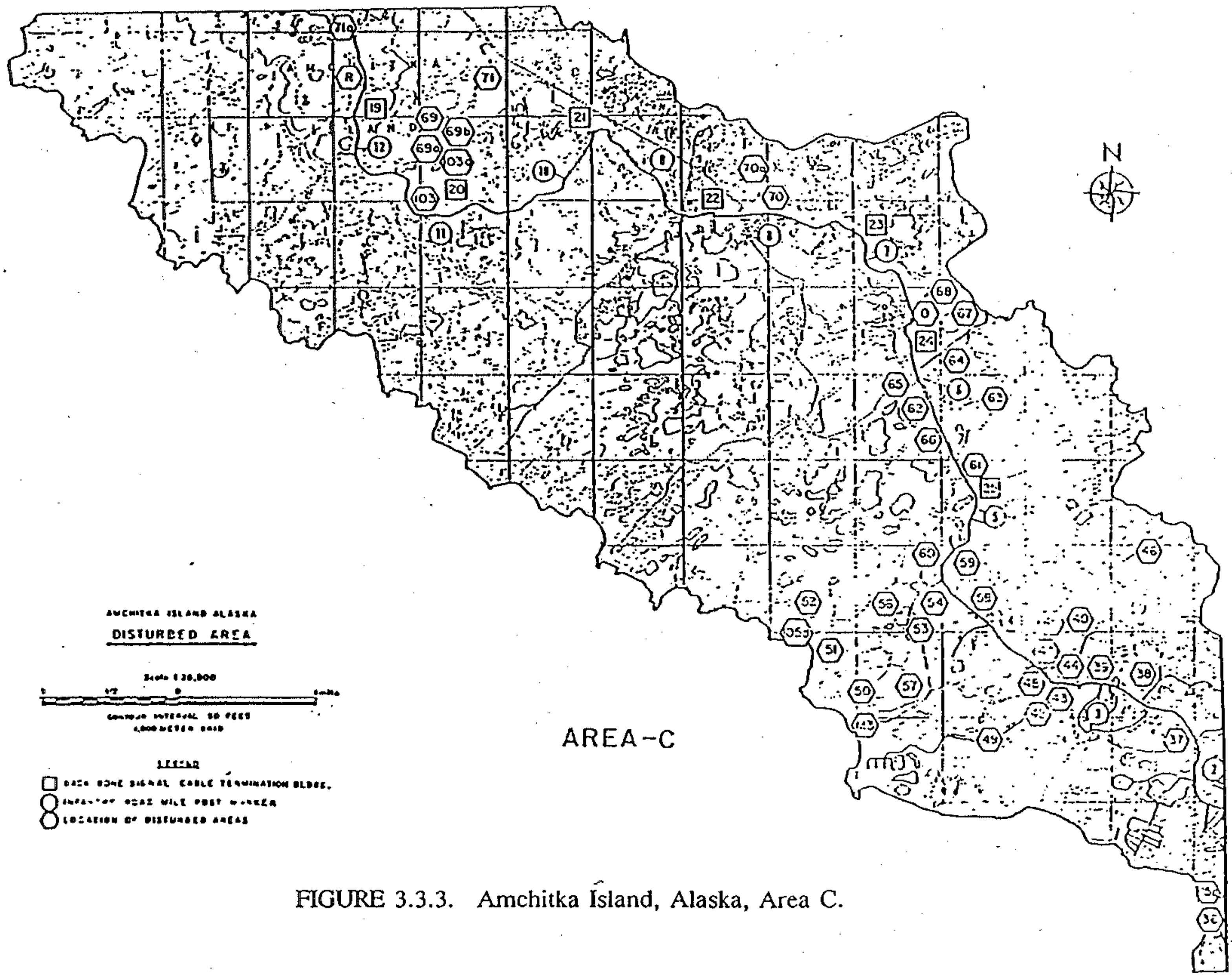


FIGURE 3.3.3. Amchitka Island, Alaska, Area C.

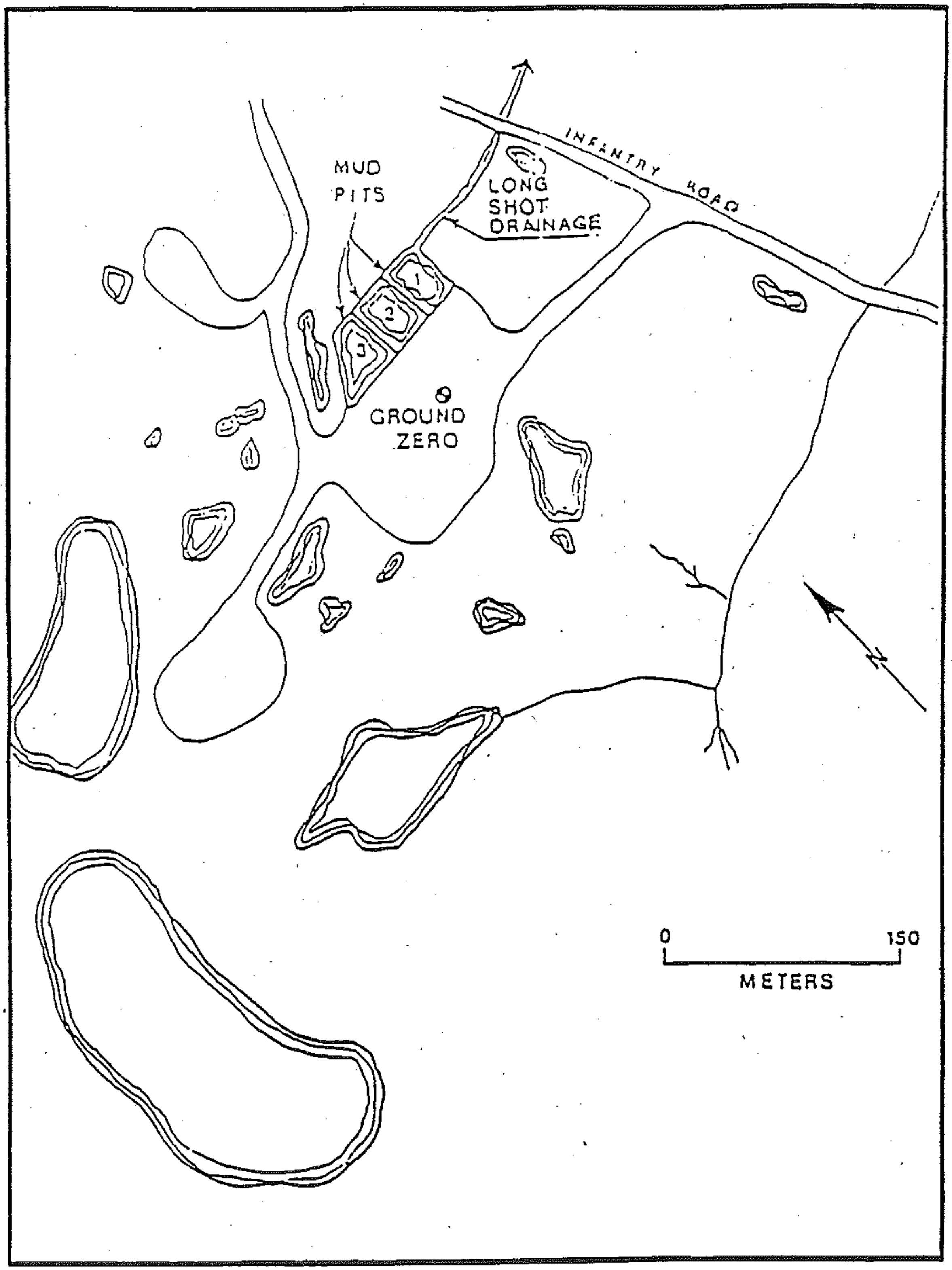


FIGURE 3.3.4. Collection Sites and Other Prominent Features in the Long Shot Ground Zero Vicinity.

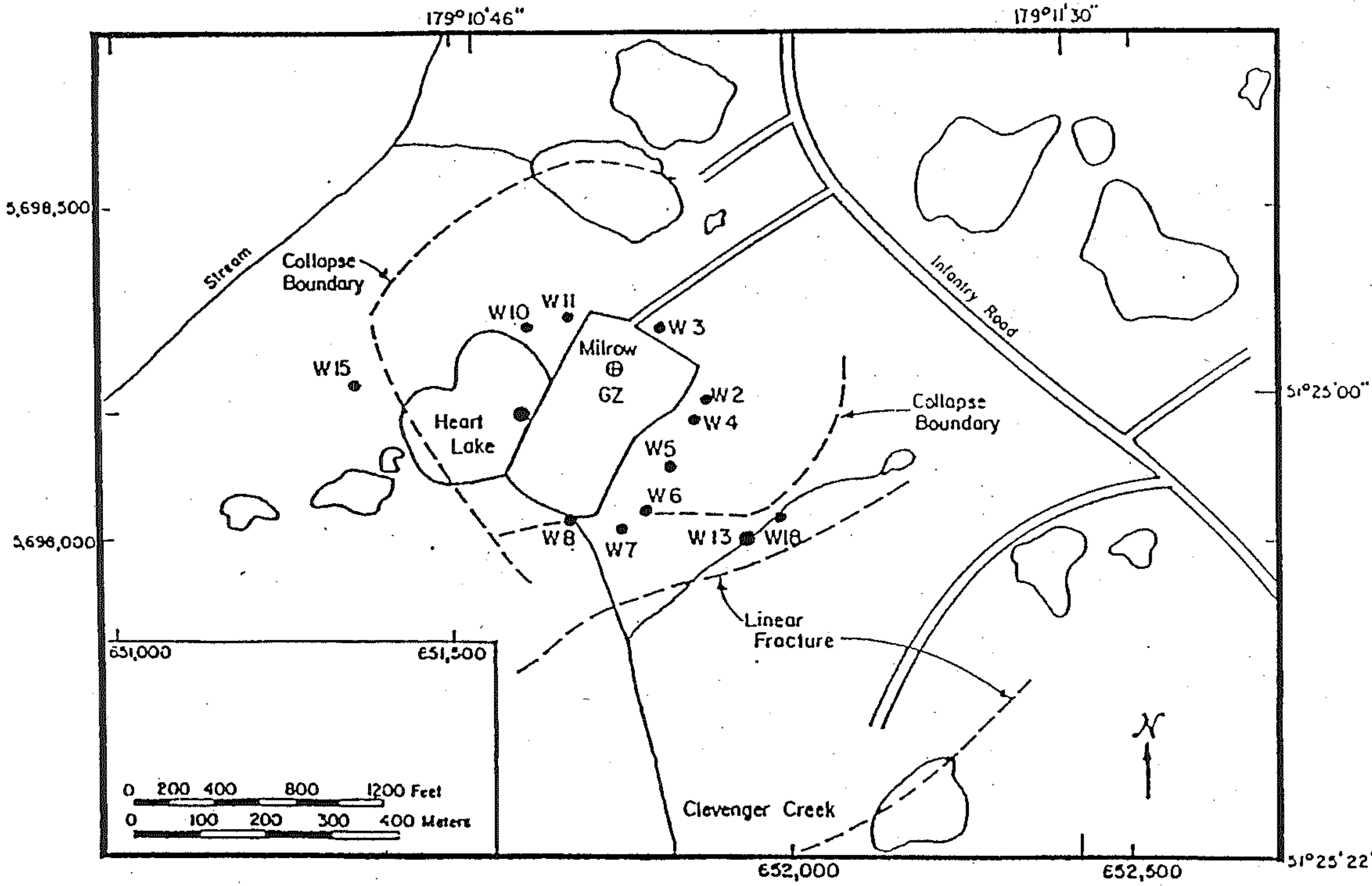


FIGURE 3.3.5. Location of Sampling Stations at Milrow Site. Dashed Lines Represent Major Post-Event Fractures.

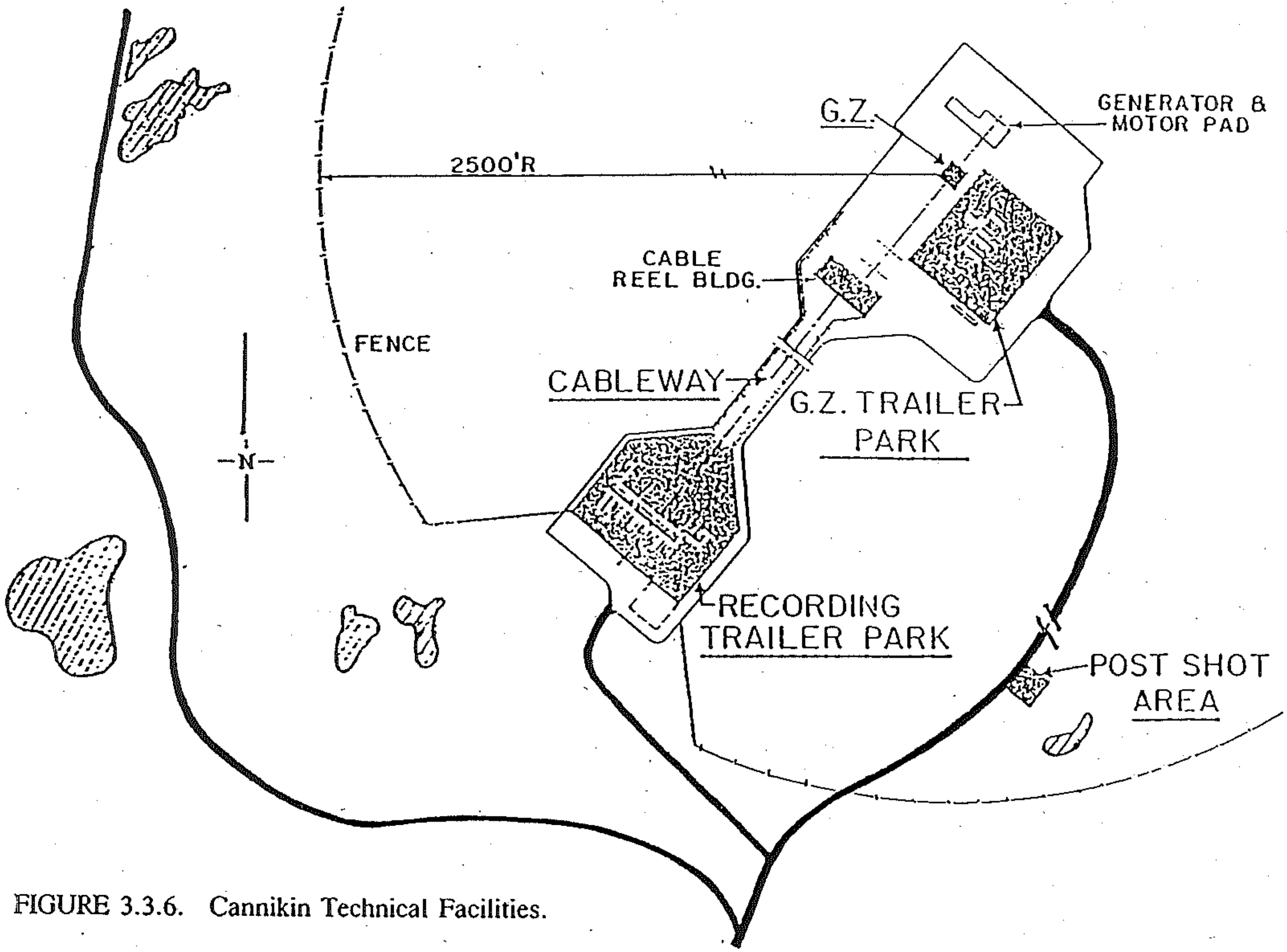


FIGURE 3.3.6. Cannikin Technical Facilities.

The islands surrounding Amchitka are also a part of the Aleutian Islands National Wildlife Refuge. The closest inhabited islands are the Adak Naval Station which is 300 km to the east and the Shemya Air Force Base which is 370 km to the west. All of the Aleutian Islands, except for a few of the easternmost ones, are in the Aleutian Islands National Wildlife Refuge. Other than construction of the radar site, there is minimal land use in and around Amchitka Island.

Amchitka lies entirely within the Alaska Aleutian physiographic province and, biologically speaking, is an archetype of a maritime tundra regime.[9] The entire island serves as a wildlife refuge and hence, is a sensitive environment. However, when the refuge was established by Presidential Executive Order No. 1733, on March 3, 1913, it contained the following provision:[9]

> "Establishment of this reservation shall not interfere with use of the Islands for lighthouse, military, or naval purposes... ."

The nuclear detonations and subsequent radionuclide contamination were in compliance with the law that established the wildlife refuge.

Within the refuge on Amchitka Island exist several species that are endangered in other areas of the country. These include the bald eagle, the emperor goose, the winter wren, and the peregrine falcon. Aleutian Canada geese were introduced to the island in March 1971.[15] Only one permanent land-dwelling mammal exists on the island, and that is the Norway Rat which was introduced during World War II. The only sensitive sea-dwelling mammal that resides at Amchitka is the sea otter, of which a current population of 2,500 to 4,000 exists.[9]

HYDROGEOLOGIC SUMMARY

The following description of the hydrology of Amchitka Island is directly quoted from Merrit et al.[9]

> Amchitka Island is composed of stratified volcanic rocks that vary widely in hydraulic properties. Because of the low interstitial permeability in most of the rocks, ground water moves most actively in the upper few hundred meters where fractures in the rock are numerous and more open. Together with the thick mantle of vegetation and peat, the shallow aquifers comprise a ground-water reservoir that responds strongly to infiltration of precipitation. Flows of most

> streams and levels of many of the lakes are sustained during dry periods by discharge from the shallow ground-water system. Direct surface runoff of precipitation occurs frequently, and the quality of the surface water during these periods is influenced by salt spray from the oceans.
>
> Hydraulic tests and temperature measurements in deep drill holes show that the hydraulic head decreases with depth beneath the island. The rocks have sufficient permeability to permit slow downward flux of small amounts of fresh ground water in response to this gradient to estimated depths of more than 3,000 ft where it moves laterally and upward along an interface with saltwater to discharge at the ocean floor.
>
> If the system is disturbed, as in a nuclear test, the minimum flow time from the shot cavity to the Bering Sea is approximately 100 to 3,000 years.[9,3]

Owing to the geology of Amchitka Island, there exist two flow systems or aquifers, a shallow fresh water system which grades into a deeper saline one. The materials in the upper few meters to perhaps a few hundred meters beneath the surface of Amchitka Island are relatively quite permeable and, where unsaturated, are capable of accepting recharge readily. Most ground water in this shallow zone apparently moves in very local systems and discharges in lakes and streams. Only a small portion of recharge infiltrates to the deeper flow system which is characterized by fracture flow, and discharges into the Bering Sea. It was within this aquifer that the nuclear testing was conducted.

The top of the shallow fresh water zone occurs at an elevation that is concurrent with the land surface (0 to 1,150 ft). The deeper flow system extends to a maximum depth of −3,750 ft where it begins to mix with oceanic waters. Construction crews at Amchitka utilize surface water resources. Historically, potable water has been taken from small surface impoundments constructed for that purpose[8] and springs emanating from the upper aquifer.[9] It is assumed that the present resources are obtained from the same sources.

The following excerpt from Merrit et al.[9] describes the weather of Amchitka Island.

Amchitka Island has a pronounced maritime climate. The day-to-day weather is marked by change-ability because of the great frequency with which migratory pressure systems pass along the North Pacific storm track. In the absence of local effects, such as surface heating and nocturnal cooling, which exert a large influence on weather conditions at a continental location, the Aleutian weather results almost entirely from large-scale pressure systems and their associated weather fronts.

During the summer season fog predominates as a result of the advection of relatively warm, moist air over the colder ocean surface. The air in the air-sea interface layer is cooled to the saturation point and extensive fog results. The summer fog often persists for days at a time.

An analysis by the Air Resources Laboratory-Las Vegas determined that the 5 year climatological record from the 1940's adequately defines the local climate and weather.[9] The weather data summary is presented in Table 3.3.1. The net precipitation for Amchitka is +33 in/year.[1]

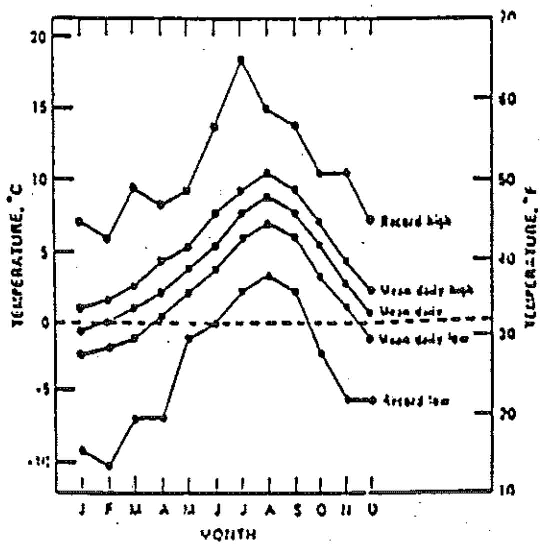
HUMAN RECEPTORS

Human habitation of Amchitka has been sporadic and brief since late 1973. The only known visitors to the island have been scientific, monitoring, and evaluation teams that stay for only a few weeks of the year.[9,6] Previous to 1980, the only teams with access to Amchitka were a group from the U.S. Fish and Wildlife Service trying to transplant Canada Geese. From 1980 to 1986, the island was uninhabited except for yearly visits by EPA monitoring teams. The spring of 1986 was marked by a survey of Amchitka as a site of an over-the-horizon radar. The survey team consisted of 84 people from the Navy and a construction company by the name of Chris Berg from Anchorage, Alaska. Beginning in the spring of 1987, a construction team arrived and is currently at 162 people (Chuck Costa, personal communication, February 17, 1988). The closest permanent populations to Amchitka are Adak Naval Station (190 miles to the east) with a 1980 population of 3,315; Shemya Air Force Base (230 miles to the west) with a 1980 population of 600; and a small U.S Coast Guard contingent of 29 just west of Shemya. The nearest non-military community is Atka (280 miles to the east) which has a population of 93.[9,17]

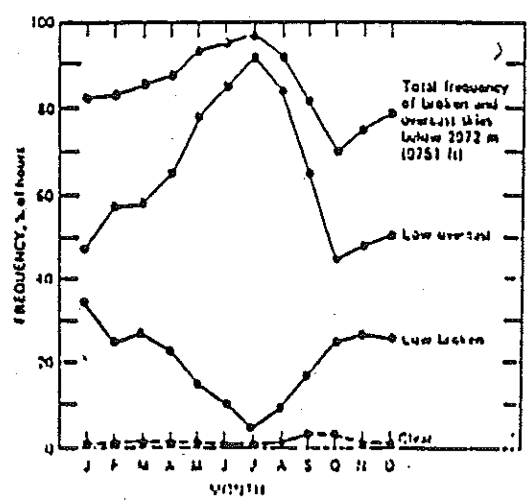
Table 1—Climatological Data for Amchitka Island, . a, from February 1943 Through June 1948*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Temperature, °C													
Record high	7.2	6.1	9.4	8.3	9.4	13.9	18.3	15.0	13.9	10.6	10.6	7.2	18.3
Mean daily max.	1.1	1.7	2.8	4.4	5.6	7.8	9.4	10.6	9.4	7.2	4.4	2.2	5.6
Daily mean	−0.6	0.0	1.1	2.2	3.9	5.6	7.8	8.9	7.8	5.6	2.8	0.6	3.9
Mean daily min.	−2.2	−1.7	−1.1	0.6	2.2	3.9	6.1	7.2	6.1	3.3	1.1	−1.1	2.2
Record low	−8.9	−10.0	−6.7	−6.7	−1.1	0.0	2.2	3.3	2.2	−2.2	−5.6	−5.6	−10.0
Av. No. of days with a minimum of													
< −4.4°C	3	2	2	1	0	0	0	0	0	0	†	1	9
< −2.2°C	12	9	6	2	0	0	0	0	0	0	1	6	36
≤0.0°C	28	24	22	13	3	†	0	0	0	2	10	22	124
Av. No. of days with a maximum of <0.0°C	9	6	4	1	0	0	0	0	0	0	1	6	27
Precipitation, mm													
Mean monthly	71	51	33	58	41	25	89	104	74	97	71	114	828
Av. No. of days with													
>0.25 mm	19	17	13	13	11	13	16	20	16	20	20	20	198
>6.35 mm	4	2	1	2	3	1	4	6	4	5	2	6	40
>12.70 mm	1	†	0	1	1	0	3	3	1	2	1	3	16
Percent of hours with rain	9	11	13	24	23	29	40	41	26	21	23	14	
Percent of hours with snow	18	24	16	9	2	†	†	0	0	1	5	15	
Snow depth at 0800 local standard time, cm													
Av. No. of days with depths of													
>2.54 cm	17	13	1	†	0	0	0	0	0	0	3	7	41
>5.08 cm	15	10	0	†	0	0	0	0	0	0	2	5	32
>15.24 cm	4	3	0	0	0	0	0	0	0	0	0	1	8
>30.48 cm	1	0	0	0	0	0	0	0	0	0	0	0	1
Surface wind													
Mean speed, m/sec	11	11	11	9	8	7	7	8	8	9	9	11	9
Percent of hours with speed >14 m/sec	29	28	26	19	6	4	3	4	9	16	19	28	16

*From U. S. Department of the Air Force, no date (a) and no date (b).
†Less than 0.5 day or percent.



Monthly temperature data.



Sky condition.

TABLE 3.3.1. AMCHITKA METEOROLOGICAL DATA.

Amchitka itself has not had a civilian population since 1849, nor are there domestic or agricultural wells on the island. Therefore, the risk to human receptors is minimal.

ENVIRONMENTAL RECEPTORS

Numerous species of birds, fish and ocean-going mammals live and breed on the land and water surrounding Amchitka Island. Several of these species, the bald eagle, the emperor goose, the winter wren, the peregrine falcon, the Aleutian Canada goose, and the Sea Otter are rare or endangered in other areas of North America.[5] If radionuclides were to reach the surface of Amchitka, then these species, as well as the existing flora, could act as environmental receptors.

HISTORY

Amchitka Island was the location of three nuclear tests. The first test was conducted on October 29, 1965, as a part of the Vela Uniform program, a DOD project designed to improve the capability to detect, identify, and locate underground nuclear explosions.[18] The second test was conducted on October 2, 1969, as part of a seismic calibration study for larger yield detonations.[18] The third and final test, conducted on November 6, 1971, was an underground test of the warhead of the Spartan anti-ballistic missile.[18] As a result of the nuclear testing on Amchitka, three underground cavities have been contaminated with radionuclides, as well as some surficial areas.[9,19,3] Chemical contamination of the environment has been reported as well.[9,1]

The chronology of Amchitka Island is summarized in Table 3.3.2.

WASTE GENERATION AND DISPOSAL

The radioactive contamination that has occurred at Amchitka was generated during three nuclear tests. These tests were one-time events, thus further introduction of radionuclides to the Amchitka environment is not expected.

Historical records indicate no release or burial of chemicals on Amchitka Island.[1] However, chemically contaminated soils were found at Amchitka at very low concentrations and in widespread locations.[1] In addition, nonradiogenic components of the nuclear device are also present within the shot cavity. One such component is lead. The toxicity and quantity of these components are relatively

TABLE 3.3.2. CHRONOLOGY OF AMCHITKA ISLAND.

1964		Spring	Negotiations begin with various potential biological contractors
Feb. 4	Rat Island earthquake (Ms = 7.75).	June	Reconnaissance by Battelle biologists.
Feb. 13-17	Party on Amchitka to investgate earthquake damage.	June 2	Proposed biological program discussed with Interior.
April	Party on Amchitka to pick tentative Long Shot site.	Summer	ADFG § sea otter harvest.
May 5	U.S. Atomic Energy Commission (AEC) brought into Long Shot planning and program.	July 1	Existing Battelle contract (for studies in Panama) modified to include Amchitka Bioenvironmental Program.
May 16 - Dec. 14	Exploratory drilling and other field investigations to confirm site suitability for Long Shot.	August	General biological field work started.
Dec. 23	Island evacuated.	Nov. 7	Conference with Interior and ADFG § on sea otter.
1965			
April 3	Population building for Long Shot begins.	**1968**	
June 2	AEC-DOD (Department of Defense) memorandum of agreement for Long Shot.	Jan. 29-31	Conference with Interior and State of Alaska on cooperation in sea otter transplants.
Oct. 12 - Nov. 2	LRB/UW* biologists in field for Long Shot biological program.	June 3 - Oct. 18	Archaeological site survey.
Oct. 27	Device in place and stemmed.	Summer	ADFG § sea otter transplant, with FWS ¶ and AEC assistance.
Oct. 29	Long Shot detonated.		
Nov. 18 - Dec. 10	Project Breccia† field studies, including some biological studies.	Sept. 24	Briefing on Amchitka Bioenvironmental Program for the Plan on Biological and Medical Sciences, Committee on Polar Research, National Academy of Sciences.
December	Island evacuated.		
1966			
June 23	Site Selection Committee (SSC) starts looking for a high-yield supplemental nuclear test site in the lower 48 states.	All Year	Biological field work; emphasis on baseline studies.
August	More field studies for Project Breccia - 20 people.	**1969**	
		June 18	Public announcement of Milrow.
August	Permission granted by the Department of the Interior for use of Amchitka by the AEC.	Summer	ADFG § sea otter transplant, with AEC assistance.
		Sept. 25	President Nixon authorizes Milrow detonation.
Nov. 18	SSC duties expanded to include Amchitka.	October 2	Milrow detonated.
Nov. 30 - Dec. 6	Field reconnaissance by U.S. Geol. Survey - 16 people.	All Year	Biological field work; emphasis on pre- and post-Milrow studies.
1967		**1970**	
Jan. 13	DMA‡ authorizes construction.	May	ADFG § sea otter harvest.
February	Population buildup for Milrow begins.	June 12	Draft Environmental Statement for Cannikin issued.

TABLE 3.3.2. CHRONOLOGY OF AMCHITKA ISLAND (continued).

July	ADFG § sea otter transplant, with AEC assistance.	1973	
Aug. 26–27	Symposium on Amchitka bioenvironmental studies at AIBS meeting, Bloomington, Ind.	April 11	Work on this book starts with meeting of principals in Denver.
All Year	Biological field studies; post-Milrow and pre-Cannikin studies.	Summer	Many disturbed areas recontoured and reseeded with grass; island cleanup and camp demobilization continues.
1971		Sept. 8	Amchitka evacuated.
Spring	FWS ¶ experiments with transplants of the Aleutian Canada Goose.	September	Control of Amchitka returned to Interior.
June	Final Environmental Statement for Cannikin issued.	All Year until Sept.	Biological field work; post-Cannikin studies.
June	ADFG § sea otter transplant, with AEC assistance.	1974	
Oct. 27	Cannikin device in place, stemming starts.	May 2 – June 1	Spring 1974 Scientific Task Force** – 37 people.
Oct. 29	President Nixon authorizes Cannikin detonation.	Aug. 26 Sept. 4	Fall 1974 Scientific Task Force** – 36 people.
Nov. 6	Supreme Court denies injunction against Cannikin; Cannikin detonated.	1975	
		Aug. 8 Sept. 9	1974 Scientific Task Force** – 13 people.
All Year	Biological field work; emphasis on pre- and post-Cannikin studies.	1976 – 1980	FWS ¶ puts small staff on Amchitka to study Aleutian Canada Geese as the first step in reestablishment of a breeding population of these geese.
1972			
Feb. 25	Postshot drilling for radiochemical samples completed; Amchitka cleanup starts.	1976	
		Aug. 10–18	1976 scientific party visits** – 2 people.
May	Seismic stations removed.	1980 – 1986	Various DOE Bioenvironmental Survey teams visited the island.
May 19–21	Long Shot related holes sealed and abandoned.		
Summer	Retrograde shipments start.	1986	
Sept. 19–26	All remaining holes sealed and abandoned.	May	Navy "Over the Horizon Radar" Survey team – 84 people.
All Year	Biological field work; evaluation of Cannikin effects.	1987 – Present	Construction of "Over the Horizon Radar" – 162 people.

* Laboratory of Radiation Biology, University of Washington.

† A military-sponsored investigation of possible surface indications of clandestine underground nuclear tests (reported in Shacklette et al., 1970).

‡ Division of Military Application, U.S. Atomic Energy Commission.

§ Alaska Department of Fish and Game. For details on sea otter transplants and harvests, see Abegglen, Chap. 20, this volume.

¶ U.S. Fish and Wildlife Service, Department of the Interior.

** For continued evaluation of test effects and environmental monitoring for radioactivity.

minor to that of the radioactive component of the weapon residues. Radioactive contaminated liquids generated during drillback operations into the Cannikin test site were pumped back into the test cavity and radioactively contaminated soils were packaged and transported to NTS for burial.[1]

OVERALL SITE AND HAZARD ASSESSMENT

The three sites located on Amchitka have had a preliminary HRS conducted utilizing the exist HRS system since the new system is not available. The highest S_m was calculated as 12.05 and exists at the Long Shot site.

It is recommended that sampling of the site be continued. In addition, data collected during migration studies of radionuclides at NTS should be applied to the Amchitka sites to further quantify the likelihood of release from the cavity.

SITE SPECIFIC DESCRIPTION - LONG SHOT

Name of Site - Long Shot Nuclear Test, Amchitka Island, Alaska

Site Location and History - The site of the Long Shot nuclear test is located on Amchitka (Figure 3.3.2). A map of the site is on Figure 3.3.4.[11]

Amchitka Island was the location of three nuclear tests. The first test conducted there, the Long Shot test was on October 29, 1965, was a part of the Vela Uniform program, a DOD project designed to improve the capability to detect, identify, and locate underground nuclear explosions.[18] Table 3.3.2[9] contains the chronology of the Long Shot test.

WASTE GENERATION AND DISPOSAL

Radionuclides produced during an underground nuclear test are usually contained. The estimated amount of waste generated by the Long Shot nuclear test was 2.4×10^{12} Ci at 1 minute after the detonation. This radioactivity is initially produced by a complex mixture of 300 radioisotopes of 36 elements. The radionuclides are dispersed in such a large volume of material that even if there is a fire or explosion hazard in their concentrated states, no such hazard exists in their presently dilute state. Radioactivity is also produced by neutron-activated materials present at the detonation of the device.[4] By 1988, the majority of radioisotopes have reached more stable forms and the radioactivity has dramatically decreased.

Chemical wastes may be present within the Long Shot cavity as nonradiogenic residue of the nuclear device. The quantities of this waste should be relatively small in comparison to the radioactive component.

KNOWN RELEASES

The following description of the extent of radionuclide contamination is taken directly from Merrit et al.[9]

> Air, water, and biological samples collected before and after the 1965, 1969, and 1971 underground nuclear detonations at Amchitka Island were analyzed for natural and fallout radionuclides by gamma spectrometry. Selected samples were also analyzed for tritium, ^{55}Fe and ^{90}Sr. The objectives were to search for and identify

radionuclides of Amchitka origin in the samples and to contribute to the general knowledge of the distribution of radionuclides in the environment. The collection of seafoods and the analysis of samples for radionuclides potentially available to man through the food web were emphasized, but other organisms were also analyzed in the search for radionuclide indicator species. The identification of the origin of the fallout radionuclides in the samples required accurate measurement of the radionuclides in both the pre-event and post-event samples, since some fallout radionuclides were present at Amchitka before the 1965 event and other fallout radionuclides arrived during the 11-year period of study.

The samples were principally collected in areas likely to be contaminated if any seepage of radionuclides from the site of the underground detonations occurred. Of the 81 types of organisms analyzed, 37 were vertebrates (2 mammals, 22 fish, and 13 birds), 20 were invertebrates, 11 were marine algae, 4 were freshwater plants, and 9 were terrestrial plants; several thousand were analyzed.

The studies showed that there has been no escape of radionuclides from the underground sites of the three nuclear detonations at Amchitka Island, except for trace quantities of radionuclides, principally tritium, in water and soil gas samples from the immediate vicinity of the SGZ for the 1965 event. Two naturally-occurring radionuclides, ^{40}K and ^{7}Be, were the most abundant radionuclides in the samples, usually by a factor of 10 or more, except for ^{137}Cs in lichen samples. All levels were well below applicable Radiation Protection Guides, often being near the statistical limit of detection.

Several other studies corroborate the findings of the above report.[19,1,15,8,11] Chemical contamination has also been documented at the Long Shot site. Trace quantities of barium, dichlorodiflouromethane, acetone, arsenic, methylene chloride, acetone, xylene, and benzene were detected in soil samples at the Long Shot SGZ and Long Shot mud pit #2. The most concentrated contaminant appears to be acetone, however, the result is suspect. Assuming that acetone was used at this time, which cannot be confirmed, it is unlikely that it would still be present since it is a highly volatile compound. Second, trace concentrations of acetone were detected in the blank which accompanied the sample, indicating contamination during the analytical process.

POTENTIAL FOR DIRECT CONTACT OR FIRE/EXPLOSION HAZARD

Amchitka is the most remote of all the nuclear test areas within the boundaries of the United States. There are only 162 persons presently on the island as construction workers for the Navy. Owing to its limited access and the minor radiological and chemical contamination of the site, there is only minimal hazard to direct contact.[9] There has not been an observed incident in which hazardous substances from the Long Shot site have caused injury, illness, or death to any humans or animals. Owing to the great depth of burial, the accessibility to the majority of the contamination is minimal.

Owing to the minor chemical concentrations, there appears to be no potential hazard for fire and explosion at the Long Shot site. Containment of the radionuclides is believed almost complete. If these radioactive isotopes were in concentrated forms, some would be very reactive and incompatible, however, in their presently diffused state, no such reactions are possible now or in the future. The nearest population and buildings are in the main camp which is approximately 5 miles away. Since Amchitka Island is a wildlife refuge, the entire area can be considered a sensitive environment. From the above information, and the large quantity of diffuse waste present immediately after detonation, there is only a slight hazard from fire and explosion at this site.

POTENTIAL FOR GROUND-WATER RELEASES

Known releases of radionuclides to the ground water have occurred.[9] The maximum waste present at the site was 2.4×10^{12} Ci within the Long Shot cavity at one minute after detonation.

Ground water from wells is not utilized on Amchitka as water is derived from surface impoundments and springs.[6,9]

NUMBER OF WELLS WITHIN A FOUR-MILE RADIUS

A number of drillholes were drilled in connection with the Long Shot, Milrow, and Cannikin Events. The total number of drillholes within a 4-mile radius of the Long Shot cavity is approximately 39 (the location of all those wells closest to the

Long Shot site are on Figure 3.3.7). Thirty-seven of these boreholes were drilled by the Atomic Energy Commission and two wells existed from World War II. Abandonment plans for all 39 holes were prepared as part of the demobilization program for Amchitka. Thirty-one bore holes were sealed and abandoned by September, 1973. The eight holes (six AEC and two military holes) which remain may be used as ground-water sampling points in the long-term monitoring program.[12] When the long-term monitoring program terminates, these eight holes will be abandoned.[12]

As detailed earlier, the deeper contaminated aquifer discharges into the ocean,[3,9] while the shallow surficial aquifer acts as a recharge conduit for the deeper system as well as surficial lakes and streams.[9] The contamination of the mud pits at Long Shot further demonstrates the interconnectedness of the two aquifers within 2 miles of the Long Shot cavity.

POTENTIAL FOR SURFACE WATER RELEASES

Several seeps containing trace amounts of radionuclides have been found at the mud pits at the Long Shot ground zero.[9,19,1,11,8,15] The mud pits on the Long Shot site drain by surface drainage into Kiril of Bay (Figure 3.3.4).[11] Therefore, there is documentable evidence of surface water contamination occurring at the Long Shot site.

Surface water intakes do not exist on the 1 mile drainage system from the Long Shot site to the Bering Sea. This, combined with the trace amounts of contaminants found within the surface water, and the lack of inhabitants, creates only minimal hazard from surface water contamination. A slight hazard exists for the flora and fauna of the wildlife refuge, which can be considered to be a sensitive environment.

POTENTIAL FOR AIR RELEASES

There has been small amounts of gaseous radionuclides from the Long Shot underground nuclear detonation.[9] If radionuclides are going to vent from an underground detonation, they usually do so within a couple of days from the shot as depressurization of the cavity occurs. Venting did not occur during the test at the Long Shot site.[9,19,1,11,8,15] However, subsequent monitoring has detected trace amounts of tritium emanating as soil gas directly above the crater.[9] The concentra-

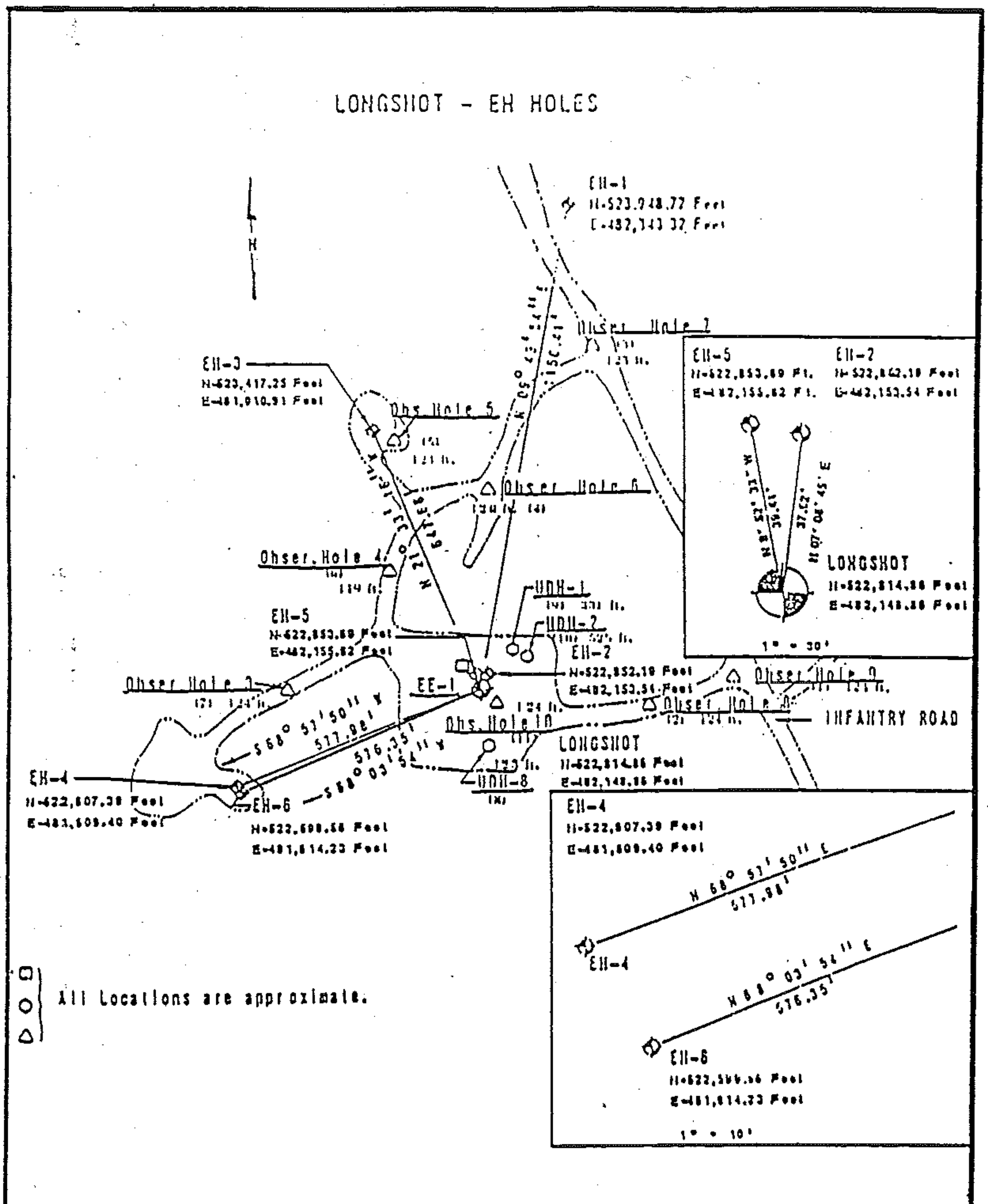


FIGURE 3.3.7. Long Shot – EH Holes.

tions for this gas were measured at a maximum level of 1800 T.U., a level well below the standards set by the International Commission of Radiological Protection[9] of 9×10^5 T.U. The very minute traces of radionuclides found in soil gases, combined with the lack of a permanent population, indicate a very small potential for further hazardous release of airborne contaminants.

THREATS TO THE FOOD CHAIN AND ENVIRONMENT

The following is taken directly from Merrit et al.:[9]

> Many species of fish of commercial importance and otherwise were collected and analyzed for their radionuclide content. The species that best represented the potential transfer of radionuclides from the sea to man were selected for analysis.
>
> Of special interest are seafoods and other organisms that may be eaten by man. Although there are no significant commercial fisheries in the immediate vicinity of Amchitka, radionuclide data were obtained for salmon, ptarmigian, otter, Dolly Varden, halibut and crab. Analysis of the samples indicates no unusual kinds or amounts of radionuclides.

The lack of radionuclides in these possible game animals indicates little threat to the food chain as it relates to man. Other species analyses indicate little or no threat to other species that exist in the higher trophic levels.[9]

CONCLUSION AND RECOMMENDATIONS

A preliminary HRS was conducted for the Long Shot site and is included in Appendix 3.3.A.1. Under the existing scoring system, the migratory score for Long Shot is 12.05.

SITE SPECIFIC DESCRIPTION

Name of Site - Milrow Nuclear Test, Amchitka Island, Alaska

Location - The site of the Milrow nuclear test is located on Amchitka (Figure 3.3.2). A map of the site is on Figure 3.3.5.[19]

HISTORY

Amchitka Island was the location of three nuclear tests. The second test conducted there, the Milrow Test, was detonated on October 2, 1969, at a yield of 1 Mt and was a seismic calibration study conducted in preparation for the Cannikin event. Table 3.3.1[9] contains the chronology of the Milrow test.

WASTE GENERATION AND DISPOSAL

Radionuclides produced during the underground nuclear test at Milrow were contained. The estimated amount of waste generated by the Milrow nuclear test was 3.0×10^{13} Ci at 1 minute after the detonation. Radioactivity is also produced by neutron activated materials present at the detonation of the device.[4] By 1988, the majority of radioisotopes have reached more stable forms and the radioactivity has decreased from its initial levels.

The disposal of chemical wastes at the Milrow Site is present as nonradiogenic residue of the nuclear device. The quantities of this material are believed to be minor when compared to the radioactive wastes.

KNOWN RELEASES

See Known Releases under Long Shot.

Chemical contamination of the surface has been documented at the Milrow site. Trace quantities of methylene chloride were detected in soil samples at the Milrow SGZ.

POTENTIAL FOR DIRECT CONTACT OR FIRE/EXPLOSION HAZARD

Amchitka is the most remote of all the nuclear test areas within the boundaries of the United States. There are only 162 persons presently on the island as construction workers for the Navy. Owing to its limited access and the minor radiological and chemical contamination of the site, there is only minimal hazard to direct contact.[9] There has not been an observed incident in which hazardous substances from the Milrow site has caused injury illness or death to any humans or animals. Owing to the great depth of burial, the accessibility to the majority of the contamination, is minimal.

> Owing to the minor chemical concentrations at the surface, there is not a potential hazard for fire and explosion at the Milrow site. Containment of the radionuclides is almost complete. If these radioactive isotopes were in concentrated forms, some would be very reactive and incompatible, however, in their presently diffused state, no such reactions are possible now or in the future. The nearest population and buildings are in the main camp which is approximately five miles away. Since Amchitka Island is a wildlife refuge, the entire area can be considered a sensitive environment. From the above information, there is only a slight hazard from fire and explosion at this site.

POTENTIAL FOR GROUND-WATER RELEASES

The release of radionuclides to the ground-water flow system is suspected, since the Milrow test was detonated well below the ground-water table.[9] Those radionuclides most susceptible to transport, such as tritium, are suspected to be following the flow system to the Bering Sea. The maximum waste present at the site was 3.0 x 10^{13} curies within the Milrow cavity at one minute after detonation. A few of the radionuclides present in the Milrow nuclear blast are given in Table 3.3.3 along with associated indices for toxicity, persistence, ignitability, reactivity and incompatibility.[20]

Ground water from wells is not utilized on Amchitka, water is derived from surface impoundments and springs.[6,9]

NUMBER OF WELLS WITHIN A FOUR-MILE RADIUS

A number of drillholes were drilled in connection with the Long Shot, Milrow, and Cannikin Events. The total number of drillholes within a 4-mile radius of the Milrow cavity is 39 (the location of those wells closest to the Milrow site is on Figure 3.3.5). Thirty-seven of these boreholes were drilled by the Atomic Energy Commission and two wells existed from World War II. Abandonment plans for all 39 holes were prepared as part of the demobilization program for Amchitka.

Thirty-one boreholes were sealed and abandoned by September 1973. The eight holes (six AEC and two military holes) which remain may be used as ground-water sampling points in the long-term monitoring program.[12] When the long-term monitoring program terminates, these eight holes will be abandoned.[12]

As detailed earlier, the deeper contaminated aquifer discharges into the ocean,[3,9] while the shallow surficial aquifer acts as a recharge conduit for the deeper system, as well as surficial lakes and streams.[9] Therefore, the deep and shallow aquifer systems on Amchitka are hydraulically interconnected.

POTENTIAL FOR SURFACE WATER RELEASES

There is no documentation of surface water releases at the Milrow site.[9,19,1,11,8,15] The potential for such a release is minor as the hydraulic gradient for the Amchitka flow system is down and out to the Bering Sea and not to land surface.[9,3] The potential for surface water release at the Milrow site is very small.

There are no surface water intakes on the 1-mile long drainage system from the Milrow site to the Bering Sea. The average slope is not known at this time, nor is the 1 year, 24 hr rainfall. This evidence, combined with the trace amounts of contaminants found within the surface water and the great depth of burial of the cavity, creates a small hazard from surface water contamination at the Milrow site.

POTENTIAL FOR AIR RELEASES

There has been no documented escape of radionuclides from the Milrow underground nuclear detonation.[9] If radionuclides are going to vent from an underground detonation, they usually do so within a couple of days from the shot as depressurization of the cavity occurs. Venting did not occur at the Milrow site.[9,19,1,11,8,15] Since a venting of radionuclides did not occur, there exists only a slight potential for a hazardous release of airborne contaminants.

THREATS TO THE FOOD CHAIN AND ENVIRONMENT

The following is taken directly from Merrit et al., 1979:[9]

> Many species of fish of commercial importance and otherwise were collected and analyzed for their radionuclide content. The species that best represented the potential transfer of radionuclides from the sea to man were selected for analysis.

> Of special interest are seafoods and other organisms that may be eaten by man. Although there are no significant commercial fisheries in the immediate vicinity of Amchitka, radionuclide data were obtained for salmon, ptarmigan, otter, Dolly Varden, halibut and crab. Analysis of the samples indicate no unusual kinds or amounts of radionuclides.

The lack of radionuclides in these possible game animals indicates little threat to the food chain as it relates to man. Other species analyzed in Merrit et al. (1979) indicate little or no threat to other species that exist in the higher trophic levels.

CONCLUSION AND RECOMMENDATIONS

A preliminary HRS was conducted for the Milrow site and is included in the Appendix 3.3.A.2. Under the existing scoring system, the migratory score for Milrow is 0.0. Detailed topographic maps and climatic summaries for the 1 year, 24 hr rainfall were not available thus, the worst cases were assumed for this score.

SITE SPECIFIC DESCRIPTION - CANNIKIN

Name of Site - Cannikin Nuclear Test, Amchitka Island, Alaska

Location - The site of the Cannikin nuclear test is located on Amchitka (Figure 3.3.2). A map of the site is on Figure 3.3.6.[13]

HISTORY

Amchitka Island was the location of three nuclear tests. The third test conducted there, the Cannikin Test, was detonated on November 6, 1971, at a yield of approximately 5 Mt and was a proof-test of the nuclear warhead for the Spartan anti-ballistic missile system. Table 3.3.1[9] contains the chronology of the Cannikin test.

WASTE GENERATION AND DISPOSAL

Radionuclides produced during an underground nuclear test are usually contained. The estimated amount of waste generated by the Cannikin nuclear test was 1.5×10^{14} curies at one minute after the detonation. Radioactivity is also produced by neutron activated materials present at the detonation of the device.[4] By 1988, the majority of radioisotopes have reached more stable forms and the radioactivity has dramatically decreased from its initial levels.

The historical disposal of chemical wastes, other than those nonradiogenic components of the device, is not documented for the Cannikin site.

KNOWN RELEASES

The following description of the extent of radionuclide contamination is described in the Known Releases section of Long Shot.

Surficial chemical contamination has been found at the Cannikin Site. Trace quantities of barium, 2-butanone, 1-butanol, acetone, 1, 4-dioxane were detected in soil samples at the Cannikin SGZ. The amounts detected were well below hazardous concentrations.

POTENTIAL FOR DIRECT CONTACT OR FIRE/EXPLOSION HAZARD

Amchitka is the most remote of all the nuclear test areas within the boundaries of the United States. There are only 162 persons presently on the island as construction workers for the Navy. Owing to its limited access and the minor radiological and chemical contamination of the site, there is only minimal hazard to direct contact.[9] There has not been an observed incident in which hazardous substances from the Cannikin site have caused injury, illness, or death to any humans or animals. Owing to the great depth of burial, the accessibility to the majority of the contamination is minimal.

Owing to the minor chemical concentrations at the surface, there is not a potential hazard for fire and explosion at the Cannikin site. Containment of the radionuclides is almost complete. If these radioactive isotopes were in concentrated forms, some would be very reactive and incompatible, however, in their presently diffused state, no such reactions are possible now or in the future. The nearest population and buildings are in the main camp which is approximately ten miles away. Since Amchitka Island is a wildlife refuge, the entire area can be considered a sensitive environment. From the above information, there is only a slight hazard from fire and explosion at the Cannikin site.

POTENTIAL FOR GROUND-WATER RELEASES

The release of radionuclides to the ground-water flow system is suspected, since the Cannikin test was detonated well below the ground-water table.[9] Those radionuclides most susceptible to transport, such as tritium, are suspected to be following the flow system to the Bering Sea. The maximum waste present at the site was 1.5×10^{14} Ci within the Cannikin cavity at one minute after detonation. A few of the radionuclides present in the Cannikin nuclear blast are given in Table 3.3.3 along with associated indices for toxicity, persistence, ignitability, reactivity and incompatibility.[20]

Ground water from wells is not utilized on Amchitka, water is derived from surface impoundments and springs.[6,9]

NUMBER OF WELLS WITHIN A FOUR-MILE RADIUS

A number of drillholes were drilled in connection with the Long Shot, Milrow, and Cannikin Events.

The total number of wells within a 4-mile radius of the Cannikin cavity is 39. Thirty-seven of these boreholes were drilled by the Atomic Energy Commission and two wells were left over from World War II. Abandonment plans for all 39 holes were prepared as part of the demobilization program for Amchitka. Thirty-one bore holes were sealed and abandoned by September, 1973. The eight holes (six AEC and two military holes) which remain may be used as ground-water sampling points in the long-term monitoring program.[12] When the long-term monitoring program terminates, these eight holes will be abandoned.[12] The reference for this information is in the Appendix.

As detailed earlier, the deeper contaminated aquifer discharges into the ocean,[3,9] while the shallow surficial aquifer acts as a recharge conduit for the deeper system as well as surficial lakes and streams.[9] Therefore, the deep and shallow aquifer systems on Amchitka are hydraulically interconnected.

POTENTIAL FOR SURFACE WATER RELEASES

There is no documentation of surface water releases at the Cannikin site.[9,19,1,11,8,15] The potential for such a release is minor as the hydraulic gradient for the Amchitka flow system is down and out to the Bering Sea and not to land surface.[9,3] The potential for surface water release at the Cannikin site is believed to be very small.

There are not any known surface water intakes on the approximately 1-1/2 miles long drainage system from the Cannikin site to the Bering Sea. This evidence, combined with the trace amounts of contaminants found within the surface water, and the good degree of containment derived by the great depth of burial, indicates only a minimal hazard from surface water contamination.

POTENTIAL FOR AIR RELEASES

There has been no documented escape of radionuclides from the Cannikin underground nuclear detonation.[9] If radionuclides are going to vent from an underground detonation, they usually do so within a couple of days from the shot as depressurization of the cavity occurs. Venting did not occur at the Milrow site.[9,19,1,11,8,15] Since a venting of radionuclides did not occur and Amchitka lacks of a permanent population, there exists only a slight potential for a hazardous release of airborne contaminants.

THREATS TO THE FOOD CHAIN AND ENVIRONMENT

The lack of radionuclides and chemicals in these potential game animals indicates little threat to the food chain as it relates to man. Other species analyzed in

Merrit et al. (1979) indicate little or no threat to species that exist in the higher trophic levels.

CONCLUSION AND RECOMMENDATIONS

A preliminary HRS was conducted for the Cannikin site and is included in Appendix 3.3.A.3. Under the existing scoring system, the migratory score for Cannikin is 0.00. Detailed topographic maps and climatic summaries for the 1 year, 24 hr rainfall were not available, thus the worst cases were assumed for this score.

The reader is referred to the "Overall Site Assessment" section for recommendations.

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APPENDIX 3.3.A.1
HRS WORKSHEETS
LONG SHOT

FIRE AND EXPLOSION WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
[1] Containment	(1) 3	1	1	3	7.1
[2] Waste Characteristics					7.2
Direct Evidence	(0) 3	1	0	3	
Ignitability	(0) 1 2 3	1	0	3	
Reactivity	(0) 1 2 3	1	0	3	
Incompatibility	(0) 1 2 3	1	0	3	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			8	20	
[3] Targets					7.3
Distance to Nearest Population	(0) 1 2 3 4 5	1	0	5	
Distance to Nearest Building	(0) 1 2 3	1	0	3	
Distance to Sensitive Environment	(0) 1 2 3	1	0	3	
Land Use	0 1 2 (3)	1	3	3	
Population Within 2-Mile Radius	(0) 1 2 3 4 5	1	0	5	
Buildings Within 2-Mile Radius	(0) 1 2 3 4 5	1	0	5	
Total Targets Score			3	24	
[4] Multiply 1 x 2 x 3			24	1,440	
[5] Divide line 4 by 1,440 and multiply by 100			S_{FE} = 1.67		

DIRECT CONTACT WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	8.1

If observed release is given a score of 45, proceed to line 4.

If observed release is given a score of 0, proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Accessibility	0 1 2 (3)	1	3	3	8.2
3 Containment	0 (15)	1	15	15	8.3
4 Waste Characteristics					8.4
Toxicity	0 1 2 (3)	5	15	15	
5 Targets					8.5
Population Within a 1-Mile Radius	(0) 1 2 3 4 5	4	0	20	
Distance to a Critical Habitat	(0) 1 2 3	4	0	12	
Total Targets Score			0	32	
6 If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			0	21,600	
7 Divide line 6 by 21,600 and multiply by 100			S_{DC} = 0		

GROUND WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 (45)	1	45	45	3.1
If observed release is given a score of 45, proceed to line 4.					
If observed release is given a score of 0, proceed to line 2.					
2 Route Characteristics					3.2
Depth to Aquifer of Concern	0 1 2 3	2		6	
Net Precipitation	0 1 2 3	1		3	
Permeability of the Unsaturated Zone	0 1 2 3	1		3	
Physical State	0 1 2 3	1		3	
	Total Route Characteristics Score			15	
3 Containment	0 1 2 3	1		3	3.3
4 Waste Characteristics					3.4
Toxicity/Persistence	0 3 6 9 12 15 (18)	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
	Total Waste Characteristics Score		26	26	
5 Targets					3.5
Ground Water Use	0 (1) 2 3	3	3	9	
Distance to Nearest Well/Population Served	(0) 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
	Total Targets Score		3	49	
6 If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			3,510	57,330	
7 Divide line 6 by 57,330 and multiply by 100			S_{gw} = 6.12		

SURFACE WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 **45**	1	45	45	4.1
If observed release is given a score of 45, proceed to line 4.					
If observed release is given a score of 0, proceed to line 2.					
2 Route Characteristics					4.2
Facility Slope and Intervening Terrain	0 1 2 **3**	1	3	3	
1-yr. 24-hr. Rainfall	0 1 2 **3**	1	3	3	
Distance to Nearest Surface Water	0 1 **2** 3	2	4	6	
Physical State	0 1 2 **3**	1	3	3	
Total Route Characteristics Score				15	
3 Containment	0 1 2 3	1	3	3	4.3
4 Waste Characteristics					4.4
Toxicity/Persistence	0 3 6 9 12 15 **18**	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 **8**	1	8	8	
Total Waste Characteristics Score			26	26	
5 Targets					4.5
Surface Water Use	**0** 1 2 3	3	0	9	
Distance to a Sensitive Environment	0 **1** 2 3	2	2	6	
Population Served/ Distance to Water Intake Downstream	**0** 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
Total Targets Score			2	55	
6 If line 1 is 45, multiply 1 x 4 x 5					
If line 1 is 0, multiply 2 x 3 x 4 x 5			2,340	64,350	
7 Divide line 6 by 64,350 and multiply by 100		S_{SW} = 3.64			

AIR ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 (45)	1	45	45	5.1
Date and Location:					
Sampling Protocol:					

If line 1 is 0, the $S_a = 0$. Enter on line 5.

If line 1 is 45, then proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Waste Characteristics					5.2
Reactivity and Incompatibility	(0) 1 2 3	1	0	3	
Toxicity	0 1 2 (3)	3	9	9	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			17	20	
3 Targets					5.3
Population Within 4-Mile Radius	(0) 9 12 15 18 21 24 27 30	1	0	30	
Distance to Sensitive Environment	0 1 2 (3)	2	6	6	
Land Use	0 1 2 (3)	1	3	3	
Total Targets Score			9	39	
4 Multiply 1 x 2 x 3				35,100	
5 Divide line 4 by 35,100 and multiply by 100			S_a = 19.61		

HRS SCORE FOR LONG SHOT

$S_{gw} = 6.12$

$S_{sw} = 3.64$

$S_a = 19.61$

$$S_m = \frac{1}{1.73} \sqrt{S_{gw} + S_{sw} + S_a}$$

$$S_m = \frac{1}{1.73} \sqrt{6.12 + 3.64 + 19.61}$$

$$S_m = 12.05$$

$S_{FE} = 1.67$

$S_{DC} = 0.0$

APPENDIX 3.3.A.2
HRS WORKSHEETS
PROJECT MILROW

FIRE AND EXPLOSION WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Containment	(1) 3	1	1	3	7.1
2 Waste Characteristics					7.2
Direct Evidence	(0) 3	1	0	3	
Ignitability	(0) 1 2 3	1	0	3	
Reactivity	(0) 1 2 3	1	0	3	
Incompatibility	(0) 1 2 3	1	0	3	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			8	20	
3 Targets					7.3
Distance to Nearest Population	(0) 1 2 3 4 5	1	0	5	
Distance to Nearest Building	(0) 1 2 3	1	0	3	
Distance to Sensitive Environment	(0) 1 2 3	1	0	3	
Land Use	0 1 2 (3)	1	3	3	
Population Within 2-Mile Radius	(0) 1 2 3 4 5	1	0	5	
Buildings Within 2-Mile Radius	(0) 1 2 3 4 5	1	0	5	
Total Targets Score			3	24	
4 Multiply 1 x 2 x 3			24	1,440	
5 Divide line 4 by 1,440 and multiply by 100			S_{FE} = 1.67		

DIRECT CONTACT WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	8.1

If observed release is given a score of 45, proceed to line 4.

If observed release is given a score of 0, proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Accessibility	0 1 (2) 3	1	2	3	8.2
3 Containment	(0) 15	1	0	15	8.3
4 Waste Characteristics					8.4
Toxicity	0 1 2 (3)	5	15	15	
5 Targets					8.5
Population Within a 1-Mile Radius	(0) 1 2 3 4 5	4	0	20	
Distance to a Critical Habitat	(0) 1 2 3	4	0	12	
Total Targets Score			0	32	
6 If line 1 is 45, multiply 1 x 4 x 5					
If line 1 is 0, multiply 2 x 3 x 4 x 5			0	21,600	
7 Divide line 6 by 21,600 and multiply by 100		S_{DC} =	0		

GROUND WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 (45)	1	45	45	3.1

If observed release is given a score of 45, proceed to line 4.

If observed release is given a score of 0, proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Route Characteristics					3.2
Depth to Aquifer of Concern	0 1 2 3	2		6	
Net Precipitation	0 1 2 3	1		3	
Permeability of the Unsaturated Zone	0 1 2 3	1		3	
Physical State	0 1 2 3	1		3	
Total Route Characteristics Score				15	
3 Containment	0 1 2 3	1		3	3.3
4 Waste Characteristics					3.4
Toxicity/Persistence	0 3 6 9 12 15 (18)	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			26	26	
5 Targets					3.5
Ground Water Use	(0) 1 2 3	3	0	9	
Distance to Nearest Well/Population Served	(0) 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
Total Targets Score			0	49	
6 If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			0	57,330	
7 Divide line 6 by 57,330 and multiply by 100		S_{gw} =	0		

SURFACE WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	4.1
If observed release is given a score of 45, proceed to line 4.					
If observed release is given a score of 0, proceed to line 2.					
2 Route Characteristics					4.2
Facility Slope and Intervening Terrain	0 1 2 (3)	1	3	3	
1-yr. 24-hr. Rainfall	0 1 2 (3)	1	3	3	
Distance to Nearest Surface Water	0 1 2 (3)	2	6	6	
Physical State	0 1 2 (3)	1	3	3	
Total Route Characteristics Score			15	15	
3 Containment	(0) 1 2 3	1	0	3	4.3
4 Waste Characteristics					4.4
Toxicity/Persistence	0 3 6 9 12 15 (18)	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			26	26	
5 Targets					4.5
Surface Water Use	(0) 1 2 3	3	0	9	
Distance to a Sensitive Environment	0 (1) 2 3	2	2	6	
Population Served/Distance to Water Intake Downstream	(0) 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
Total Targets Score			2	55	
6 If line 1 is 45, multiply 1 x 4 x 5					
If line 1 is 0, multiply 2 x 3 x 4 x 5			0	64,350	
7 Divide line 6 by 64,350 and multiply by 100		S_{SW} =	0		

AIR ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	5.1
Date and Location:					
Sampling Protocol:					
If line 1 is 0, the $S_a = 0$. Enter on line 5. If line 1 is 45, then proceed to line 2.					
2 Waste Characteristics					5.2
Reactivity and Incompatibility	0 1 2 3	1		3	
Toxicity	0 1 2 3	3		9	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1		8	
Total Waste Characteristics Score				20	
3 Targets					5.3
Population Within 4-Mile Radius	0 9 12 15 18 21 24 27 30	1		30	
Distance to Sensitive Environment	0 1 2 3	2		6	
Land Use	0 1 2 3	1		3	
Total Targets Score				39	
4 Multiply 1 x 2 x 3				35,100	
5 Divide line 4 by 35,100 and multiply by 100		$S_a = 0$			

HRS SCORE FOR PROJECT MILROW

$$S_m = \frac{1}{1.73}\sqrt{S_{gw} + S_{sw} + S_a}$$

$$S_m = \frac{1}{1.73}\sqrt{0.0 + 0.0 + 0.0}$$

$$S_m = 0.0$$

$$S_{FE} = 1.67$$

$$S_{DC} = 0.0$$

APPENDIX 3.3.A.3
HRS WORKSHEETS
PROJECT CANNIKIN

FIRE AND EXPLOSION WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
[1] Containment	(1) 3	1	1	3	7.1
[2] Waste Characteristics					7.2
Direct Evidence	(0) 3	1	0	3	
Ignitability	(0) 1 2 3	1	0	3	
Reactivity	(0) 1 2 3	1	0	3	
Incompatibility	(0) 1 2 3	1	0	3	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			8	20	
[3] Targets					7.3
Distance to Nearest Population	(0) 1 2 3 4 5	1	0	5	
Distance to Nearest Building	(0) 1 2 3	1	0	3	
Distance to Sensitive Environment	(0) 1 2 3	1	0	3	
Land Use	0 1 2 (3)	1	3	3	
Population Within 2-Mile Radius	(0) 1 2 3 4 5	1	0	5	
Buildings Within 2-Mile Radius	(0) 1 2 3 4 5	1	0	5	
Total Targets Score			3	24	
[4] Multiply 1 x 2 x 3			24	1,440	
[5] Divide line 4 by 1,440 and multiply by 100			S_{FE} = 1.67		

DIRECT CONTACT WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
[1] Observed Release	(0) 45	1	0	45	8.1

If observed release is given a score of 45, proceed to line 4.

If observed release is given a score of 0, proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
[2] Accessibility	0 1 (2) 3	1	2	3	8.2
[3] Containment	(0) 15	1	0	15	8.3
[4] Waste Characteristics					8.4
Toxicity	0 1 2 (3)	5	15	15	
[5] Targets					8.5
Population Within a 1-Mile Radius	(0) 1 2 3 4 5	4	0	20	
Distance to a Critical Habitat	(0) 1 2 3	4	0	12	
Total Targets Score			0	32	
[6] If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			0	21,600	
[7] Divide line 6 by 21,600 and multiply by 100			S_{DC} = 0		

GROUND WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 (45)	1	45	45	3.1

If observed release is given a score of 45, proceed to line 4.

If observed release is given a score of 0, proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Route Characteristics					3.2
Depth to Aquifer of Concern	0 1 2 3	2		6	
Net Precipitation	0 1 2 3	1		3	
Permeability of the Unsaturated Zone	0 1 2 3	1		3	
Physical State	0 1 2 3	1		3	
Total Route Characteristics Score				15	
3 Containment	0 1 2 3	1		3	3.3
4 Waste Characteristics					3.4
Toxicity/Persistence	0 3 6 9 12 15 (18)	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			26	26	
5 Targets					3.5
Ground Water Use	(0) 1 2 3	3	0	9	
Distance to Nearest Well/Population Served	(0) 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
Total Targets Score			0	49	
6 If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			0	57,330	
7 Divide line 6 by 57,330 and multiply by 100		S_{gw} =	0		

SURFACE WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	4.1

If observed release is given a score of 45, proceed to line 4.

If observed release is given a score of 0, proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Route Characteristics					4.2
Facility Slope and Intervening Terrain	0 1 2 (3)	1	3	3	
1-yr. 24-hr. Rainfall	0 1 2 (3)	1	3	3	
Distance to Nearest Surface Water	0 1 2 (3)	2	6	6	
Physical State	0 1 2 (3)	1	3	3	
Total Route Characteristics Score			15	15	
3 Containment	(0) 1 2 3	1	0	3	4.3
4 Waste Characteristics					4.4
Toxicity/Persistence	0 3 6 9 12 15 (18)	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			26	26	
5 Targets					4.5
Surface Water Use	(0) 1 2 3	3	0	9	
Distance to a Sensitive Environment	0 1 2 (3)	2	6	6	
Population Served/ Distance to Water Intake Downstream	(0) 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
Total Targets Score			6	55	
6 If line 1 is 45, multiply 1 x 4 x 5					
If line 1 is 0, multiply 2 x 3 x 4 x 5			0	64,350	
7 Divide line 6 by 64,350 and multiply by 100		S_{SW} =	0		

AIR ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	5.1
Date and Location:					
Sampling Protocol:					
If line 1 is 0, the S_a = 0. Enter on line 5. If line 1 is 45, then proceed to line 2.					
2 Waste Characteristics					5.2
Reactivity and Incompatibility	0 1 2 3	1		3	
Toxicity	0 1 2 3	3		9	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1		8	
Total Waste Characteristics Score				20	
3 Targets					5.3
Population Within 4-Mile Radius	0 9 12 15 18 21 24 27 30	1		30	
Distance to Sensitive Environment	0 1 2 3	2		6	
Land Use	0 1 2 3	1		3	
Total Targets Score				39	
4 Multiply 1 x 2 x 3				35,100	
5 Divide line 4 by 35,100 and multiply by 100		S_a = 0			

HRS SCORE FOR
PROJECT CANNIKIN

$$S_m = \frac{1}{1.73} \sqrt{S_{gw} + S_{sw} + S_a}$$

$$S_m = \frac{1}{1.73} \sqrt{0.0 + 0.0 + 0.0}$$

$$S_m = 0.0$$

$S_{FE} = 1.67$

$S_{DC} = 0.0$

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SECTION 3.4

COVER SHEET

NAME OF SITE:	Project Shoal
LOCATION:	The Project Shoal site is located in the Sand Springs Mountain Range, approximately 30 miles southeast of Fallon, Nevada.
DISPOSITION:	The site was returned to Bureau of Land Management control in 1970. The Department of Energy maintains rights to access the site for sampling.

PRELIMINARY ASSESSMENT REPORT
PROJECT SHOAL NUCLEAR TEST SITE

INTRODUCTION

Project Shoal was part of a joint program of the U.S. Department of Defense and the Atomic Energy Commission (AEC) aimed at improving the ability to detect and identify underground nuclear explosions. The project combined two experiments recommended by panels of experts in 1959 and 1960. The first recommendation was for detonating a nuclear device in granite to determine the effect of this different medium on the resulting seismic waves (all previous underground nuclear explosions had been in tuff). The second was to detonate a device underground in an earthquake-prone area in hopes of comparing the seismic activity from natural earthquakes and underground nuclear explosions and improving techniques for differentiating between the two.

Seismic areas in several states were considered for Project Shoal, but most either failed to meet the geologic criteria or were too close to human populations. In 1961, the Sand Springs Range in Churchill County, Nevada, was selected as a tentative Project Shoal site. After a year-long geologic exploration of the area, a site was chosen and preparations for the test began in late 1962.

OVERALL FACILITY DESCRIPTION

The Shoal site is in the northern part of the Sand Springs Range about 30 miles southeast of Fallon, Nevada (see Figure 3.4.1). The surface ground zero (SGZ) is in the center of 4 miles^2 of BLM land that was withdrawn from the public domain and assigned to the AEC in September 1962. The AEC was also granted right of entry to a 20-mile by 20-mile area surrounding the site.

ENVIRONMENTAL SETTING

The site is located on a high (5,200 ft above sea level), gently rolling plateau that falls away steeply to valley floors to the east and west. No permanent bodies of water or streams exist in the area; the major intermittent drainage coarse leads to Fairview Valley to the east. The area is covered with sparse low vegetation. No endangered species are known to exist in the area, and it is not close to any National Parks or Monuments, wilderness areas, or other sensitive environments.

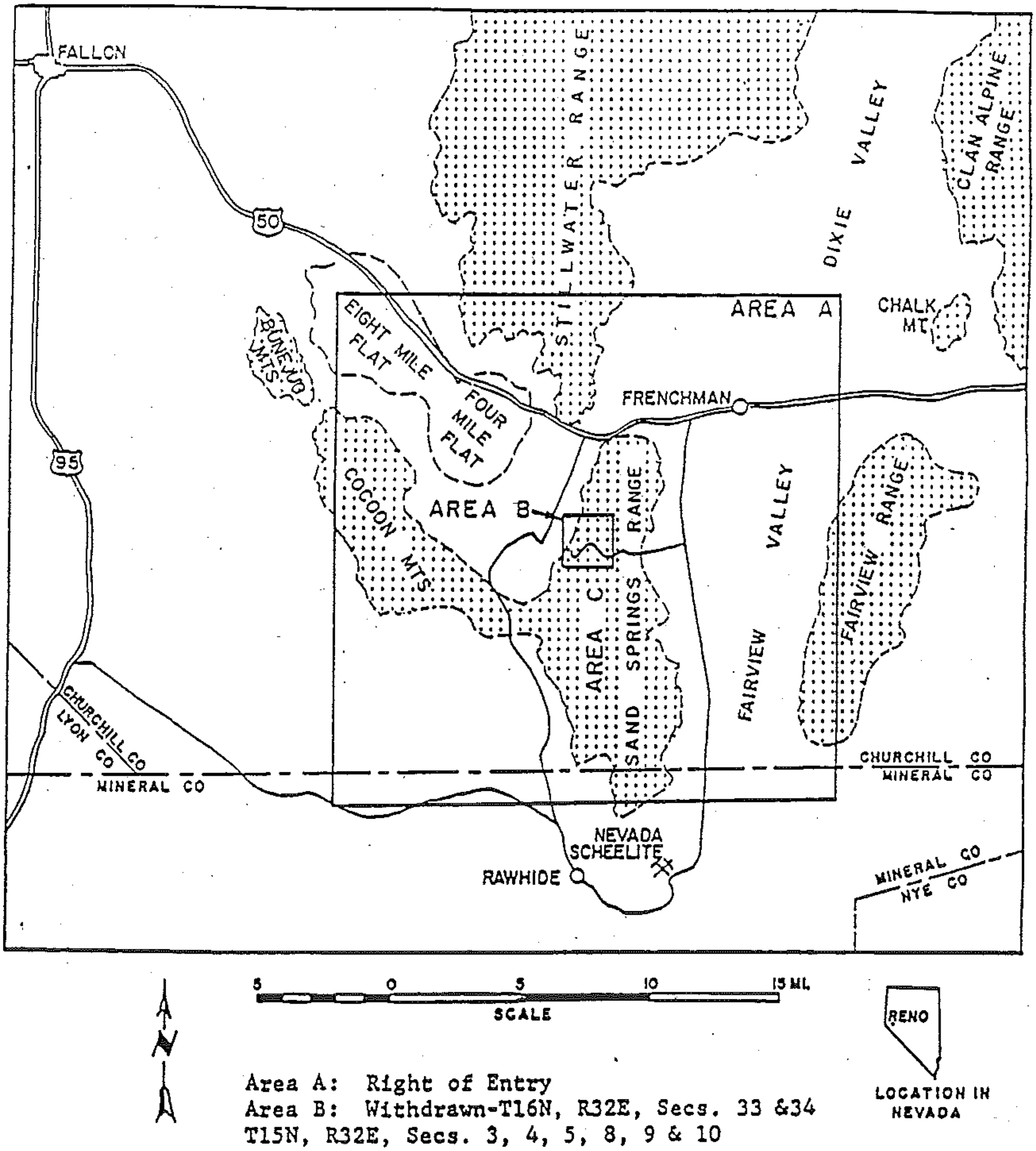

FIGURE 3.4.1. Map of the Project Shoal Site.

HYDROGEOLOGIC SUMMARY

The water table lies about 970 ft below the ground surface, with the piezometric surface sloping away from the site to both the east and the west. The underlying granitic rocks have little capacity to transmit water.

Annual precipitation at the site averages about 8 in. from rainfall and snowfall combined.

HUMAN RECEPTORS

The site is surrounded by unimproved rangeland, and there are no human populations within 4 miles. A ranch 5 miles to the west is the closest inhabited area. In 1987, Frenchman Station (8 miles to the northeast) was abandoned and dismantled as a result of Department of Defense activities.

There are numerous mines in the area, but only two inactive tungsten mines lie within 4 miles of the site. The only active mine within 10 miles is a gold mine 5 miles north of the site.

Six water wells exist within 4 miles of the site. Four of these are AEC (now DOE) test wells drilled as part of the preliminary exploration of the area and since transferred to the BLM. A stock well of unknown depth lies 4 miles northwest and a 315-ft domestic well lies 4 miles west of the site.

ENVIRONMENTAL RECEPTORS

Environmental receptors at the Shoal Test Site are comprised of typical basin and range flora and fauna, such as coyote and mull deer. (No known existence of federally listed threatened or endangered species has been documented in the area.)

HISTORY

Excavation at the site began with the mining of a 12-ft x 6-ft vertical shaft to a depth of 1,320 ft. At the bottom of the shaft, an 8-ft x 8-ft horizontal drift was mined 320 ft to the west and 1,050 ft to the east. The eastern part of the drift terminated in a 30-ft vertical "buttonhook" within which the nuclear device was placed. Five sand plugs were then placed in the drift and shaft to help prevent the release of radioactivity from the explosion.

The device, with an estimated yield of 12.5 kt, was detonated on October 26, 1963. The explosion created a chimney 170 ft in diameter and 460 ft high. Except for a 36-ft void at the top, the chimney is filled with rubble.

Deactivation of the site began almost immediately after the explosion. All traces of the equipment were removed by January 31, 1964, and the site was placed on standby status. A permanent concrete slab was put over the shaft, and the other boreholes leading to the cavity were permanently sealed.

The site was released by the AEC to the BLM in 1970.[3] At that time, it was anticipated that the U.S. Navy would request use of the land for inclusion in the Fallon Naval Auxiliary Air Station.

No information has been found concerning current use of the site and inspection schedules.

WASTE GENERATION AND DISPOSAL

Precise details of the Shoal test are classified, but a fission explosion of 12.5 kt would be expected to produce about 3 x 10^{11} Ci of radioactivity one minute after detonation.[1] Virtually all of the high-level radiation from Shoal was believed confined to the melt-rubble mixture at the bottom of the chimney. There was no venting of particulate debris during or after the explosion.

KNOWN RELEASES

Minor levels of radioactivity did reach the surface during drillback operations after the shot, but most of this release was gas that was safely channeled into filters and traps. Contaminated soil and cuttings from the post-shot drilling were mixed with clean soil and buried. The contaminants were short-lived radioisotopes of iodine and xenon that have since decayed to below detectable levels. A final radiological survey of the surface showed no radiation levels above natural background.

Off-site monitoring by the Public Health Service included ground and aerial readings on the day of detonation, whole-body counting of all monitors, and analysis of air, water, and milk samples collected periodically for a year after the event. In addition, a long-term hydrological monitoring program has collected and analyzed water samples from five nearby wells since 1972. No radioactivity above background levels has been detected off-site.[3,4]

POTENTIAL FOR DIRECT CONTACT OR FIRE/EXPLOSION

No ignitable or explosive substances are present, so the potential for fire and explosion is minimal. Direct contact with this waste is unlikely due to the depth of burial. The disposal of contaminated drill cuttings may pose a hazard although these radionuclides had short half lives and have likely decayed.[2]

POTENTIAL FOR GROUND-WATER RELEASE

As the device was detonated below the water table, it can be assumed that the ground water in the immediate vicinity is contaminated. Calculations indicated that it would take 12 years for the chimney to fill with water, after which time the natural ground-water conditions would prevail. However, because of the very low ground-water velocities, direct flow to the vicinity of the nearest well was projected to take at least 750 years. Other calculations showed that tritium would move only 3,300 ft in the 130 years needed for the estimated concentration to decay to the Recommended Concentration Guide level. As the nearest well capable of producing is 15,000 ft away, there appears to be no radiological danger to any present local water sources.

POTENTIAL FOR SURFACE RELEASE

Except for the buried contaminated soil and drill cuttings, no known radioactive objects which are water-soluble or flood-transportable were left on or near the surface.

Virtually all of the residual radioactivity from the explosion remains trapped in the chimney and drift and surrounding fractured rock. The site area is seismically active, and future earthquakes could cause rearrangement of the rubble in the chimney and further collapse of the ceiling. However, with more than 800 ft of granite between the top of the chimney and the surface, a complete collapse of the chimney resulting in release of radioactivity to the surface is unlikely.

With the granite shield over the chimney intact, the only way radioactivity could reach the surface is through man-made openings (shafts, drifts, and boreholes). The collapse of the original shaft below 1,060 ft, the intervening sand plugs, and the concrete slab over the shaft at the surface prevent access to the radioactive melt through the original shaft and drift. The other holes leading to the cavity have also been sealed. In addition, an excavation and drilling exclusion area has been established in the region between 180 ft and 1,700 ft below the SGZ and out to a horizontal distance of 3,300 ft from the SGZ.

Assuming that the site is inspected often enough to ensure that no drilling into the cavity is taking place, there is little chance that any radioactivity will reach the surface. The potential for direct contact or release into the air or occasional surface water is therefore minimal.

POTENTIAL FOR AIR RELEASE

The potential for further air release of radioactivity is minimal as all drill holes into the cavity have been plugged.

CONCLUSION AND RECOMMENDATIONS

A preliminary HRS was conducted for the Shoal site and is included in Appendix 3.4.A. The Shoal site scored an S_m score of 3.52. This value was calculated from the existing HRS system as the new one was not available as of March 17, 1988.

It is recommended that ground-water monitoring be continued. Further investigation is suggested to quantify the quantity and toxicity buried near the surface. These data should then be used to direct further actions.

REFERENCES

All information in this preliminary assessment that is not otherwise attributed was taken from the Shoal site disposal report (the second reference below).

1. Glasstone, S. and P. J. Dolan. 1977. The Effects of Nuclear Weapons, third edition. U.S. Department of Defense and Department of Energy.

2. U.S. Atomic Energy Commission. 1970. Site Disposal Report, Fallon Nuclear Test Site (Shoal). Holmes & Narver, Inc. NVO-73.

3. U.S. Department of Energy. 1984. Long-term Hydrologic Monitoring Program, Project Shoal Site. NVO-276.

4. U.S. Public Health Service. 1964. Final Report of Off-site Surveillance, Vela Uniform Project Shoal. Southwestern Radiological Health Laboratory. VUF-1009.

APPENDIX 3.4.A
HRS WORKSHEETS
PROJECT SHOAL

FIRE AND EXPLOSION WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Containment	(1) 3	1	1	3	7.1
2 Waste Characteristics					7.2
Direct Evidence	(0) 3	1	0	3	
Ignitability	(0) 1 2 3	1	0	3	
Reactivity	(0) 1 2 3	1	0	3	
Incompatibility	(0) 1 2 3	1	0	3	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			8	20	
3 Targets					7.3
Distance to Nearest Population	(0) 1 2 3 4 5	1	0	5	
Distance to Nearest Building	(0) 1 2 3	1	0	3	
Distance to Sensitive Environment	(0) 1 2 3	1	0	3	
Land Use	(0) 1 2 3	1	0	3	
Population Within 2-Mile Radius	(0) 1 2 3 4 5	1	0	5	
Buildings Within 2-Mile Radius	(0) 1 2 3 4 5	1	0	5	
Total Targets Score			0	24	
4 Multiply 1 x 2 x 3			0	1,440	
5 Divide line 4 by 1,440 and multiply by 100		S_{FE} = 0			

DIRECT CONTACT WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	8.1

If observed release is given a score of 45, proceed to line 4.

If observed release is given a score of 0, proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Accessibility	0 1 2 (3)	1	3	3	8.2
3 Containment	(0) 15	1	0	15	8.3
4 Waste Characteristics					8.4
Toxicity	0 1 2 (3)	5	15	15	
5 Targets					8.5
Population Within a 1-Mile Radius	(0) 1 2 3 4 5	4	0	20	
Distance to a Critical Habitat	(0) 1 2 3	4	0	12	
Total Targets Score			0	32	
6 If line 1 is 45, multiply 1 x 4 x 5					
If line 1 is 0, multiply 2 x 3 x 4 x 5			0	21,600	
7 Divide line 6 by 21,600 and multiply by 100		S_{DC} = 0			

GROUND WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 (45)	1	45	45	3.1
If observed release is given a score of 45, proceed to line 4.					
If observed release is given a score of 0, proceed to line 2.					
2 Route Characteristics					3.2
Depth to Aquifer of Concern	(0) 1 2 3	2	0	6	
Net Precipitation	(0) 1 2 3	1	0	3	
Permeability of the Unsaturated Zone	0 1 2 (3)	1	3	3	
Physical State	0 1 2 (3)	1	3	3	
Total Route Characteristics Score				15	
3 Containment	0 1 2 3	1		3	3.3
4 Waste Characteristics					3.4
Toxicity/Persistence	0 3 6 9 12 15 (18)	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			26	26	
5 Targets					3.5
Ground Water Use	0 (1) 2 3	3	3	9	
Distance to Nearest Well/Population Served	(0) 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
Total Targets Score			3	49	
6 If line 1 is 45, multiply 1 x 4 x 5					
If line 1 is 0, multiply 2 x 3 x 4 x 5			3,510	57,330	
7 Divide line 6 by 57,330 and multiply by 100		S_{gw} =	6.12		

SURFACE WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	4.1

If observed release is given a score of 45, proceed to line 4.

If observed release is given a score of 0, proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Route Characteristics					4.2
Facility Slope and Intervening Terrain	0 1 2 (3)	1	3	3	
1-yr. 24-hr. Rainfall	0 1 (2) 3	1	2	3	
Distance to Nearest Surface Water	(0) 1 2 3	2	0	6	
Physical State	0 1 2 (3)	1	3	3	
Total Route Characteristics Score			8	15	
3 Containment	0 1 2 (3)	1	3	3	4.3
4 Waste Characteristics					4.4
Toxicity/Persistence	0 3 6 9 12 15 (18)	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			26	26	
5 Targets					4.5
Surface Water Use	(0) 1 2 3	3	0	9	
Distance to a Sensitive Environment	(0) 1 2 3	2	0	6	
Population Served/ Distance to Water Intake Downstream	(0) 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
Total Targets Score			0	55	
6 If line 1 is 45, multiply 1 x 4 x 5					
If line 1 is 0, multiply 2 x 3 x 4 x 5			0	64,350	
7 Divide line 6 by 64,350 and multiply by 100		S_{SW} =	0		

AIR ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	5.1
Date and Location: During Production Testing					
Sampling Protocol:					
If line 1 is 0, the S_a = 0. Enter on line 5. If line 1 is 45, then proceed to line 2.					
2 Waste Characteristics					5.2
Reactivity and Incompatibility	0 1 2 3	1		3	
Toxicity	0 1 2 3	3		9	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1		8	
Total Waste Characteristics Score				20	
3 Targets					5.3
Population Within 4-Mile Radius	0 9 12 15 18 21 24 27 30	1		30	
Distance to Sensitive Environment	0 1 2 3	2		6	
Land Use	0 1 2 3	1		3	
Total Targets Score				39	
4 Multiply 1 x 2 x 3				35,100	
5 Divide line 4 by 35,100 and multiply by 100		S_a = 0			

HRS SCORE FOR PROJECT SHOAL

$$S_m = \frac{1}{1.73} \sqrt{S_{gw} + S_{sw} + S_a}$$

$$S_m = \frac{1}{1.73} \sqrt{6.1 + 0.0 + 0.0}$$

$$S_m = 3.52$$

$$S_{FE} = 0.0$$

$$S_{DC} = 0.0$$

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PRELIMINARY ASSESSMENT REPORT
PROJECT RIO BLANCO

INTRODUCTION

Project Rio Blanco was a joint government industry experiment using nuclear explosives to stimulate the flow of natural gas from low permeability formations which could not be economically produced through conventional methods. The project consisted of the simultaneous detonation of three nuclear explosions on May 17, 1973, in a 7,000 ft well in northwestern Colorado (Figure 3.5.1).[1] The experiment was designed to fracture a 1,300 ft section of the Fort Union and Mesa Verde gas sands. The explosives were located at depths of 5,838.5, 6,229.7, and 6,689.5 ft and had a total explosive yield of approximately 90 kt.[1]

FACILITY DESCRIPTION

Four distinct areas comprised the project site (Figure 3.5.3).[1] The first, or emplacement well location was an irregularly shaped area of approximately 3.2 acres with an adjoining drilling mud reserve pit approximately 20 ft deep, 145 ft long, and 45 ft wide. The second area was the flare stack location which was primarily undisturbed with the exception of cleared vegetation and a concrete flare stack foundation. The third area included the RB-AR-2 well and Fawn Creek Government No. 1 well locations and was a contiguous area roughly rectangular in shape of about 3.4 acres. The principal topographical alteration on this third area was the 15 ft deep, 120 ft long by 80 ft wide drilling mud reserve pit. The fourth area, the RB-U-4 well location, was a balance cut and fill area of approximately two acres which included a 20 ft deep, 180 ft long by 60 ft wide drilling mud reserve pit.[1]

ENVIRONMENTAL SETTING

The entire Piceance Creek Basin area is zoned by Rio Blanco County for agriculture use, which permits agricultural farming, ranching, forestry, recreation, and accessory uses (Figure 3.5.4).[3]

The principal land use of the Piceance Creek Basin is to graze livestock. The pinon-juniper-native grass vegetative types have provided forage for livestock for at least 90 years.[3]

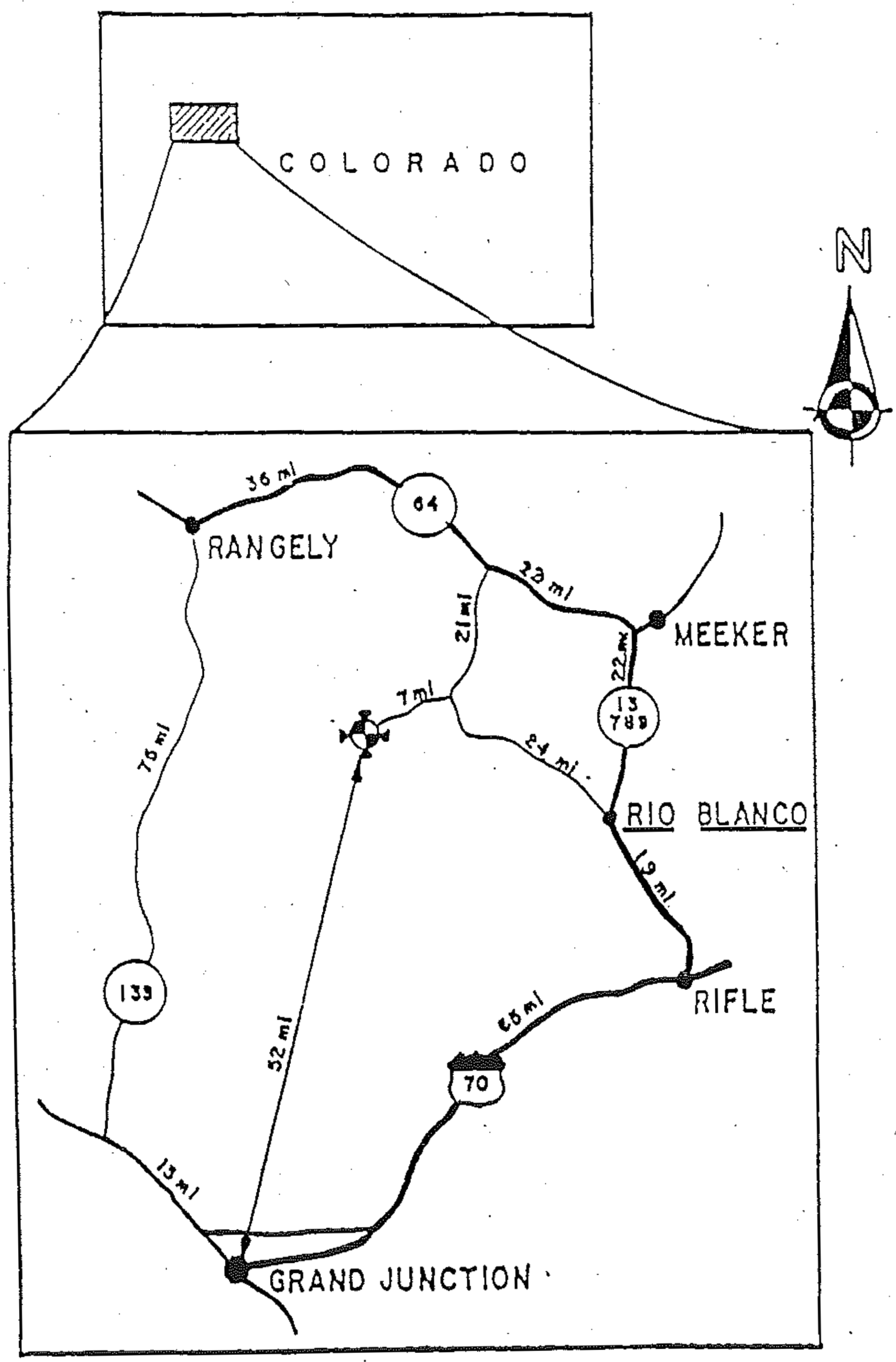


FIGURE 3.5.1. Project Rio Blanco Site Location Map.

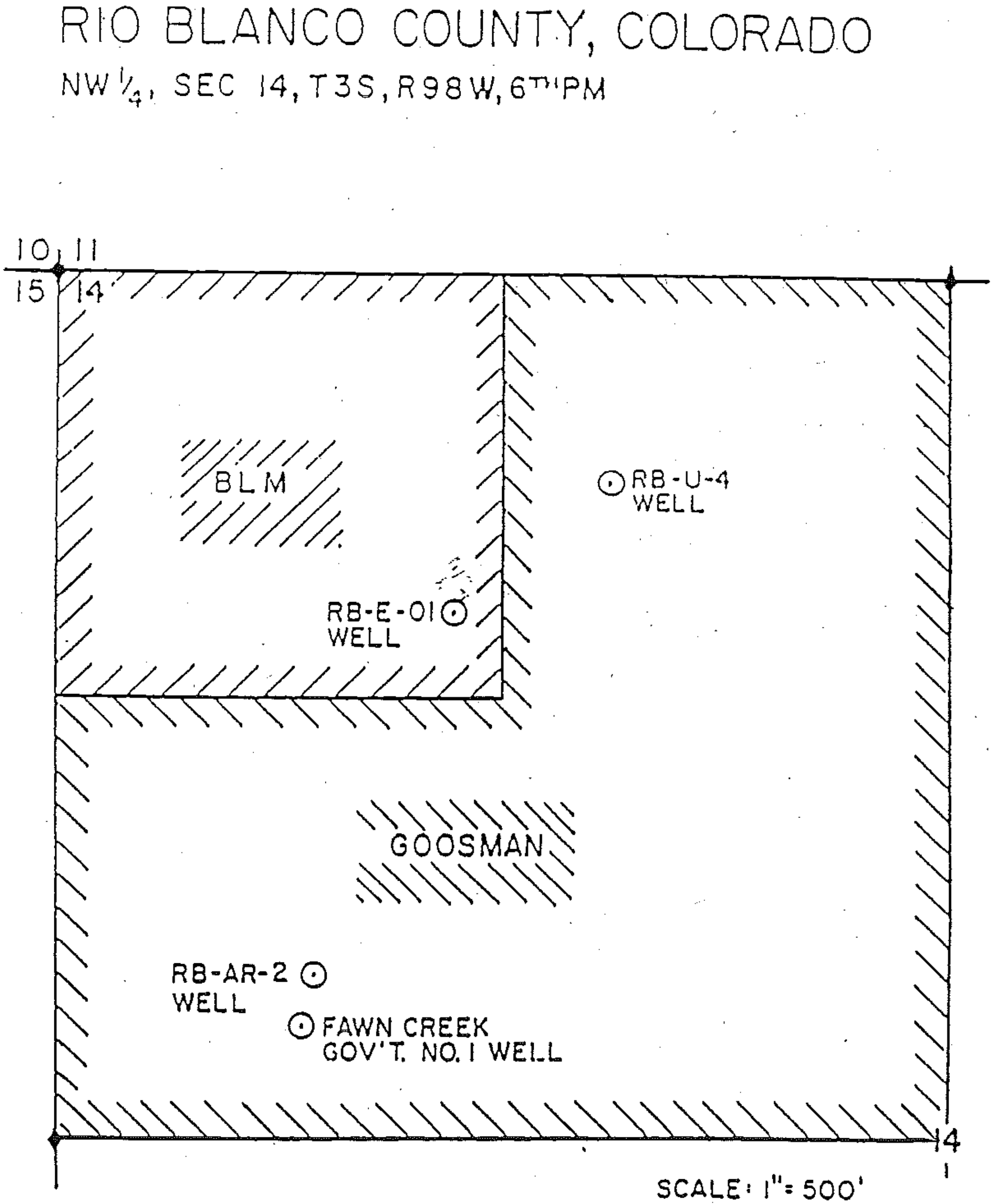


FIGURE 3.5.2. Land Surface Ownership Plat.

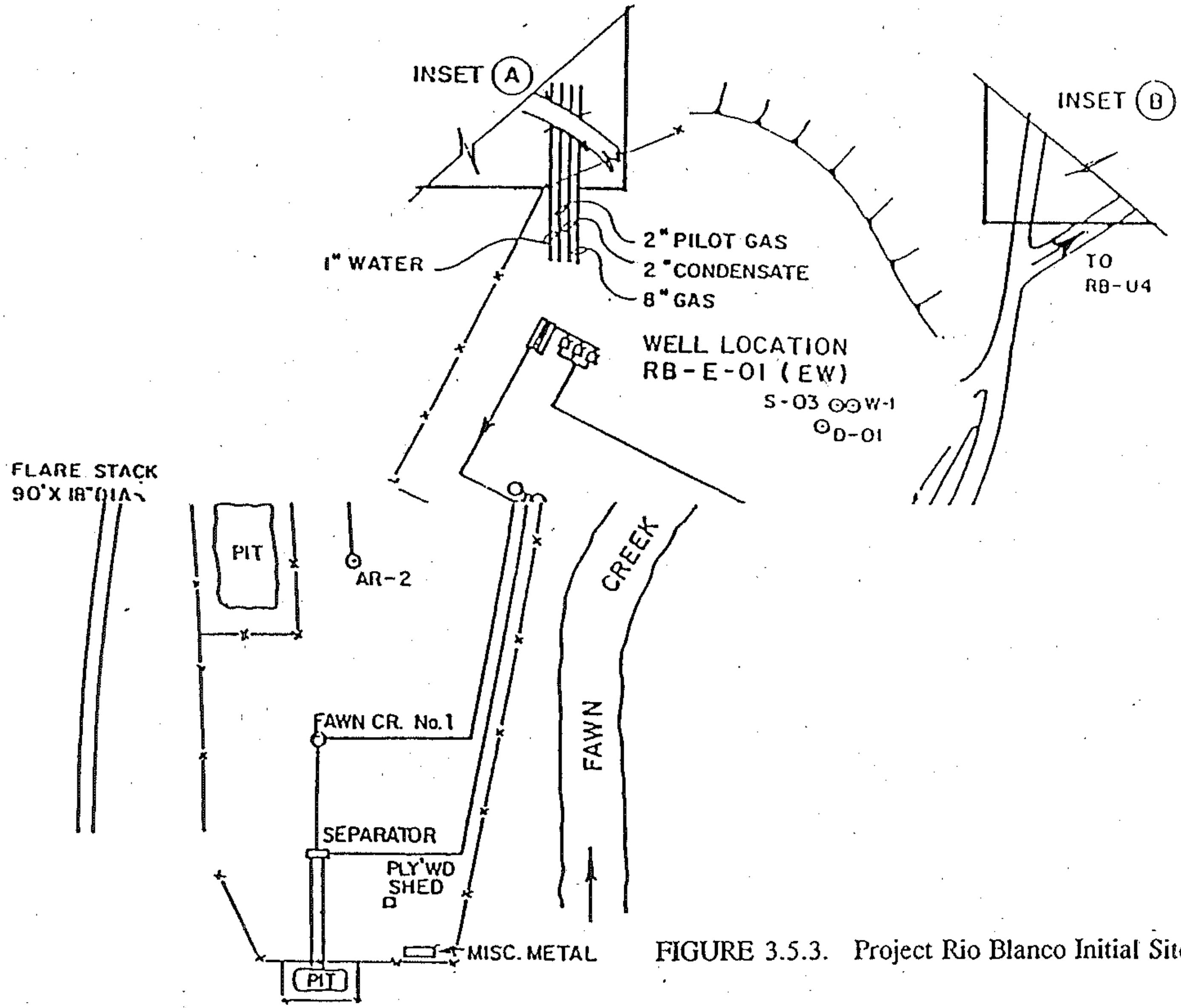


FIGURE 3.5.3. Project Rio Blanco Initial Site Status.

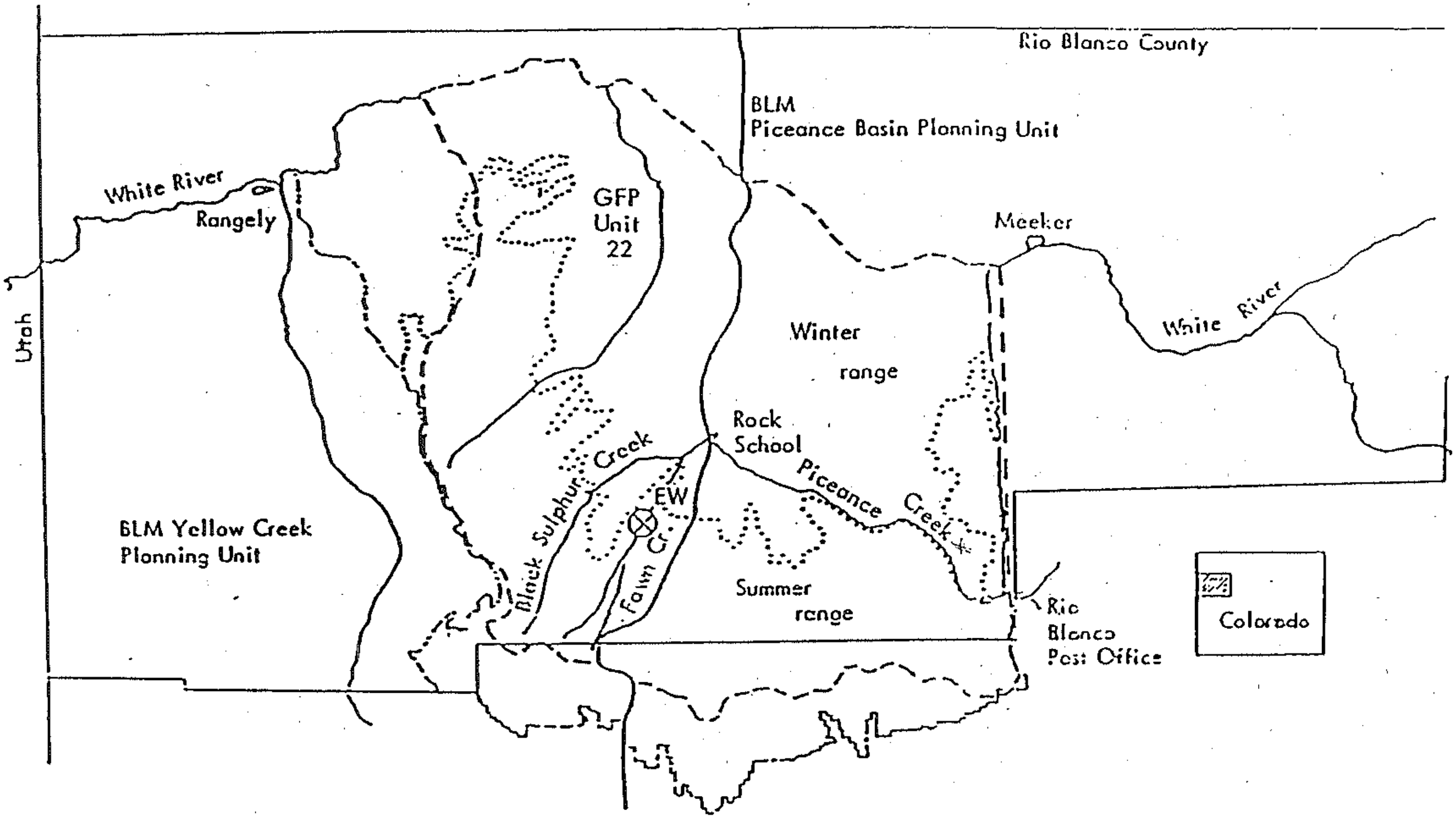


FIGURE 3.5.4. Northern Piceance Creek Basin, Divided as Shown into the Piceance Creek and Yellow Creek Planning Units of the Bureau of Land Management. The Central Area, Within the Heavy Dashed Line, is Game Management Unit 22 of the Colorado Division of Game, Fish, and Parks. Shown Also are the Usual Winter and Summer Ranges for Deer.

The livestock industry is the largest contributor to the county's agricultural economy. In recent years, the number of sheep raised in the county has slightly exceeded the number of cattle. The number of cattle grazing the BLM Yellow Creek and Piceance Basin planning units (covering most of the northern Piceance Creek Basin) is approximately 10,300 or 28 percent of the total for Rio Blanco County. For sheep, the estimate is 9,300 or 17 percent of the total.[3]

The entire site lies within the boundaries of Game Management Unit 22, Colorado Division of Game, Fish, and Parks (Figure 3.5.4). There are hunting seasons for deer, elk, mountain lion, and many wild fowl species.[3]

Little sport fishing exists in the project area. The predominant fish species in Piceance Creek are the mountain sucker and the speckled dace, neither of which is considered sport fish.[3]

There is also a small campground at the confluence of Cow Creek and Piceance Creek, about 20 miles southeast of the EW. In addition, there are camping facilities at Rio Blanco Lake, some 22-1/2 miles north. Other than these two distinct locations, the area has not been developed for camping. During the fall hunting season, however, deer and elk hunters camp in undeveloped areas throughout the basin.[3]

HYDROGEOLOGIC SUMMARY

Figure 3.5.5[4] is a diagrammatic cross-section of the Piceance Creek Basin showing the major aquifers of the project area: the alluvium aquifer, and the "A" and "B" members of the Green River aquifer system.

The alluvium is a source of ground water in the Piceance Creek Basin and is capable of storing and transmitting more water per unit volume than any of the bedrock aquifers. However, the alluvial aquifer is limited to belts less than a mile wide along the major drainages, consequently, the total volume of water encountered in the alluvium is small compared to the underlying Green River ground-water system. The alluvium thickness varies from 0 to 140 ft, and the saturated thickness reaches 100 ft.[4]

The alluvial aquifer is recharged by precipitation, applied surface water, streams, and infiltration from the Green River Formation. The aquifer discharges to streams, springs, wells, and to the atmosphere by evapotranspiration.[4]

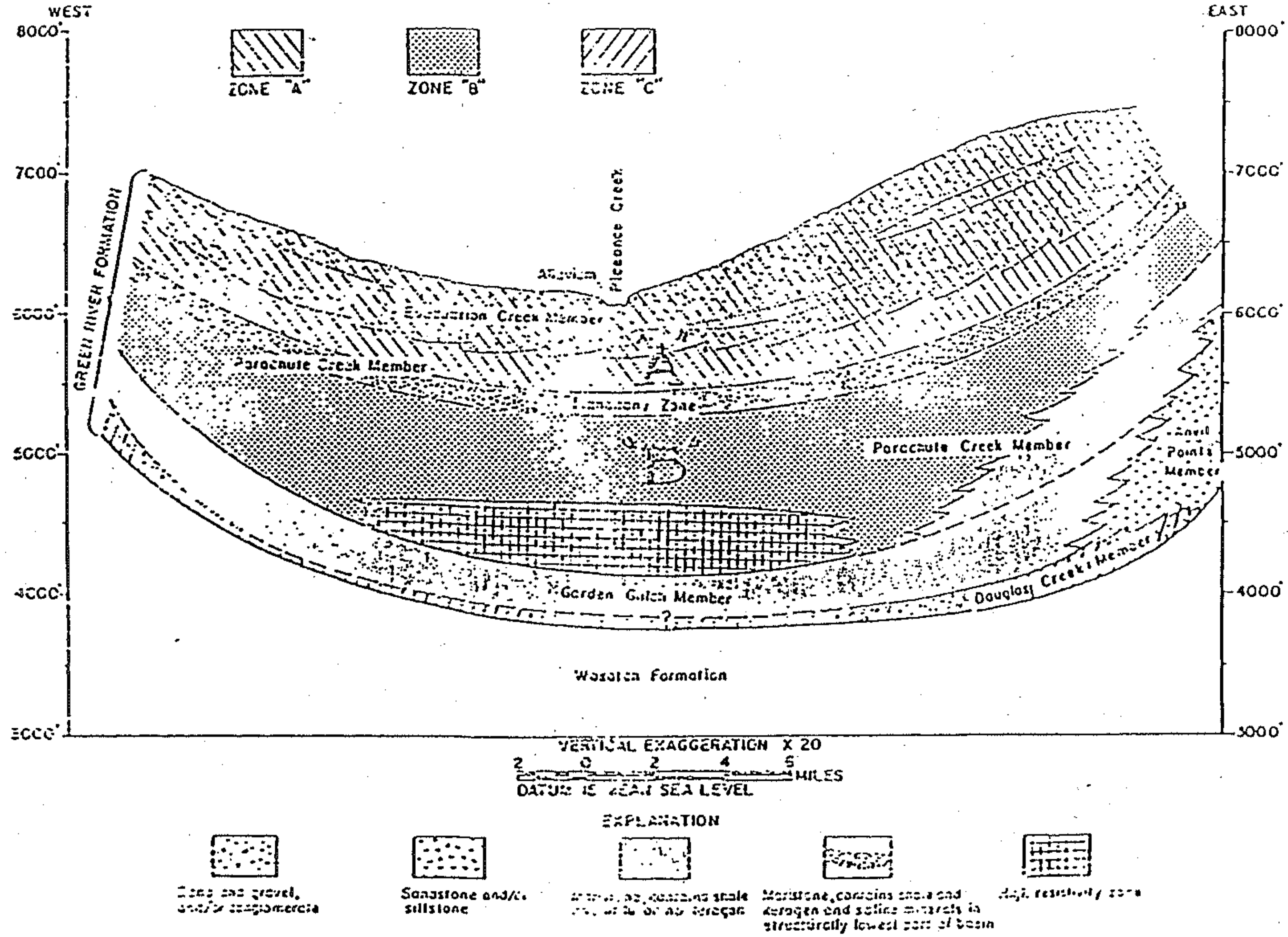


FIGURE 3.5.5. Diagrammatic East–West Cross-Section of Piceance Creek Basin, Showing Relation of Members in Green River Formation and Various Ground Water Zones (after Coffin, 1968).

The dissolved-solids concentration of water in the alluvium ranges from 250 to 25,000 mg/l. Water in alluvium in the upper reaches of the major drainages contains less than 700 mg/l dissolved solids. In general, the principal ions in the alluvial water of Piceance Creek are predominantly calcium, magnesium, sodium, and bicarbonate; the dissolved-solids concentration increases downstream.[4]

The principal aquifer in the basin is the Green River system. This has been divided by the Mahogany Zone aquitard into an upper poor transmissivity "A" subsystem and a lower good transmissivity "B" subsystem. Figure 3.5.5 is a diagrammatic cross-section showing the relationship of various strata and the principal aquifers of the area.[4]

Circulation in the upper segment of the main Green River ground-water system, marked A on Figure 3.5.5, is quite complex. The primary permeability in this member is in the vertical fracture network. These fractures are not distributed uniformly. In general, the fracture density decreases as rock plasticity and thickness increase; thus, the fracture density and resulting permeability vary in a three-dimensional manner. Spring discharge from the aquifer is common in canyon walls and valley margins.[4]

Water salinities vary from 250 ppm in the basin recharge area to 1,800 ppm in the center of the basin. Transmissivities as high as 2,000 gpd/ft have been determined from wells tested in the center of the basin.[4]

The "B" subsystem is the principal, "confined" ground-water zone in the Piceance Basin. The "B" subsystem is recharged along the southern margin of the basin, where the fracture system provide limited communication through the aquitard. The "B" zone exhibits intermittent hydraulic continuity with the "A" zone, via faults and poorly-cemented wells.[4] The variation in static water level, in the wells which tested both zones, indicates only a tenuous connection between the "A" and "B" zones.

The "B" member of the Green River aquifer system varies in salinity from 250 ppm in the recharge area to more than 65,000 ppm just above the high resistivity zone shown in Figure 3.5.5. Transmissivities range from 3,000 gpd/ft near the basin margin to 20,000 gpd/ft in the center of the basin.[5]

The porous zones below the base of the Green River ground-water system are so discontinuous and of such poor transmissivities that they do not constitute a significant aquifer in the project area.[5]

Within a 10-mile radius of the emplacement well, water is used from all three of the above described aquifers. Usage is primarily for domestic and agricultural purposes.[6]

The climate in the project area is semi-arid with the mean annual precipitation varying from 12 in. in the northern Piceance Creek Valley to 25 in. along the drainage divide in the south. Most of this precipitation occurs as snow from December to April and as thunderstorms during late summer.[5] The 2 year, 24-hr rainfall value is 0.8 in.

A wide temperature variation occurs with summer highs of about 100°F in the valley and winter lows of minus 40°F along the southern drainage divide. Snow may persist on the higher ridges from October to May and in the lower valleys from December to March.[5]

HUMAN RECEPTORS

The population in the vicinity of the site can be seen from Figure 3.5.6. The immediate project area is sparsely populated.[3] Because cattle and sheep raising is the principal livelihood, most of the people live on scattered ranches. Only 63 persons are estimated to live within a 10-mile radius of the EW and 97 more within a 20-mile radius.[3] The population less than 2 miles from the emplacement well is thought to be zero, but exact data are not available.

LOCATION OF DOMESTIC AND AGRICULTURAL WELLS NEAR THE TEST SITE AND POPULATION SERVED BY WELLS

Wells in the area of interest do not contribute significantly to the supply of water for domestic or agricultural purposes, and none are currently used for industrial purposes.[6]

Within a 10-mile radius of the EW, about 15 windmills are being used to fill stock tanks. These are usually located on wells 250 to 350 ft deep and as a rule their yield is small (usually 1 to 2 gal/min.).[6] Operation of these windmills occurs only in the spring and fall during migration of cattle from summer to winter grazing areas.[6] Only one ranch within 10 miles of the EW and one other just outside this radius are believed to use well water for domestic purposes.[6]

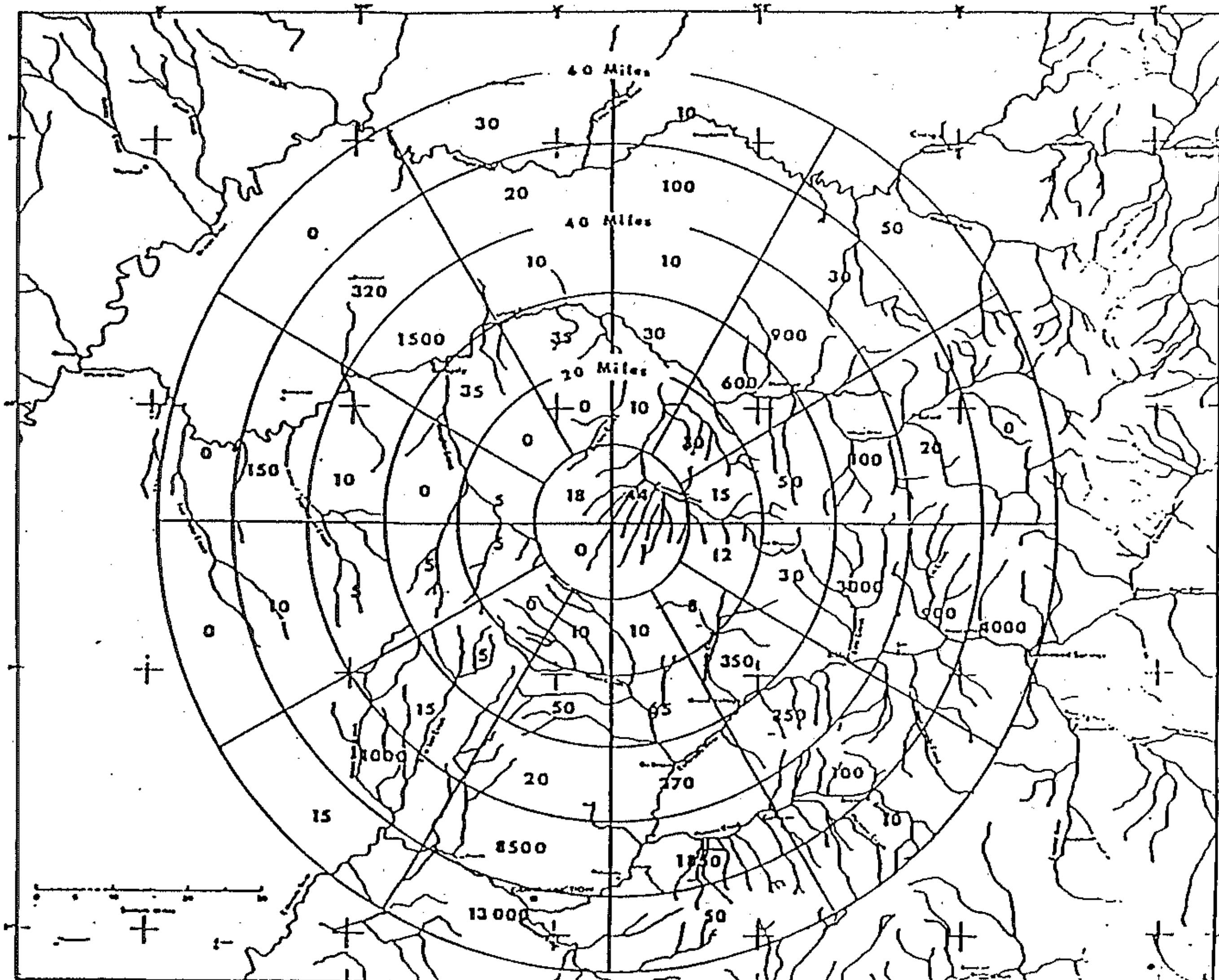


FIGURE 3.5.6. Estimated Distribution of Population to 60 Miles from EW.

The nearest well tapping, the "A" member of the Green River aquifer system, is about 6.5 miles from the EW, but in a direction which is almost perpendicular to the ground-water flow. Even assuming that the flow were toward this well, any contaminated water would take 200 years to reach it.[3]

The nearest well in the "B" member of the Green River aquifer is 3.6 miles from the EW[3], again in a direction almost perpendicular to the ground-water flow. If the water were assumed to be flowing toward this point, the radioactivity would take some 43 years to get there.[3]

ENVIRONMENTAL RECEPTORS

Primary environmental receptors of concern in the project area are the grazing cattle and sheep.[3] These are of particular concern due to the radiation contamination pathway that exists in the forage-cow-milk-food chain.

In addition to livestock, game animals such as deer, elk, mountain lion, wildfowl, and fish are also possible environmental receptors.[3] Available data suggested that no endangered species live near the ground zero (GZ) site.

HISTORY

CER Geonuclear Corporation and Lawrence Livermore Laboratory (LLL) designed Project Rio Blanco as an experiment to prove the economic feasibility of gas stimulation using nuclear explosives. Experimental objectives were centered on the concept of maximizing gas production while minimizing engineering and operational costs.[7]

CER evaluated the Equity Oil Company leases in the Piceance Basin and Proposed Project Rio Blanco in 1970. The project definition agreement was signed between the Atomic Energy Commission (AEC) and CER on December 18, 1970.[7]

The AEC and CER signed the project execution contract on April 12, 1973. Emplacement of the three nuclear explosives took place on May 3, 4, and 5. Stemming was started on May 9 and completed on May 11. Detonation authority was received on May 14. The Project Rio Blanco detonation was conducted on May 17 at 10:00 am.[7]

Gas production testing and project evaluation continued through June 1976.[2] The site cleanup and restoration planning phase began in December 1975 and was concluded with the issuance of an operational plan, Project Rio Blanco Site Cleanup and Restoration Plan, NVO-173, in May 1976. Actual site restoration activities were conducted during the period from July to November 1976.[2] Project Rio Blanco Site Restoration Final Report, NVO-183, January 1978, summarizes the activities throughout the restoration period and describes the final site status, including the disposition of all project facilities and status of all project-related wells after plug and abandonment and recompletion work.[1]

WASTE GENERATION AND DISPOSAL

The radioactive contamination that has occurred at Rio Blanco was generated during the simultaneous detonation of three, 30 kt nuclear explosives. This test was a one-time event, thus further introduction of radionuclides to the Project Rio Blanco environment is not expected.

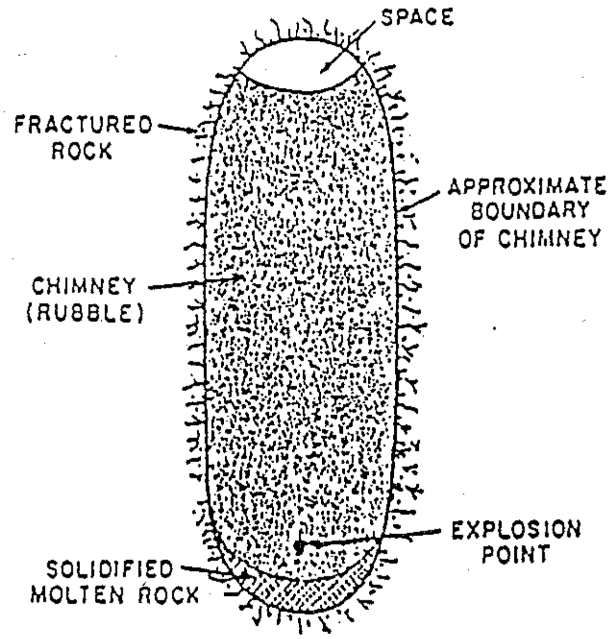
A deep underground explosion is one occurring at such a depth that the effects are essentially fully contained. The surface above the detonation point may be disturbed, by the formation of a shallow subsidence crates or a mound, and ground tremors may be detected at a distance. There is no significant venting of the weapon residues to the atmosphere, although some of the noncondensible gases present may seep out gradually through the surface. The United States has conducted many deep underground tests, especially since September 1961. Almost all of the explosion energy of these tests has been contained in the ground, the thermal radiation is almost completely absorbed by the ground material, so that it does not represent a significant hazard. Most of the neutrons and early gamma rays are also removed, although the capture of the neutrons may cause a considerable amount of induced radioactivity in various materials present in the soil and rock. This will constitute a small part of the residual nuclear radiation, of importance only in the close vicinity of the point of burst and except in the few cases of accidental venting or seepage of a small fraction of the residues, the radioactivity from these explosions has also been confined.

The phenomena of deep underground detonations can be described best in terms of four phases having markedly different time scales. First, the explosion energy is released in one second. As a result, the pressure in the hot gas bubble formed will rise to several million atmospheres and the temperature will reach approximately 1×10^{8}°F within a few seconds. In the second (hydrodynamic) stage, which generally is of a few tenths of a second duration, the high pressure of the hot gases initiates a strong shock wave which breaks away and expands in all directions with a velocity equal to or greater than the speed of sound in the rock medium. During the hydrodynamic phase, the hot gases continue to expand, although more slowly than initially, and form a cavity of substantial size. At the end of this phase the cavity will have attained its maximum diameter and its walls will be lined with molten rock. The shock wave will have reached a distance of some hundreds of feet ahead of the cavity and it will have crushed or fractured much of the rock in the region it has traversed. The shock wave will continue to expand and decrease in strength eventually becoming the leading wave of a train of seismic waves. During the third stage, the cavity will cool and the molten rock will collect and solidify at the bottom of the cavity. Finally, the gas pressure in the cavity decreases to the point when it can no longer support the overburden. Then, in a matter of seconds to hours, the roof falls in and this is followed by progressive collapse of the overlying rocks. A tall cylinder, commonly referred to as a "chimney", filled with broken rock or rubble is formed (Figure 3.5.7). If the top of the chimney does not reach the ground surface, an empty space, roughly equivalent to the cavity volume, will remain at the top of the chimney. However, if the collapse of the chimney material should reach the surface, the ground will sink into the empty space thereby forming a subsidence crater. The column of the roof and the formation of the chimney represent the fourth phase of the underground explosion.

The simultaneous explosions of the 3, 30 kt nuclear devices created a cylindrical chimney having an overall height of approximately 1,350 ft and a radius from the center line of the chimney of some 80 ft. The maximum extent of fracture from the centerline of the chimney is less than 400 ft. During production testing of the RB-E-01 well, it was concluded that the three detonation cavities were not in communication, therefore, the above-stated chimney height is probably an over-estimate.[14]

Gas within the chimney is expected to consist primarily of methane (-54 to 42 volume percent); carbon dioxide (30 to 25 volume percent); hydrogen (10 to 13 volume percent); and water vapor (6 to 20 volume percent).[14]

The radioisotopes of primary interest in all of the natural gas created by the explosion are krypton-85 approximately 2,000 Ci; and tritium — approximately 3,000 Ci. Essentially all of the ^{85}Kr and about 10 percent of the ^{3}H are mixed with



The rubble chimney formed after collapse of the cavity in a deep underground nuclear detonation.

FIGURE 3.5.7. Typical Characteristics of Underground Nuclear Weapons Testing Cavity.

the chimney gas. Other contributions to the total radioactivity of the chimney gas are small amounts of carbon-14; argon-37; and argon-39.[14]

No burial of radioactive material was made at the Rio Blanco site.[15] Except for the RB-AR-2 well entry, radioactive particulates resulting from the test event were contained in the chimney area.[15] During the last stages of RB-AR-2 drilling, some drilling tools were contaminated with low level ^{137}Cs and ^{90}Sr. Control of this operation prevented any spread of the contamination to the rig or environs.[15]

A deep zone (5,630 to 6,072 ft below the surface) in the FCG Well No. 1 was used for the disposal of all contaminated water generated by production test operations and by decontamination operations. Pursuant to a permit issued by the State of Colorado to CER Geonuclear Corporation, 23,349 barrels of water containing 177.9 Ci ^{3}H, 4.3 mCi ^{137}Cs, and 1 mCi ^{90}Sr were injected into this zone of the well.[15] During the site cleanup, 1,341 more barrels containing 68.5, 0.7, and 0.0007 mCi of ^{3}H, ^{137}Cs, and ^{90}Sr respectively, were injected.[15]

Contaminated soil, solid waste, and solidified liquids resulting from site cleanup were barreled and shipped to Beatty, Nevada for burial at the Nuclear Engineering Company facility. On September 22, 1976, 73, 55-gallon drums containing approximately 0.023 Ci of predominantly tritium with minute amounts of ^{137}Cs and ^{90}Sr were shipped.[15]

Approximately 575 barrels of tritiated water were generated during gas zone swabbing operations and flow testing of FGC Well No. 1 following the plugging and sealing off of the lower disposal level. This water, containing 15.9 mCi of tritium, was evaporated to the atmosphere by a "hot oil truck" process.[15]

During production testing of the RB-E-01 well, approximately 52 Ci of ^{3}H, 776 Ci of ^{85}Kr, and 89 Ci of ^{37}Ar were released to the flare stack, with fractional curie amounts of ^{39}Ar, ^{14}C, and 131m Xe. A trace quantity, on the order of 10^{-5} Ci, of ^{203}Hg, was released during the second drawdown. ^{203}Hg was not detected during the first drawdown.[14]

During production testing of the RB-AR-2 well, 23 Ci of ^{3}H and 242 Ci of ^{85}Kr were released to the flare stack.[18]

KNOWN RELEASES

Radiological monitoring at Rio Blanco was begun in October 1971 and continued until July 31, 1974. The data obtained by the program have been reported by the Eberline Instrument Corporation in quarterly reports.[9,10,11] The reports describe the procedures and equipment used in the program, and these reports document that there has been no detectable increase in environmental radiation as a result of the nuclear detonations of Project Rio Blanco.[9,10,11,12]

During production testing of the emplacement well (RB-E-01), approximately 52 Ci of ^{3}H, 776 Ci of ^{85}Kr, and 89 Ci of ^{37}Ar were released to the atmosphere through flaring.[14]

Production testing of the RB-AR-2 well resulted in the approximate release of 23 Ci of ^{3}H and 242 Ci of ^{85}Kr to the atmosphere by flaring.[14]

During production testing, 23,349 barrels of water containing 177.9 Ci ^{3}H, 4.3 mCi ^{137}Cs, and 1 mCi ^{90}Sr were injected in the Fawn Creek Government No. 1 well.[15] Site cleanup operations generated 1,341 more barrels of contaminated water containing 68.5, 0.7, and 0.0007 mCi of ^{3}H, ^{137}Cs, and ^{90}Sr respectively, which were also injected in the FCG No. 1 well.[14]

POTENTIAL FOR DIRECT CONTACT OR FIRE/EXPLOSION HAZARD

No potential for direct contact, fire, or explosion exist at the Project Rio Blanco site due to the great depth which this test was conducted. Any possible danger of direct contact that might have existed near remaining surface facilities has been removed by surface cleanup activities.[1]

No observed direct contact is known to have occurred. The surface site is easily accessible to the public; however, the wastes are inaccessible. The exact population within a 1-mile radius is not known and was estimated to be less than 100. No critical habitats are known to exist.

Containment is considered complete since the wastes are buried a great distance below the surface and wells penetrating the contaminated area have been plugged and abandoned.

No incidents involving fire or explosion are known to have occurred. The wastes are considered to be completely contained and have no likely chance of burning or exploding.

The exact population within a 2-mile radius of the site is not known, and is approximated to be less than 100. The nearest population is estimated to be between 50 and 200 ft and less than 26 buildings are estimated to be within a 2-mile radius of the site. The land use surrounding the site is predominantly agriculture and recreation.

POTENTIAL FOR GROUND-WATER RELEASE

The most likely mechanisms for ground-water contamination from subsurface nuclear detonation is by migration of radioactive gases up fractures induced in the overlying formation or by migration up the emplacement well annulus.[3] The nuclear explosives used in Project Rio Blanco were detonated over 4,000 ft below the nearest aquifer. It is unlikely that fracturing in the formation above the explosives could extend for this great a distance.[3] An extensive monitoring program of the major aquifers of the area has not shown any evidence of contamination.[13] Surface monitoring at the emplacement well after detonation did not indicate any seepage of contaminants up the annulus.[7]

Ground-water contamination surrounding the detonation cavity did occur. However, water from this horizon is not currently used nor is it useable.

NUMBER OF WELLS WITHIN A FOUR-MILE RADIUS

Three wells are within 4 miles of the site.[3] Two of these are 120 ft deep and are likely producing from the "B" member of the Green River aquifer.[3] The third is a 20 ft deep well producing from the alluvium aquifer.[3]

Within 2 miles of the test site, the "A" and "B" members of the Green River aquifer are clearly separated by the Mahogany Zone aquitard. This separation is evidenced by a noted difference in geochemistry between the two aquifers.[4]

POTENTIAL FOR SURFACE WATER RELEASE

In a subsurface test such as Rio Blanco, the two most likely pathways for a surface water release come from contaminated discharge from one of the three aquifers or from runoff from decontamination operations of subsurface drilling and testing equipment.

The physical state of the waste is thought to be liquid.

As previously mentioned, the chance of aquifer contamination is extremely remote due to the depth of emplacement of the explosives.[3] Therefore, surface water contamination is highly unlikely via this route.

Decontamination practices at the test site are carefully outlined in Project Rio Blanco Site Restoration Final Report.[1] As stated in this report, contaminated runoff from decontamination procedures was collected and later injected into the Fawn Creek Government No. 1 well. Therefore, risk of surface water contamination from this operation is small.

Extensive environmental monitoring programs have shown no release to the surface water in the test site area.[9,10,11,12]

Within a 10 mile radius of the study site, approximately 25 springs are used for domestic and irrigation purposes. Of these 25 springs, only eight are used for domestic supply,[8] and as stated above none have shown any evidence of contamination.[9,10,11,12]

The site is located less than 1,000 ft from a local river which is not thought to represent a domestic supply in the area. The 2 year, 24 hr rainfall value is 8 in. No sensitive environments are known to exist in the area.

The population within a 4-mile radius is conservatively estimated to be less than 100. The land surrounding the site used for agriculture and recreation.

POTENTIAL FOR AIR RELEASE

The potential for releases to the atmosphere existed during the detonation and post-detonation operations primarily through leakage of radioactive gases up the annulus of the emplacement well or re-entry well. Environmental monitoring during these operations did not indicate any releases to the environment.[12]

During production testing of the stimulated well (RB-E-01) and RB-AR-2 well, radioactive gases were released to the atmosphere through flaring as was planned.[13]

To further reduce the risk of radioactive gas seeps, all wells that were in contact with the detonation cavity have been plugged and abandoned.[1] As a result of the containment procedures described above, little chance exists for further release to the atmosphere.

THREATS TO FOOD CHAIN AND ENVIRONMENT

Based upon the cleanup data, there appears to be little likelihood of further introduction of radionuclides into the biosphere. Data reported in references 9, 10, 11, and 12 suggest that the release of radioactivity into the atmosphere did not pose a threat to the environment.

CONCLUSION AND RECOMMENDATION

A preliminary HRS was conducted for the Rio Blanco site and is included in Appendix 3.5.A. The preliminary migratory HRS score for the Rio Blanco site was 15.11. The Fire and Explosion score was 15.11, while the Direct Contact score was 0.0. These scores are preliminary and based upon available data at the time of writing. Conservative estimates were used where data was uncertain.

It is recommended that the long-term Hydrologic Monitoring Program be continued.

The monitoring program should be reviewed and updated periodically based upon new hydrologic data as they become available.

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APPENDIX 3.5.A
HRS WORKSHEETS
RIO BLANCO

FIRE AND EXPLOSION WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Containment	(1) 3	1	1	3	7.1
2 Waste Characteristics					7.2
Direct Evidence	(0) 3	1	0	3	
Ignitability	(0) 1 2 3	1	0	3	
Reactivity	(0) 1 2 3	1	0	3	
Incompatibility	(0) 1 2 3	1	0	3	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			8	20	
3 Targets					7.3
Distance to Nearest Population	0 1 2 3 (4) 5	1	4	5	
Distance to Nearest Building	0 1 (2) 3	1	2	3	
Distance to Sensitive Environment	(0) 1 2 3	1	0	3	
Land Use	0 1 2 (3)	1	3	3	
Population Within 2-Mile Radius	0 (1) 2 3 4 5	1	1	5	
Buildings Within 2-Mile Radius	0 (1) 2 3 4 5	1	1	5	
Total Targets Score			11	24	
4 Multiply 1 x 2 x 3			88	1,440	
5 Divide line 4 by 1,440 and multiply by 100			S_{FE} = 6.11		

DIRECT CONTACT WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	8.1
If observed release is given a score of 45, proceed to line 4. If observed release is given a score of 0, proceed to line 2.					
2 Accessibility	0 1 (2) 3	1	2	3	8.2
3 Containment	(0) 15	1	0	15	8.3
4 Waste Characteristics					8.4
Toxicity	0 1 2 (3)	5	15	15	
5 Targets					8.5
Population Within a 1-Mile Radius	0 (1) 2 3 4 5	4	4	20	
Distance to a Critical Habitat	(0) 1 2 3	4	0	12	
Total Targets Score			4	32	
6 If line 1 is 45, multiply 1 x 4 x 5					
If line 1 is 0, multiply 2 x 3 x 4 x 5			0	21,600	
7 Divide line 6 by 21,600 and multiply by 100		S_{DC} =	0		

GROUND WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 (45)	1	45	45	3.1
If observed release is given a score of 45, proceed to line 4.					
If observed release is given a score of 0, proceed to line 2.					
2 Route Characteristics					3.2
Depth to Aquifer of Concern	0 1 2 3	2		6	
Net Precipitation	0 1 2 3	1		3	
Permeability of the Unsaturated Zone	0 1 2 3	1		3	
Physical State	0 1 2 3	1		3	
Total Route Characteristics Score				15	
3 Containment	0 1 2 3	1		3	3.3
4 Waste Characteristics					3.4
Toxicity/Persistence	0 3 6 9 12 15 (18)	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			26	26	
5 Targets					3.5
Ground Water Use	(0) 1 2 3	3	0	9	
Distance to Nearest Well/Population Served	(0) 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
Total Targets Score			0	49	
6 If line 1 is 45, multiply 1 x 4 x 5					
If line 1 is 0, multiply 2 x 3 x 4 x 5			0	57,330	
7 Divide line 6 by 57,330 and multiply by 100		S_{gw} =	0		

SURFACE WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	4.1
If observed release is given a score of 45, proceed to line 4.					
If observed release is given a score of 0, proceed to line 2.					
2 Route Characteristics					4.2
Facility Slope and Intervening Terrain	0 1 2 (3)	1	3	3	
1-yr. 24-hr. Rainfall	(0) 1 2 3	1	0	3	
Distance to Nearest Surface Water	0 1 2 (3)	2	6	6	
Physical State	0 1 2 (3)	1	3	3	
Total Route Characteristics Score			12	15	
3 Containment	(0) 1 2 3	1	0	3	4.3
4 Waste Characteristics					4.4
Toxicity/Persistence	0 3 6 9 12 15 (18)	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			26	26	
5 Targets					4.5
Surface Water Use	0 1 (2) 3	3	6	9	
Distance to a Sensitive Environment	(0) 1 2 3	2	0	6	
Population Served/ Distance to Water Intake Downstream	(0) 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
Total Targets Score			6	55	
6 If line 1 is 45, multiply 1 x 4 x 5					
If line 1 is 0, multiply 2 x 3 x 4 x 5			0	64,350	
7 Divide line 6 by 64,350 and multiply by 100		S_{SW} =	0		

AIR ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 (45)	1	45	45	5.1
Date and Location: During production testing.					
Sampling Protocol:					
If line 1 is 0, the S_a = 0. Enter on line 5. If line 1 is 45, then proceed to line 2.					
2 Waste Characteristics					5.2
Reactivity and Incompatibility	(0) 1 2 3	1	0	3	
Toxicity	0 1 2 (3)	3	9	9	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			17	20	
3 Targets					5.3
Population Within 4-Mile Radius	0 (9) 12 15 18 21 24 27 30	1	9	30	
Distance to Sensitive Environment	(0) 1 2 3	2	0	6	
Land Use	0 1 2 (3)	1	3	3	
Total Targets Score			12	39	
4 Multiply 1 x 2 x 3			9,180	35,100	
5 Divide line 4 by 35,100 and multiply by 100			S_a = 26.15		

HRS SCORE FOR
PROJECT RIO BLANCO

$$S_m = \frac{1}{1.73} \sqrt{(0)^2 + (0)^2 + (26.15)^2}$$

$$S_m = 15.11$$

$S_{FE} = 6.11$

$S_{DC} = 0.0$

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PRELIMINARY ASSESSMENT REPORT
PROJECT RULISON

INTRODUCTION

Project Rulison was the second nuclear gas stimulation experiment, co-sponsored by the U.S. Atomic Energy Commission and the Austral Oil Company, and was designed to determine the potential increase in production by using a nuclear explosive to stimulate and enhance natural gas recovery in the Mesa Verde formation of the Rulison Field, Garfield County, Colorado[3] (Figure 3.6.1).[1]

On September 10, 1969, under the technical direction of the Los Alamos Scientific Laboratory (LASL), a 43 kt fission-type nuclear explosive was detonated at a depth of 8,426 ft in an emplacement well (designated R-E) on Colorado's western slope. Re-entry drilling operations through a separate re-entry well (designated R-Ex), located 300 ft southeast of the emplacement well, began in April and was completed in July of 1970. This re-entry well was designed to production test the stimulated zone.[3]

Production testing took place over a 7-month period and included four separate flow periods.[3]

The well was shut-in after the last test in April 1971 and left in a standby condition until a general cleanup was undertaken in 1972. Cleanup work at the site commenced on July 10, 1972, and was completed on July 25, 1972. The purpose was to decontaminate, if necessary, and remove from the site equipment and materials not needed for possible future gas production.[3]

During the period September 1, 1976 through October 12, 1976, the R-E and R-Ex wells were plugged and abandoned, and the equipment that remained after the 1972 general cleanup was decontaminated, if necessary, and removed from the site.[3]

FACILITY DESCRIPTION

Figure 3.6.2 is a map of the Rulison surface facility at the completion of flare testing, showing the surface location of emplacement well (R-E), re-entry well R-Ex, gas flare stack, and associated production facilities.[3] The entire facility was enclosed by protective fencing with locked gates.

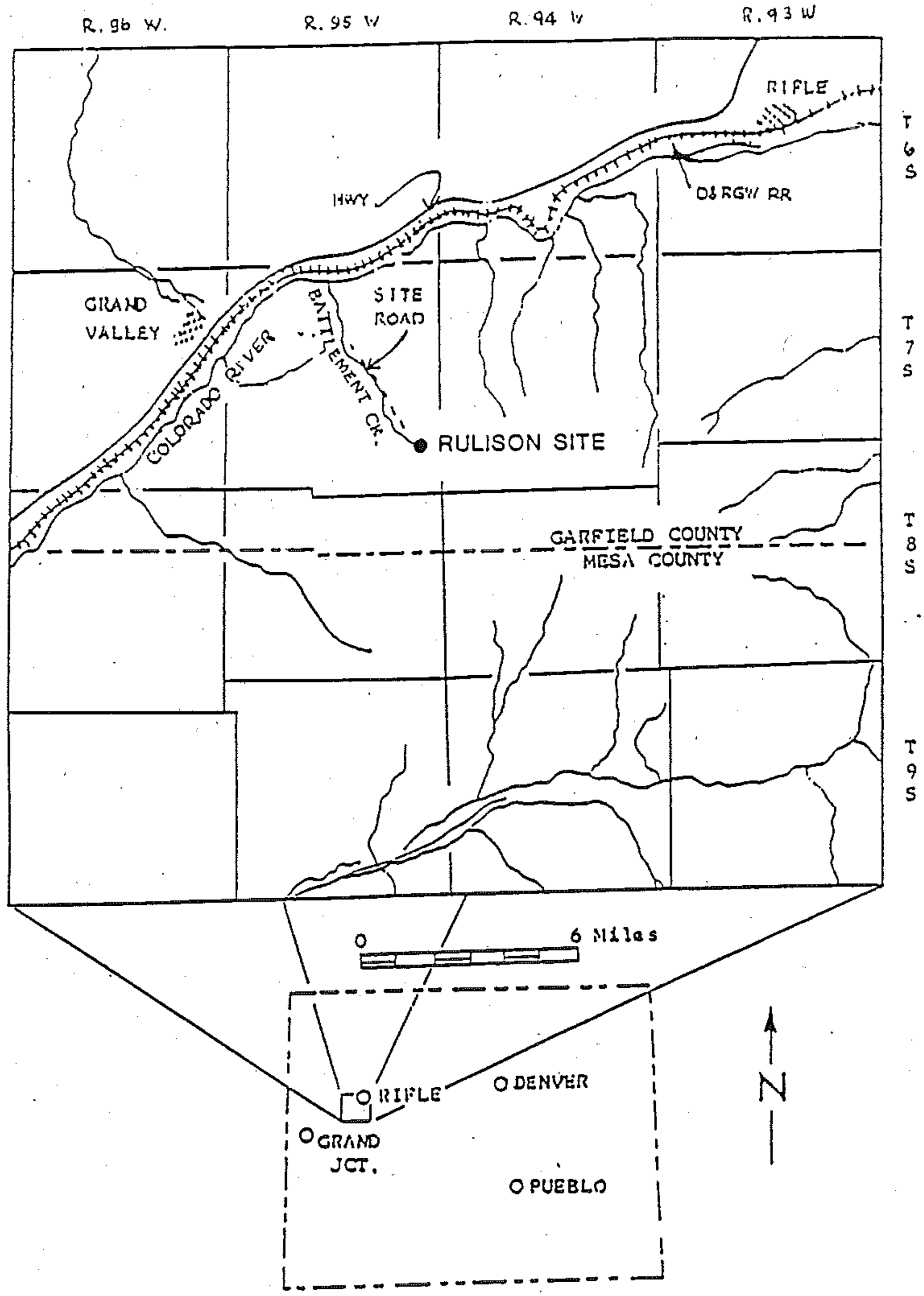


FIGURE 3.6.1. Index Map of Project Rulison Site (map from PL-4-5-69).1

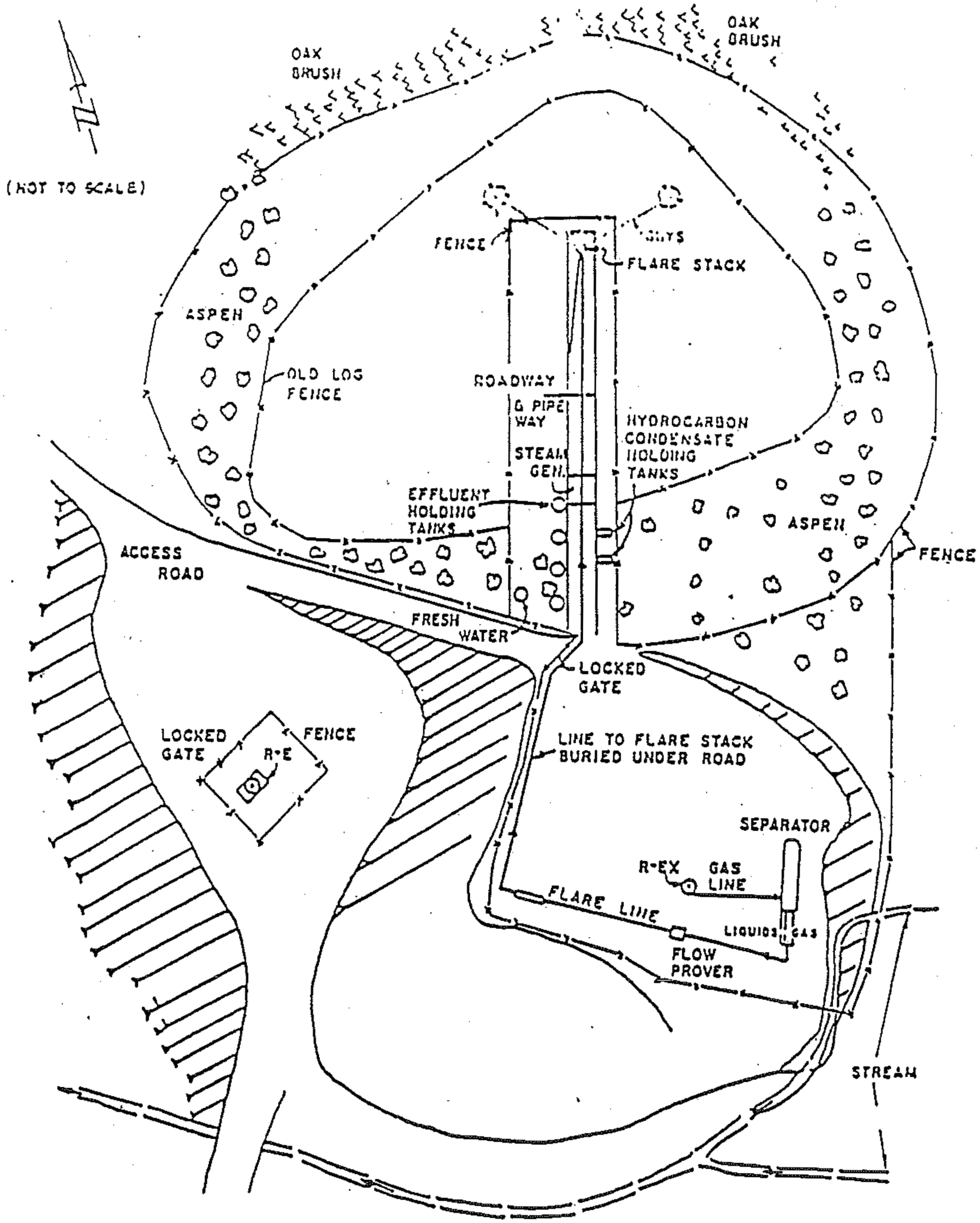


FIGURE 3.6.2. Rulison Site at Completion of Flare Testing.

Figure 3.6.3 shows the site facilities after the completion of the general site cleanup of July 1973. Remaining facilities included Christmas tree assemblies for the R-E and R-Ex well. Protective fencing with locked gates remained in place at this stage.[3]

During the period from September 1 through October 12, 1976, plugging operations were completed on the R-E and R-Ex wells and the site was given a "final" cleanup effort and complete radiological survey.[3]

The only materials left on the site were a power pole with fuse box, a telephone line, a concrete slab, and a small monument over the re-entry well designating drilling restrictions.[3]

All mud pits and other excavations were backfilled and both the upper and lower drilling pads leveled and dressed. The land owner was consulted regarding the condition of the site prior to final departure, and indicated his satisfaction with its condition.[3]

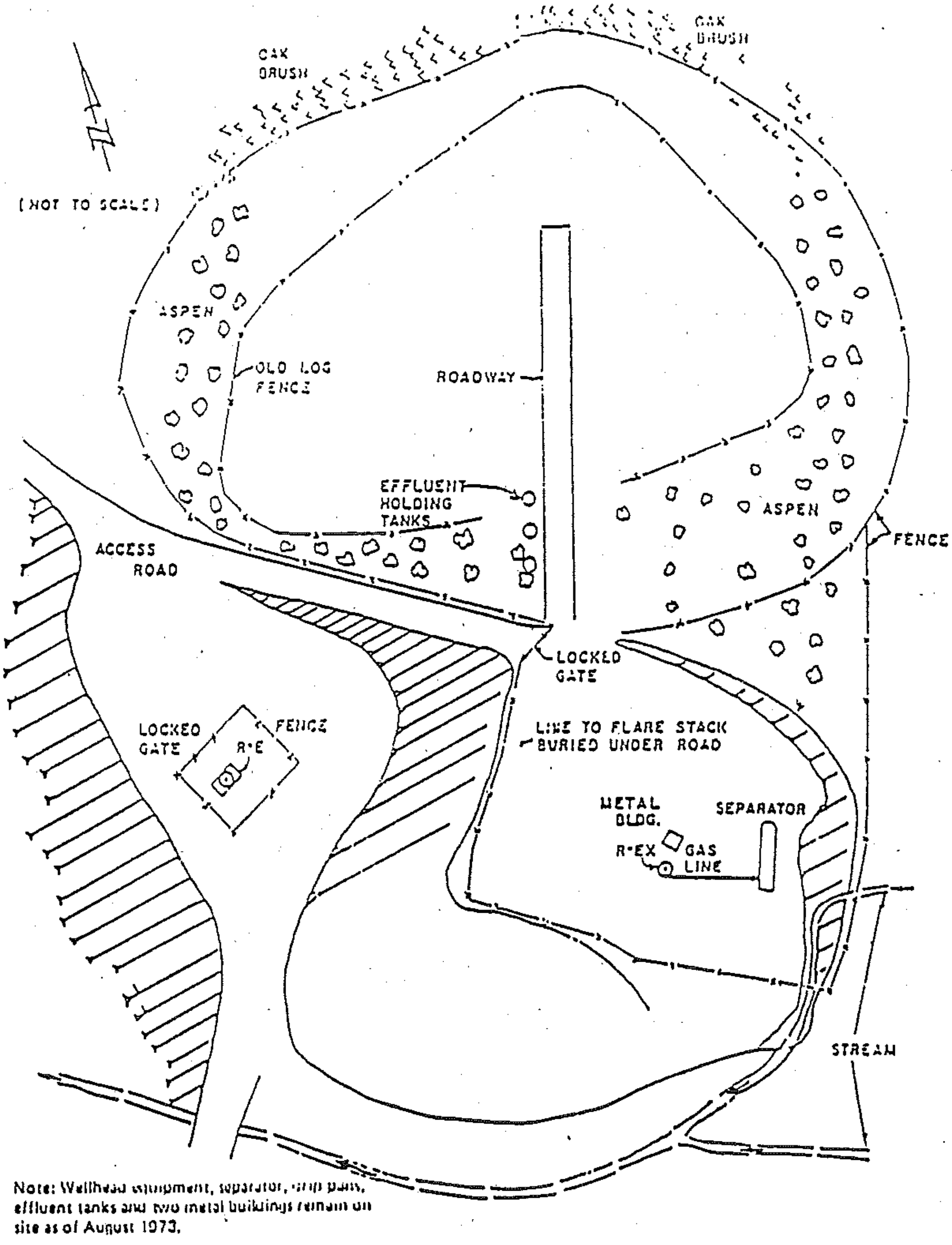
The fence surrounding the emplacement well (R-E) was taken down, rolled up, and given to the Rulison site land owner. All other fencing around the perimeter of the site was left in place at the request of the Rulison land owner.[3]

ENVIRONMENTAL SETTING

Project Rulison ground zero (GZ) is located on the East Fork of Battlement Creek, a few hundred feet east of the main Battlement Creek and separated from the latter by a low ridge. Both forks of Battlement Creek lie in a narrow, V-shaped valley that heads at the edge of Battlement Mesa about 2 miles southeast of GZ. About 2-1/2 miles northwest of GZ, the narrow valley widens onto a gently sloping bench, Morrisania Mesa, that extends almost to the Colorado River. Battlement Creek crosses this bench and enters the Colorado about 5-1/2 miles northwest of GZ.[4]

Figure 3.6.4 shows the location of Rulison GZ in relation to Battlement Creek and the Colorado River.

Morrisania Mesa, below Rulison GZ, reportedly has about 1,900 acres of cropland, irrigated from Battlement Creek. Crops include alfalfa and grass hay, fruit orchards, and irrigated pasture. Most of the 30 households on the Battlement Creek ditch system have irrigated kitchen gardens.[4]



Note: Wellhead equipment, separator, drip pans, effluent tanks and two metal buildings remain on site as of August 1973.

FIGURE 3.6.3. Rulison Site at Completion of the General Site Cleanup Effort (July 1973).

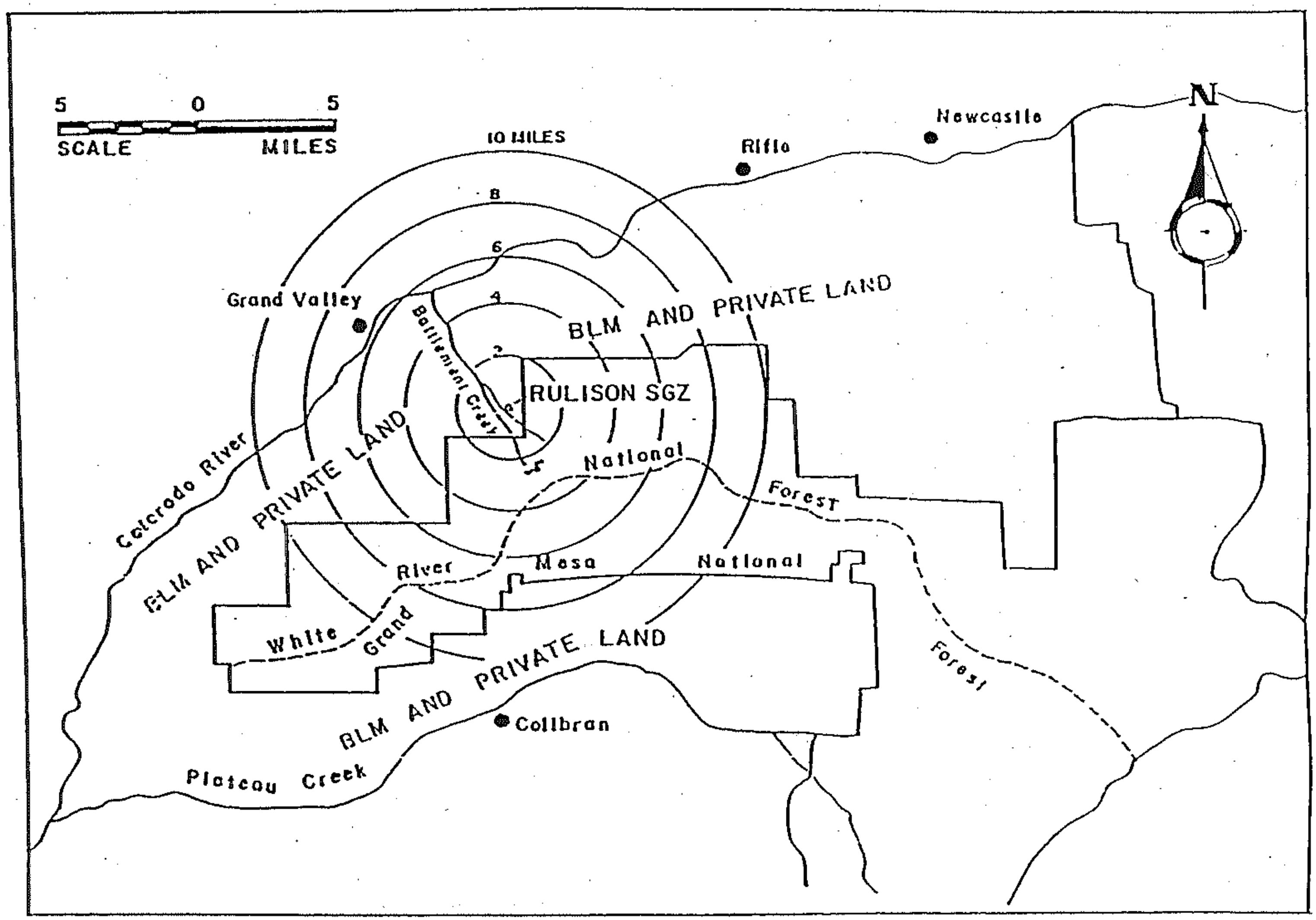


FIGURE 3.6.4. Project Rulison Site Area. BLM = Bureau of Land Management.

Beef cattle comprise the main livestock production in the vicinity of Rulison GZ. Cattle are wintered (from December to mid-April) on the benchland along the Colorado River. Principal winter feed is hay, most of which is produced locally. Starting about the middle of April, cattle go onto native forage on private lands and move onto Bureau of Land Management (BLM) allotments about May 1. The BLM Battlement Creek Common Use Allotment, immediately down the valley from Rulison GZ, provides grazing for about 200 cattle units (cow and calf) from May 1 through June 15. From June 15 through October 15, the cattle are on National Forest land on the upper slopes and top of Battlement Mesa, after which they are moved down to pasturage at lower levels on BLM or private land. The carrying capacity of the National Forest Range on the Battlement Creek Cattle and Horse Allotment (ca 11,000 acres south, southeast and east of Rulison GZ) averages about one cow unit (cow and calf or 1.5 yearlings) per 29 acres. However, about half of the total acreage is rated as unusable (bare rock or dense timber without forage value), so the actual pasturage supports about one cow unit per 15 acres. This suggests a fairly dense vegetation and good productivity on the usable part of the range.[4]

The most important big-game species found in the vicinity of Rulison GZ is the western mule deer. The deer winter (from December through April) on the benchlands along the Colorado River, including Morrisania Mesa. From as early as mid-April to as late as mid-May, depending on weather conditions, the deer start moving up the slopes toward summer range on top of Battlement Mesa. The migration from summer to winter range occurs from late October through November. Deer migrating between summer range on Battlement Mesa and winter grounds on Morrisania Mesa and adjoining Holmes Mesa move through Battlement Creek Valley, passing close to Rulison GZ.

During winter and during migrations, the principal plants deer browse are big sagebrush, serviceberry, mountain mahogany, and Gambel's oak. Forage during the summer is reported to be mostly forbs.

Small populations of elk and bighorn sheep are found in the vicinity of Rulison GZ. The total summer elk population on Battlement Mesa is estimated to be about 250 animals. During the summer, the elk range widely over the Mesa. By the end of December, they are off the Mesa top and on their winter grounds in the upper valleys of streams originating on Battlement Mesa. Some 15 to 20 elk winter at the head of Wallace Creek, southwest of Rulison GZ. Another 6 to 75 animals winter on the upper Mamm and Divide Creeks, 15 to 20 miles east of GZ. The balance of the Battlement Mesa elk herd spends the winter in the Plateau Creek drainage, south of the Mesa.[4]

The regular hunting season for elk is usually mid-October through early November. The archery season is mid-August through mid-September.[4] No statistics are available on the number harvested.

An estimated 75 head of bighorn sheep range on the rocky western tip of Battlement Mesa, 8 to 10 miles southwest of Rulison GZ. About six sheep permits are issued each season, but usually only one to two animals are taken.[4]

Blue grouse, sage grouse, and wild turkey are hunted to some extent in the Rulison site area, mostly by local residents. No statistics are available on the number harvested.[4]

Battlement Creek and the Battlement Reservoirs in which the creek originates are both fished to some extent, mainly by local residents. The reservoirs have been stocked with cutthroat trout and fishing is considered good in them; however, they do not attract large numbers of fishermen because of difficulty of access. Battlement Creek is stocked with rainbow trout and has a native population of cutthroats. No statistics are available on fishing pressure or catches.[4]

HYDROGEOLOGIC SUMMARY

The rocks underlying the Rulison site range in age from Quaternary to Precambrian. Marine and nonmarine sedimentary rocks, approximately 18,000 ft thick, underlie the site. Figure 3.6.5 is a diagrammatic geologic cross-section through the study site, showing the major geologic formations.[5]

The drilling of the exploratory (R-Ex) and emplacement (R-E) holes at the Rulison site penetrated the following formations, in descending order: alluvium of Quaternary age, Green River and Wasatch formations of Eocene age, an unnamed unit of Paleocene age, Ottio Creek formation of Paleocene age, and Mesa Verde group of late Cretaceous age (Figures 3.6.5 & 3.6.6). The Mesa Verde group is of special interest because the nuclear device was detonated within this group.[5]

The Quaternary deposits include mudflows, talus accumulations, fan and pediment gravel, slump blocks, and the alluvium of Battlement Creek and the

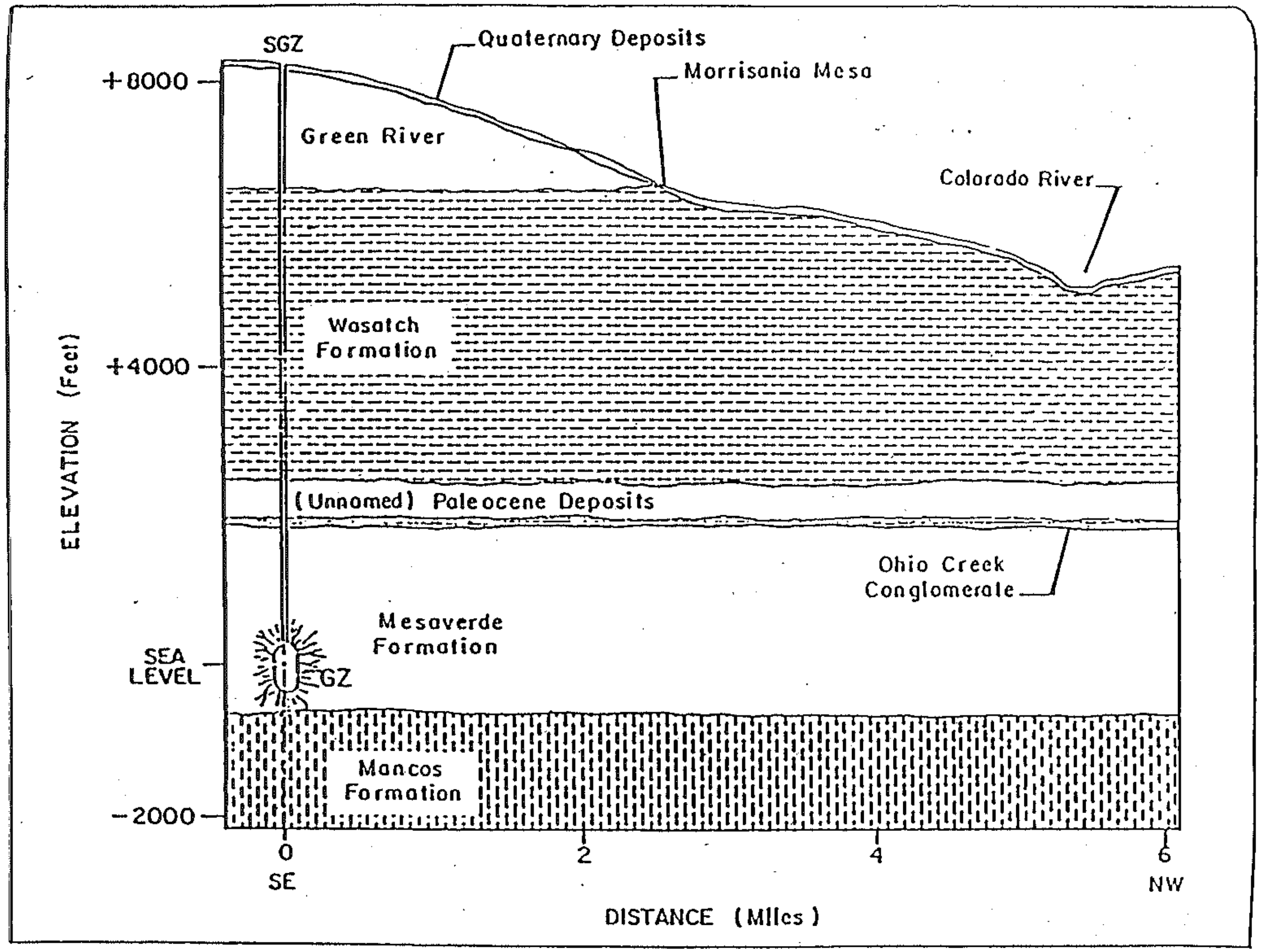


FIGURE 3.6.5. Geologic Cross-Section of Rulison Site Along Trend of Battlement Creek.

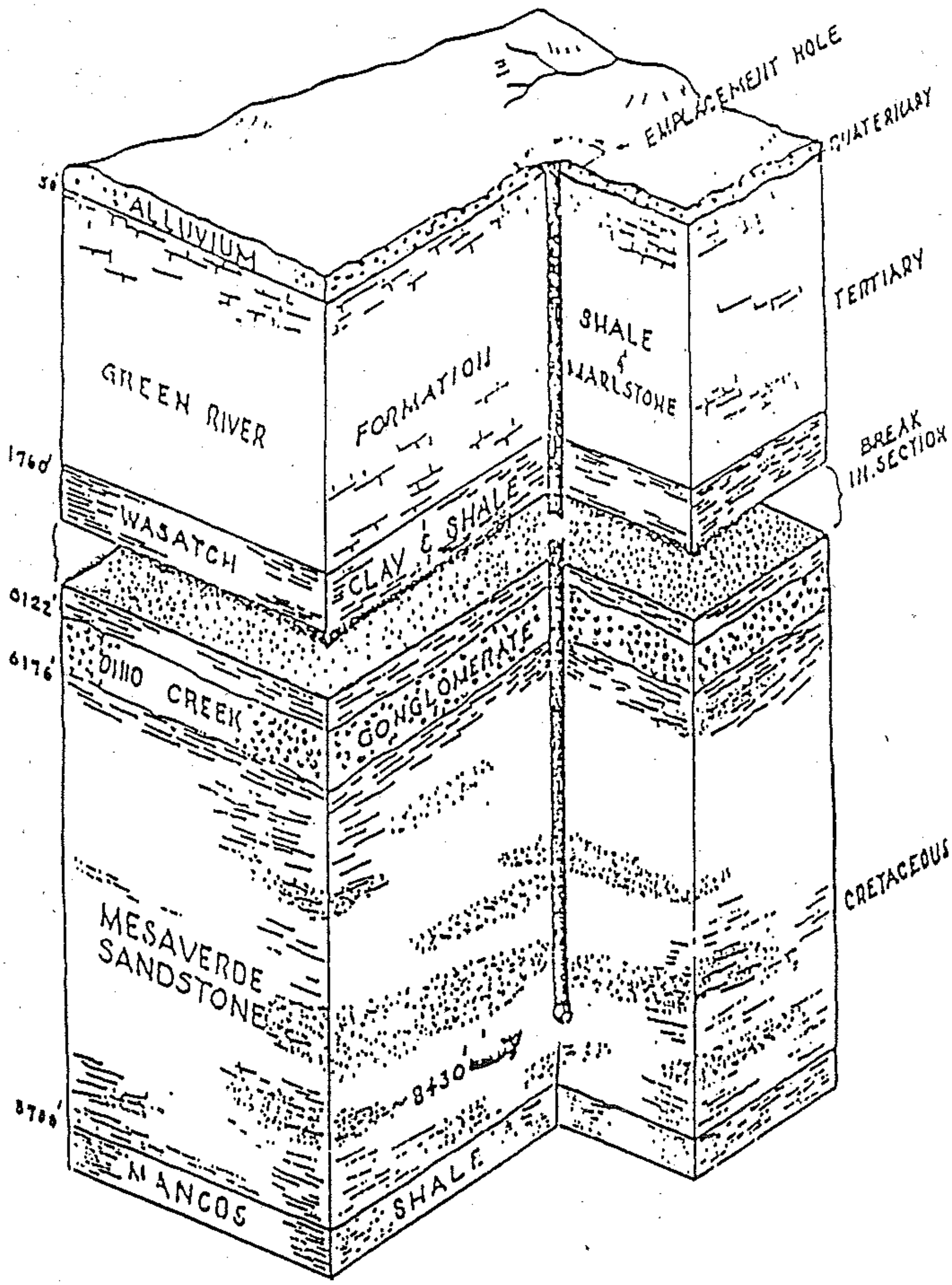


FIGURE 3.6.6. Project Rulison — Generalized Geologic Cross-Section.

Colorado River. These deposits generally range in thickness from 20 to 40 ft, but locally they may be more than 100 ft thick.[5]

The Quaternary deposits are of particular importance, providing nearly all of the areas ground-water resources.[5] However, these deposits are approximately 1.5 miles above the emplacement depth, making contamination unlikely. As a result, hydrogeologic investigations were concentrated on possible water-bearing zones of much greater depths since they represented a more likely target for contamination due to their proximity to the nuclear explosive.[5]

The Green River formation has only minor amounts of ground water. The Wasatch formation is not generally a source of water. The Fort Union formation is not known to yield water in the Rulison area, and the Ohio Creek formation yields only minor amounts of water locally. The Mesa Verde group yields no significant ground water.[6]

Hydrologic tests were performed only on Ohio Creek and Mesa Verde formation rocks encountered in exploration drill hole R-Ex. Little information was obtained about the hydraulic properties of rocks above 6,000 ft of depth.[1]

Six drill stem tests were run in the vicinity of the shot point. The USGS interpreted the chemical character of fluids collected from tubing after each drill stem test in exploration hole R-Ex as indicating that little mobile water occurs in the zones tested. Three of these tests, 7,066 to 7,080, 7,196 to 7,198, and 7,312 to 7,320 ft below land surface resulted in pressure build-up curves that could be extrapolated to infinite time by the Van Everdinger method to estimate the virgin aquifer pressures.[1]

The actual distribution of pressures above 7,066 ft are not well known. However, these can be no general upward or downward movement of water in this interval, and lateral flow must predominate.[1] Below 7,066 ft, pressures drop off rapidly and downward movement of water is expected to a point within or below the 7,312 to 7,320 ft interval. Since the pressure increases below this interval, a drain exists between 7,312 and about 8,442 ft where lateral flow is possible.

The three drill stem tests analyzed indicate relatively steep pressure build-up curves as a function of time, but low fluid recoveries. A possible explanation of this phenomenon is that the predominant permeability belongs to a fracture system.[1] The presence of many linears on the geologic map at the Rulison Area tend to support this hypothesis.[1] If this is the case, lateral flow of water could occur at significant velocities in terms of usual ground-water flow rates. However, since the interfracture blocks in the sandstone beds must also have some permeability, all water would also have to flow through these low permeability blocks.[1] The average water velocity is therefore expected to be extremely low.[1]

The direction of ground-water flow in the alluvium is expected to be northward, consistent with topographic slope. Rocks below the alluvium dip two degrees or less to the north and ground-water flow in these rocks is expected to be northward also.[1]

The average annual precipitation at the Rulison site is 20 in. and temperatures range from -10°F to +98°F.[6]

All known wells within a 6.2 mile radius of the emplacement hole were inventoried, and selected wells were inventoried within the 6.2 mile to 12.4 mile radius. As can be seen from Figure 3.6.7, 11 domestic wells and one irrigation well are located within a four-mile radius of surface ground zero (SGZ).[5] Table 3.6.1 lists the wells inventoried, their location (which is plotted in Figure 3.6.7), use, depth, owner, year completed, depth to water, and yield.[5]

Production is almost exclusively from the alluvial aquifer described in the previous section.[1] Little or no communication exists between the alluvial aquifer and the deeper bedrock formations in the SGZ area.[1]

HUMAN RECEPTORS

Based on the 1980 population census, about 60 people live within 5 miles of SGZ and 300 people live from 5 to 10 miles from SGZ.[6] Approximately four permanent habitations are located closer than 3.5 miles.[6]

ENVIRONMENTAL RECEPTORS

Primary environmental receptors of concern in the project area are cattle, deer, elk, wild fowl, and fish.[4]

HISTORY

See Introduction.

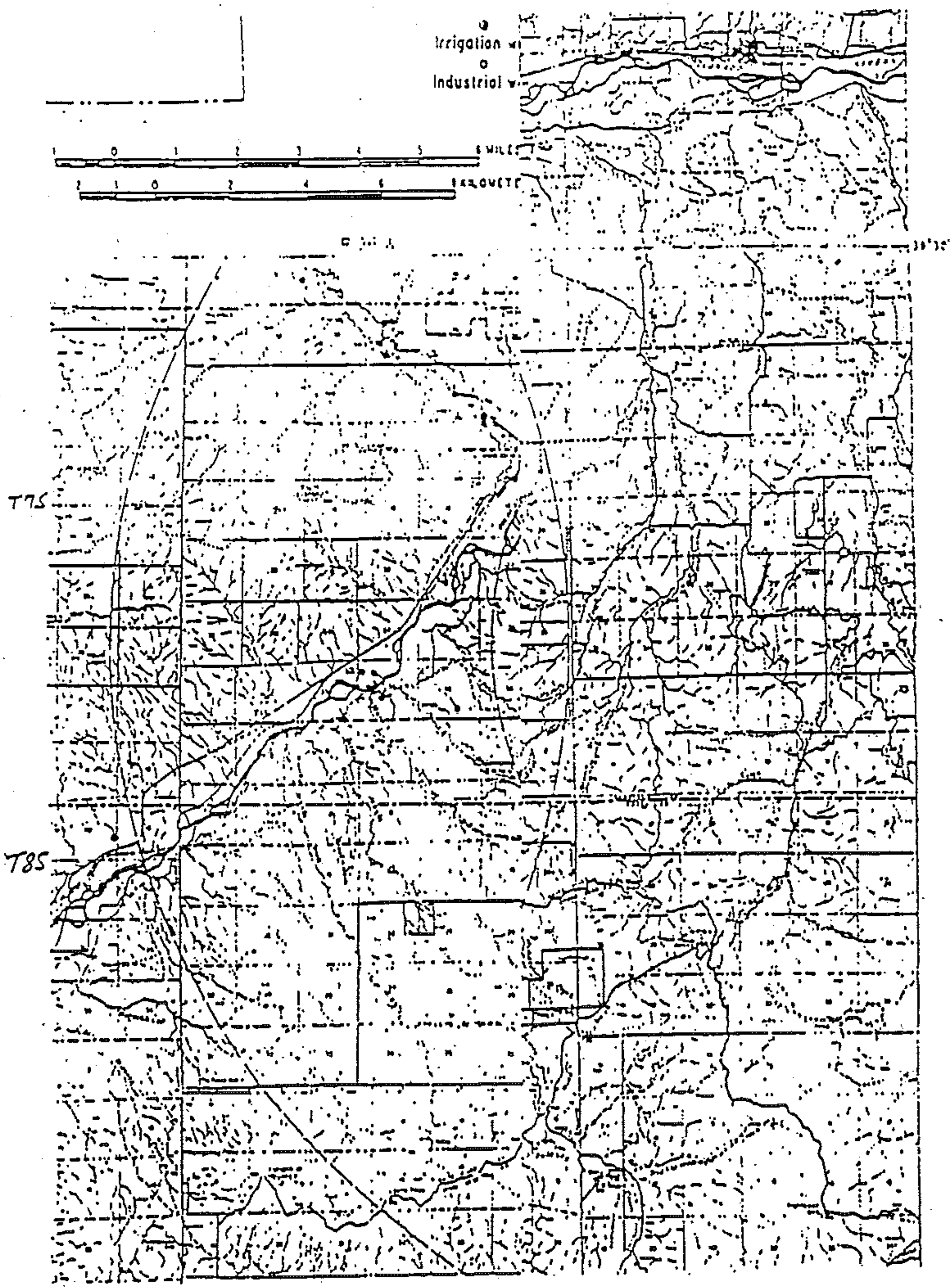


FIGURE 3.6.7. Location of Wells in the Vicinity of the Rulison Site.

WASTE GENERATION AND DISPOSAL

The radioactive contamination that has occurred at Rulison was generated during the detonation of a single 43 kt nuclear explosive. This test was a one time event, thus further introduction of radionuclides to the Project Rulison environment is not expected.

Diagnostic data obtained at the time of detonation, as well as preliminary reports on measurement of ground motion by U.S. Coast & Geodetic Survey and Sandia Corporation, indicate that the Rulison device behaved about as expected, i.e., a nominal yield of 40 kt.[1]

Environmental Research Corporation predictions of cavity dimensions for nominal yield, together with the chimney volume and the void space in the chimney (cavity volume) calculated from their predictions, are given in Table 3.6.2.[1]

Quantities of radionuclides computed to be present at zero time plus 180 days are given in Table 3.6.3. Of the nuclides listed, several will exist as gases (Kr, Xe, H, CH_4) and as volatiles (I, Cs, H_2O); others will be refractory (Sr, Y, Ru, Ba). Only those radionuclides having half-lives greater than one-half year (Kr^{85}, Sr^{90}, Ru^{106} - Rh^{106}, Cs^{137} Pm^{147}, and H^3) are likely to be significant in evaluation of hazard to the hydrologic environment.[1]

Source term concentrations were calculated by assuming that the explosion-related nuclides as shown in Table 3.6.3 are completely and uniformly mixed with a quantity of water equivalent to the volume of the cavity void space (Table 3.6.2)

TABLE 3.6.2. PHYSICAL EXPLOSION EFFECTS.

	Maximum	Mean	Minimum	Units
Cavity radius	108	90	72	feet
Cracking radius	580	485	390	feet
Chimney height	451	376	301	feet
Cavity volume (or chimney void space)	5.28×10^6	3.05×10^6	1.56×10^6	ft^3
Chimney volume	16.5×10^6	9.57×10^6	4.90×10^6	ft^3

TABLE 3.6.3. FISSION-PRODUCT AND NEUTRON INDUCED ACTIVITY IN CAVITY, 180 DAYS AFTER DETONATION.[1]

Nuclide	Half Life	Curies
^{85}Kr	10.76 y	0.96×10^3
	50.6 d	0.91×10^5
^{90}Sr	28.8 y	0.59×10^4
^{91}Y	59 d	1.01×10^5
^{95}Zr	65 d	1.82×10^5
^{95}Nb	35 d	0.32×10^6
^{103}Ru	40 d	0.41×10^5
^{103}Rh	57 min	0.41×10^5
^{106}Ru	1.0 y	1.52×10^5
^{106}Rh	30 sec	1.52×10^5
^{131}I	8.05 d	1.13
^{133}Xe	5.27 d	0.86×10^{-3}
^{137}Cs	30 y	0.75×10^4
^{137}Ba	2.6 min	0.69×10^4
^{140}Ba	12.8 d	0.34×10^3
^{140}La	40 h	0.40×10^3
^{141}Ce	32.5 d	0.52×10^5
^{143}Pr	13.7 d	0.63×10^3
^{144}Ce	285 d	1.47×10^5
^{144}Pr	17.3 min	1.47×10^5
^{147}Pm	2.6 y	0.28×10^5
^{3}H	12.26 y	10^3 to 10^4
^{37}A	34.3 d	10 to 10^2
^{39}A	260 y	2 to 2×10^1
^{14}C	5770 y	10^{-2} to 10^{-1}

anticipated to be formed by the detonation. This assumption is conservative, leading to high values for radionuclide concentrations, because it is known that significant fractions of refractory nuclides will be incorporated in the melt. On the other hand, significant fractions of volatile or refractory nuclides having gaseous precursors (such as ^{90}Sr and ^{137}Cs) will be distributed in the rubble chimney.

No burial of radioactive solids was conducted at the Rulison site. Radioactive nuclide particulates resulting from the detonation are contained in the detonation-formed cavity.[3] On October 4, 1976, 0.166 Ci of tritium in wastewater and drilling mud were pumped into the Mesa Verde formation at a depth of approximately 5,300 to 5,800 ft for disposal.[3] It should be noted that the potable aquifers above this depth were previously cemented off during emplacement drilling.[3]

Contaminated material and soil resulting from the general and the final clean-ups were shipped to Beatty, Nevada for burial at the Nuclear Engineering Company facility. On July 20, 1972, 3,000 gallons of fluid containing 0.69 Ci of tritium were shipped by tank truck.[3] On July 22, 1972, 32 packages of contaminated solid waste and six 55-gallon steel drums of solidified liquid waste, both containing an estimated 73 mCi of tritium, were shipped.[3] On October 8, 1976, as a result of the final cleanup, 68 55-gallon steel drums of contaminated soil and other solid waste containing a total of 0.018 Ci of tritium were shipped.[3] The total amount of tritium shipped to burial from the Rulison site as a result of both the general and final cleanup operations was estimated to be 0.781 Ci. No other radioactive nuclide was involved in either cleanup.[3]

KNOWN RELEASES

The Rulison explosive was emplaced near the base of the Mesa Verde formation at a depth of 8,426 ft.[7] This depth of burial was considerably greater than that required for explosion containment under normal testing purposes.[7] Essentially all of the explosion produced radionuclides were contained within the Mesa Verde formation.[7] Ground water in this formation was estimated to move at a maximum rate of 1 ft/day, the most probable rate being closer to zero.[7] Assuming the 1 ft/day rate of flow, tritium, the primary radionuclide of interest, would move less than 1 mile before decaying to a concentration less than the established radiation concentration guide for drinking water.[7]

The U.S. Geological Survey conducted a pre-shot inventory of wells and springs in the Rulison area between March 20, 1969, and May 25, 1969.[7] The purpose of the inventory was to document the condition of wells and springs and to collect water samples for chemical and radiochemical analysis.[7] All known wells within a 6.2 mile radius of the Rulison emplacement hole were inventoried. Selected wells and springs were inventoried within a 10 to 20 mile radius. A total of 29 samples were selected for background radiochemical analysis. Subsequently, a sampling network of 21 stations was established to provide the basis for evaluating post-shot changes in radionuclide concentrations.[7]

The pre-established hydrologic network of 21 stations initiated for radiochemical analysis was sampled 10 days after the Rulison event.[7] Analysis confirmed that the event was not responsible for any increases in radioactivity in surface or ground-water supplies.[7]

The only radiation released to the atmosphere occurred during production testing operations.[8] The total radioactivity estimated to have been released to the environment during the production tests included 1,064 Ci of ^{85}Kr, 2,824 Ci of ^{3}H, 2.4 Ci of ^{14}C and 0.00011 Ci of ^{203}Hg[8]. A few Ci of ^{37,39}Ar and naturally occurring ^{222}Rn were also released with the gas. ^{37,39}Ar, ^{14}C, ^{3}H and ^{203}Hg were activation products of naturally-occurring stable elements present at the detonation point.[8]

An extensive on-site and off-site radiation surveillance effort failed to detect any radioactivity other than ^{3}H and ^{85}Kr in the environment.[8] Typically, the concentrations of these isotopes in the air ranged from about a 10-millionth to 100-millionth of their concentrations in the gas.[8]

A preliminary analysis of exposure to members of the public as a result of the entire series of production tests indicated that the maximum dose received was much less than 0.04 mrem.[8] Work reported by LLL Bio Medical Division indicates the actual population dose was about one order of magnitude lower (about 0.003 mrem), while the Environmental Protection Agency's Laboratory in Las Vegas estimates an even lower dose (about 0.001 mrem).[8]

In the immediate test site area, some soil contamination occurred during decontamination procedures of surface and subsurface equipment. Detailed sampling programs conducted by the Eberline Instrument Corporation, Sante Fe, New Mexico, delineated areas with above acceptable levels of tritium in soil moisture. Contaminated soils were packaged and removed from the site.[3] The surface area at the Rulison site has now been released for unrestricted use.[3]

POTENTIAL FOR DIRECT CONTACT OR FIRE/EXPLOSION HAZARD

Due to the depth of emplacement of the explosive package, no potential for direct contact, or fire and explosion hazard exists at the Rulison site.

Some surface contamination was present as a result of production testing and decontamination of surface and subsurface equipment. All waste materials with contamination levels above background were appropriately packaged and disposed of at the project's termination.[6] Extensive surface sampling after the final cleanup of 1976 indicated that no hazards due to radioactivity are currently present at, or in proximity to, the land surface at the Rulison site[6].

No observed incident involving direct contact is known to have occurred. The surface site is easily accessible to the public; however, the waste are contained deep underground.

The exact population within a one-mile radius is not known. A maximum population value of 1 to 100 was used for HRS scoring. There are no known critical habitats in the area

No fire or explosion, other than planned gas flaring, has been observed at the site and incompatible mixtures are not expected to exist. The wastes are considered to be completely contained and have no chance of burning or exploding.

The nearest population to the site is conservatively estimated to be between 50 and 200 ft. The population within a two-mile radius is less than 100. The surrounding land is used for agricultural and recreational purposes. Less than 26 buildings are estimated to be present within a two-mile radius.

POTENTIAL FOR GROUND-WATER RELEASE

As described earlier, the Rulison explosive was emplaced near the base of the Mesa Verde formation at a depth of 8,426 ft.[7] The maximum rate of ground-water movement in the formation estimated to be 1 ft/day. At this rate it is estimated that tritium, the primary radionuclide of concern, would move less than 1 mile before decaying to a concentration below the established radiation concentration guide for drinking water.[7]

All potable aquifers encountered were cased and cemented to prevent contamination during re-entry drilling and production testing.[7]

Hydrologic monitoring of all wells and springs within a 6.2 mile radius of the site confirmed that the Rulison event was not responsible for any increase in radioactivity in surface or ground-water supplies.[7] A long-term hydrological monitoring program is still in effect, even though a release to ground water other than that already released in the Mesa Verde formation is unlikely.

An observed release of radiation to ground water occurred within the Mesa Verde formation. However, water is not used from this horizon. The distance to the aquifers of concern is greater than 150 ft.

POTENTIAL FOR SURFACE WATER RELEASE

As stated in the above section, hydrologic monitoring of all wells and springs within a 6.2 mile radius of the site confirmed that the Rulison event was not believed responsible for any increase in radioactivity in surface or ground-water supplies.[7] A long-term hydrological monitoring program is still in effect, even though the potential for a release to surface waters is not likely.[7]

Within a 6.2 mile radius of the Rulison site, 25 springs are present (Figure 3.6.7). Table 3.6.3 shows the location and use of all springs within 6.2 miles of the Rulison site and selected springs within 12.4 miles.[5]

No observed release of wastes to surface waters is known to have occurred; even though the site is less than 1,000 ft from surface water. Surface waters are thought to be used primarily for irrigation and stock watering, however, some domestic use is possible. It is conservatively estimated that fewer than 100 people may drink the surface water within 2,000 ft of the site.

The physical state of the waste is thought to be liquid and containment is considered complete due to the great depth of the waste below the surface. The 2 year, 24 hr rainfall value is 8 in. No known sensitive environment are present in the area.

POTENTIAL FOR AIR RELEASES

Essentially all of the explosion produced radionuclides in the Rulison event were contained within the Mesa Verde formation. The only contaminants released at the Rulison site were in the form of gases during the gas production testing phase. All gas releases were carefully controlled. An extensive on-site and off-site radiation surveillance effort failed to detect any radioactivity other than ^{3}H and ^{85}Kr in the environment. Typically, the concentrations of these isotopes in air ranged from about a 10-millionth to a 100-millionth of their concentration in the gas.[8]

During the final cleanup effort (September 1 through October 12, 1976), the R–E and R–Ex wells were plugged and abandoned.[6] After plugging operations were completed, no further potential for releases to the air existed.

Figures 3.6.8 and 3.6.9 show the as-plugged condition of the R–E and R–Ex wells.[2] For a detailed description of operational procedures during plugging and abandonment see Project Rulison Well Plugging and Site Abandonment Final Report NVO–187.[2]

Remaining wastes are not considered to be reactive, nor are incompatible mixtures thought to be present.

The population within a four–mile radius is conservatively estimated to be less than 100. The land surrounding the site is used for agriculture and recreation.

THREATS TO FOOD CHAIN AND ENVIRONMENT

No threats to the food chain are believed present at or in the vicinity of the Project Rulison test site.

CONCLUSION AND RECOMMENDATIONS

Radiation was released to the environment during Project Rulison production testing. The R–E and R–Ex wells have been plugged to prevent the escape of radiation.

The explosive was detonated 8,426 ft below the surface in the Mesa Verde formation. Given the extremely low permeability of this formation, radionuclide migration is expected to be very limited. However, surface and subsurface water quality monitoring is still being conducted near the Rulison test site.

A preliminary HRS was conducted for Project Rulison and is included in Appendix 3.6.A. A preliminary migratory HRS score was calculated to be 15.12. The only contributing score was the air route due to the release of radioactivity during testing. It is unlikely that further air releases will occur.

It is recommended that the hydrologic monitoring program be continued and periodically updated as new hydrologic data become available.

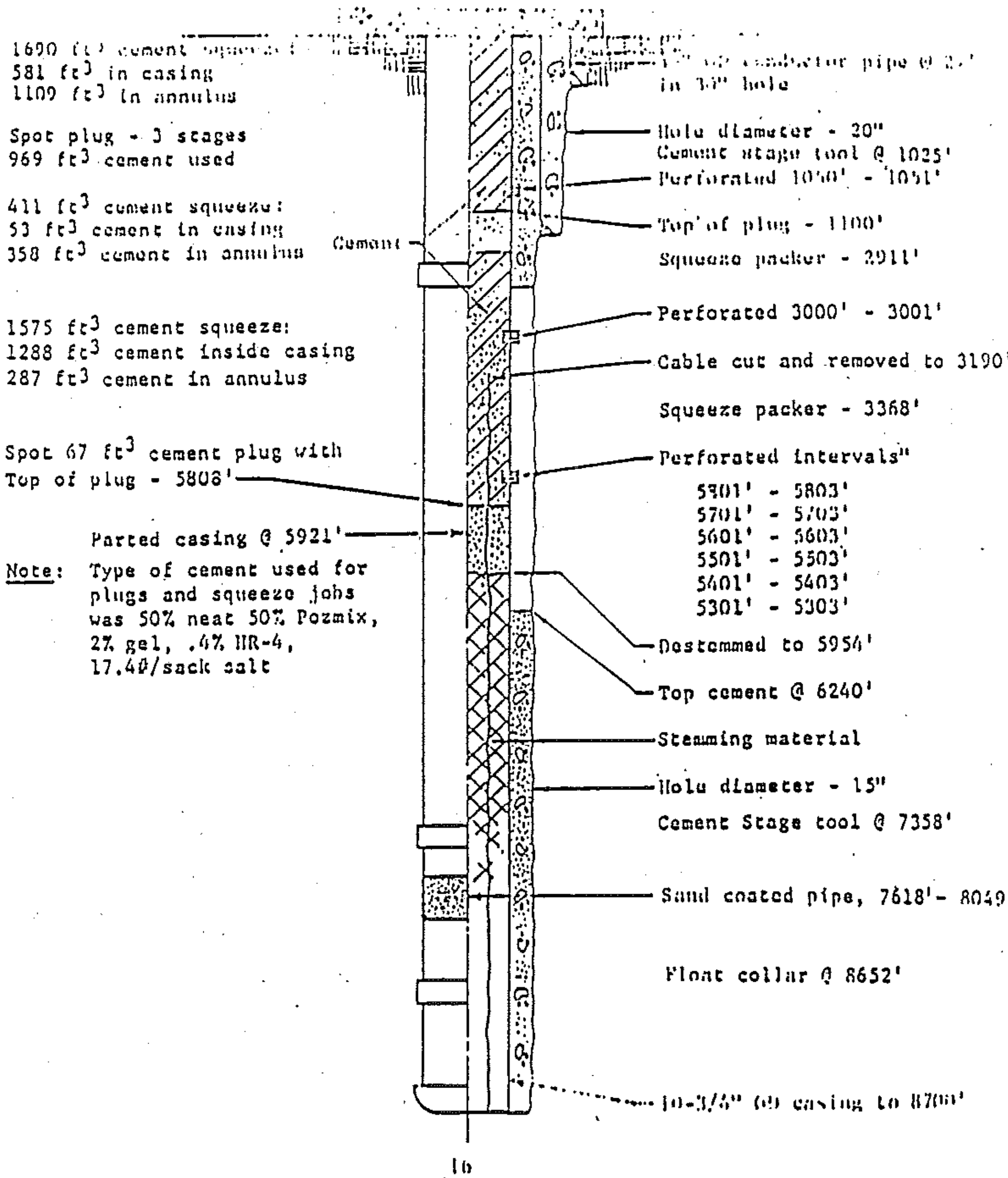


FIGURE 3.6.8. Hayward #25-95 "A" Emplacement Hole (R-E), As-Built Plugging Condition.

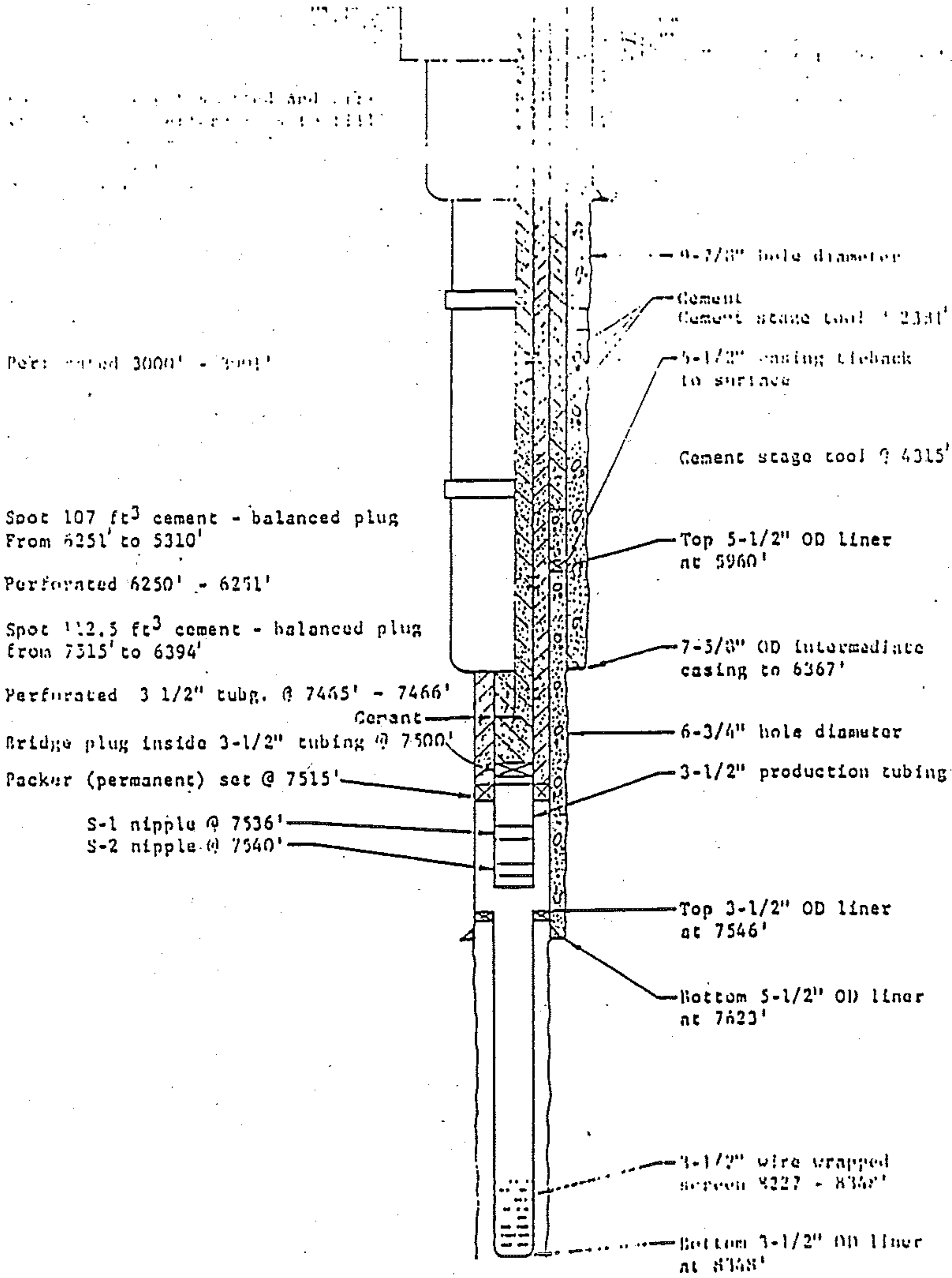


FIGURE 3.6.9. Abandonment Procedure of Well R-Ex.

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APPENDIX 3.6.A
HRS WORKSHEETS
RULISON

FIRE AND EXPLOSION WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Containment	(1) 3	1	1	3	7.1
2 Waste Characteristics					7.2
Direct Evidence	(0) 3	1	0	3	
Ignitability	(0) 1 2 3	1	0	3	
Reactivity	(0) 1 2 3	1	0	3	
Incompatibility	(0) 1 2 3	1	0	3	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			8	20	
3 Targets					7.3
Distance to Nearest Population	0 1 2 3 (4) 5	1	4	5	
Distance to Nearest Building	0 1 (2) 3	1	2	3	
Distance to Sensitive Environment	(0) 1 2 3	1	0	3	
Land Use	0 1 2 (3)	1	3	3	
Population Within 2-Mile Radius	0 (1) 2 3 4 5	1	1	5	
Buildings Within 2-Mile Radius	0 (1) 2 3 4 5	1	1	5	
Total Targets Score			11	24	
4 Multiply 1 x 2 x 3			88	1,440	
5 Divide line 4 by 1,440 and multiply by 100			S_{FE} = 6.1		

DIRECT CONTACT WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
[1] Observed Release	(0) 45	1	0	45	8.1
If observed release is given a score of 45, proceed to line 4. If observed release is given a score of 0, proceed to line 2.					
[2] Accessibility	(0) 1 2 3	1	0	3	8.2
[3] Containment	(0) 15	1	0	15	8.3
[4] Waste Characteristics					8.4
Toxicity	0 1 2 (3)	5	15	15	
[5] Targets					8.5
Population Within a 1-Mile Radius	0 (1) 2 3 4 5	4	4	20	
Distance to a Critical Habitat	(0) 1 2 3	4	0	12	
Total Targets Score			4	32	
[6] If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			0	21,600	
[7] Divide line 6 by 21,600 and multiply by 100			S_{DC} = 0		

GROUND WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 (45)	1	45	45	3.1
If observed release is given a score of 45, proceed to line 4.					
If observed release is given a score of 0, proceed to line 2.					
2 Route Characteristics					3.2
Depth to Aquifer of Concern	0 1 2 3	2		6	
Net Precipitation	0 1 2 3	1		3	
Permeability of the Unsaturated Zone	0 1 2 3	1		3	
Physical State	0 1 2 3	1		3	
Total Route Characteristics Score				15	
3 Containment	0 1 2 3	1		3	3.3
4 Waste Characteristics					3.4
Toxicity/Persistence	0 3 6 9 12 15 (18)	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			26	26	
5 Targets					3.5
Ground Water Use	(0) 1 2 3	3	0	9	
Distance to Nearest Well/Population Served	(0) 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
Total Targets Score			0	49	
6 If line 1 is 45, multiply 1 x 4 x 5					
If line 1 is 0, multiply 2 x 3 x 4 x 5			0	57,330	
7 Divide line 6 by 57,330 and multiply by 100		S_{gw} = 0			

SURFACE WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	4.1

If observed release is given a score of 45, proceed to line 4.

If observed release is given a score of 0, proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Route Characteristics					4.2
Facility Slope and Intervening Terrain	0 1 2 (3)	1	3	3	
1-yr. 24-hr. Rainfall	(0) 1 2 3	1	0	3	
Distance to Nearest Surface Water	0 1 2 (3)	2	6	6	
Physical State	0 (1) 2 3	1	1	3	
Total Route Characteristics Score			10	15	
3 Containment	(0) 1 2 3	1	0	3	4.3
4 Waste Characteristics					4.4
Toxicity/Persistence	0 3 6 9 12 15 (18)	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			26	26	
5 Targets					4.5
Surface Water Use	0 1 2 (3)	3	9	9	
Distance to a Sensitive Environment	(0) 1 2 3	2	0	6	
Population Served/ Distance to Water Intake Downstream	0 4 6 8 (10) 12 16 18 20 24 30 32 35 40	1	10	40	
Total Targets Score			19	55	
6 If line 1 is 45, multiply 1 x 4 x 5					
If line 1 is 0, multiply 2 x 3 x 4 x 5			0	64,350	
7 Divide line 6 by 64,350 and multiply by 100		S_{SW} =	0		

AIR ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 (45)	1	45	45	5.1
Date and Location: During production testing.					
Sampling Protocol:					
If line 1 is 0, the S_a = 0. Enter on line 5. If line 1 is 45, then proceed to line 2.					
2 Waste Characteristics					5.2
Reactivity and Incompatibility	(0) 1 2 3	1	0	3	
Toxicity	0 1 2 (3)	3	9	9	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			17	20	
3 Targets					5.3
Population Within 4-Mile Radius	0 (9) 12 15 18 21 24 27 30	1	9	30	
Distance to Sensitive Environment	(0) 1 2 3	2	0	6	
Land Use	0 1 2 (3)	1	3	3	
Total Targets Score			12	39	
4 Multiply 1 x 2 x 3			9,180	35,100	
5 Divide line 4 by 35,100 and multiply by 100			S_a = 26.15		

HRS SCORE FOR RULISON

S_{gw} = 0.0

S_{sw} = 0.0

S_a = 26.15

$$S_m = \frac{1}{1.73}\sqrt{(0)^2 + (0)^2 + (26.15)^2}$$

S_m = 15.12

S_{FE} = 6.1

S_{DC} = 0.0

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SECTION 3.7

COVER SHEET

NAME OF SITE:	Gasbuggy Site, New Mexico
LOCATION:	The site is located in north central New Mexico in Rio Arriba County, 55 miles east of Farmington.
DISPOSITION:	The Gasbuggy test was conducted on U.S. Forest Service land under lease to El Paso Natural Gas Co. T29N R4W Section 36 was withdrawn from the BLM for use by AEC (now DOE) as well as subsequent surface and subsurface rights. Radionuclides were released to the subsurface environment at the time of the shot. Surface release of radionuclides (to the atmosphere) occurred during gas production testing in 1968, 1969, and 1973.

PRELIMINARY ASSESSMENT REPORT
GASBUGGY SITE, NEW MEXICO

INTRODUCTION

The Gasbuggy site is located in Rio Arriba County, New Mexico, approximately 55 air miles east of Farmington, New Mexico. The Gasbuggy device was the first U.S. underground nuclear experiment for the stimulation of low-productive natural gas reservoirs.

Project Gasbuggy (Plowshare Series) was sponsored by the Division of Peaceful Nuclear Explosives (DPNE). The Gasbuggy site is on an El Paso Natural Gas (EPNG) Company lease in the San Juan Basin and is surrounded by other EPNG lease holdings.

The primary purpose of the Gasbuggy experiment was to determine if nuclear stimulation could economically release gas that could not be economically produced from underground reservoirs by conventional methods. The experiment involved the detonation of a nuclear device designed to have a 29 kt yield. The nuclear explosive was emplaced at a depth of 4,240 ft below the land surface in the Lewis Shale just below the natural gas-producing Pictured Cliffs sandstone formation. The Gasbuggy device was detonated on December 10, 1967.[1]

OVERALL FACILITY DESCRIPTION

In the case of Gasbuggy, a single detonation occurred followed by several testing phases. The underground ground zero (GZ) and the surface facilities are treated in this report as a single facility site.

The Project Gasbuggy site is located in the southwest quarter of Section 36, T29N, R4W, New Mexico Principal Meridian. It is located on the eastern side of the San Juan Basin, a structural feature of the Colorado Plateau Province located in northwestern New Mexico and southwestern Colorado (see Figure 3.7.1). The nearest large town is Farmington, New Mexico, with a population of 23,000. The nearest community is Dulce, New Mexico, 20 miles to the northeast with a population of about 500. There were no habitations within a five-mile radius at the time the Gasbuggy experiment was conducted. The population remains the same at the date of 1986.[1] The test site was within the Carson National Forest and adjacent to the Jicarilla Apache Indian Reservation. The existing oil and gas leases for the

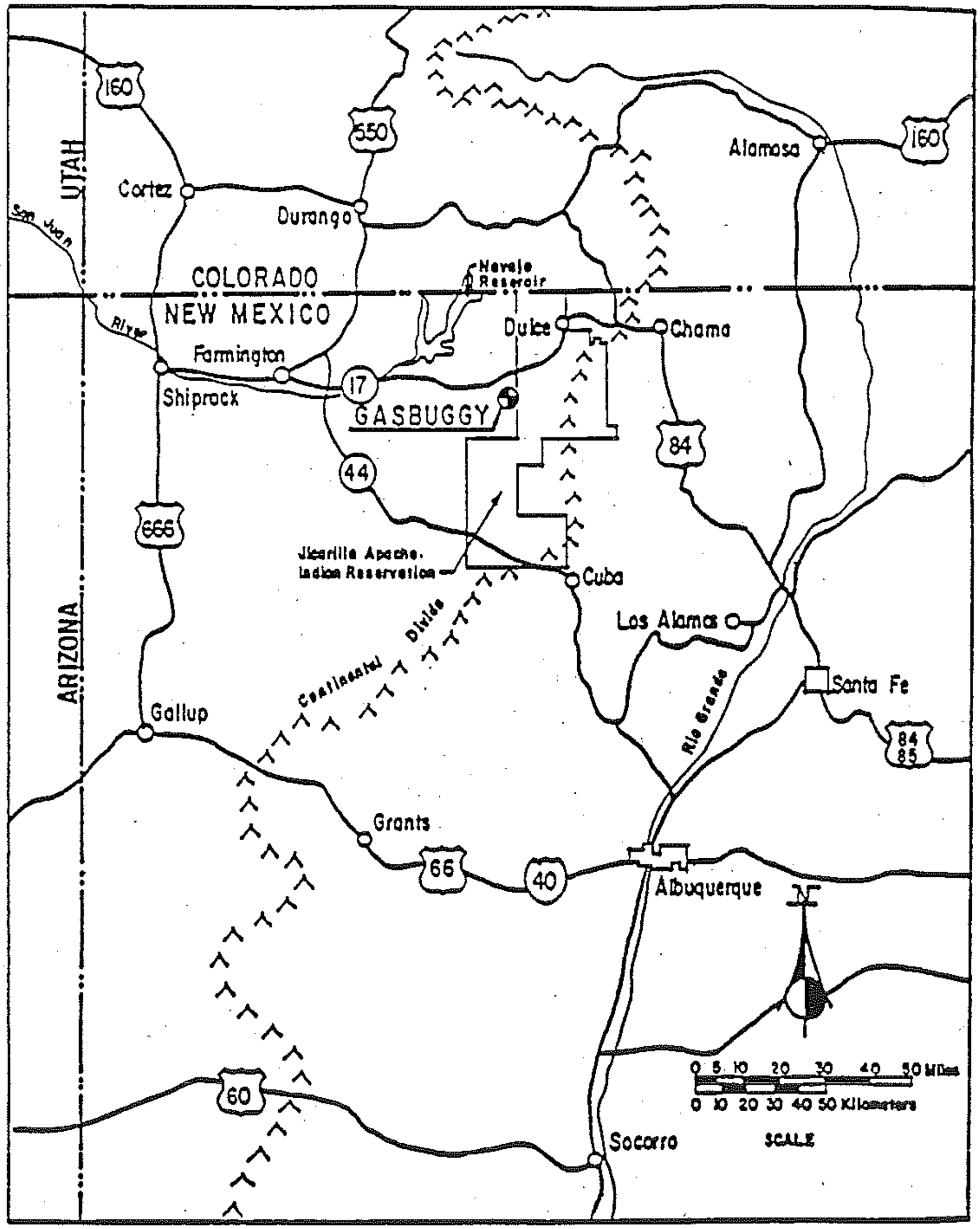

FIGURE 3.7.1. Location Map for Gasbuggy Site.

lands in the immediate area of the test location are held by EPNG (see Figures 3.7.2 and 3.7.3).[2]

The project installations, consisting of the GZ area, the recording trailer park (RTP), the control point (CP), and the helicopter pad were located on lands within the Carson National Forest. The use of these lands for the Gasbuggy Project was established in a Memorandum of Understanding between the U.S. Forest Service and the U.S. Atomic Energy Commission. Additionally, by land withdrawal action of Public Land Order 4232, dated June 22, 1967, the Bureau of Land Management withdrew from all forms of appropriation, including mining and mineral leasing laws, and reserved for the use of the Atomic Energy Commission the surface and subsurface of lands within Section 36, T29N, R4W, New Mexico Principal Meridian. Surface and subsurface operating rights to lands within the southwest one-fourth of the described section were reserved for the use of the AEC under stipulations of Contract AT(04-3)-711. Access to the project site was by a road traversing the Jicarilla Apache Indian Reservation. Upgrading and extending this roadway was accomplished by the New Mexico State Highway Department through EPNG under stipulations in Contract AT(04-3)-711. This road was provided for Project Gasbuggy use, but the project did not acquire control or responsibility for its maintenance.[3]

ENVIRONMENTAL SETTING

The test location is surrounded by typical canyon and plateau topography of the Colorado Plateau Province. Elevations range from 6,800 to 7,500 ft in the surrounding area and from 7,000 to 7,300 ft in the immediate test area. The San Juan River, at its nearest point, is 20 miles away. Navajo Dam, which was completed in 1963, is located some 23 miles distant.[1] There are believed to be no critical habitats at the site. Land use is primarily cattle grazing.

HYDROGEOLOGIC SETTING

Project Gasbuggy is located on the eastern side of the San Juan Basin. This structural feature is about 180 miles long and 135 miles wide. It covers the eastern part of the Navajo physiographic section of the Colorado Plateau Province. Rocks in and around the test site range in age from pre-Cambrian to recent. Total thickness of sedimentary rocks in the Central Basin ranges from 10,000 to 15,000 ft. The formations penetrated by drilling at the Gasbuggy site are in descending

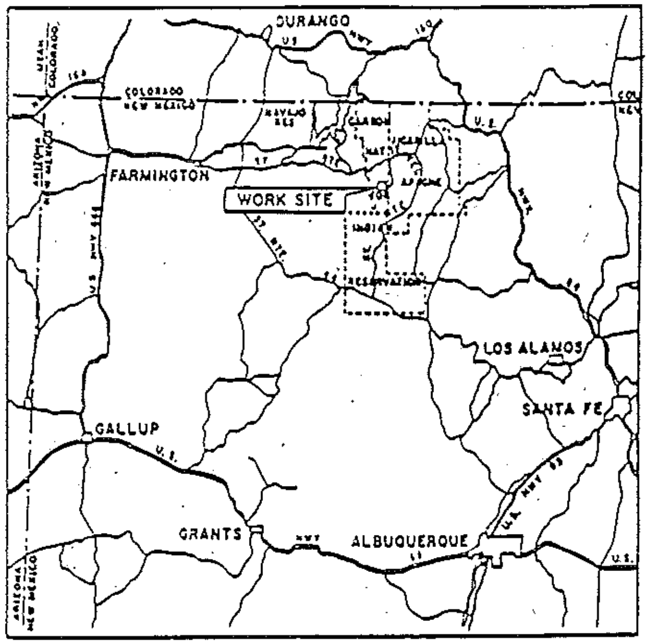

FIGURE 3.7.2. Project Gasbuggy Area Map.

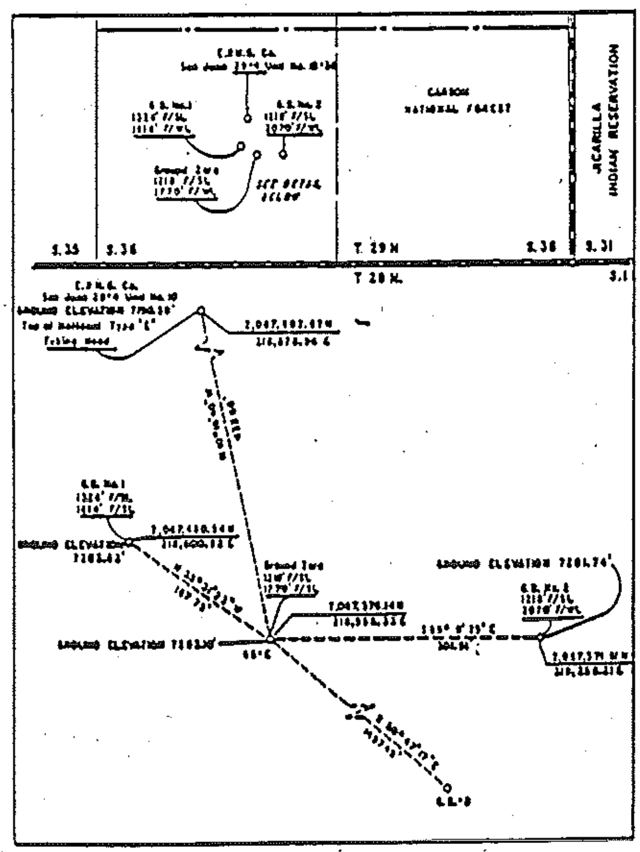

FIGURE 3.7.3. Project Gasbuggy Ground Zero Plot Plan.

order: Surficial alluvium (recent); San Jose formation; Nacimiento formation; the Ojo Alamo sandstone formation all of Tertiary age; the Kirtland Shale formation; the Fruitland formation; Pictured Cliffs sandstone formation; and Lewis Shale formation all of late Cretaceous age. The Pictured Cliffs sandstone is of primary importance because it was within this formation that the Gasbuggy chimney was formed by the detonation in the underlying Lewis Shale. See Figures 3.7.4, 3.7.5, and 3.7.6 for stratigraphic section and geologic cross section.[1]

1. Pictured Cliffs Sandstone

   The Pictured Cliffs sandstone is predominantly a marine sandstone. It is underlain by the Lewis Shale. At the Gasbuggy test site, the Pictured Cliffs sandstone is about 290 ft thick and is chiefly a light-gray, fine- to very fine-grained sandstone interbedded with dark, sandy shales. The sandstone beds bear natural gas and contain minor coal fragments, carbonaceous layers, and traces of oil. The formation is not known to yield substantial amounts of water and is not a water producer at the Gasbuggy site.

2. Fruitland Formation and Kirtland Shale

   The Fruitland formation and the Kirtland Shale overlie the Pictured Cliffs sandstone in ascending stratigraphic order. These formations comprise a 260-ft interval of gray to dark-green shale and siltstone. Abundant carbonaceous material and coal generally are associated with beds of shale. Coal stringers in the Fruitland formation yield small amounts of water in some parts of the basin. The Kirtland Shale lacks aquifer characteristics and probably does not release water to wells in the Gasbuggy area.

3. Ojo Alamo Sandstone

   The Ojo Alamo sandstone overlies the Kirtland Shale and is about 180 ft thick at the Gasbuggy site. The formation consists primarily of a light-gray, fine- to medium-grained, clayey sandstone, but also contains a few minor beds of shale. The Ojo Alamo sandstone generally is water bearing, and it yields water to domestic wells along the San Juan River 50 miles west of the test site where the formation is 1,700 ft higher than it is at the Gasbuggy site. At the test site, the formation yields minor amounts of water.

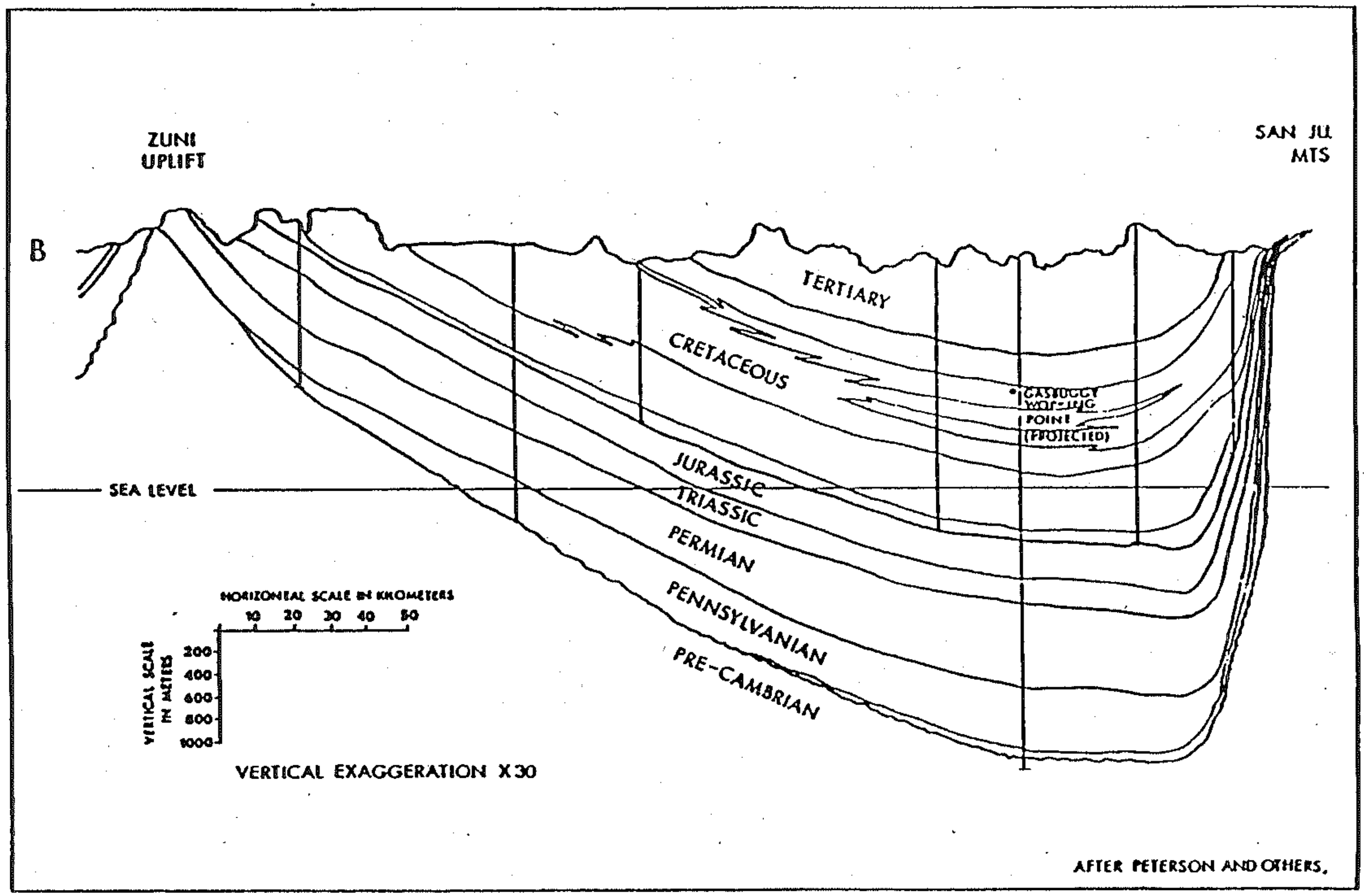

FIGURE 3.7.4. South-North Geologic Cross Section Across the San Juan Basin.

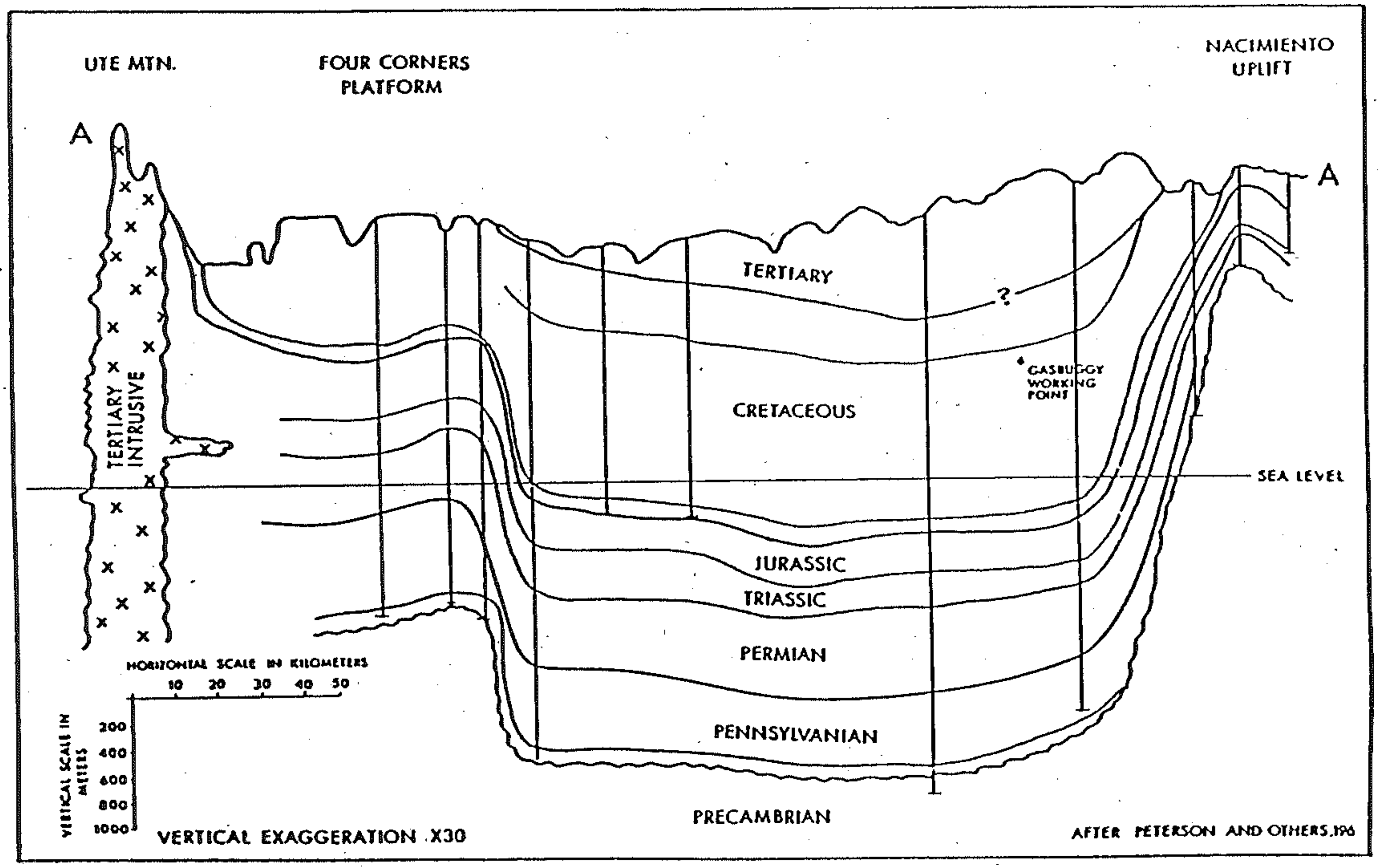

FIGURE 3.7.5. West-East Geologic Cross Section Across the San Juan Basin.

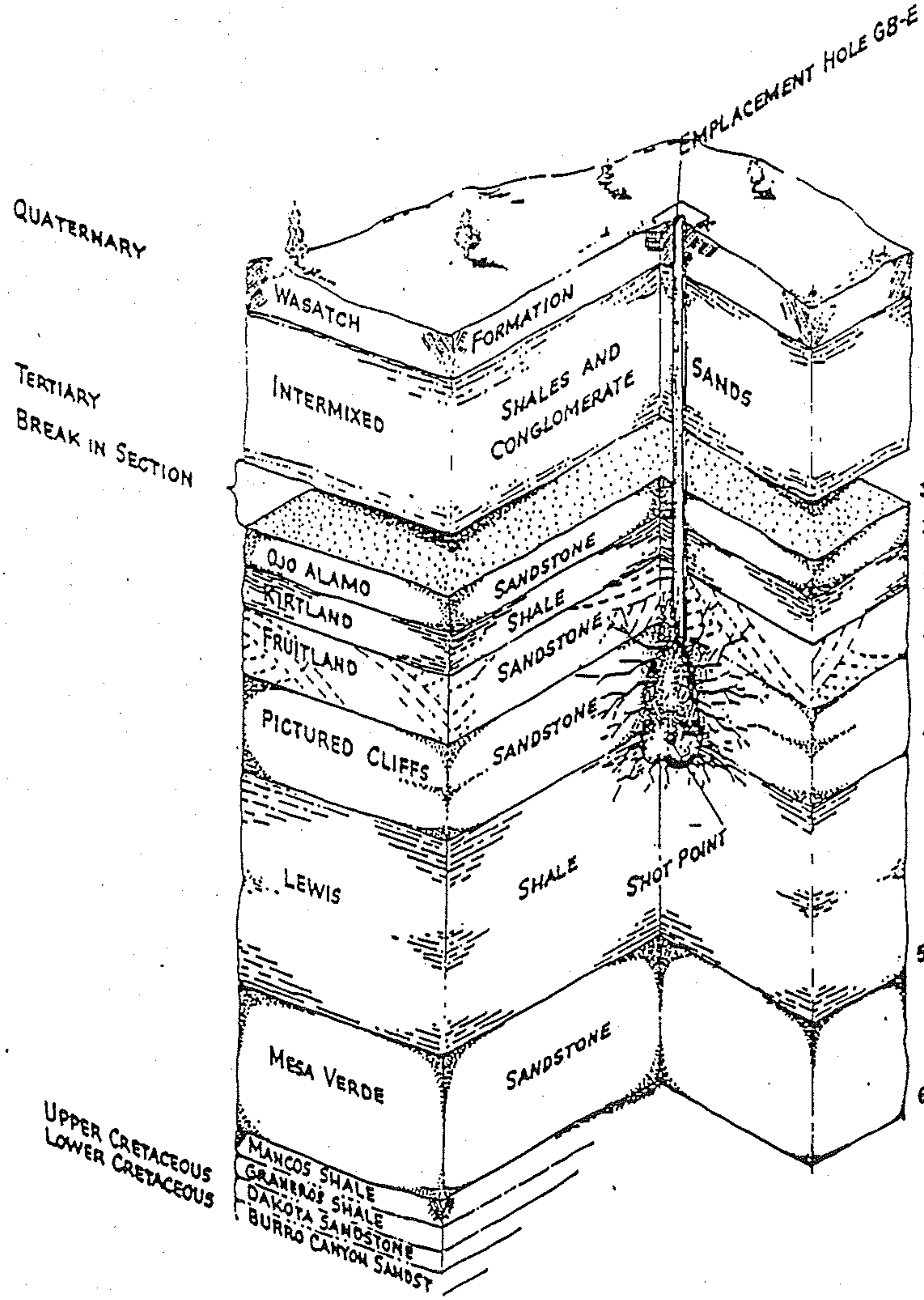

FIGURE 3.7.6. Project Gasbuggy Generalized Geologic Cross Section.

4. Nacimiento and San Jose Formations

The Nacimiento and San Jose formations are continental flood-plain deposits and are the predominant surface formations in the Gasbuggy area. At the test site, they comprise a 3,500-ft sequence of fine- to medium-grained, locally conglomeratic sandstone, interbedded with claystone and sandy, variegated shale. The beds of sandstone in the San Jose and Nacimiento formations commonly contain water, but these water-bearing zones probably are far enough above the explosion point at the test site to be unaffected by the nuclear event.

The surficial alluvium, the San Jose formation, the Nacimiento formation, and the Ojo Alamo sandstone are the principal aquifers in the Gasbuggy area.[1]

The Ojo Alamo sandstone was the only water-producing formation considered to be within the "unlikely but remotely possible" range of fracturing from the nuclear detonation. Hydrologic testing was limited to the Ojo Alamo sandstone.[6]

The direction of the ground-water movement in the San Juan Basin is not well known. The major discharge point for water moving in the Ojo Alamo sandstone probably is the San Juan River, 50 miles northwest of the test site. An estimate of the rate of ground-water movement was computed by using known, or assumed, values for the permeability and porosity of the aquifer and for the hydraulic gradient of the water in the aquifer.[1]

The coefficient of permeability of the Ojo Alamo sandstone was determined to be approximately 0.017 gal/day/ft^2. This value was derived by using a coefficient of transmissivity of 3 gal/day/ft and an effective aquifer thickness of 180 ft as determined from data collected from holes GB-1 and GB-2. A hydraulic gradient of 30 ft/mi across the central basin was assumed. An average porosity of 13 percent was determined from core samples analyzed by Core Laboratories, Inc. Calculations based upon these values indicate that the average rate of ground-water movement in the Ojo Alamo sandstone across the basin is about 0.0001 ft/day, or 0.04 ft/yr.[1]

High total dissolved solids make water from this aquifer unsuitable for irrigation or domestic use.[1]

All known wells and springs within a five-mile radius of GZ were investigated during June 1967 as were all accessible wells and springs between the five- and ten-mile radius. Locations of these wells and springs are plotted on Figure 3.7.7 and listed in Tables 3.7.1 (wells) and 3.7.2 (springs). The 13 wells investigated range in depth from 54 to 229 ft and are completed in alluvium. Well yields in the range of 1 to 3 gpm are considered good. Specific conductance of the water ranges from 700 to 2,600 micromhos/cm at 25°C.[6] No wells in the area are known to tap the deeper Ojo Alamo aquifer.[6]

Twenty-three springs of the contact type were investigated. The springs discharge from sandstones in the San Jose formation of Eocene age. Some of the springs are seeps with little or no visible flow; others are characterized by yields generally ranging from 1 to 8 gpm. Specific conductance of spring water ranges from 370 to 2,300 micromhos/cm at 25°C.[6]

No springs or wells within a five-mile radius from the site are used for human consumption. Springs and some wells that likely serve for stock watering are within a three-mile radius from GZ. With the exception of well EPNG 10-36, these are believed to intersect the shallow alluvial/San Jose aquifer system only. Selected wells and springs are sampled yearly as part of a long-term hydrologic monitoring program.[6,1]

Surface water is present in La Jara Creek approximately 2.5 miles from the surface facilities. The Creek is ephemeral and is sampled yearly when water is flowing (personal communication, EPA-EMSL). La Jara Creek has shown no tritium contamination above background precipitation.[7] The Creek is not believed to be used for human consumption, but is likely used by stock for watering.

Climatological data for the Gasbuggy area have been collected at Governador, New Mexico (El Paso Camp) for a 20-year period of record. This station, located about 10 miles from GZ, is considered representative of the Gasbuggy area. Data presented in NVO-277 incorrectly presents the average precipitation. Data from the HRS document suggests that the average annual precipitation is approximately 10 in/yr.[8] The average annual lake evaporation is 48 in.[8] Temperatures range from the lower 70°'s F in July and August to the upper 20°'s F in December. Recorded extremes are +105°F in August to -28°F in February.[1] The 2 year, 24 hr precipitation value is 1.6 in.

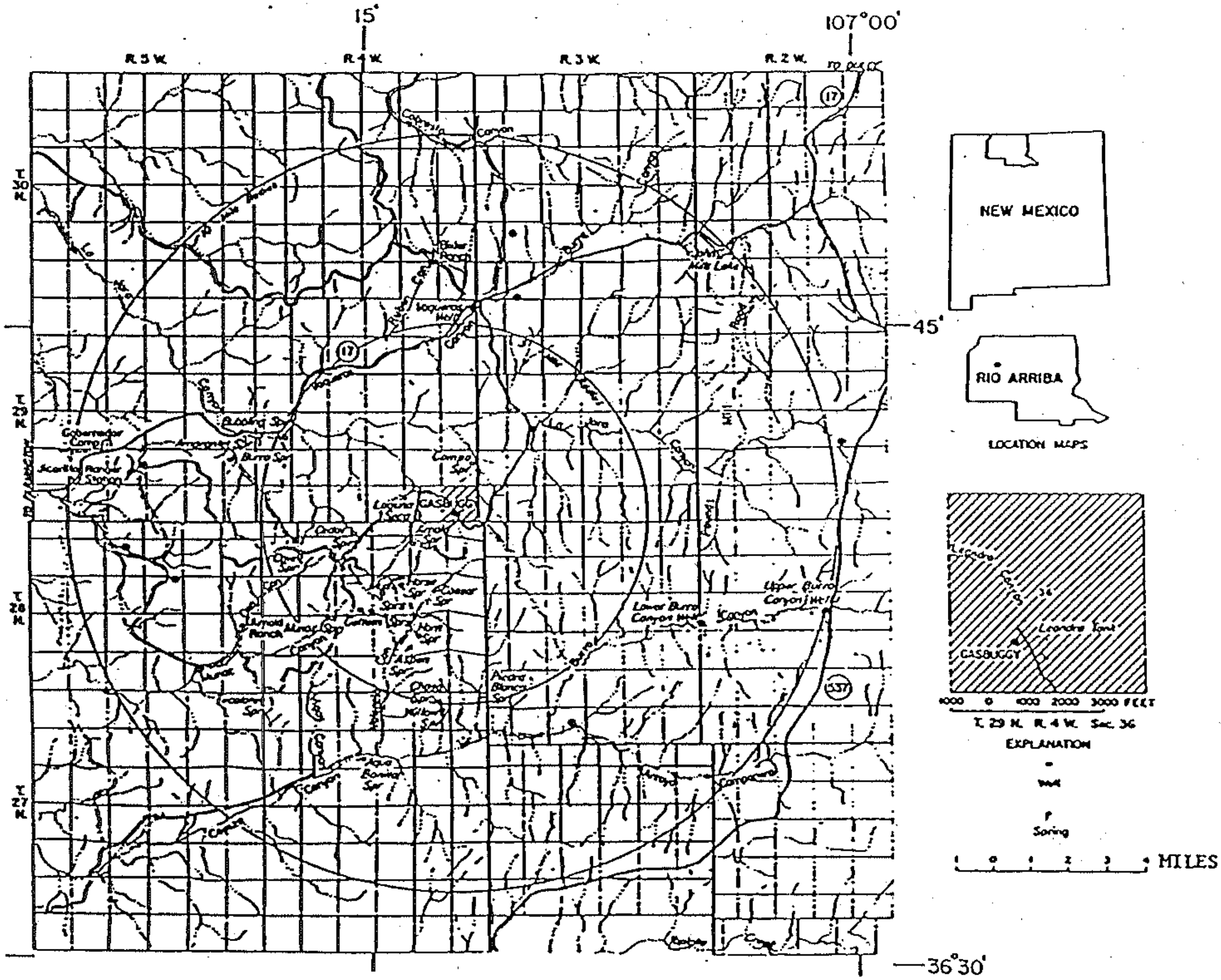

FIGURE 3.7.7. Location of Wells and Springs Within a 10-Mile Radius of Project Gasbuggy Site.

TABLE 3.7.1. RECORDS OF WELLS INVENTORIED WITHIN A 10-MILE RADIUS OF PROJECT GASBUGGY SITE, RIO ARRIBA COUNTY, NEW MEXICO.

Location Number	Owner or Name	Year Completed	Depth (feet)	Diameter (inches)	Altitude (feet)	Water Level: Depth Below Land Surface (feet)	Water Level: Date	Strati-graphic Unit	Pump	Power	Use of Water	Distance from ground zero (miles)	Specific conductance (micromhos per cm at 25°C)	Remarks
28.2.15.144	Jicarilla Apache Reservation	-	152	6	7,234	110.2	6-29-67	Qal	P	W	S	10.2	2,100	Upper Burro Canyon Well
28.2.18.331	do	-	229	6	7,089	72.2	6-29-67	Qal	P	W	S	7.1	3,000	Lower Burro Canyon Well
28.3.33.233	do	-	81	6	6,920	51.8	6-29-67	Qal	P	I	S	6.3	-	--
28.5.16.213	U.S. Bur. Land Management	-	95	6	6,580	57.5	6-30-67	Qal	P	I	S	8.6	-	--
28.5.22.221	do	-	-	-	6,698	-	-	-	P	W	S	7.5	700	Yield 1 gpm; temp. 50°F
28.5.35.144	Russell Arnold	1950	-	6	6,630	-	-	Qal	P	I	D,S	7.9	-	Reported yield 11 gpm; reported depth 54 ft.
29.2.22.441	Jicarilla Apache Reservation	1962	198	6	7,150	174.1	6-29-67	Qal	P	W	S	10.2	1,500	Yield 1 gpm; temp. 44°F
29.3.20.234	do	-	75	7	6,875	22.2	6-29-67	Qal	P	W	S	3.1	2,600	Yield 3 gpm; temp. 43°F
29.4. 1.223	U.S. Forest Service	1953	115	7	6,680	29.9	6-30-67	Qal	N	N	N	5.6	-	Vaqueros well old ranger station
29.5.28.422	U.S. Bur. Land Management	-	130(?)	7	6,650	122.4	6-30-67	Qal	P	W	S	8.2	-	--
30.3.29.132	Jicarilla Apache Reservation	-	-	7	7,235	-	-	-	P	W	S	7.5	850	Yield 2 gpm; temp. 47°F
30.3.32.343	do	-	200	7	7,038	64.1	6-29-67	Qal	P	W	S	5.9	-	--
30.4.35.221	Fred Bixler	-	175	6	7,140	52.7	6-29-67	Qal	P	W	D	6.6	-	Reported yield 3 gpm

Location Number: See text for explanation of well-numbering system.
Depth: Depths listed are measured depths to the nearest foot.
Diameter: Diameter of the casing to the nearest inch.
Altitude: Altitude of land surface at well. Altitude interpolated from U.S.G.S. topographic maps, scale 1 24,000 and contour interval 20 feet.
Water Level: Measured depths below land surface, to nearest tenths of a foot.
Stratigraphic Unit: Qal - Alluvium.
Type of Pump: P - plunger or cylinder; N - none.
Type of Power: W - wind; I - internal combustion.
Use of Water: S - stock; D - domestic.
Note: Unless specified, all wells are drilled and cased to total depth.

TABLE 3.7.2. RECORDS OF SPRINGS INVENTORIED WITHIN A 10-MILE RADIUS OF PROJECT GASBUGGY SITE, RIO ARRIBA COUNTY, NEW MEXICO.

Location Number	Owner	Name	Topographic situation	Altitude (feet)	Stratigraphic Unit	Yield (gpm)	Date	Use of Water	Temperature (°F)	Distance from ground zero (miles)	Specific conductance (micromhos per cm at 25°C)	Remarks
S27. 4. 1.222	U.S. Forest Service	Piedra Blanca	Stream Channel	6,960	Tsj	0.2	6-29-67	S	-	4.9	-	Temp. 55°F at discharge point, developed spring
S27. 4. 2.232	do	Chosa	do	7,095	Tsj	.1	6-27-67	N	46	5.0	1,400	Discharge from SS above SH
S27. 4. 2.234	do	Willow	do	7,050	Tsj	.1	6-27-67	N	43	5.2	2,200	--
S27. 4. 9.414	do	Agua Bonita	Hillside	6,730	Tsj	8.6	6-26-67	S	49	7.1	1,500	Good spring, developed
S27. 5. 1.224	do	Tecolota	Stream Channel	7,190	Tsj	-	6-30-67	S	48	7.0	850	Dammed; yield not measured
S28. 4. 9.342	do	Cedar	Hillside	7,350	Tsj	<.1	6-21-67	S	47	2.6	470	Partially developed
S28. 4.14.113	do	Arnold	do	7,200	Tsj	<.1	6-23-67	N	47	1.3	950	--
S28. 4.17.311	do	Cave	do	7,410	Tsj	.1	6-21-67	S	48	4.2	370	Partially developed, stock tank
S28. 4.21.444	do	Gettem	Stream Channel	7,200	Tsj	.2	6-28-67	S	44	3.4	1,400	--
S28. 4.21.444a	do	-	do	7,200	Tsj	<.1	6-28-67	N	43	3.4	-	--
S28. 4.22.134	do	Mud	do	7,210	Tsj	-	6-27-67	S	52	2.9	-	Series of seeps. Called Hungry by U.S. Forest Service
S28. 4.22.241	do	Horse	do	7,260	Tsj	-	6-23-67	N	43	2.4	-	Seep
S28. 4.23.234	do	Caesar	do	7,130	Qal	~.6	6-23-67	S	-	2.1	1,950	Developed, stock tank seepage in excess of measured flow
S28. 4.26.312	do	Horn	do	7,180	Tsj	.1	6-27-67	N	48	3.4	2,300	Called Aspen by U.S. Forest Service
S28. 4.27.444	do	Aspen	do	7,135	Tsj	.1	6-27-67	N	54	3.8	-	Seep, called Horn by U.S. Forest Service
S28. 4.29.221	do	Munoz	Hillside	7,080	Tsj	.5	6-21-67	S	43	4.3	-	--
S28. 5.25.142	Arnold Ranch	-	Valley flat	6,780	Tsj(?)	-	6-30-67	S	48	6.4	-	Seep
S28. 5.25.142a	do	-	do	6,790	Tsj(?)	-	6-30-67	S	47	6.4	-	Seep
S29. 4.19.412	do	Bubbling	do	6,555	Tsj	4.3	6-23-67	S	45	5.1	1,290	Developed
S29. 4.19.421	do	-	do	6,570	Tsj	4.0	6-23-67	N	45	4.9	900	--
S29. 4.25.241	do	Campo	Stream Channel	6,920	Tsj	-	6-22-67	N	45	1.5	-	Seep
S29. 5.24.413	do	Amarante	Hillside	6,570	Tsj	.6	6-23-67	N	44	5.8	815	--
S29. 5.25.132	do	Burro	do	6,580	Tsj	~.3	6-23-67	S	50	6.0	740	Developed, stock tank

Location Number: Number preceded by S designates spring location (see text for explanation of well-numbering system).
Altitude: Altitude of land surface at spring. Altitude interpolated from U.S.G.S. topographic map, scale 1:24,000 and contour interval 20 feet.
Stratigraphic Unit: Tsj - San Jose Formation; Qal - Alluvium.
Yield: Measured unless specified.
Use: S - stock; N - none.

HUMAN RECEPTORS

The site is both remote and uninhabited, yet readily accessible by paved highway. The nearest sizable town was Farmington, New Mexico, 55 air miles to the west of the site, with a population of 23,000. The nearest community was Dulce, New Mexico, approximately 20 miles to the northeast, with a population of about 500. There were no houses or buildings within a five-mile radius of the site at the time of the test.[2] These conditions are believed to be accurate today. Two residences, based upon the water supply data in Table 3.7.1, are located approximately 7 miles from the site (Arnold Ranch and Bixler Ranch).

ENVIRONMENTAL RECEPTORS

The Gasbuggy site is currently used for grazing and also is expected to support a wide variety of flora and fauna typical of northern New Mexico. Based upon discussions with Carson National Forest personnel, the site and its surroundings are not considered critical habitat for any currently federally listed threatened or endangered species. Bald Eagles and Peregrine Falcons are found to the south at Navajo Lake, however, nesting sites are not believed to be present near the Gasbuggy site (personal communication, USFS). This site is not fenced.

SITE HISTORY

As early as 1958, El Paso Natural Gas Company (EPNG) investigated the application of nuclear explosive stimulation to a gas reservoir by initiating correspondence with the University of California, Lawrence Radiation Laboratory (LRL), Livermore, in connection with the Pinedale Unit Area, covering approximately 92,000 acres in Sublette County, Wyoming. However, EPNG did not propose a field test at that time.

A study was initiated by the AEC San Francisco Operations Office (SAN), EPNG, and the U.S. Bureau of Mines (USBM), utilizing accepted technology of the industry, performing the necessary calculations, and making the engineering evaluations for such a project. EPNG furnished the geologic data and ownership and location information, while LRL provided consulting service pertaining to effects of nuclear explosions and to resulting radioactivity in the gas.

On June 17, 1965, Mr. Howard Boyd, Chairman of the Board, EPNG, presented the feasibility study dated May 14, 1965 to the AEC suggesting nuclear explosive stimulation of a natural gas reservoir and proposing that the experiment be jointly conducted.

On June 24, 1965, the Division of Peaceful Nuclear Explosives, USAEC, requested a comprehensive review and evaluation of the proposed project. This review was undertaken in the summer of 1965 by LRL. A report on the review was distributed on July 30, 1965 to EPNG, USBM, and the AEC recommending that Gasbuggy be conducted.

Following a 6-month period of relative inactivity, the Gasbuggy concept was re-examined. An updated Technical Concept was distributed on October 17, 1966. EPNG proposed to make available to the AEC the EPNG gas lease on Federal land for use as a site for a nuclear experiment and offered technical assistance in the design and execution of an experiment.

On January 31, 1967, Contract No. AT(04-3)-711 was signed by AEC/HQ, the Department of the Interior, and EPNG. On February 9, 1967, the Manager, NVOO, was authorized by the General Manager, AEC, to act as the authorized representative of the Contracting Officer for the administration of the contract.

On February 11, 1967, EPNG began drilling the first pre-shot test well, GB-1, which was completed on March 17 to a total depth of 4,306 ft. On April 9, EPNG began drilling the second test well, GB-2, which was completed on May 5 to a total depth of 4,248 ft. Gas reservoir tests in conjunction with GB-1 and EPNG Well 10-36 were conducted.

On April 5, 1967, the AEC accepted the site for the execution of Project Gasbuggy based on the recommendations of: a) the NVOO staff as to the acceptability of the site from overall safety and operational considerations, and b) LRL, EPNG, and USBM as to site suitability for conduct of project technical programs.

On June 25, 1967, drilling was begun on emplacement hole GB-E.

Authorization for the execution of the Gasbuggy detonation was received from DPNE on November 29, 1967.

The original readiness date of October 18, 1967 was delayed by construction difficulties with the emplacement hole. A new readiness date of December 6, 1967 was established, but later delayed to December 10, 1967 due to technical difficulties. The device was fired on December 10, 1967.

Re-entry drilling in hole GB-ER ("R" indicating the same hole has been re-entered) was begun on December 13, 1967. On January 10, 1968, at a depth of 3,907 ft (333 ft above the detonation point), communication with the chimney was established.

The Gasbuggy site initial re-entry was completed by January 31, 1968 and the site placed on a standby status with gas sampling continuing at monthly intervals. Production testing and reservoir evaluation were tentatively planned to begin within 6 to 9 months, depending upon results of the radiochemistry analysis and the availability of funds.

A 15-day production test was begun June 28, 1968. This test was conducted to determine bottom-hole temperatures and pressures and to determine build-up times after flowing the well at 5 million cu ft/day (5 MMcf/D). Following this test, the well was shut in and remained so until long-term production testing was initiated in November 1968.

On November 4, 1968, a long-term production testing program of Well GB-ER was begun. The test program consisted of three 30-day production tests at successively lower (and constant) chimney pressures followed by a 7-month production test at a still lower pressure. A final pressure blowdown was begun October 28, 1969, and terminated on November 14, 1969. At this time, GB-ER was shut in for long-term pressure build-up.

Other field activities during the above time interval included the following:

1. Re-entry of Pre-shot Test Well GB-2

   During June 1968, GB-2R was completed to 4,224 ft with production tubing landed at that depth in open hole. The open hole apparently collapsed, pinched the tubing, and prevented the use of the hole for production testing.

2. Re-entry of Well 10-36 (Pre-shot Production Well)

   During October 1968, stemming material was removed from the 5.5-in. casing to a depth of 3,612 ft where casing damage prevented further penetration. The well was then completed in the Ojo Alamo sandstone formation as an aquifer monitor well.

3. Well GB-3

During August and September 1969, GB-3 was drilled to a depth of 4,800 ft to investigate changes in the Ojo Alamo and Pictured Cliffs formations and in the underlying shale. An extensive coring program utilizing logs and natural flow gauges was used in defining reservoir characteristics.[2]

In 1973, another gas flaring program was initiated. The program ran from May 15, 1973 to November 6, 1973 (personal communication, EPA-EMSL, 1988).

WASTE GENERATION AND DISPOSAL

Waste generated at the site primarily consists of radioactive contaminants. No non-radioactive wastes were found on the site in 1985.[5]

Radionuclides were produced as a result of detonation of the nuclear explosive. These nuclides consists of both gaseous, liquid, and solid isotopes. The total radioactivity produced at shot time plus 1 min/kt of yield is estimated to be 3 x 10^{10} Ci. For the yield of Gasbuggy (29 kt), this yields an estimate of 87 x 10^{10} Ci at 1 minute after detonation. Much of this radiation is from short-lived radioisotopes however, and quickly decays.

A sample of water collected from the 3,000-ft depth in GB-ER well above the shot cavity on January 2, 1968 contained tritium at a concentration of $(1.6 \pm 0.3)10^{-4}$ μCi/ml (1.6 x 10^5 pci/l). Another sample collected from the same location on January 6, 1968 contained $(6.0 \pm 0.4)10^{-4}$ μCi/ml (6.0 x 10^5 pci/l). Water collected directly from the drill stem on January 10, 1968 contained $(30 \pm 1)10^{-4}$ μCi/ml (3.0 x 10^6 pci/l). Ice removed from the top of GB-ER on January 16, 1968 contained $(25 \pm 0.7)10^{-4}$ μCi/ml. None of the water samples from GB-ER contained detectable amounts of other beta emitters except ^{133}Xe.[2] These results show tritium levels above drinking water standards in the fluids in the shot cavity.

Fluids produced during the gas flaring and production phases were contaminated with waste produced from the nuclear explosion. Tritium and ^{85}Kr were the primary radionuclides from the detonation that were found in the gas or liquids during production tests in June and July 1968, and the series of tests which began in November 1968. This was also true of the tests in 1973.

Water and some oil were carried up the tubing with the gas in the emplacement re-entry well (GB-ER) when the velocity of the gas was sufficient to carry up the water. Most of this liquid was removed by two bulk liquid separators and was stored in a metal tank until analyzed for radioactive material.

The limited tests in June and July 1968 produced 1,440 gallons of water. This water was placed in 36 55-gallon drums, gelled, and sent to the Nevada Test Site (NTS) for disposal. These 36 drums contained a total of 7.2 Ci of tritium. Five 55-gallon drums with HTO in dirt containing a total of 0.1 Ci of tritium and one 55-gallon drum with 0.03 Ci of tritium in assorted wastes were also shipped to NTS. For the subsequent series of tests, 118,440 gallons of water were separated. The bulk of this water was produced during three rapid drawdown periods at high flow rates designed to reduce the downhole pressure.[2]

The disposal of this quantity of water by forming a gel in barrels and transporting the barrels to a waste disposal site would have been too costly. The water produced would have required approximately 2,725 barrels to be prepared and shipped. The tritium contained in the separated water also constituted only about 5 to 10 percent of the tritium released by burning the gas.

A steam/spray system was designed to vaporize the water into the flame at the top of the flare stack. Two pipes with nozzles were attached at the top of the flare stack and the liquids were sprayed directly into the gas being flared. When the flow rate of the gas was approximately 2 MMcf/D or greater, the water was completely vaporized. With lower flow rates, the water was first passed through a steam generator and then introduced into the gas flare as steam. The objective in both cases was to completely vaporize the water.

EPNG conducted, on a variable schedule, downhole pressure and temperature bomb runs on the GB-ER well. The bomb was lowered to 3,790 ft for the measurements. Liquid (water and oil) and sludge entered the bomb through a small hole. The composition of the liquid varied from day to day. The amount of liquid collected was highly variable.

The liquid was removed from the bomb and assayed for tritium by liquid scintillation spectrometry. In some cases, much less than a milliliter of liquid was obtained and the samples were not analyzed. Many of the samples were so highly colored by sludge that extreme quenching precluded accurate analysis without extensive sample pre-treatment. Centrifuging and distillation were performed when sample volume permitted.[2]

The first rapid decrease in pressure from 870 psi to 700 psi lasted 6 days at a flow rate of 5 MMcf/D. During this period, 5,172 gallons of water were produced. The next reduction, a month later at the same flow rate, from 700 psi to 500 psi downhole pressure, lasted 9 days and 18,500 gallons of water were produced. The third reduction of downhole pressure, from 500 psi to 260 psi, lasted 24 days and 76,441 gallons of water were produced. During this period, the well was flared wide open and flow rates gradually decreased from 3.42 MMcf/D on February 18, 1969 to 0.95 MMcf/D on March 14, 1969. Water production reached 220 gal/hr during portions of this period and the well was shut in several times because water production exceeded maximum disposal capability with existing equipment and storage facilities. A 6-month production test, maintaining a constant downhole pressure of 260 psi, commenced March 14, 1969. The flow rate decreased gradually to a flow rate of 300 Mcf/D. A total of 119,880 gallons of liquid waste were handled, including the 1,440 gallons sent to NTS.[3]

KNOWN RELEASES

A System to Analyze Low Levels of Krypton and Tritium (STALLKAT) was designed and built by LRL. This system was designed so that the gas flowed through two chambers at a flow rate of approximately 1.8 liter/min. The tritium chamber had a volume of 15.9 cm^3 and contained a CaF_2(Eu) scintillation detector 0.010 in. thick x 1.75 in. in diameter. The krypton chamber had a volume of 3,665 cm^3 and contained a CaF_2(Eu) scintillation detector 0.030 in. thick x 1.75 in. in diameter. The signals from the detectors were amplified and pulse height selected by single channel analyzers. The tritium detector was kept at a temperature of −10°C by a refrigeration system. A scaler and a count rate meter were driven by the analyzer output. The scaler output drove a printer. The entire system was calibrated using standard krypton and tritium gas supplied by LRL. Frequent gas samples taken to LRL for analysis verified the calibration of this on-line system. The limit of detection for the STALLKAT was 2×10^{-5} µCi/cc for tritium and 1.3×10^{-7} µCi/cc for ^{85}Kr.

The STALLKAT employed a bulk liquid trap, a particulate filter, and a desiccant moisture trap before the detectors. Although the pre-filter and traps had no effect upon the monitoring of krypton, these traps remove tritiated distillate (oil and water) from the gas prior to the gas flowing to the detectors. In order to determine the tritium content of the vapor which was not seen by the on-line detectors, freeze-out samples were collected and analyzed for tritium.

The STALLKAT was used during all production tests through November 1969.

The total tritium released during the June and July 1968 tests were based on the analysis of gas samples by LRL. The total ^{85}Kr released during this period was based on STALLKAT readings.

The tritium released during the tests that began in November 1968 was composed of three parts: 1) tritium in the gas monitored by the STALLKAT; 2) tritium in the wastewater monitored by liquid scintillation spectrometry of water samples taken during the steam/spray operations; and 3) the tritium in the vapor phase as monitored by liquid scintillation spectrometry of freeze-out samples collected after the bulk liquid separation. The ^{85}Kr results for this period are based on STALLKAT readings. Through November 1969, 2,432 Ci of tritium and 364 Ci of ^{85}Kr were released to the environment.[2] During the tests of 1973, 127 Ci of tritium and 7.7 Ci of krypton-85 were released into the air (personal communication, EPA-EMSL, 1988).

Surveillance provided during the flaring operations of the production testing phase consisted of monthly trips to the site by three or four SWRHL personnel to collect environmental samples. The surveillance consisted of:

1. Collecting special air samples for tritium in atmospheric moisture.
2. Collecting snow, vegetation, and soil samples on three trips.
3. Collecting cryogenic samples with an aircraft during September and October 1969.

There were 86 atmospheric moisture samples collected during the production flaring, and 31 of these samples collected from within 13 miles of the site showed tritium levels greater than background. The highest level of atmospheric tritium was found in the samples collected within 0.3 miles from the site in November 1968, just after production flaring was begun. One of these samples contained tritium levels of 116 pCi/ml H_2O, or 500 pCi/m^3 air. This is less than one percent of the off-site RCG. Levels of tritium in the atmospheric continued to decrease after mid-1969, only occasional atmospheric samples contained levels of tritium above background.

Four cryogenic air samples were collected in the flaring plume with an aircraft in September and October 1969. These samples contained tritium from 10 to 17 pCi/m^3 air. None of these samples contained radioisotopes of xenon. The September samples contained no radioisotopes of krypton, while the October samples indicated levels of 350 and 450 pCi/m^3 air for radioisotopes of krypton.

Twelve snow samples were collected from 0.3 to 1.3 miles from the flare during January and February 1969. All of these samples contained tritium at or near background levels. Several vegetation and soil samples were collected within 2.2 miles of the site in November 1968 which contained tritium above background levels.

Tritium concentrations in vegetation ranged from 4.1 to 36 pCi/ml H_2O and soil ranged from <0.8 to 7.1 pCi/ml H_2O. A second set of vegetation and soil samples was collected in July 1969 from the same area. The levels in these samples were lower, with vegetation ranging from 3.4 to 8.4 pCi/ml H_2O and soil from 0.9 to 2.0 pCi/ml H_2O. The last set of vegetation and soil samples was collected in October 1969, with tritium levels in all samples at background.[2]

No levels of tritium or other isotopes were detected which were reported to present a hazard to people or livestock in the off-site area.[2]

During cleanup and decommissioning operation in 1978, 175 barrels of low level tritium contaminated water from the steam decontamination operation accumulated in the "Red Tank" after the GB-ER wellbore was sealed. The water was subsequently disposed of by vaporization to the atmosphere using the steam generator. The tritium level in this water ranged from 14.7 pCi/ml to 43.7 pCi/ml, and a total of 1.31 mCi was released to the atmosphere over a period of 25 days in September 1978. During the water vaporization and steam decontamination activities, air moisture samples were collected by molecular sieve units around the site. All of the moisture samples thus collected were less than the lower limit of detection (LLD) for tritium air moisture.

Approximately 60.5 barrels of tritium contaminated water and sludge at an average of 1439 pCi/ml, and 7.3 barrels of tritium contaminated water and sludge at an average of 350 pCi/ml were pumped from the produced water storage tank which is referred to throughout this document as the "Red Tank" and decon sump, respectively, and injected into the GB-ER cavity before the re-entry well was plugged. The tubing and annulus were then flushed with 3 annulus volumes of H_2O. The total tritium content of the injected fluid was 18.7 mCi. The water did not contain other radioactive isotopes above detection limits except naturally occurring radioactive elements.[4] The total volume of fluid injected was approximately 27,000 gallons.

POTENTIAL FOR DIRECT CONTACT OR FIRE/EXPLOSION HAZARD

As a result of site cleanup in 1978, only low levels of tritium remain at the Gasbuggy site. The maximum soil water concentration of tritium found in 1973 was 11,200 pCi/ml (11,200,000 pCi/l) at a depth of 4 ft near the gas flare stack. In 1978, a sample collected very near this site yielded 1,303 pCi/ml. Table 3.7.3 shows the results of soil samples collected during the 1978 cleanup.

The site clearance criteria are given below[1]:

Surface Water	
Tritium	300 pCi/ml
Buildings, Equipment, & Materials	
Tritium (non-removable)	5,000 pCi/100 cm^2
Tritium (removable)	1,000 pCi/100 cm^2
Soil	
Tritium in Soil Moisture	30,000 pCi/ml
Beta-Gamma (including worldwide fallout) (measured at 1 cm)	0.05 mrad/hr

The cleanup operation (reported in PNE-G-89) indicates that the potential for direct contact with wastes at the Gasbuggy site is small but significant, although most soil water levels of tritium were below drinking water standards. Uptake of tritium by plants or volatilization poses a potential pathway for direct contact.

A survey was made in 1985 to determine if non-radioactive wastes were located at the surface facilities of Gasbuggy. The historical records search indicated no potential hazardous waste release sites at Gasbuggy, either radioactive or non-radioactive. There was no documented burial of hazardous material at this installation. All decontamination operations were performed by steam cleaning. The installation contained a concrete decontamination pad and plastic-lined sump which were never used. Due to a lack of first-hand information, nine "operational

TABLE 3.7.3. POST OPERATIONAL SURFACE SOIL SAMPLES.[4]

Sample Number	Collection Date	Site Location	Soil Moisture ^3H pCi/ml
1	9/23/78	Near Red Tank and Pump Shack	< LLD
2	"	"	3.3
3	"	"	< LLD
4	"	"	< LLD
5	"	"	< LLD
6	"	"	< LLD
7	"	Along waterline from Red Tank	< LLD
8	"	"	< LLD
9	"	Along gas lines	< LLD
10	"	"	< LLD
11	"	"	< LLD
12	"	"	< LLD
23	"	Along old flare line	< LLD
24	"	"	< LLD
25	"	"	< LLD
26	"	"	< LLD
27	"	"	< LLD
28	"	"	< LLD
29	"	Around new operational location of Red Tank and Decon Pan	< LLD
30	"	"	3.0
31	"	"	< LLD
32	"	"	< LLD
33	"	"	1.7
34	"	"	10.5
35	"	"	4.0
36	"	"	3.9
37	"	"	2.6
38	"	"	2.4
39	"	"	1.8
40	"	Around Steamer Shack	5.9
41	"	"	6.6
42	"	"	2.9
43	9/25/78	Around Steamer Shack	63.1
44	"	Under Steamer Sump	60.7
13	"	Where the separators sat	< LLD
14	"	"	< LLD
15	"	"	< LLD
16	"	"	2.5
17	"	"	< LLD

TABLE 3.7.3. (continued)

Sample Number	Collection Date	Site Location	Soil Moisture ^3H pCi/ml
18	9/25/78	"	< LLD
19	"	6'N from GB–ER	< LLD
20	"	6'E from GB–ER	17.3
21	"	6'S from GB–ER	2.1
22	"	6'W from GB–ER	< LLD
46	"	At GB–ER	7.8
45	"	2.5' Under Steamer Sump	280

(LLD 2pCi/ml @ 3σ counting error for Tritium)

areas" were sampled. These sites are listed in Table 3.7.4. The location of the sites are shown on Figure 3.7.8. There were no hazardous substances detected in the sample collected at the Gasbuggy Test Site.[5]

Mud reserve pits were filled-in during site restoration.[3] It is unknown if these pits contained any hazardous constituents associated with drilling mud. They did not however, contain radioactive contamination.[1] The drilling muds should pose no hazard from fire and explosion.

POTENTIAL FOR GROUND-WATER RELEASE

Teledyne Isotopes, Palo Alto Laboratory, prepared a ground-water contamination prediction for Project Gasbuggy. This prediction is based, in part, on hydrologic data gathered and interpreted by the U.S. Geological Survey (USGS). Teledyne Isotopes determined that it was most unlikely that fractures or radioactive contamination from the detonation would even reach the Ojo Alamo sandstone formation. In the exceedingly unlikely event that they did reach Ojo Alamo sandstone, it would be the only viable route for radionuclide transport away from the Gasbuggy site. Ground water in Ojo Alamo flows in a generally westward direction. Its most probable discharge point is the San Juan River, some 50 miles northwest of the Gasbuggy site. Hydraulic tests on the Ojo Alamo sandstone by the USGS showed it to have low transmissivity. Ground water moving away from the site is estimated to have a velocity of 0.04 ft/yr. The low transmissivity and the decreasing head with depth preclude any significant areal contamination of the aquifer. Tritium, strontium-90, and cesium-137 will decay to concentrations well

TABLE 3.7.4. OPERATIONAL AREAS INVESTIGATED AT GASBUGGY TEST SITE.

Site	Site Number	Site Location	Depth of Soil Samples
Red Tank	1	90′ from GZ @ 355 degrees	Surface
"Drip Pan Decon Area"	2	115′ from GZ @ 16 degrees	Composite – Surface to 6′
"Drip Pan Decon Area"	2	110′ from GZ @ 31 degrees	Composite – Surface to 6′
"Mud Pit Burial Area"	3	195′ from GZ @ 37 degrees	3′
"Steamer" Area	4	178′ from GZ @ 31 degrees	3′
Flare Stack	5	200′ from GZ @ 41 degrees	Composite – Surface to 0.5′
Flare Stack	5	200′ from GZ @ 41 degrees	Composite – 21″ to 27″
East of GZ	6	6′ from GZ @ 90 degrees	Surface
Mud Pit D	7	40′ from GZ @ 318 degrees	5′
Mud Pit C	8	223′ from GZ @ 347 degrees	3′
Mud Pit A	9	282′ from GZ @ 85 degrees	2.5′

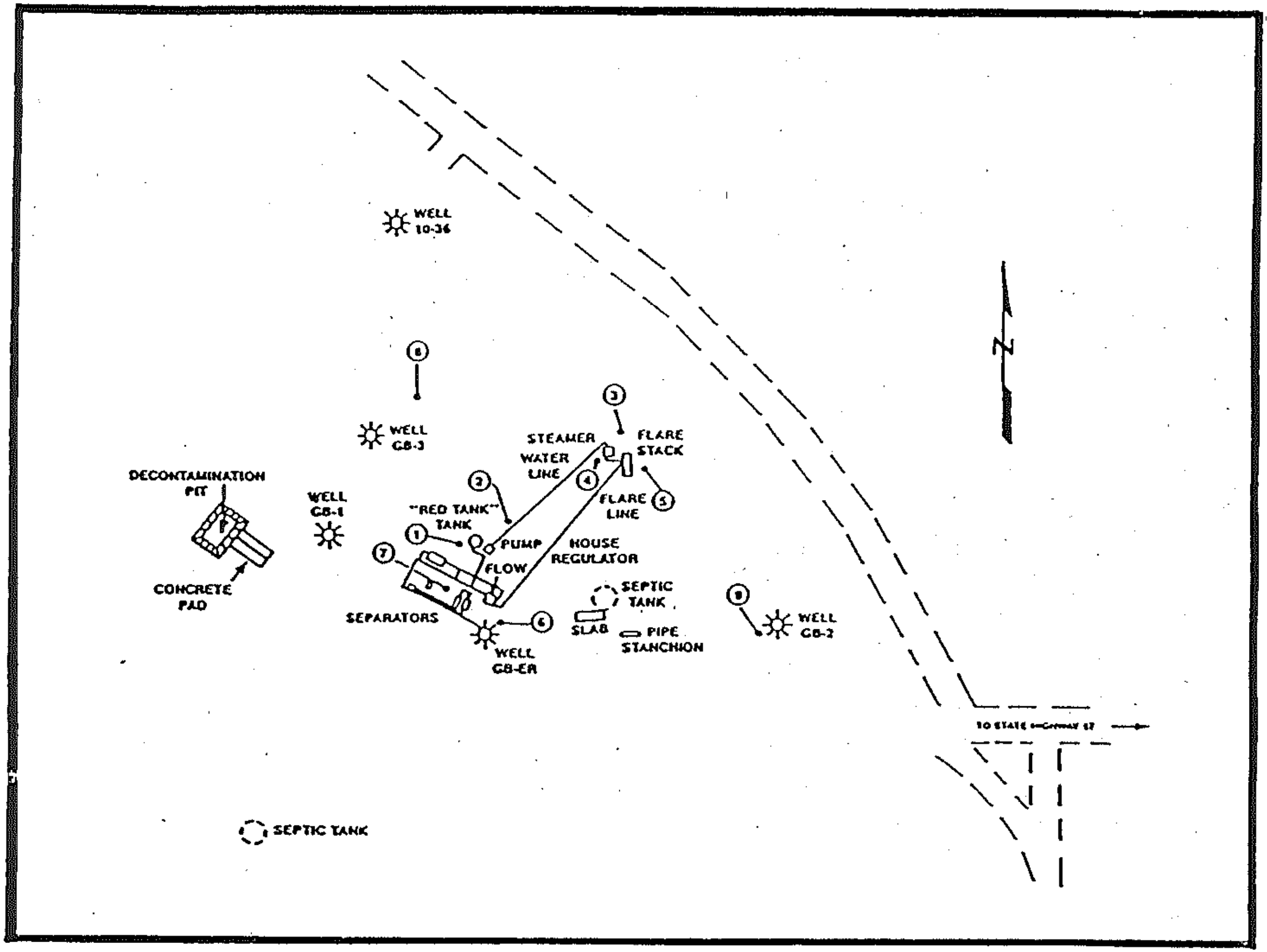

FIGURE 3.7.8. Potential Hazardous Waste Release Sites Investigated at the Gasbuggy Test Site. A Description of Each Site Identified is Given in Table 4.

below concentration guides before moving even a small fraction of the 50-mile distance. High total dissolved solids make water from this aquifer unsuitable for irrigation or domestic use.[1]

A long-term hydrologic monitoring program is on-going to determine any ground-water migration of wastes for the shot cavity. The monitoring locations are given in Table 3.7.5 and shown in Figure 3.7.9.[1]

Yearly samples are collected and analyzed by EPA-Las Vegas. The results are given in Table 3.7.6.

TABLE 3.7.5. LONG-TERM HYDROLOGIC MONITORING LOCATIONS.

Wells	Depth (ft) (Meters)	Aquifer	Location
1. EPNG Well 10-36	3,620 (1,103.7)	Ojo Alamo	436 feet NNW of Gasbuggy GZ. In unsurveyed T29N, R4W
2. *Jicarilla Apache Reservation North Well	Unknown		28.3.33.233 (6.5 miles)
3. *Jicarilla Apache Reservation North Well	200 (60.9)	Wasatch	30.3.33.343 (6.0 miles)
4. Lower Burro Canyon Well	Unknown		28.2.18.331 (7.0 miles)
5. Fred Bixler Ranch Well	175 (53.4)	Wasatch	30.4.34.221 (7.0 miles)
6. Windmill Well No. 2	Unknown		30.4.34.221 (3 miles)
7. Jicarilla Well No. 1	Unknown		(7.5 miles)

*Sample points no longer monitored because pumps are inoperative.

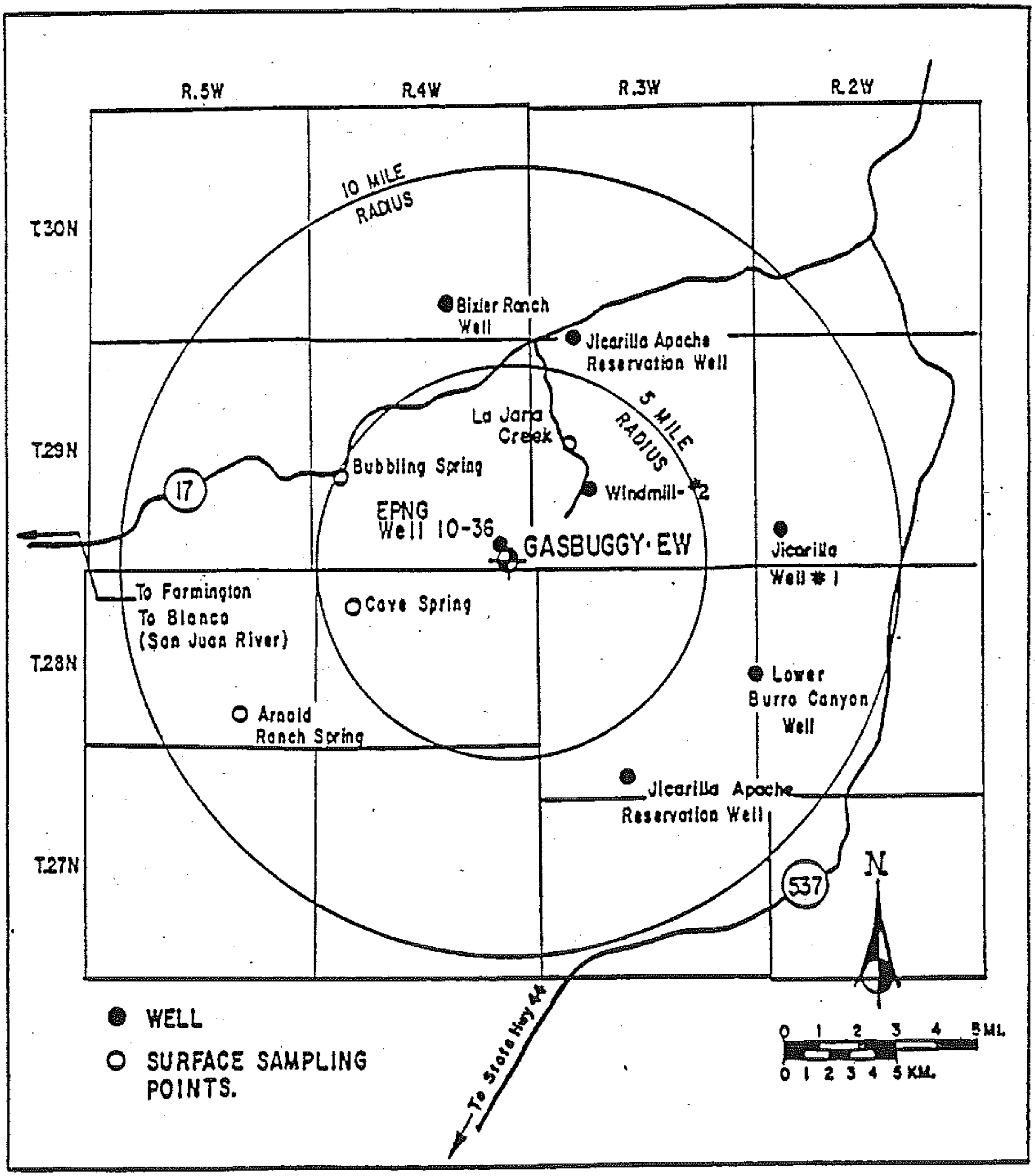

FIGURE 3.7.9. Long-Term Hydrologic Monitoring Program Sampling Points.

TABLE 3.7.6. TRITIUM RESULTS FROM LONG-TERM MONITORING PROGRAM AT GASBUGGY SITE* (pCi/l).

Sample Location	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
San Juan River	830	420	420	510	270											
La Jara Lake	740	260	350	280	220											
Arnold Ranch	<240	<250	28	<10	<8	<8	<20	<10	63	35	<9	<9	5.4	1.6	54	9.5
Bixler Ranch	<240	<250	21	13	8	11	<20	19	30	26	13	18	13	21	20	23
Bubbling Spring	310	<240	240	<13	140	110	120	8.5	86	110	87	110	54	75	120	82
Cave Spring	<210	<240	27	9	12	12	<220	<10	<10	49	57	100	68	80	120	38
Cedar Spring																73
La Jara Creek						110	70	72	120	78	81	100	64	90	69	62
Lower Burro Canyon	<210	<250	<8	<8	6	<9	<20	<20	94	20	<9	<11	4.1	63	120	
EPNG Well 10-36	<210	<250	38	13	<7	17	16	<20	<10	46	20	18	300,400**	390	320	35
Well 28.3.33.333S	<210					93	67									73
Jicarilla No.1													11	7.2	69	-0.96
Well 30.3.32.343N	230													54	96	59
Windmill No. 2			<22	8	27	<24	<20	<20	26	24						8
Ducle City Supply	510	<250	380	260	230											

*Tritium enrichment procedures used on most samples after 1973.

Data compiled from EPA/EMSL yearly monitoring reports. 1987 data from Personal Communication EPA/EMSL.

**Duplicate Samples.

The results indicate that tritium levels in all shallow wells, springs, and surface waters are low and likely reflect tritium levels in recent precipitation. Well EPNG-10-36, completed at a depth of 3,620 ft, showed an increase in tritium in the 1980's. These levels, still well below drinking water standards, are not typical of a deep aquifer system. The proximity of the well to the cavity (436 ft) may indicate that some migration of shot-related tritium has occurred into the Ojo Alamo aquifer. The disposal of wastewater into the cavity during site cleanup in 1978 may have resulted in these elevated levels in well EPNG 10-36. No drinking water wells are completed in this aquifer within 4 miles of the site.[8]

The potential for migration of waste from the cavity to drinking water wells is slight based upon the low transmissivity of the Ojo Alamo aquifer. In addition, all wells used during the testing have been sealed and abandoned (see PNE-G-89 for abandonment procedure used). The migration potential of tritium in soil to the ground water and shallow wells and springs is also low due to the low levels of tritium in the soil and the affects of dilution.

Surface and Municipal Supplies	Location Distance From SGZ
1. Arnold Ranch Spring	8 miles
2. Cave Springs	4 miles
3. Bubbling Spring (SE side Highway 17)	5 miles
4. La Jara Creek	3.5 miles

POTENTIAL FOR SURFACE WATER RELEASE

As a result of surface cleanup and well abandonment, the potential for surface water release appears insignificant. Releases from tritium in the soil also appear negligible due to dilution by precipitation. Release from the cavity is also believed to be impossible.

Surface water sampling of La Jara Lake Creek has shown no anomalous or above background tritium levels.

The land surrounding the GZ is described as relatively flat to gently rolling. Natural revegetation, as well as seeding during site restoration, has significantly reduced the possibility of surface erosion.[3]

POTENTIAL FOR AIR RELEASE

With the abandonment of all wells completed in the shot cavity, there is insignificant potential for air release. Volatilization of tritium remaining in soil water is also believed to be negligible.

THREATS TO FOOD CHAIN AND ENVIRONMENT

Uptake of soil water tritium by on-site vegetation and subsequent introduction into the food chain is likely. Samples of vegetation collected in 1978 are given below in Table 3.7.7 and shows plant water in excess of drinking water standards.[4] It is believed that the area is used for grazing and as such, uptake may pose a hazard.

TABLE 3.7.7. ENVIRONMENTAL VEGETATION SAMPLE RESULTS.

Collection Date	Vegetation Samples Location	Total Tritium* pCi/ml Water
9/20/78	S. Side of Road	2.8 ± 0.5
9/20/78	N. Side of Road	<3.2 ± 0.5
9/21/78	Red Tank Area	10.4 ± 0.3
9/21/78	Separator Area	7.7 ± 0.3
9/21/78	Stack Area	470 ± 2.6
9/21/78	Profile Hole #16	7.2 ± 0.6

*Free water and organically bound.

CONCLUSION AND RECOMMENDATIONS

A preliminary hazard score of the Gasbuggy site (based upon the old HRS) is presented in Appendix 3.7.A. The resulting score of 5.24 indicates that the site poses little hazard. Long-term hydrologic monitoring should continue to determine if significant migration of cavity wastes or soil water tritium is occurring.

The anomalous rise in tritium levels in EPNG-10-36 between 1984 and 1986 should be reviewed in detail to determine its cause. Such data is useful in interpreting the migration potential from the cavity. It is also recommended that further studies be conducted to determine the extent of and impacts of tritium uptake by plants and animals in the area since the area is believed to be used for cattle grazing.

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APPENDIX 3.7.A
HRS WORKSHEETS
GASBUGGY SITE

FIRE AND EXPLOSION WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Containment	(1) 3	1	1	3	7.1
2 Waste Characteristics					7.2
Direct Evidence	(0) 3	1	0	3	
Ignitability	(0) 1 2 3	1	0	3	
Reactivity	(0) 1 2 3	1	0	3	
Incompatibility	(0) 1 2 3	1	0	3	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			8	20	
3 Targets					7.3
Distance to Nearest Population	(0) 1 2 3 4 5	1	0	5	
Distance to Nearest Building	(0) 1 2 3	1	0	3	
Distance to Sensitive Environment	(0) 1 2 3	1	0	3	
Land Use	0 1 2 (3)	1	3	3	
Population Within 2-Mile Radius	(0) 1 2 3 4 5	1	0	5	
Buildings Within 2-Mile Radius	(0) 1 2 3 4 5	1	0	5	
Total Targets Score			3	24	
4 Multiply 1 x 2 x 3			24	1,440	
5 Divide line 4 by 1,440 and multiply by 100			S_{FE} = 1.67		

DIRECT CONTACT WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	8.1

If observed release is given a score of 45, proceed to line 4.

If observed release is given a score of 0, proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Accessibility	0 1 2 (3)	1	3	3	8.2
3 Containment	0 (15)	1	15	15	8.3
4 Waste Characteristics					8.4
Toxicity	0 1 2 (3)	5	15	15	
5 Targets					8.5
Population Within a 1-Mile Radius	(0) 1 2 3 4 5	4	0	20	
Distance to a Critical Habitat	(0) 1 2 3	4	0	12	
Total Targets Score			0	32	
6 If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			0	21,600	
7 Divide line 6 by 21,600 and multiply by 100			S_{DC} = 0		

GROUND WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 (45)	1	45	45	3.1
If observed release is given a score of 45, proceed to line 4. If observed release is given a score of 0, proceed to line 2.					
2 Route Characteristics					3.2
Depth to Aquifer of Concern	0 1 2 3	2		6	
Net Precipitation	0 1 2 3	1		3	
Permeability of the Unsaturated Zone	0 1 2 3	1		3	
Physical State	0 1 2 3	1		3	
Total Route Characteristics Score				15	
3 Containment	0 1 2 3	1		3	3.3
4 Waste Characteristics					3.4
Toxicity/Persistence	0 3 6 9 12 15 18	1		18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1		8	
Total Waste Characteristics Score			26		
5 Targets					3.5
Ground Water Use	0 (1) 2 3	3	3	9	
Distance to Nearest Well/Population Served	(0) 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
Total Targets Score			3	49	
6 If line 1 is 45, multiply 1 x 4 x 5; If line 1 is 0, multiply 2 x 3 x 4 x 5			3,510	57,330	
7 Divide line 6 by 57,330 and multiply by 100			S_{gw} = 6.12		

SURFACE WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	4.1
If observed release is given a score of 45, proceed to line 4.					
If observed release is given a score of 0, proceed to line 2.					
2 Route Characteristics					4.2
Facility Slope and Intervening Terrain	(0) 1 2 3	1	0	3	
1-yr. 24-hr. Rainfall	0 (1) 2 3	1	1	3	
Distance to Nearest Surface Water	(0) 1 2 3	2	0	6	
Physical State	0 1 2 (3)	1	3	3	
Total Route Characteristics Score			4	15	
3 Containment	0 1 2 (3)	1	3	3	4.3
4 Waste Characteristics					4.4
Toxicity/Persistence	0 3 6 9 12 15 18	1		18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1		8	
Total Waste Characteristics Score			26	26	
5 Targets					4.5
Surface Water Use	0 1 2 (3)	3	3	9	
Distance to a Sensitive Environment	(0) 1 2 3	2	0	6	
Population Served/ Distance to Water Intake Downstream	(0) 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
Total Targets Score			3	55	
6 If line 1 is 45, multiply 1 x 4 x 5					
If line 1 is 0, multiply 2 x 3 x 4 x 5			936	64,350	
7 Divide line 6 by 64,350 and multiply by 100		S_{SW}	= 1.45		

AIR ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 (45)	1	45	45	5.1
Date and Location: 1968, 1973					
Sampling Protocol:					

If line 1 is 0, the S_a = 0. Enter on line 5.

If line 1 is 45, then proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Waste Characteristics					5.2
Reactivity and Incompatibility	(0) 1 2 3	1	0	3	
Toxicity	0 1 2 (3)	3	9	9	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			17	20	
3 Targets					5.3
Population Within 4-Mile Radius	(0) 9 12 15 18 21 24 27 30	1	0	30	
Distance to Sensitive Environment	(0) 1 2 3	2	0	6	
Land Use	0 1 2 (3)	1	3	3	
Total Targets Score			3	39	
4 Multiply 1 x 2 x 3			1,890	35,100	
5 Divide line 4 by 35,100 and multiply by 100			S_a = 6.53		

HRS SCORE FOR
GASBUGGY SITE

$S_{gw} = 6.12$

$S_{sw} = 1.45$

$S_a = 6.53$

$$S_m = \frac{1}{1.73} \sqrt{S_{gw}^2 + S_{sw}^2 + S_a^2}$$

$S_m = 5.24$

$S_{FE} = 1.67$

$S_{DC} = 0$

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SECTION 3.8

COVER SHEET

NAME OF SITE: Gnome-Coach, Eddy County, New Mexico

LOCATION: The Gnome Coach site is located in Eddy County, New Mexico approximately 31 miles southeast of the city of Carlsbad, New Mexico in Section 34, T23S, R30E New Mexico Principal Meridian. Ground zero (GZ) for the Gnome event is located at N100, 643.97, E100, 760.64.

DISPOSITION: The Gnome-Coach site is currently under U.S. Bureau of Land Management jurisdiction within the BLM Big Sinks Planning Unit. Project Gnome was the first event under the Plowshare Program. The 680 acre site was withdrawn from the public land under Public Land Order 2526, October 1961. Radionuclide contamination of the site occurred on and subsequent to December 10, 1961 with detonation of the Gnome device which had a yield of 3.1 kt. The shot vented to the atmosphere with downwind fall-out. A proposed subsequent event, Project Coach, was canceled. Initial site cleanup occurred in 1968 and 1969. Subsequent evaluation for reversion of the land to BLM control indicated significant radiation at the surface. A second cleanup occurred from August 1977 through September 1979. Approximately 35,750 cu yds of contaminated material were placed in the Gnome cavity and underground workings. At the conclusion of cleanup the land was recommended for reversion with restrictions on any future drilling.

PRELIMINARY ASSESSMENT REPORT
PROJECT GNOME-COACH

INTRODUCTION

The Plowshare Program in the 1960's was directed at developing nuclear devices exclusively for peaceful purposes. Project Gnome was the first scientific experiment in that program. The Gnome site is located approximately 30 miles southeast of Carlsbad, New Mexico, in Eddy County (see Figure 3.8.1). The site comprises 680 acres (640 in Section 34 and the NW¼, NW¼ Section 10, T23S, R30E New Mexico Principal Meridian).

Project Gnome was detonated December 10, 1961 with a nuclear yield of 3.1 ± 0.5 kt. The shot-point was in bedded salt at a depth of 1,184 ft. Preparations for a second Plowshare experiment, Project Coach, were began at the Gnome site, but after construction of the entry drift and shot-point room, the event was canceled.

Re-entry activities at the Gnome site, in June 1962, resulted in contamination of the ground surface. Also, the Gnome detonation vented gases to the atmosphere that resulted in minor downwind fallout and radionuclide contamination. In March 1968, the U.S. Department of Energy Nevada Operations Office (DOE/NV) began planning for site decontamination and decommissioning to permit release of the area to the U.S. Bureau of Land Management (BLM). The initial cleanup in 1968 and 1969 was accomplished within guidelines that specified removal of contaminated material above 0.1 mR/h beta plus gamma as measured by a 30 mg/cm^2 Geiger Mueller (GM) counter.[3] Most contaminated materials were placed in the Gnome entry shaft and cavity and some was covered at land surface. All drill holes, other than those for long-term hydrologic monitoring, were plugged.

In April 1972, a survey indicated that contaminated debris had been exposed through weathering. In 1979 a second cleanup was accomplished to more strict guidelines using more sensitive instruments to identify contaminated materials. In this operation approximately 39,330 tons (35,750 cu yds) of contaminated soils and salt were slurried into the Gnome cavity and Gnome-Coach underground workings. Approximately 62 tons of contaminated materials were also shipped to the Nevada Test Site for disposal. At the conclusion of this cleanup, the site met

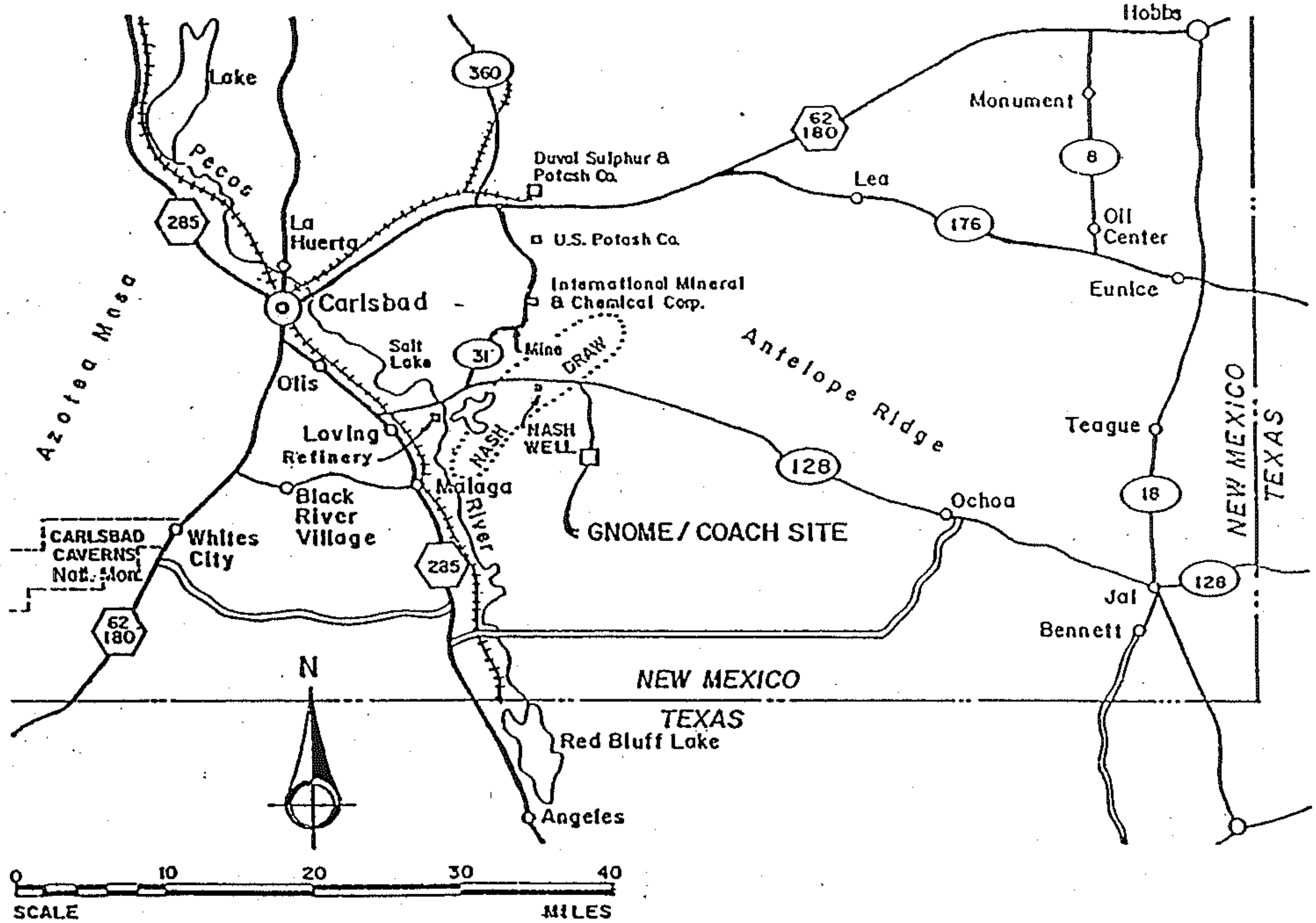


FIGURE 3.8.1. Carlsbad Area and Gnome-Coach Site (from DOE, 1979).

the decontamination criteria of 2 x 10^{-5} µCi/g for beta-gamma emitters in soil, averaged over 0.25 hectares, and 3 x 10^{-2} µCi/ml of tritium in soil moisture.[3]

Subsequent to the second cleanup operation, hydrologic monitoring has indicated rising water levels in the Gnome cavity and Coach workings. By 1987, water levels were above the top of the only aquifer zones at the site.

OVERALL FACILITY DESCRIPTION

The Gnome-Coach site encompasses all of Section 34, T23S, R30E, and the NW ¼ of the NW ¼ of Section 10 T23S, R30E NMPM. The 40 acre parcel in Section 10 was used as project field headquarters. Layout and principal features of the site in Section 34 are shown in Figure 3.8.2. Underground workings at the site are shown with dashed lines in that figure. All surface facilities were removed during the decontamination operations with the exceptions of the well heads on the hydrologic monitoring holes (LRL-7 and DD-1) and a monument with a historical plaque. Well DD-1 is not shown in Figure 3.8.2, but is located at approximately GZ.

ENVIRONMENTAL SETTING

The Gnome-Coach site has reverted to public land status under BLM jurisdiction. Drilling on the property is prohibited. The area is fenced with a cattle guard at the north entrance. Thus, livestock are excluded from the area. All major land disturbances were shaped and contoured during the cleanup operations to blend with the surrounding terrain. Surrounding land is public land managed by BLM under multiple use guidelines. Principal land use is livestock grazing.

EPA and DOE personnel visit the Gnome-Coach site on an annual basis to collect hydrologic data. No other uses of this land are known.

The Gnome-Coach site lies in the Pecos River Valley in the Great Plains physiographic province, close to the Rocky Mountains province. The terrain is flat to gently rolling with vegetation typical to this province. The site is not known to be environmentally sensitive in terms of either flora or fauna.

HYDROGEOLOGIC SUMMARY

Relief from the Gnome-Coach shaft head, elevation 2,211 ft, to the Pecos River which flows through the southwestern part of the area is approximately 427

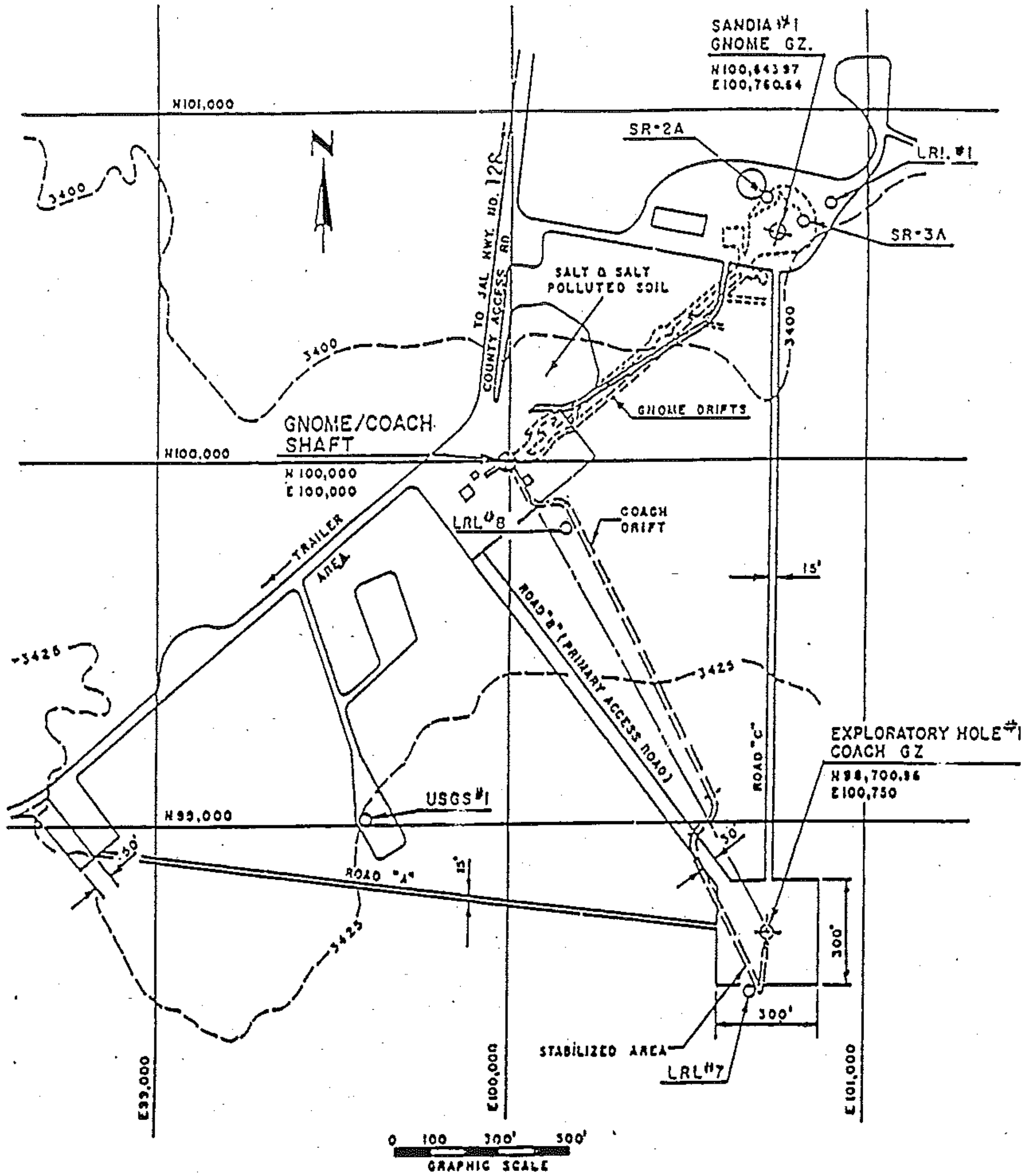


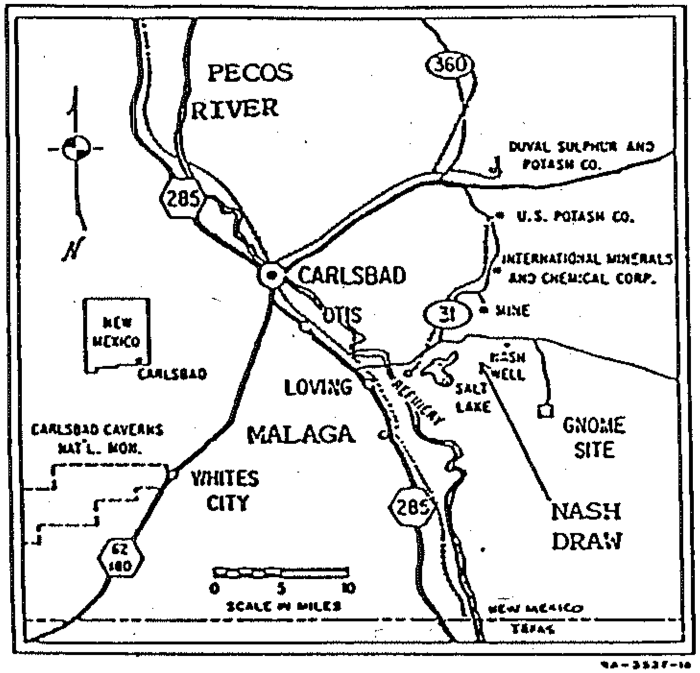
FIGURE 3.8.2. Project Gnome-Coach Site Plan (from DOE, 1979).

ft (Figure 3.8.3). Some karst topography occurs in the area, caused by ground-water solution and subsequent collapse of salt and anhydrite in the Salado and Rustler Formations. Nash Draw, 7 miles east of the Gnome-Coach site, is a solution-caused surface depression. The draw leads southwestward toward the Pecos River. Laguna Grande de la Sal is in Nash Draw, where brine springs occur. Immature drainage courses characterize the land surface, generally leading to local depressions. Wind blown sand and caliche comprise most of the surface materials. A gently rolling aspect results from these physical conditions. The land surface slopes northwestward less than one-half degree. Sand dunes are present up to 20 ft high; such features have maximal length of 295 ft and width of 50 ft.[7]

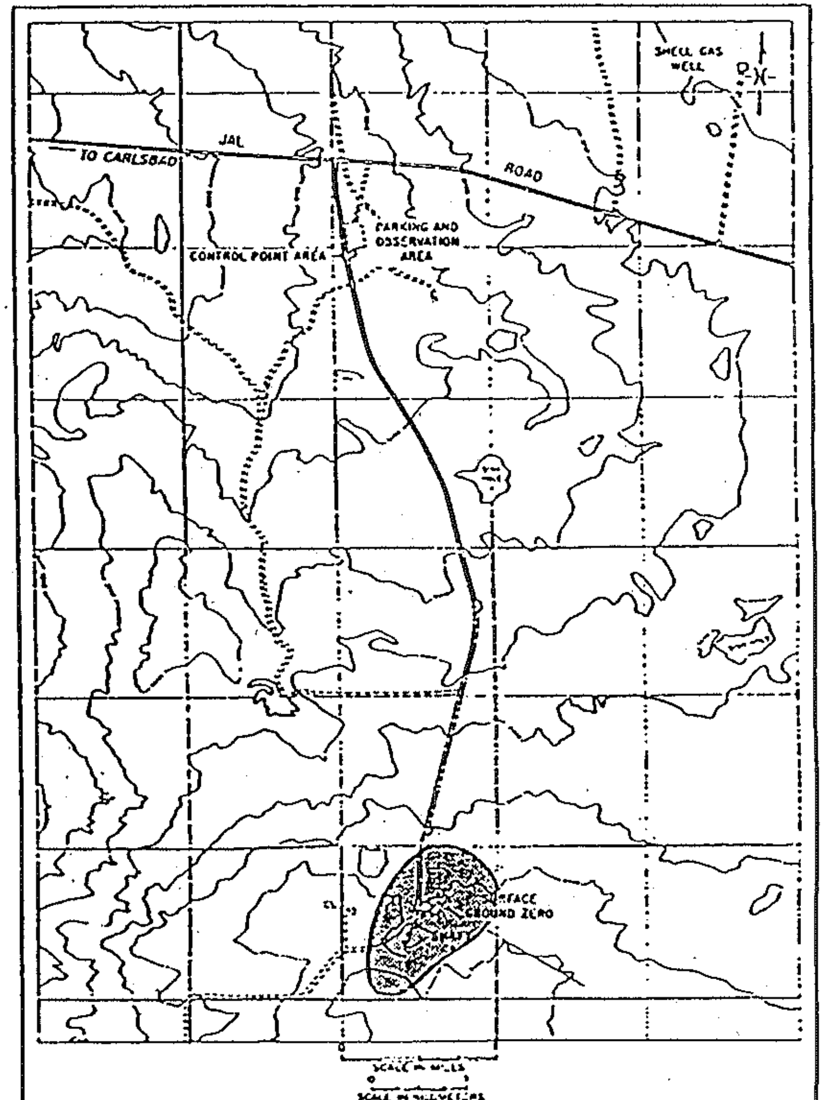
The Pecos River is a perennial stream supported by ground-water discharge from the alluvial basin south of Carlsbad. Near the Texas-New Mexico stateline, maximum summer time low flows in the Pecos River approach 10 cu ft/sec.[7] To the east of the bottomlands of the Pecos River, there are many depressions which receive surface runoff. The largest depression, the Laguna Grande de la Sal, is within Nash Draw. There is apparently no transmission by infiltration to the Pecos River from these depressions.[7]

The host rock at the Gnome working point is the Permian Salado Formation.[12,13] The Salado is unconformably overlain by the Rustler Formation (Permian) which is, in turn, uncomformably overlain by the Dewey Lake red beds (Permian). The Gatuna Formation (Pleistocene) uncomformably overlies the Dewey Lake. Surface deposits consist of the recent unconsolidated Mescalero Formation which is composed of wind blown quartz sand, in part, cemented by caliche. Stratigraphy of the Gnome-Coach site is shown in Figure 3.8.4 and the units are described in Table 3.8.1. Sedimentary rocks at the Gnome site are very gently dipping, bedded, and unfaulted. Northeasterly trending anticlines are common in the lower parts of the Salado Formation. Below 1,476 ft, gentle easterly dips (less than 5°) occur. Sink holes developed by solution of soluble constituents in the rustler Formation occur 2 miles northwest and 2.5 miles northeast of GZ. Simplicity of structure and stratigraphy and relatively uncomplicated lithology of the detonation host rock characterize the area.

Hydrologic characteristics of major formations in the vicinity of the Gnome-Coach site have been described as follows:



Index Map Showing Locations of Gnome Site



Topographic Map of Gnome Shot Area

CI = 50 ft.

FIGURE 3.8.3. Location and Topography of the Gnome Site (from Gardner and Sigalove, 1970).

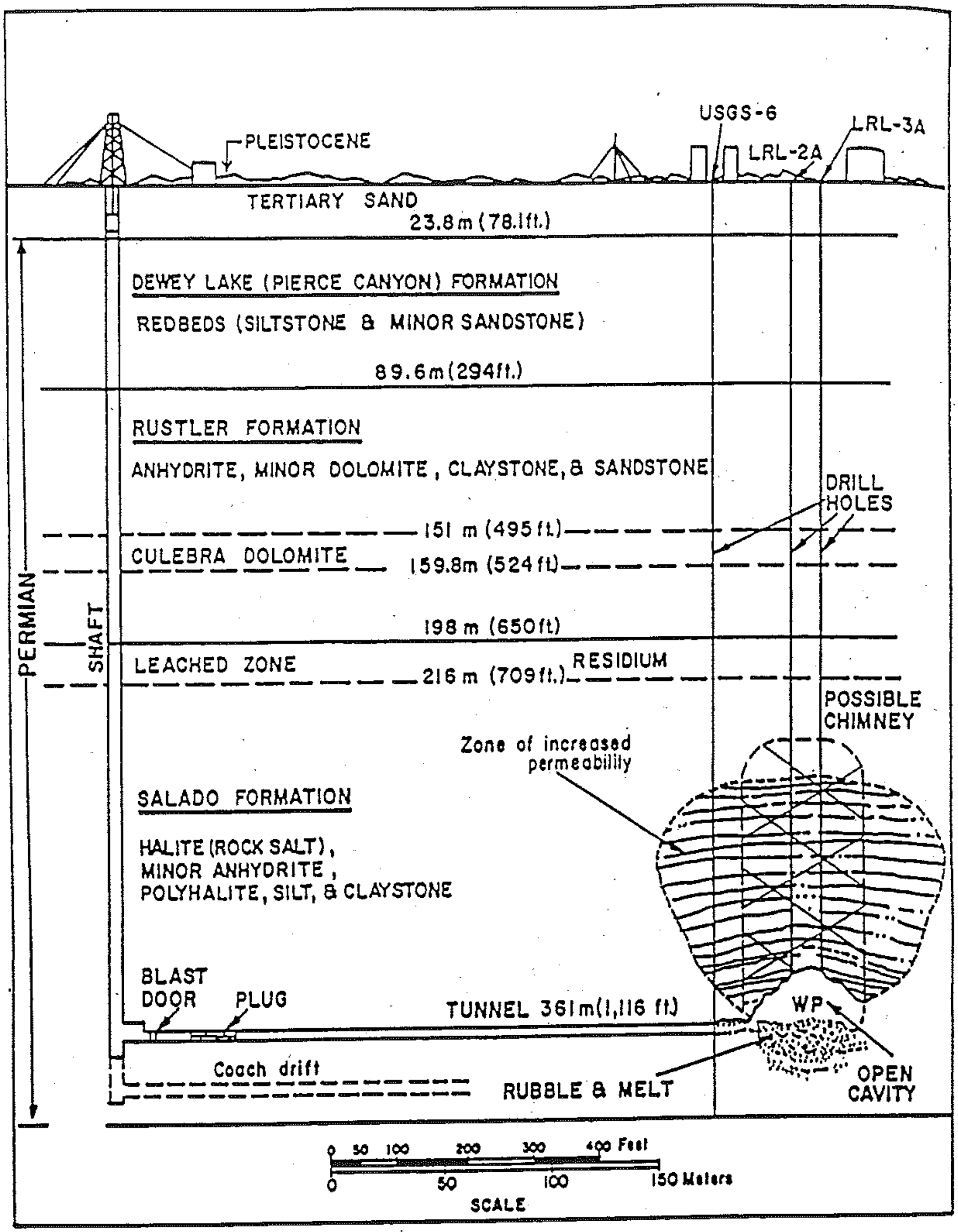


FIGURE 3.8.4. Section through the Gnome Site (from DOE, 1982).

TABLE 3.8.1. GENERALIZED SECTION OF THE ROCKS EXPOSED IN THE PROJECT GNOME AREA (from Cooper, 1962).

System	Series	Group	Formation	Member	Thick-ness (feet)	Physical Character	Water Supply
Quaternary	Recent		Windblown sand		0-100±	Very fine to coarse reddish-brown sand.	Yields no water to wells in Project Gnome area.
			Playa lake deposits		?	Silt, quartz, and gypsum sand.	May yield small quantities of water in large playa lakes.
			Alluvium		0-200±	Silt, sand, gravel, and conglomerate.	Yields large quantities of water to wells near Pecos River.
			Caliche		0-30±	Limestone with included sand grains and rock fragments.	Yields no water to wells in Project Gnome area.
	Pleistocene (?)		Gatuna		0-200±	Clay, silt, sand, gravel, and conglomerate. Reddish-orange to gray.	Yields small quantities of water to wells in parts of area.
Tertiary	Pliocene		Ogallala		0-300±	Silt, sand, and gravel.	Yields fairly large quantities of water to wells north and east of project area.
Triassic	Upper	Dockum	Upper Red Beds		0-1,000±	Shale, siltstone, and sandstone. Red to brown.	Yields small quantities of water to wells in some localities.
			Santa Rosa Sandstone		0-300±	Sandstone, conglomerate, interbedded with claystone. Red to gray.	Yields small quantities of water to wells in places in eastern part of area.
Permian	Ochoa		Pierce Canyon Red Beds (Dewey Lake Red Beds of west Texas)		0-350±	Siltstone, sandy shale, shale, and sandstone. Red to reddish-orange with greenish-gray reduction spots.	Not known to yield water to wells in Project Gnome area.
			Rustler	Forty-niner	0-80±	Gypsum, gray to white. Siltstone, claystone, and sandstone, reddish-brown with greenish-gray reduction spots.	May yield water to wells in parts of the area.
				Magenta	0-30±	Dolomite, gray to magenta. Anhydrite and selenite.	Yields small quantities of water to wells in in Nash Draw.
				Tamarisk	0-120±	Gypsum, gray to red. Siltstone and claystone, reddish-brown.	May yield water to wells in parts of the area.
				Culebra Dolomite	10-40±	Dolomite, grayish-white.	Principal aquifer at site of Project Gnome.
				Lower	90-180±	Sandstone, claystone, and gypsum. Reddish-brown to light gray.	May yield water to wells in parts of the area.
			Castile		0-1,600±	Gypsum and siltstone. Gray to red.	Not known to yield water to wells in area.

a. Salado Formation. Reference 11 states that "no water is known to be moving through the Salado Formation in this area". Extensive aquifers do exist in other areas, however, in the Salado-Rustler residium, Rustler dolomites, Triassic sandstones, and Tertiary and Quaternary deposits.

b. Salado-Rustler Residium. The residium or leached zone is composed of insoluble clay, silt, gypsum, and anhydrite which remain after removal by solution of the soluble portions of the Salado Formation. Ground-water flow in the leached zone is generally south-southwest toward the Pecos River where it discharges at the rate of about 140 gal/min. The gradient is about 1.42 ft/mi. Water was not found in this stratum at the Gnome site, but was found approximately one-half mile west in USGS test holes 4 and 5.[12,13]

c. Culebra Dolomite Member of the Rustler Formation. The Culebra Dolomite Member (a dolomitic limestone) of the Rustler Formation is the only significant aquifer at the Gnome shaft and GZ.[7] The Rustler Formation contains very little water in the area east of Nash Draw. It is overlain there by Permian clays of the Dewey Lake Formation which are effective aquicludes. Culebra Dolomite water is highly mineralized.

   The direction of ground-water flow in the Culebra Dolomite is generally southward, down Nash Draw. The salt lake in Nash Draw is fed by ground water from the Culebra Dolomite, as well as by wastes from the U.S. Borax and Chemical Company refining operations when the facility was in operation. To the east of Nash Draw, flow is westward toward Nash Draw. To the north and south of Nash Draw, flow is south and southwest toward the Pecos River. Flow velocity has been estimated to be less than 1 ft/day.[12,13]

d. Triassic Rocks. It is believed that water in the Triassic rocks discharges in the subsurface to the deep alluvial basin centered near the New Mexico-Texas stateline or just south of T26S, R31E.[11]

   Water very probably moves primarily through joints and along bedding planes in these strata. The probable flow velocity is on the order of 0.3 ft/day.[11] Water from the Triassic beds is of better quality than water from the Culebra Dolomite; consequently, it is suitable for domestic use as well as stock watering. Triassic rocks are not present at the Gnome site.

e. Tertiary-Quaternary Beds. The occurrences of water in beds of Tertiary and Quaternary age is erratic in the area. Much of the water is found in local perched or semiperched beds which discharge ground water downward into deeper zones. Chemical quality of water from the perched zones in the eastern part of the area is usually good. Mineralization of the water increases with depth. In the deeper alluvial basins, water is similar to water from either the Triassic or Permian aquifer that discharges into the alluvium.

Ground-water movement in the alluvium to the west of the Pecos River is toward the river. This water is derived initially from the upstream Pecos River by leakage from irrigation canals and drainage of water in the Carlsbad Irrigation District. There is no ground water in the Tertiary-Quaternary beds at the Gnome site.

Regional distribution of principal aquifers surrounding the site is shown in Figure 3.8.5. Regional ground-water gradients in the Salado-Rustler Residium (Figure 3.8.6) and the Culebra Dolomite (Figure 3.8.7) hydrostratigraphic units are from the northeast of the Gnome-Coach site toward Nash Draw and the Pecos River.

Climate in the Carlsbad area is semiarid and is characterized by low relative humidity.[7] The mean annual precipitation is 12.3 in. Long-term records indicate a range of from less than 3 in. to over 30 in. of annual precipitation. Rainfall is distributed throughout the year in such a pattern (Figure 3.8.8) that the warm months, May through October, average 8.5 in. of precipitation.[4] The value for the 2 year, 24 hr rainfall is 2 in.

Typical continental temperature zone fluctuations occur in the area, ranging from a -24°F in January 1962 to 107°F in July of 1963. Large diurnal variations in excess of 40°F are common.

HUMAN RECEPTORS

There are no known human habitations within 4 miles of the Gnome-Coach site boundaries (Section 34). However, on the basis of nearby wells there are

GEOHYDROLOGY OF PROJECT GNOME SITE, NEW MEXICO

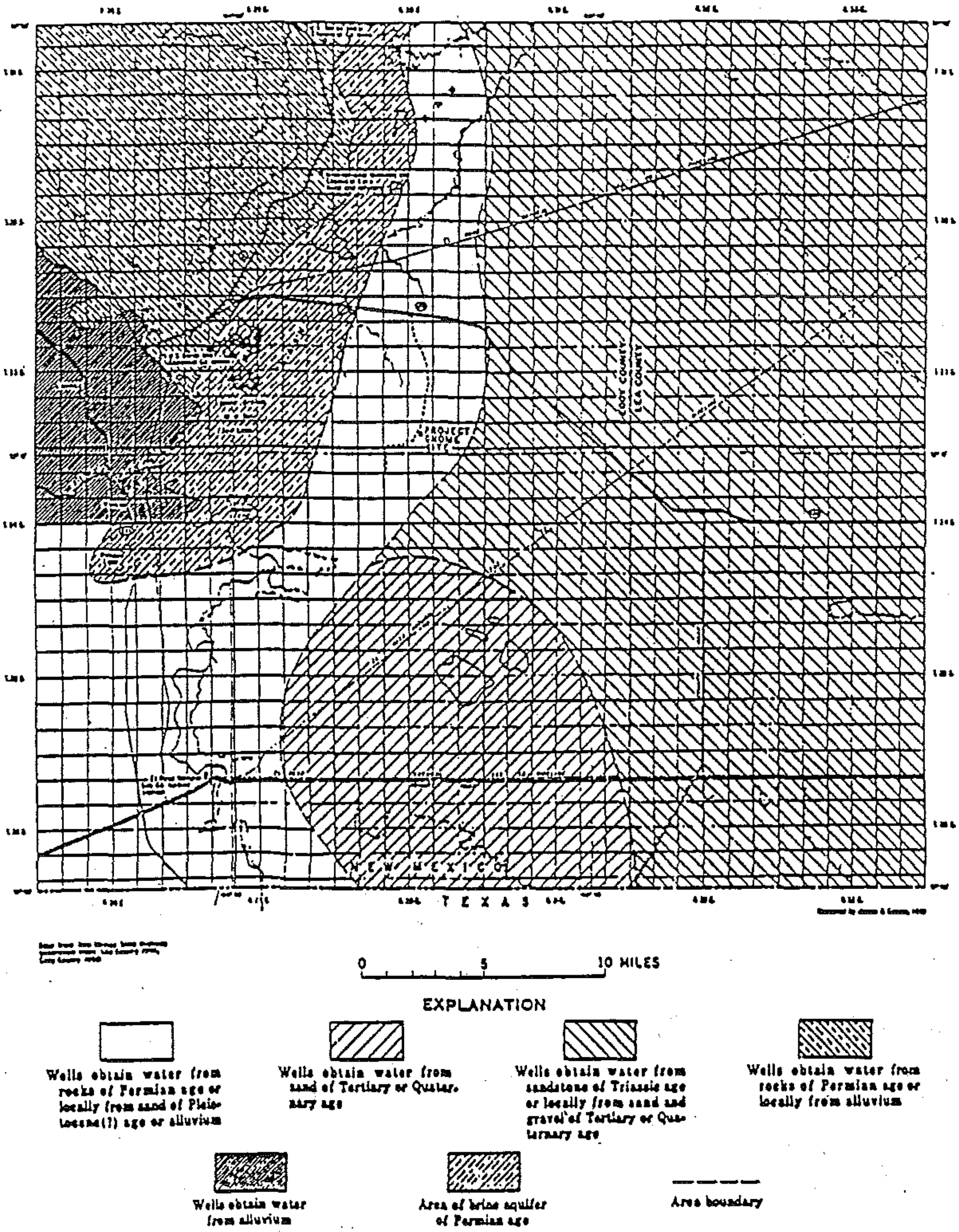


FIGURE 3.8.5. General Distribution of Water-Bearing Formations in the Project Gnome Area (from DOE, 1982).

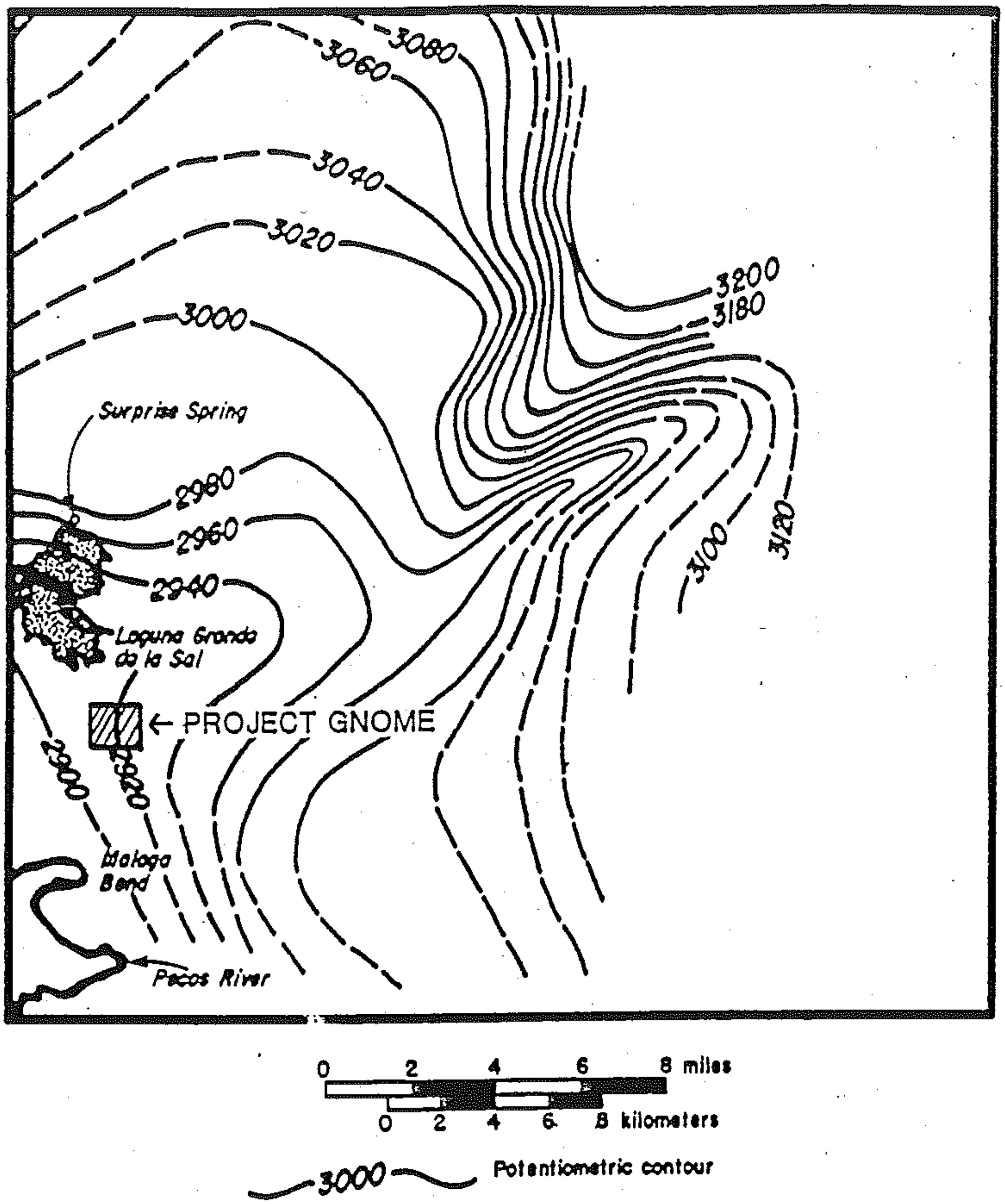


FIGURE 3.8.6. Adjusted Potentiometric Contours of the Rustler/Salado Contact Residium (modified from Chapman, 1986).

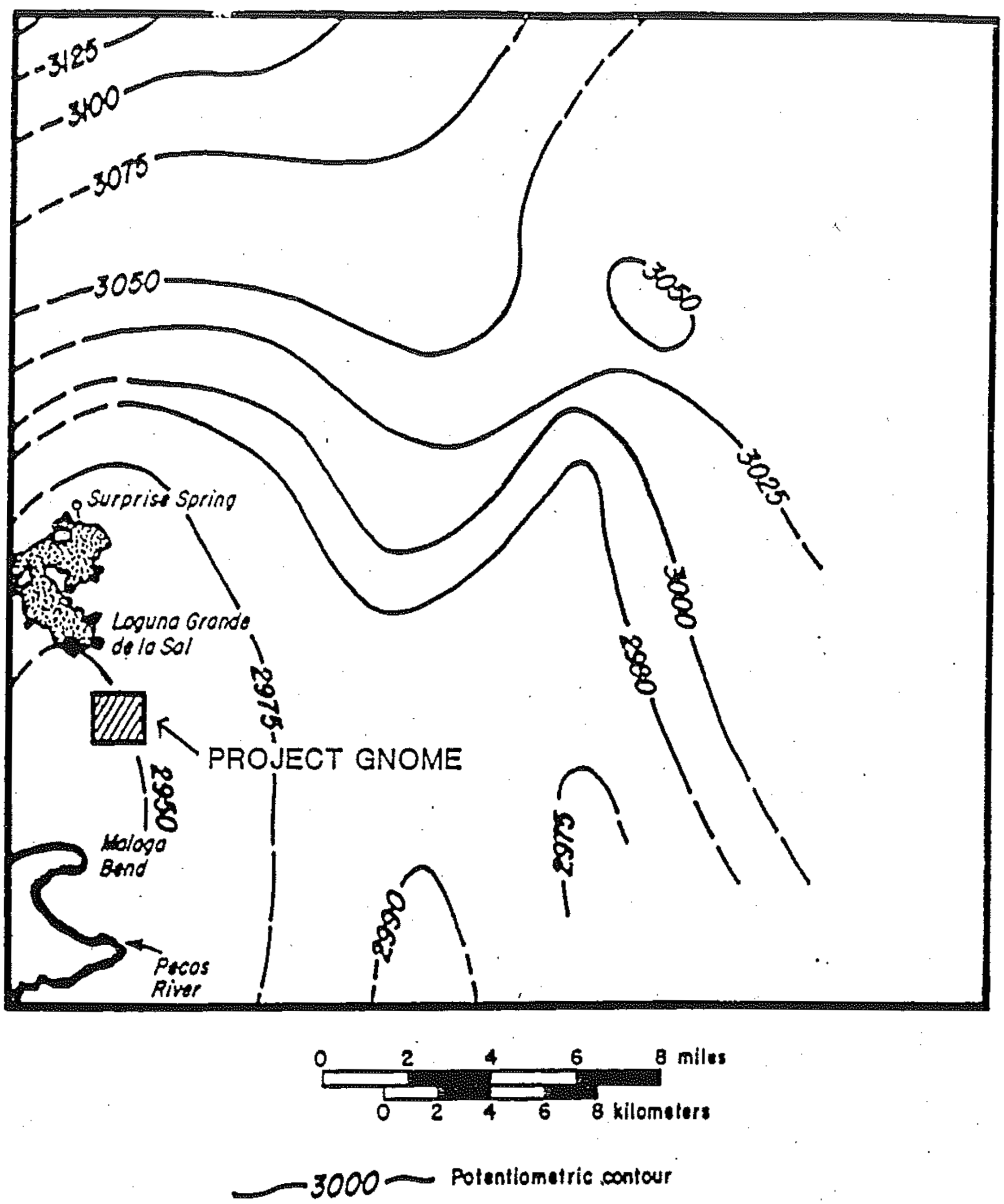


FIGURE 3.8.7. Adjusted Potentiometric Contours of the Culebra Dolomite Member of the Rustler Formation (modified from Chapman, 1986).

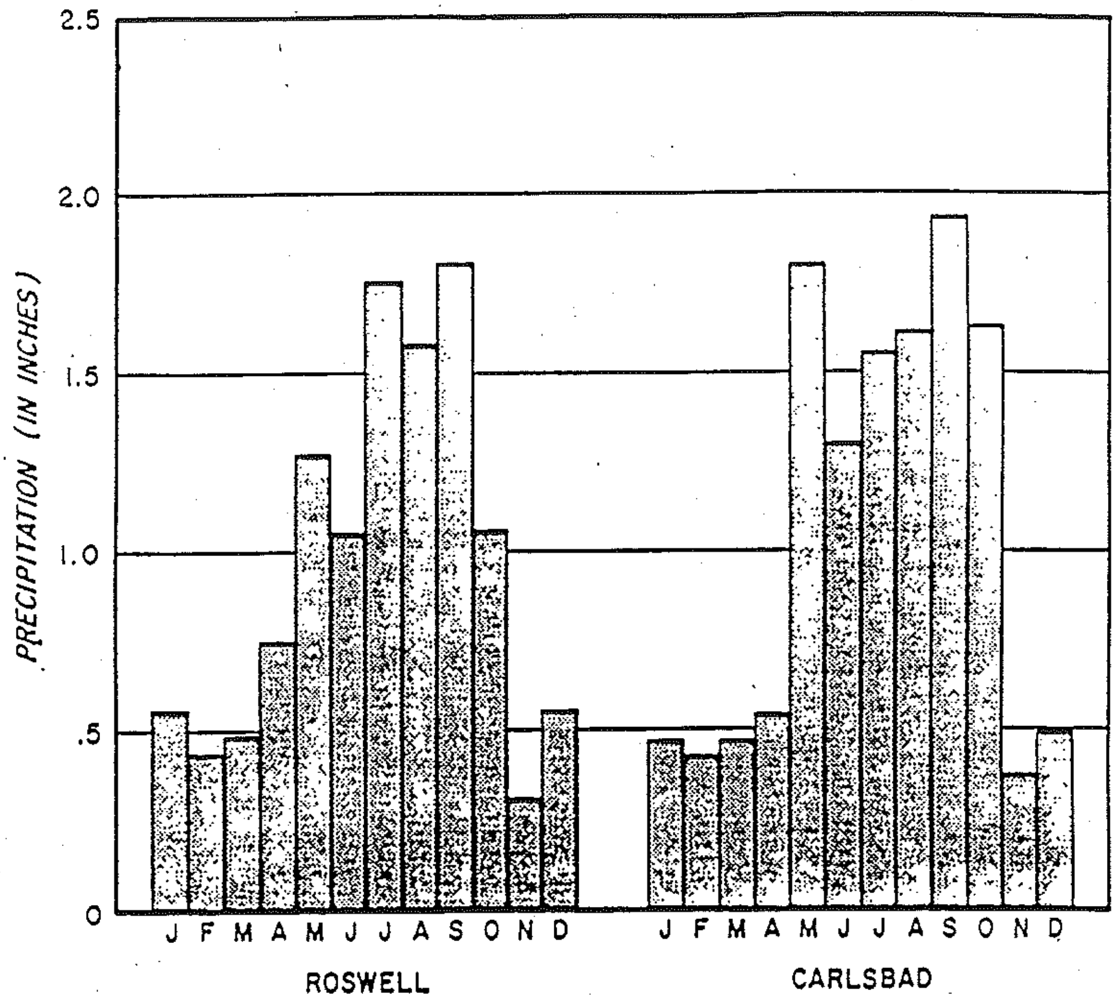


FIGURE 3.8.8. Monthly Average Precipitation Recorded at Weather Stations in the Towns of Roswell and Carlsbad (from Chapman, 1986).

apparently at least three ranches (i.e., Eaton Ranch, Moore Headquarters and "Ranch" Headquarters) (see Figure 3.8.9). Population within 4 miles is thus, believed to be less than 100 people. The surrounding area is used for public land livestock grazing and thus, subject only to occasional occupation by wranglers involved with livestock management. Many of the wells shown in Figure 3.8.9 are believed to be stock wells. Available data on some of these wells are presented in Table 3.8.2. Many of the wells that are probably used either for domestic supply or stock water are completed to approximately the same depth as the Culebra Dolomite at Gnome-Coach (± 500 ft below land surface).

ENVIRONMENTAL RECEPTORS

The Gnome-Coach site is located in southwestern desert range land. Flora and fauna are typical of the region and there are no known environmentally sensitive species. Vegetation at the site is sparse and consists mostly of range grasses and shrubs.[7] Floral and fauna lists for the area are not presented in any of the available site documents.

SITE HISTORY

Project Gnome

In June 1958, the U.S. Atomic Energy Commission approved plans for the first Plowshare Event, Project Gnome, to take place in the Salado Salt Bed of the Delaware Basin. This also was to be the first underground nuclear explosion outside of the Nevada Test Site. The objectives were: a) to determine the phenomenology of a nuclear explosion in salt; b) to determine the recoverability of isotopes from a salt medium, including device products and special isotope additions; c) to determine the recoverability of heat from a nuclear explosion in salt; d) to perform several neutron physics experiments; and e) to obtain information useful in the design of future Plowshare Events.

On March 16, 1960, authorization was granted to proceed with construction of facilities. The emplacement facility consisted of a vertical shaft 10 ft in diameter and 1,216 ft deep and a lateral drift (tunnel) which averaged 8 ft by 10 ft and extended to the northeast 1,116 ft, terminating in a button-hook configuration at the working point.

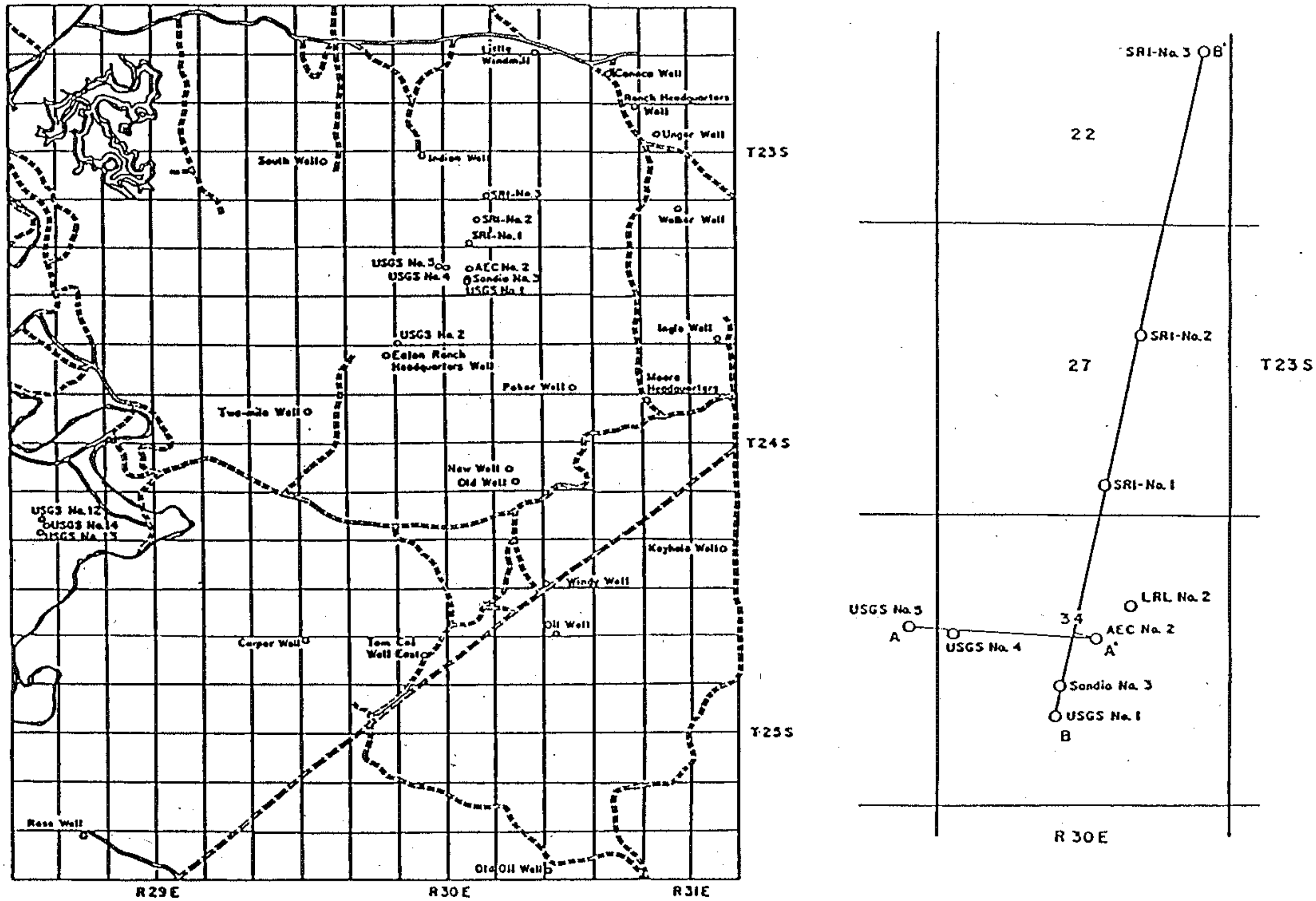


FIGURE 3.8.9. Drill Hole Locations within 15 miles of the Gnome Site (from USGS, 1962).

TABLE 3.8.2. DATA PERTAINING TO SOME HOLES SHOWN IN FIGURE 3.8.9 IN THE GNOME-COACH SITE VICINITY (after USGS, 1962).

Well Number or Local Name	Owner or Sponsor	Land-Surface Altitude (feet)	Well Depth (feet)	Water Level	Date
USGS-1	U.S. AEC	3,426	577	442.30	12-6-61
USGS-2	U.S. AEC	3,403	608	397.10	12-29-61
USGS-4	U.S. AEC	3,413	490	433.67	12-29-61
USGS-5	U.S. AEC	3,439	696	--	--
USGS-12	U.S. Geo. Sur.	2,923	307	41.45	2-25-59
USGS-13	U.S. Geo. Sur.	2,916	67	18.66	2-25-59
USGS-14	U.S. Geo. Sur.	2,925	156	31.50	2-25-59
AEC-2	U.S. AEC	3,396.40	1200	--	--
S.R.I.-1	U.S. AEC	3,357	1120	--	--
S.R.I.-2	U.S. AEC	3,318	1124	--	--
S.R.I.-3	U.S. AEC		1017	--	--
Sandia-3	U.S. AEC	3,418	1200	--	--
South Well	James and Briones	3,045	89(?)	71.3	11-23-61
Indian Well	C.H.-W.O. James	3,165	203?	177.1	11-25-61
Little Windmill	C.H.-W.O. James	3,250	(?)	260.8	4-2-59
Little Windmill	C.H.-W.O. James	3,250	316(?)	259.0	11-26-61
Unger Well	C.H.-W.O. James	3,305	357(?)	108.2	11-27-61
Walker Well	C.H.-W.O. James	3,335	224(?)	138.4	3-25-59
Ranch Headquarters	W.M. Snyder	3,510	85	66.2	12-7-61
Poker Well	W.M. Snyder	3,510	500	364.6	12-8-61
New Well	W.M. Snyder	3,425	457(?)	426.2	12-7-61
Eaton Ranch Headquarters	Wm. Eaton	3,280	194?	176.3	12-8-61
Two-mile Well	Wm. Eaton	3,200	459(?)	231.9	12-9-61
Ingle Well	W.M.Snyder	3,420	625	423.5	3-13-59
Tom Cat East	W.M. Snyder	3,220	387(?)	306.5	3-9-59
Windy Well	W.M. Snyder	3,450	483(?)	445.3	3-18-59
Conoco Well	C.H.-W.O. James	3,315	139?	94.7	4-2-59
Old Oil Well	--	3,360	459(?)	391.3	3-25-59
Carper Well	--	3,170	385(?)	263.3	3-7-59
Keyhole Well	W.M. Snyder	3,460	698	474.2	3-12-59
Ross Well	J.G. Ross	2,985	112	98.7	3-10-59

(?) Well is at least this deep.

Project Gnome was detonated on December 10, 1961, with a nuclear yield of 3.1 ± 0.5 kt. The detonation caused a cavity 80 ft in radius and 72 ft high, producing a total cavity void volume of approximately 960,700 cu ft.

Project Coach

Project Gnome post-shot re-entry activities were completed in June 1962, and limited activities were commenced for Project Coach during late 1962 and early CY 1963. The Coach objectives were: a) to produce, recover, and identify small quantities of new transuranium isotopes and possibly new heavy elements; and b) to produce and recover relatively large quantities of certain known transuranium elements of interest.

The limited construction activities for Project Coach included: a) rehabilitating the Project Gnome shaft and extending its depth to 1,284 ft; b) constructing a 12 ft wide by 10 ft high drift (at the 1,284 ft level) extending southeast 1,130 ft where it narrowed to 7 ft and continued 630 ft where a 6 ft wide by 9 ft wide high reverse drift extended upward at a 30° angle for 185 ft to the GZ room; and c) drilling four holes from the surface to the Project Coach drift. After several delays, Project Coach (initially scheduled for February or March, 1963, execution) was canceled.

When Project Coach was canceled, the site was placed in caretaker status in late 1963. The caretaker staff was reduced during 1965 and 1966 and approval to deactivate the site was given on May 27, 1968.

Gnome Cavity

The Gnome Event melted approximately 3.5 x 10^3 tons of rock salt and produced a standing cavity with a volume of approximately 9.6 x 10^5 cu ft. The cavity has a pronounced bulge at its equator. According to Reference 9, the development of this asymmetry was controlled by the pre–shot character of the rock: horizontal weaknesses in the form of bedding planes and clay layers. The molten salt mixed with the condensing radioactive debris and approximately 12.8 x 10^3 tons of rock from the cavity walls, to form a radioactive "puddle" of melt and rock breccia at the base of the cavity. This zone was blanketed by approximately 15 x 10^3 tons of rubble that resulted primarily from ceiling collapse.

During the dynamic cavity growth period of about 100 msec, radial cracks propagated closely behind the outgoing compressional shock wave. Molten rock had not yet mixed well with vaporized fission products and consequently melt injected into these cracks was not radioactive or only slightly so. Rawson et al. (1961) reported that the maximum observed extent of these fractures, measured from the center of the explosion, was approximately 131 ft laterally, 125 ft above, and 82 ft below.

Rawson et al. (1961) indicated that leakage of radioactive gases through the rock was detectable by the presence of radiation damaged salt. Generally, there was no evidence of leakage beyond 131 ft and the maximum observed extent at 215 ft was thought to be associated with fracturing to a natural cavity.

Close-in stemming failed and cavity gases vented dynamically into the placement drift. Back-up stemming confined the dynamic venting, but allowed the low pressure release of steam and gaseous fission products. The formation of radial cracks and bedding plan partings, coupled with the emplacement configuration to accommodate a neutron-physics experiment, caused the stemming failure (Rawson et al., 1961).

Rawson et al. (1961) reported a zone of increased permeability extending at least 151 ft laterally and 345 ft above the point of the explosion. The permeability increase was established by complete circulation loss of the drill fluid and is primarily associated with motions and partings along bedding planes - the major pre-shot weakness in the rock.

WASTE GENERATION AND DISPOSAL

Radioactivity at the Gnome site resulted from: 1) the event itself; 2) venting of the Gnome Event; 3) re-entry to the Gnome drift; 4) construction of the Coach facilities; and 5) radioactive ground-water tracer experiments in 1963 by the USGS at the western boundary of Section 34.

High level radioactivity at the Gnome-Coach site is believed to exist in five areas beneath land surface. These are: 1) ground water in the vicinity of wells USGS 4 and USGS 8 at the western edge of Section 34; 2) the detonation melt-zone and cavity of the Gnome Event; 3) the Gnome emplacement and re-entry drifts; 4) the Coach emplacement drift and shot-point room; and 5) the Gnome-Coach main shaft. No high level radioactivity is believed to remain at land surface.

KNOWN RELEASES

Gnome Event

The device used for the Gnome operation produced a yield of 3.1 ± 0.5 kt from the fission of ^{239}Pu. The radioactive nuclides found in the post-shot environment are from three sources:[7] a) pre-shot emplacement of isotopes; b) production of radioactive isotopes by neutron activation; and c) production of radioactive isotopes from the fission of the ^{239}Pu.

Prior to the Gnome Event, various compounds were added as part of the isotope production study. The most significant isotope was H^3.

One kt of fission releases 2.2 x 10^{23} neutrons.[7] The neutron activation products produced depend primarily upon the geologic media containing the device. Table 3.8.3 lists the most important nuclides with half lives greater than 0.5 years (plus ^{45}Ca, t½ 0.45y). In addition to nuclides formed from activation of the host rock are nuclides produced from activation of the materials added for isotope production experiments.

Table 3.8.4 lists the nuclides and activities which resulted from the neutron-induced fission of ^{239}Pu.

Radionuclides which existed after the Gnome detonation were distributed in the melt within the cavity, in fractures of the cavity walls, in the shaft, in the drifts, and in the rock-water system.

Post-detonation studies revealed that more than 99 percent of the fission products other than gaseous or volatile ones were concentrated in impurities in the salt. These radioactive nuclides remain, for the most part, in the insoluble fraction when samples are dissolved in water.[7]

Atmospheric Venting

At less than 1 minute after the event, radiation was detected at the blast door near the bottom of the shaft and at 3 minutes and 40 sec it was detected at the shaft collar.[9] At approximately 7 minutes after zero time, a gray smoke, steam, and associated radioactivity surged from the shaft opening and by 11 minutes after the explosion, large quantities of steam issued from both shaft and ventilation lines. A large flow continued for about 30 minutes before gradually decreasing. A small flow was still detected through the following day. The radioactive elements that vented through the shaft were volatile and noble gases.[9] According to Reference 3, the fall-out from this venting occurred on a track to the northwest of the shaft and at least to the edge of Section 34. Quantity or composition of this fall-out is unknown. However, in 1977 the ^{137}Cs activity was less than 0.4 μR/hr approximately 1,800 ft from the shaft along the fall-out track.[3]

TABLE 3.8.3. LONG-LIVED RADIONUCLIDES PRODUCED BY NEUTRON ACTIVATION IN A SALT DOME ENVIRONMENT (from Gardner and Sigalove, 1970).

Isotope	Curies per Kiloton Fission	Curies Produced by Gnome Event (3.5 kt)
^{3}H	3.1×10^{1}	10.85×10^{1}
^{45}Ca	3.7	1.29×10^{1}
^{22}Na	5.1×10^{-4}	1.79×10^{-3}
^{39}Ar	2.6×10^{-1}	9.1×10^{-1}
^{36}Cl	1.6×10^{-1}	5.6×10^{-1}
^{134}Cs	1.0×10^{-2}	3.5×10^{-2}
^{55}Fe	4.9×10^{-3}	1.72×10^{-2}
^{85}Kr	1.5×10^{-5}	5.2×10^{-5}
^{65}Zn	8.6×10^{-4}	3.01×10^{-3}
^{57}Co	2.0×10^{-6}	7.0×10^{-6}
^{41}Ca	2.4×10^{-4}	8.4×10^{-4}
^{60}Co	5.8×10^{-5}	2.03×10^{-4}
^{63}Ni	1.6×10^{-5}	5.6×10^{-5}
^{54}Mn	1.7×10^{-5}	5.95×10^{-5}
^{14}C	1.4×10^{-5}	4.9×10^{-5}
^{40}K	1.1×10^{-7}	3.85×10^{-7}
^{152}Eu		3.97×10^{1}
^{154}Eu		9.68
^{110m}Ag		6.88
^{151}Sm		2.2
^{108m}Ag		<2.1
^{150}Eu		<2.0
^{153}Gd		8.98×10^{-4}
^{158}Tb		6.76×10^{-5}
^{107}Pd		1.28×10^{-6}
^{166m}Ho		$<10.5 \times 10^{-9}$
^{138}La		8.87×10^{-9}
^{137}La		9.68×10^{-10}
^{135}Cs		7.82×10^{-14} C

TABLE 3.8.4. NEUTRON-INDUCED FISSION OF Pu^{239} FOR THE GNOME EVENT (Fission Spectrum Neutrons) (from Gardner and Sigalove, 1970).

Nuclide	Activity (Ci)	Nuclide	Activity (Ci)
^{106}Ru	1.4×10^{4}	^{93}Zr	10.5×10^{-3}
^{144}Ce	1.22×10^{4}	^{93m}Nb	10.5×10^{-3}
^{147}Pm	2.24×10^{3}	^{135}Ca	10.1×10^{-3}
^{137}Cs	7.0×10^{2}	^{79}Se	3.04×10^{-3}
^{155}Eu	4.2×10^{2}	^{126}Sn	2.24×10^{-3}
^{90}Sr	2.4×10^{2}	^{107}Pd	1.71×10^{-3}
^{125}Sb	1.36×10^{2}	* ^{102}Rh	10.1×10^{-4}
^{85}Kr	4.5×10^{1}	^{129}I	5.6×10^{-4}
^{151}Sm	2.87×10^{1}	* ^{94}Nb	7.0×10^{-6}
* ^{134}Cs	11.2×10^{-1}	^{87}Rb	7.35×10^{-8}
* ^{154}Eu	2.62×10^{-1}	^{147}Sm	5.25×10^{-8}
^{99}Tc	8.75×10^{-2}	* ^{98}Tc	1.61×10^{-8}
* ^{110m}Ag	1.85×10^{-2}	^{144}Nd	1.92×10^{-12}
^{113m}Cd	1.19×10^{-2}	^{115}In	3.39×10^{-13}

* *Shielded Nuclides.*

Radioactive Tracer Experiment

A radioactive tracer experiment was performed at the site in 1963, using two hydrologic test wells. The USGS injected radionuclides including ^{3}H and ^{90}Sr into Well USGS 8 and pumped Well USGS 4, 180 ft distant at aquifer depth. USGS 4 is approximately 164 ft from the western boundary of Section 34. Fifty Ci of ^{3}H were placed into USGS 8. Equilibrium pumping conditions of injection and withdrawal were used.

Tritium concentration in 1966 was nearly twice one concentration guideline (CG) level at the wells but ^{90}Sr and gross β were much higher. Data are shown in Table 3.8.5.

TABLE 3.8.5. CONCENTRATIONS OF RADIOACTIVITY IN WELLS USGS 4 AND 8, GNOME-COACH TEST SITE, OCTOBER 1966 (from Gardner and Sigalove, 1970).

	USGS 4	USGS 8	CG
Gross β	34,000 pCi/l	72,000 pCi/l	1×10^{-8} µCi/ml
	(3.4×10^{-5} µCi/ml)	(7.2×10^{-5} µCi/ml)	
^{90}Sr	14,000 pCi/l	27,000 pCi/l	1×10^{-7} µCi/ml
	(1.4×10^{-5} µCi/ml)	(2.7×10^{-5} µCi/ml)	
^{3}H	1.8×10^{-3} µCi/ml	2.0×10^{-3} µCi/ml	1×10^{-3} µCi/ml

Surface and Underground Workings

Re-entry activities were completed at the Gnome site in June 1962. These post-shot activities and Project Coach construction resulted in contamination of the ground surface at the site. Until March 1968, the Gnome site remained in a standby status at which time DOE/NV began planning for site decontamination and decommissioning (D/D) in order to permit the release of the area to the control of the U.S. Bureau of Land Management (BLM) for public use.

During 1968 to 1969, the initial area cleanup was accomplished within the guidelines that specified removal of all contaminated material above 0.1 mR/h beta plus gamma as measured by a 30 mg/cm^2 Geiger Mueller (GM) portable survey instrument. Various decontamination methods were employed including disposal of radioactive material into the Gnome shaft and burial of low activity soil. During the cleanup activity all above-ground materials and facilities were removed and all drill holes were plugged except those retained for long-term hydrological monitoring.

During a routine survey of the site in April 1972, indications were found that contaminated debris, which had been originally covered by approximately 2 ft of clean fill in the salvage yard and the contaminated waste dump (CWD), had become exposed. During the period 1973 to 1977, routine surveys were made to reassess public safety and environmental conditions on and near the site.

During August and September 1977 and again from March through September 1978, detailed radiological surveys of the site were performed and decontaminating and decommissioning (D/D) plan was prepared. Basically, the D/D plan called for disposal of all surface contaminated materials in the Gnome cavity and the Gnome-Coach drifts.[10] Major site preparation activities included: 1) rehabilitation and installation of a pump at USGS Well #1 for an operational water supply and the excavation of a water storage reservoir; 2) clean-out and opening of the Gnome re-entry holes: SR-2A and LRL-7; 3) establishment of a decontamination holding area and a clean holding area; 4) fabrication and installation of the tritium effluent filter system at LRL-7; 5) installation of the crushing plant on the north side of the salt muck pile; and 6) set up of the slurry and mud tanks for the downhole disposal system.[3] After the initial downhole injection of soil and salt, this original operation was modified due to problems of keeping the soil in a slurry. The modification resulted in a downhole injection system in which the crushed soil and salt were fed directly into a hopper which was fitted with jet water nozzles. This system, in turn, washed the soil down the pipe leading directly into the cavity, bypassing the slurry tanks altogether. The water for this system was initially supplied by USGS Well #1 and later recirculated from the cavity through LRL-7.

Removal of contaminated soil and debris from the operational areas was initiated in April 1979, and continued throughout the downhole disposal operation. Soil was removed from the contaminated areas by shovels and a backhoe/front end loader, loaded on a dump truck, and deposited on the surface of the salt muck pile. In some areas where the contamination was dispersed throughout a large generalized area as in the CWD and the shaft area, the surface was scraped to a depth of approximately 6 in. or a trench was dug when contamination was located at depth. Selection of the contaminated soil volumes to be removed was based on the decontamination criterion of 2.0×10^{-5} µCi/g (20 pCi/g) of cesium-137, averaged over 0.25 hectares, and the 1977-78 survey results. To insure that all the contaminated material was removed from a selected area, after a portion was excavated, the area was surveyed with a Ludlum micro-R-meter (Model 19). This procedure was continued until the contact portable instrument readings approached environmental levels (approximately 25 µR/h). At this point, random soil samples were collected and sent to the mobile lab facility for analysis. Based on the results of these analyses, the pit or trench was backfilled, or excavation continued until the site was verified to be below the decontamination criteria (Berry, 1981).

All contaminated soil removed from the operational areas was deposited initially on the surface of the salt muck pile. The final downhole disposal operation consisted of loading a combination of soil and salt into the crusher. The crushed soil continued through a series of conveyer belts and a shaker table where all large debris, such as gloves, metal fragments, pieces of wood, etc., was sorted out and held for later disposition. The small pebble-sized salt and soil was then fed onto a final series of conveyer belts and two more crushers. The total tonnage was recorded by means of a Tecweigh conveyer scale on the final belt to the hopper. It was then dumped into the hopper and deposited into the Gnome cavity by means of a water injection system. The water for the downhole disposal operation was initially supplied by USGS Well #1. Near the end of June 1979, concern developed that the Gnome cavity would fill with water before the major portion of the soil and salt was deposited. At this time, it was proposed, reviewed, and approved by DOE/NV to recirculate the water that had accumulated in the Gnome cavity via a closed system from LRL-7 (in the Coach drift) to the re-entry hole in use.

The recirculating system consisted of a submersible pump at LRL-7, a large enclosed water storage tank on the Coach pad and a pipeline to the re-entry hole in use. The system was carefully checked for leaks to insure that there was no possible radiological hazard, as the water from Gnome cavity had elevated levels of tritium (10^{-1} μCi/ml) and cesium-137 (10^{-3} μCi/ml).

Listed below is a chronology of the major events in the downhole disposal operation:[3]

05/11/79 - Communication established between SR-2A and LRL-7.
05/12/79 - Filter system at LRL-7 online.
05/18/79 - Downhole disposal operation initiated with the slurry tank system at SR-2A.
05/22/79 - Slurry tank system abandoned, fabrication of new disposal system initiated.
05/25/79 - New disposal system (water injection) online.
06/30/79 - SR-2A abandoned (filled to bottom of injection hole).
07/02/79 - USGS Well #1 water system to SR-2A terminated, initiated fabrication of the closed recirculation water system from LRL-7, started drilling SR-3A.
07/07/79 - SR-3A abandoned due to blockage.

07/09/79 - Started drilling DD-1.

07/21/79 - Moved filter system from LRL-7 to SR-2A.

07/23/79 - Communication established in Gnome cavity through DD-1.

07/27/79 - Moved filter system from SR-2A to DD-1.

07/30/79 - Enclosed the hopper of downhole disposal system at DD-1, tested water system from LRL-7 with clean water.

08/02/79 - Downhole disposal operation restarted at DD-1.

08/25/79 - Downhole disposal operation terminated, Gnome cavity full.

At the termination of the downhole disposal operation, approximately 39,330 tons (35,750 cu yds) of contaminated soil and salt were deposited in the Gnome cavity. Based on prior estimates of the available void in the cavity and tagging through the re-entry holes throughout the operational phase, the Gnome cavity was estimated to be filled to near capacity.

Based on cesium-137 analysis of grab samples from the conveyer belt, a conservative estimate of a total of 1.06 Ci deposited in the Gnome cavity, but that a more realistic estimate would be 0.50 Ci because well over half of the material deposited in the cavity was clean (uncontaminated) salt from the salt muck pile.[3]

The air samplers for particulates and halogens were counted daily on-site and showed only natural background throughout the operation. The area monitoring TLD's showed very small excesses above background in the pre-operational surveys, and even smaller on the post-operational evaluation.

Tritium air monitoring was also accomplished as a separate program. Since elevated amounts of tritium were known to exist in the cavity, but concentration levels were not exactly known, filtering of all air released from the cavity occurred initially.

Analyses of air samples collected in this filter system indicated that the concentration of tritium in the cavity air was well below the Radiation Concentration Guide (RCDH) for uncontrolled areas (2×10^{-7} µCi/ml). Therefore, when pressure build-up in the cavity occurred, approval was obtained from DOE/NV to allow unfiltered releases of cavity air directly to the environment when necessary for operational considerations. The most conservative estimate of the total curie quantity of tritium released was approximately 34 mCi for the combined 3 months of downhole operations (Berry, 1981).

At the termination of the downhole disposal operation on August 25, 1979 there still remained contaminated soil, salt, and debris. The debris that remained was material which had accumulated during the crushing operation. All of the excess material and soil was packaged in 55 gallon drums and 4 ft by 4 ft by 7 ft wooden boxes. The containers were then transported to the NTS for burial at the low-level waste facility.

A total of 242 drums (73,972 pounds) and 14 boxes (50,200 pounds) were transferred to the NTS for disposal. The activity of this material totaled 2.67×10^{-2} Ci (based on cesium-137).

Site restoration activities included:[3]

- Removal of the cinderblock building located west of the salt muck pile.
- Removal of all miscellaneous concrete pads located throughout the Gnome site, excluding the one located over the shaft and in the warehouse area.
- Recontouring all surface areas disturbed during the contaminated soil and salt removal operation. (In some cases where a large amount of soil was removed it became necessary to bring in fill dirt. This fill was taken from clean areas on the Gnome site).
- Plugging of all re-entry holes (SR-2A, SR-3A, and LRL-8) except LRL-7 and DD-1 which were prepared to remain as long-term hydrological monitoring holes.
- Demobilization of all equipment and facilities associated with the Gnome D/D.
- Removal of all scrap metal and material located on the Gnome site.

Many of the above listed activities were accomplished during the downhole disposal operation. All Gnome site D/D activities were completed and terminated on September 23, 1979.

POTENTIAL FOR DIRECT CONTACT OR FIRE/EXPLOSION HAZARD

The 1979 cleanup of the Gnome-Coach site apparently was successful in removal of all surface and near-surface radioactivity in excess of the cleanup criteria. Thus, there is little potential for direct contact in the vicinity of GZ. A permanent restriction prohibiting any drilling or excavation between land surface and a depth of 1,500 ft has been placed on all of Section 34 (Berry, 1981).

Two boreholes to the underground workings were not plugged, DD-1 to the Gnome cavity and LRL-7 to the Coach drift, but they are capped and padlocked. Both holes are in the "Long-term Hydrologic Monitoring Program" (LTHMP). All other boreholes into the event workings have been plugged.

POTENTIAL FOR GROUND-WATER RELEASE

Release of high-level radioactivity to ground water is known to have occurred at the Gnome-Coach site near the western boundary of Section 34 (wells USGS 4 and 8) and there is evidence that release has already, or will, occur near GZ.

The Gnome-Coach shaft encountered water in the Culebra aquifer which leaked into the shaft and drift system. Efforts were made during re-entry activities to seal off the leakage, but it has been estimated that approximately 200 gal/week continued to flow down into the underground workings.[7] During the 1979 cleanup activities, water and material were added to the cavity and drift system that largely exhausted the underground void space. During the 1981 LTHMP sampling tour, wells DD-1 and LRL-7 were found to be pressurized and water levels had risen significantly. By 1987 the water level in LRL-7 had risen to 490.7 ft below land surface, or above the Culebra aquifer zone (495 to 554 ft b.l.s). The observed water level rise and pressurization are believed to be the combined result of Culebra leakage and squeezing shut of the workings by salt creep.[5] Excess hydrostatic pressures in this system will likely force high-level radioactive water from the cavity and drifts into the Culebra and Rustler-Salado Residium aquifers.

The Gnome-Coach LTHMP wells are shown in Figure 3.8.10 and radioactivity measurements for those wells since 1981 are presented in Table 3.8.6. Well DD-1 (Gnome cavity) has not been sampled since 1982. Data from wells PHS-6 and -8 suggest that radioactivity has or is, moving away from GZ toward the southeast. Movement in that direction, however, would not be expected based on regional hydraulic gradients (see Figures 3.8.6 and 3.8.7).

Ground water in the Culebra and Rustler-Salado Residium aquifers in the Gnome-Coach area is of very poor chemical quality and thus, is not used as a

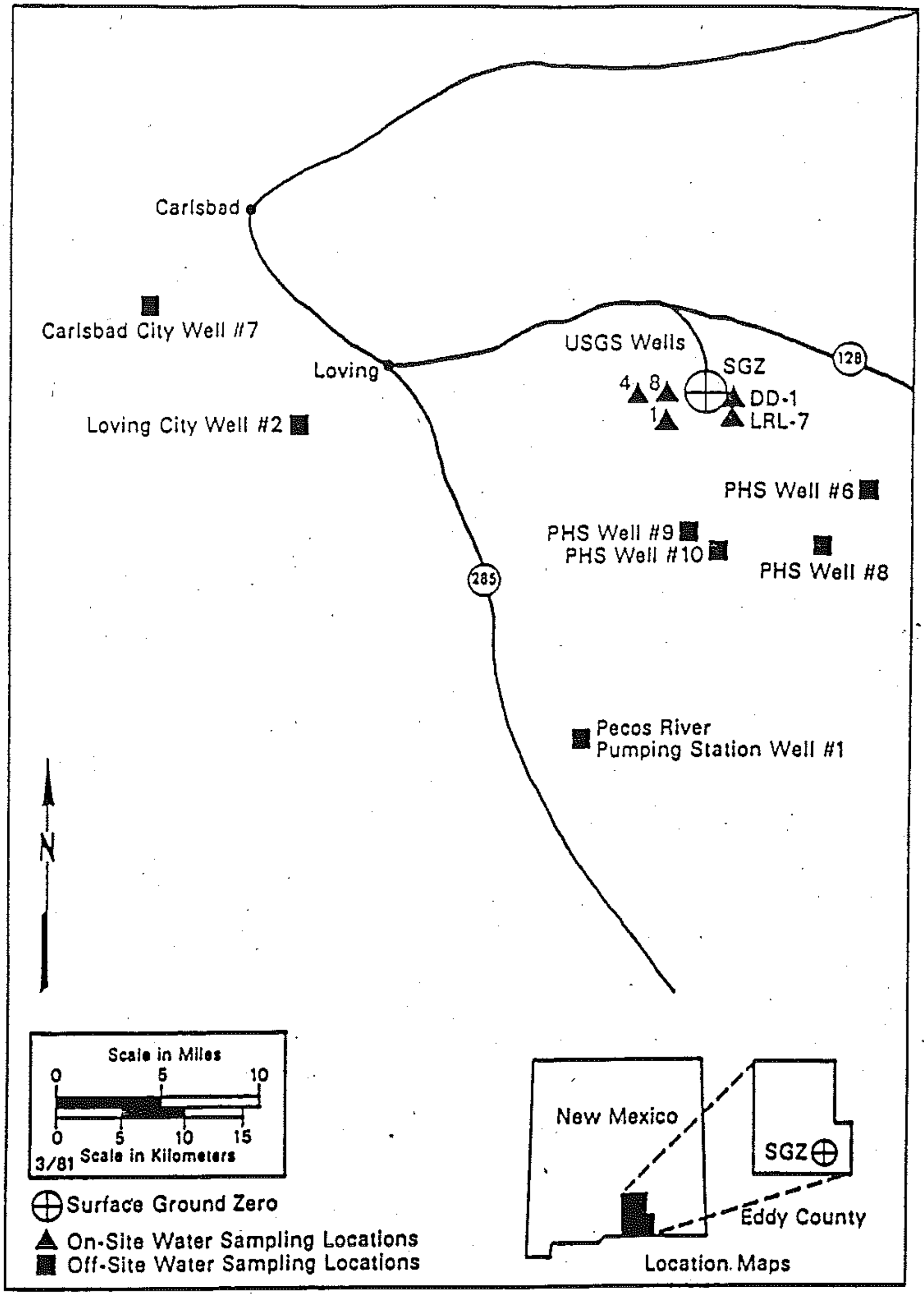


FIGURE 3.8.10. Long-Term Hydrological Monitoring Program Sampling Sites for Projects Gnome and Coach, Carlsbad, New Mexico (from EPA, 1980).

TABLE 3.8.6. GNOME-COACH LTHMP ANALYSES, 1981-1986 (from EPA, 1980 through 1986).

		Radioactivity, pCi/l ± 2 sigma						
Well	**Isotope**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**
Carlsbad #7	H^3	16	15	3.1 ± 59	-0.85 ± 5.1	8.4 ± 3.9	-2.2 ± 7.3	5.2 ± 7.6
Loving	H^3	<10	72	6.2 ± 5.7	4.9 ± 4.9	7.1± 4.2	6.3 ± 7.2	5.1 ± 7.5
Pecos	H^3	<10	<12	-1.8 ± 5.4	-0.79 ± 5.0	1.3 ± 4.6	3.3 ± 7.1	1.1 ± 8.8
USGS 1	H^3	16	<12	-4.5 ± 6.2	-2.3 ± 5.1	2.9 ± 4.5	6.3 ± 6.9	1.3 ± 7.9
USGS 4	H^3	400,000	400,000	360,000 ± 1,600	330,000± 4,100	280,000 ± 960	260,000 ± 910	220,000 ± 670
"	Sr^{90}	7,600	8,300	8,500 ± 2,600	9,000 ± 64	--	--	13,000 ± 750
"	Cs^{137}	-	16	--	10 ± 2	--	58 ± 11	--
USGS 8	H^3	440,000	340,000	290,000 ± 1,500	260,000 ± 3,800	200,000 ± 810	190,000 ± 780	160,000 ± 780
"	Sr^{90}	5,600	3,400	6,900 ± 2,100	5,700 ± 49	--	--	5,640 ± 392
"	Cs^{137}	72	29	21 ± 10	61 ± 11	95 ± 11	--	62 ± 9
PHS 6	H^3	69	64	69 ± 6	130 ± 6	80 ± 5	72 ± 7	66 ± 7
PHS 8	H^3	<10	29	5.5 ± 5.3	15 ± 5	19 ± 4	21 ± 7	26 ± 7
PHS 9	H^3	<10	<7	-4.6 ± 5.3	-1.7 ± 5.1	2.4 ± 4.4	7.6 ± 7	3.3 ± 7.8
PHS 10	H^3	11	20	-1.8 ± 5.4	-2.2 ± 5.2	18 ± 4	5.8 ± 7.4	4.0 ± 7.7
LRL 7	H^3	-	39,000	22,000 ± 440	23,000 ± 2,100	18,000 ± 260	17,000 ± 280	16,000 ± 310
"	Sr^{90}	-	870	10 ± 16	13 ± 2	--	--	10 ± 7
"	Cs^{137}	-	350	250 ± 21	220 ± 20	210 ± 16	210 ± 17	210 ± 16
DD-1	H^3	-	1.8×10^8	1.5×10^8 ± 45,000	--	--	--	--
"	Sr^{90}	-	310,000	--	--	--	--	--
"	Cs^{137}	-	900,000	970,000	--	--	--	--

domestic water supply. Thus, contamination in this area does not appear to pose an immediate health problem.

NUMBER OF WELLS WITHIN A FOUR-MILE RADIUS

Several (at least four) ranch and stock wells are located within a four-mile radius. These wells are generally completed in the Culebra dolomite. See Figure 3.8.9 for locations of some of these wells.

POTENTIAL FOR SURFACE WATER RELEASES

There are no active surface water courses on the Gnome-Coach site thus, release to surface water is not likely. The ground at the site met cleanup criteria and thus, local runoff would not likely pick up significant quantities of radiation. In the long-term, the only potential surface water release would be through ground-water discharge in the Nash Draw area and subsequent runoff to the Pecos River. There are, however, insufficient data to evaluate the significance of that unlikely occurrence.

POTENTIAL FOR AIR RELEASE

Air has been released from the Gnome cavity and Coach drift on an annual basis since 1981 in conjunction with LTHMP activities. Field tests of the released air have indicated that the vented air is not radioactive.[5]

THREATS TO THE FOOD CHAIN AND ENVIRONMENT

Because of the depth at which high level radioactive materials occur and the low level of surface radioactivity there are no plausible pathways for food chain contamination. The entire area is fenced and thus, livestock grazing is prohibited.

CONCLUSION AND RECOMMENDATIONS

There appears to be a significant release of high-level radioactive materials to the ground water in the Gnome-Coach site. However, because of the poor quality of this water and probable distances to domestic water supplies, there is no apparent near-term health problem. Further hydrogeologic investigation at this site is recommended to more adequately characterize the extent of the potential problem.

A preliminary HRS score has been developed for this site based on the data presented in this Preliminary Assessment and is included in Appendix 3.8.A. The HRS migratory score is 20.65.

In all cases, the maximum score of 26 was used for waste characterization. Exact location data were not available to determine distance from known groundwater contamination to the nearest supply well. An estimate of 1 mile was used for scoring purposes.

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APPENDIX 3.8.A
HRS WORKSHEETS
GNOME-COACH SITE

FIRE AND EXPLOSION WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
[1] Containment	(1) 3	1	1	3	7.1
[2] Waste Characteristics					7.2
Direct Evidence	(0) 3	1	0	3	
Ignitability	(0) 1 2 3	1	0	3	
Reactivity	(0) 1 2 3	1	0	3	
Incompatibility	(0) 1 2 3	1	0	3	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			8	20	
[3] Targets					7.3
Distance to Nearest Population	0 (1) 2 3 4 5	1	1	5	
Distance to Nearest Building	(0) 1 2 3	1	0	3	
Distance to Sensitive Environment	(0) 1 2 3	1	0	3	
Land Use	0 1 (2) 3	1	2	3	
Population Within 2-Mile Radius	0 (1) 2 3 4 5	1	1	5	
Buildings Within 2-Mile Radius	0 (1) 2 3 4 5	1	1	5	
Total Targets Score			5	24	
[4] Multiply 1 x 2 x 3			40	1,440	
[5] Divide line 4 by 1,440 and multiply by 100			S_{FE} = 2.78		

DIRECT CONTACT WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	8.1

If observed release is given a score of 45, proceed to line 4.

If observed release is given a score of 0, proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Accessibility	0 1 (2) 3	1	2	3	8.2
3 Containment	(0) 15	1	0	15	8.3
4 Waste Characteristics					8.4
Toxicity	0 1 2 (3)	5	15	15	
5 Targets					8.5
Population Within a 1-Mile Radius	0 1 2 3 (4) 5	4	16	20	
Distance to a Critical Habitat	(0) 1 2 3	4	0	12	
Total Targets Score			16	32	
6 If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			0	21,600	
7 Divide line 6 by 21,600 and multiply by 100			S_{DC} = 0		

GROUND WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 (45)	1	45	45	3.1
If observed release is given a score of 45, proceed to line 4.					
If observed release is given a score of 0, proceed to line 2.					
2 Route Characteristics					3.2
Depth to Aquifer of Concern	0 1 2 3	2		6	
Net Precipitation	0 1 2 3	1		3	
Permeability of the Unsaturated Zone	0 1 2 3	1		3	
Physical State	0 1 2 3	1		3	
Total Route Characteristics Score				15	
3 Containment	0 1 2 3	1		3	3.3
4 Waste Characteristics					3.4
Toxicity/Persistence	0 3 6 9 12 15 (18)	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			26	26	
5 Targets					3.5
Ground Water Use	0 1 2 (3)	3	9	9	6
Distance to Nearest Well/Population Served	0 (4) 6 8 10 12 16 18 20 24 30 32 35 40	1	4	40	8
Total Targets Score			13	49	
6 If line 1 is 45, multiply 1 x 4 x 5					
If line 1 is 0, multiply 2 x 3 x 4 x 5			15,210	57,330	
7 Divide line 6 by 57,330 and multiply by 100			Sgw = 26.5		

SURFACE WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	4.1

If observed release is given a score of 45, proceed to line 4.

If observed release is given a score of 0, proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Route Characteristics					4.2
Facility Slope and Intervening Terrain	0 (1) 2 3	1	1	3	
1-yr. 24-hr. Rainfall	0 (1) 2 3	1	1	3	
Distance to Nearest Surface Water	(0) 1 2 3	2	0	6	
Physical State	0 1 2 (3)	1	3	3	
Total Route Characteristics Score			5	15	
3 Containment	0 (1) 2 3	1	1	3	4.3
4 Waste Characteristics					4.4
Toxicity/Persistence	0 3 6 9 12 15 (18)	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			26	26	
5 Targets					4.5
Surface Water Use	(0) 1 2 3	3	0	9	
Distance to a Sensitive Environment	(0) 1 2 3	2	0	6	
Population Served/ Distance to Water Intake Downstream	(0) 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
Total Targets Score			0	55	
6 If line 1 is 45, multiply 1 x 4 x 5					
If line 1 is 0, multiply 2 x 3 x 4 x 5			0	64,350	
7 Divide line 6 by 64,350 and multiply by 100		S_{sw} = 0			

AIR ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 (45)	1	45	45	5.1
Date and Location:					
Sampling Protocol:					
If line 1 is 0, the S_a = 0. Enter on line 5. If line 1 is 45, then proceed to line 2.					
2 Waste Characteristics					5.2
Reactivity and Incompatibility	(0) 1 2 3	1	0	3	
Toxicity	0 1 2 (3)	3	9	9	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			17	20	
3 Targets					5.3
Population Within 4-Mile Radius	0 (9) 12 15 18 21 24 27 30	1	9	30	
Distance to Sensitive Environment	(0) 1 2 3	2	0	6	
Land Use	0 1 (2) 3	1	2	3	
Total Targets Score			11	39	
4 Multiply 1 x 2 x 3				35,100	
5 Divide line 4 by 35,100 and multiply by 100		S_a =	23.97		

HRS SCORE

$S_{gw} = 26.5$

$S_{sw} = 0$

$S_a = 23.97$

$$S_m = \frac{1}{1.73}\sqrt{(26.5)^2 + (0)^2 + (23.97)^2}$$

$$S_m = 20.65$$

$S_{FE} = 2.78$

$S_{DC} = 0.0$

SECTION 3.9

COVER SHEET

NAME OF SITE:	Tatum Dome, Mississippi
LOCATION:	Tatum Salt Dome, Lamar County, Mississippi, 21 miles southwest of Hattiesburg. Ground zero (GZ) is located at latitude N31°08'32", longitude W89°34'12". The devices were detonated at a depth of approximately 2,700 ft below land surface.
DISPOSITION:	The property is owned by F.M. Tatum et al., while DOE has sole and exclusive right to regulate and control access to the subsurface and the right to prevent removal of any material from the area below a depth of near sea level. The site is currently leased to a sport hunting club.

PRELIMINARY ASSESSMENT REPORT
TATUM DOME

INTRODUCTION

The Tatum Dome Test Site, located in the piney woods area of the gulf coastal plain near Hattiesburg, Mississippi (Figure 3.9.1), has been host to two nuclear detonations (Salmon and Sterling) and two non-nuclear gas detonations. Salmon was detonated in the Tatum Salt Dome in 1964. Sterling was detonated in 1966 in the cavity formed by the Salmon event. The two gas explosions were fired in the Salmon/Sterling cavity in 1969 and 1970. All detonations were totally contained within the salt dome in which they were fired.[1]

The Salmon event consisted of a 5.3 $\pm$ 0.5 kt yield nuclear detonation which occurred on October 22, 1964. The device was emplaced 2,717 ft below ground surface in Tatum Salt Dome.

The Sterling event consisted of a 380-ton yield nuclear detonation which occurred on December 3, 1966. The device was suspended in the 55-ft radius cavity, which was formed as a result of the Salmon detonation.

The Miracle Play program was a series of detonatable gas explosions in the Salmon/Sterling cavity. Events named Diode Tube and Humid Water were exploded on February 2, 1969 and April 19, 1970. Oxygen and methane comprised the explosive mixture. The reaction caused by the explosion at predicted mixture ratio caused no radionuclides to be generated, but did produce toxic carbon monoxide (CO) and water. Also, the temperature for short periods after the explosion was high enough to melt salt. Some radioactivity formerly trapped in the cavity salt may thereby have been released and mixed with water. The routine pressure bleed-down after each detonation effectively transported most toxic gas and radioactivity contaminated water vapor to the surface. Filtration and scrubbing techniques captured pollutants for later disposal.[2]

OVERALL FACILITY DESCRIPTION

The Tatum Dome site consists of decommissioned surface and below-ground facilities. Decommissioning occurred in 1972. Current activities at the site are restricted to yearly monitoring of selected wells and surface waters.

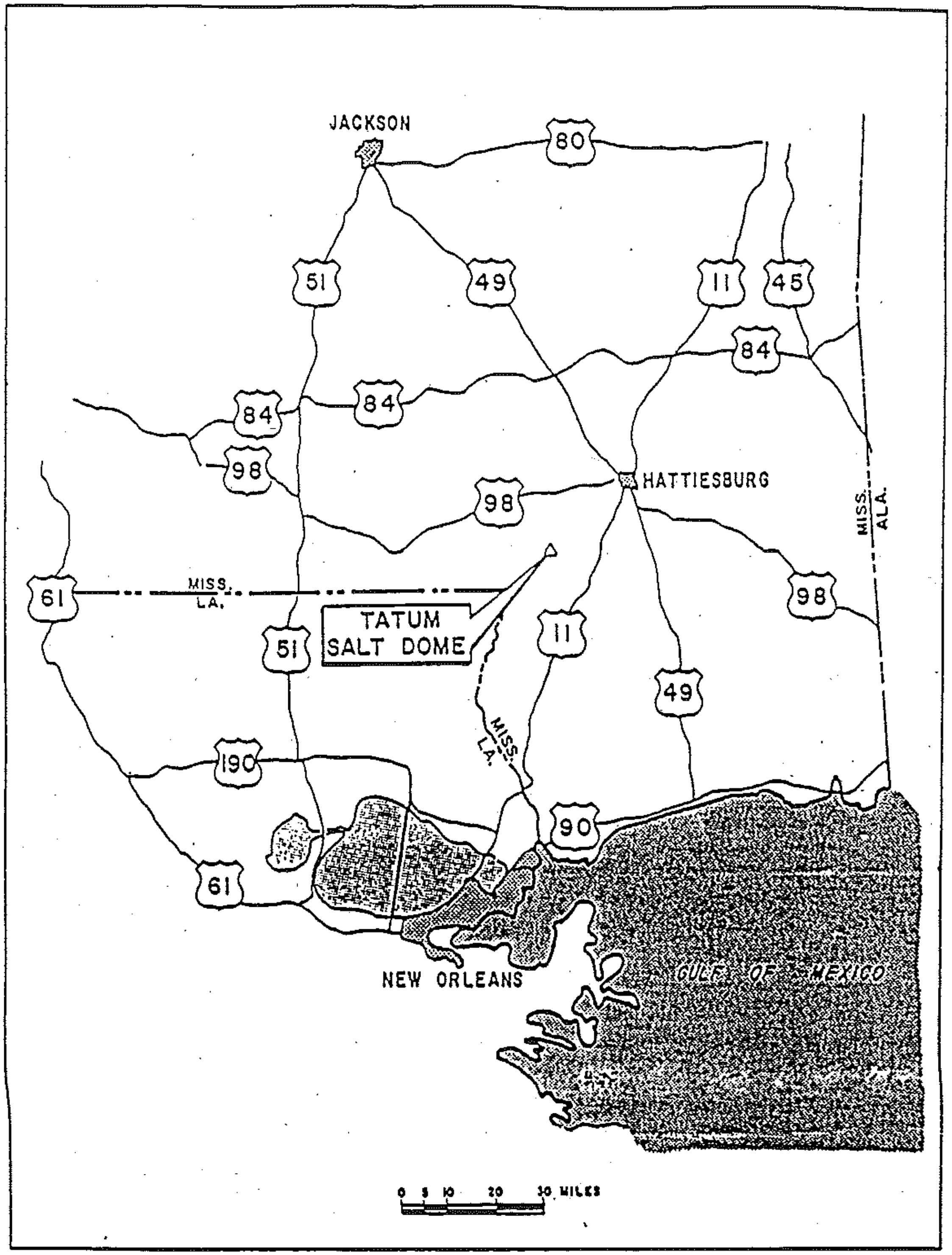


FIGURE 3.9.1. Overall Site Location Map.

The site is comprised of the Tatum Dome Leasehold, about 1,470 acres in Sections 11, 12, 13, and 14, Township 2N, Range 16W, of Lamar County, south central Mississippi, about 21 miles southwest of Hattiesburg, Mississippi (Figure 3.9.1). Access is afforded by good paved roads (U.S. 11 to Purvis, Mississippi, County Road to site) to within 1 mile of the site. A network of graded gravel roads provides good mobility within the site area. The nearest commercial airport is at Hattiesburg; the nearest major airport is at New Orleans, Louisiana, 100 road miles from the site via U.S. 10/59.

GZ is at latitude N31°08'32", longitude W89°34'12", at an elevation 241 ft above mean sea level. The devices were detonated at a depth of about 2,700 ft.

ENVIRONMENTAL SETTING

The site is the low hills of the piney woods area of the gulf coastal plain. Narrow, flat-topped ridges and intervening valleys trend south-southeast to the Gulf of Mexico. Frequent perennial and intermittent streams dissect the terrain; swamps are frequent. Grantham and Half Moon Creeks flow from east and south northward through the site, with a gradient of 6 ft/mi. Maximum site relief is 100 ft, and elevations range from 250 to 350 ft above sea level. Maximum relief to the Pearl River, about 30 miles west at Columbia, Mississippi, is 200 ft.

Locally, the central site within a half-mile radius of GZ is a topographic basin; although geologically a structural dome. Low hills on the east and west and south of the swampy courses of Grantham and Half Moon Creeks are margins of the basin. Pine and scrub oak forest the area.

Surface facilities during operation and testing were utilized for support of drilling, testing, and radiological monitoring. All AEC (now DOE) lease agreements for real property for or associated with the Tatum Dome Test Site expired June 30, 1972. An agreement, effective July 1, 1972 with F.M. Tatum et al., established restrictions granting the Government, acting through the AEC, sole and exclusive right to regulate and control access to the subsurface of the real property, whether by drilling or excavation, and the right to prevent removal of any material, whether solid, gaseous, or fluid from the 1,470-acre tract below the depth of mean sea level. This agreement for monitoring access ran for a 10-year period with an option for renewal for an additional 10-year period. Figure 3.9.2 shows the land status map as of 1972. Figure 3.9.3 is a generalized cross-section through the

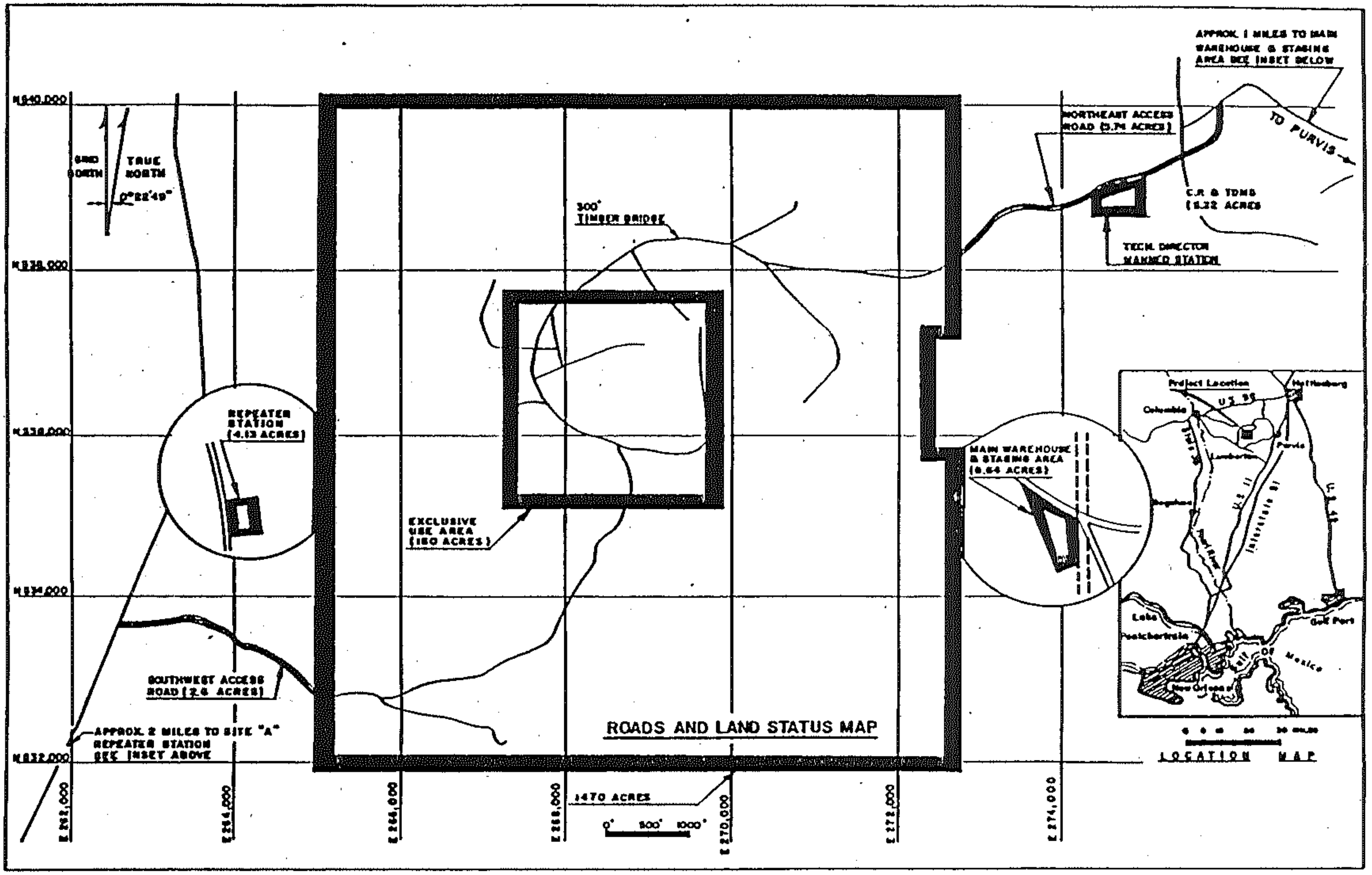


FIGURE 3.9.2. Land Status Map in the Vicinity of Tatum Dome.

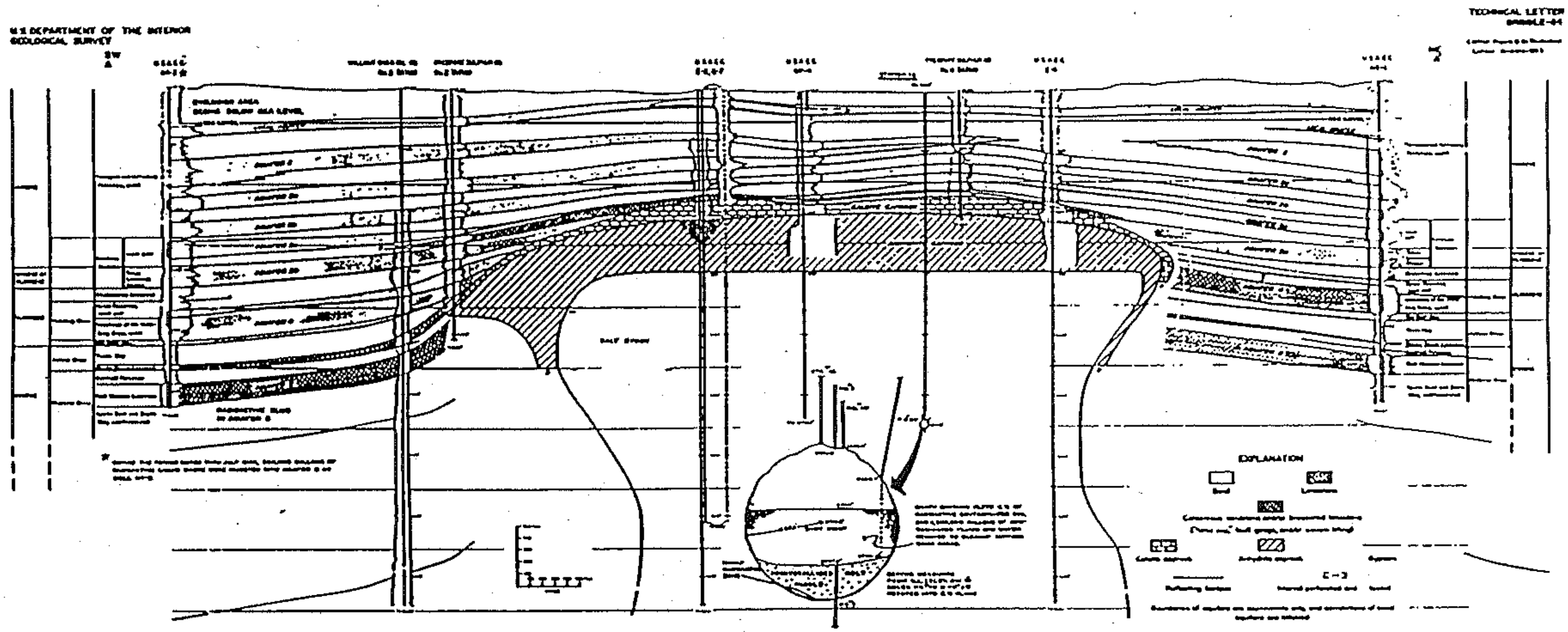


FIGURE 3.9.3. Generalized Cross-Section Through Tatum Dome.

Tatum Salt Dome showing the relationship of the emplacement and re-entry holes to the cavity.[3]

HYDROGEOLOGY

Within a two-mile radius around the site boundaries, habitations consist of widely scattered, single-family homes and farms. The town of Baxterville, at a distance of 2 miles from the site boundary to the south, has a population estimated at several hundred persons. Water supply for these residences is derived from the shallow surficial aquifer as well as Aquifer 1 (described in the Hydrology section). The town of Baxterville maintains a municipal water supply. Within a four-mile radius, seven private and public water supplies were monitored on a yearly basis for radioactivity by EPA-Las Vegas in 1975. The locations of these monitoring points are given in Figure 3.9.4.[4] Additional wells have been added to the monitoring program since 1975.

The hydrogeology of the Tatum Dome area is discussed in detail in NVO-143, NVO-200, and NVO-225. The following is taken from NVO-143.

No water is known to be present in the intrusive salt of the Tatum Dome. The salt is nearly impermeable and, therefore, has little or no capacity to transmit water. Analysis of post-shot data indicates that radionuclides were contained within the salt mass and that ground water from the aquifers intersecting and overlying the dome has not penetrated the salt or the cavity.

Five numbered aquifers, plus a shallow "local aquifer," are present to depths of 2,000 ft near the edge of the salt dome (Figure 3.9.3). In addition, a local caprock aquifer exists. The caprock aquifer, located only over the top of the dome, consists of fractured limestone (calcite) and anhydrite. The water-filled fracture system may extend from the salt through the caprock to connect hydrologically with Aquifers 3 and 4.

Surface runoff and recharge to the local aquifer occur from an average of almost 60 in. of annual precipitation. This water is discharged as seeps and springs into Half Moon and Grantham Creeks, which flow to the north and west, respectively. Shallow domestic wells produce from gravels and sands of the so-called "local aquifer," the top of which is found at depths of 60 to 150 ft in the dome area.

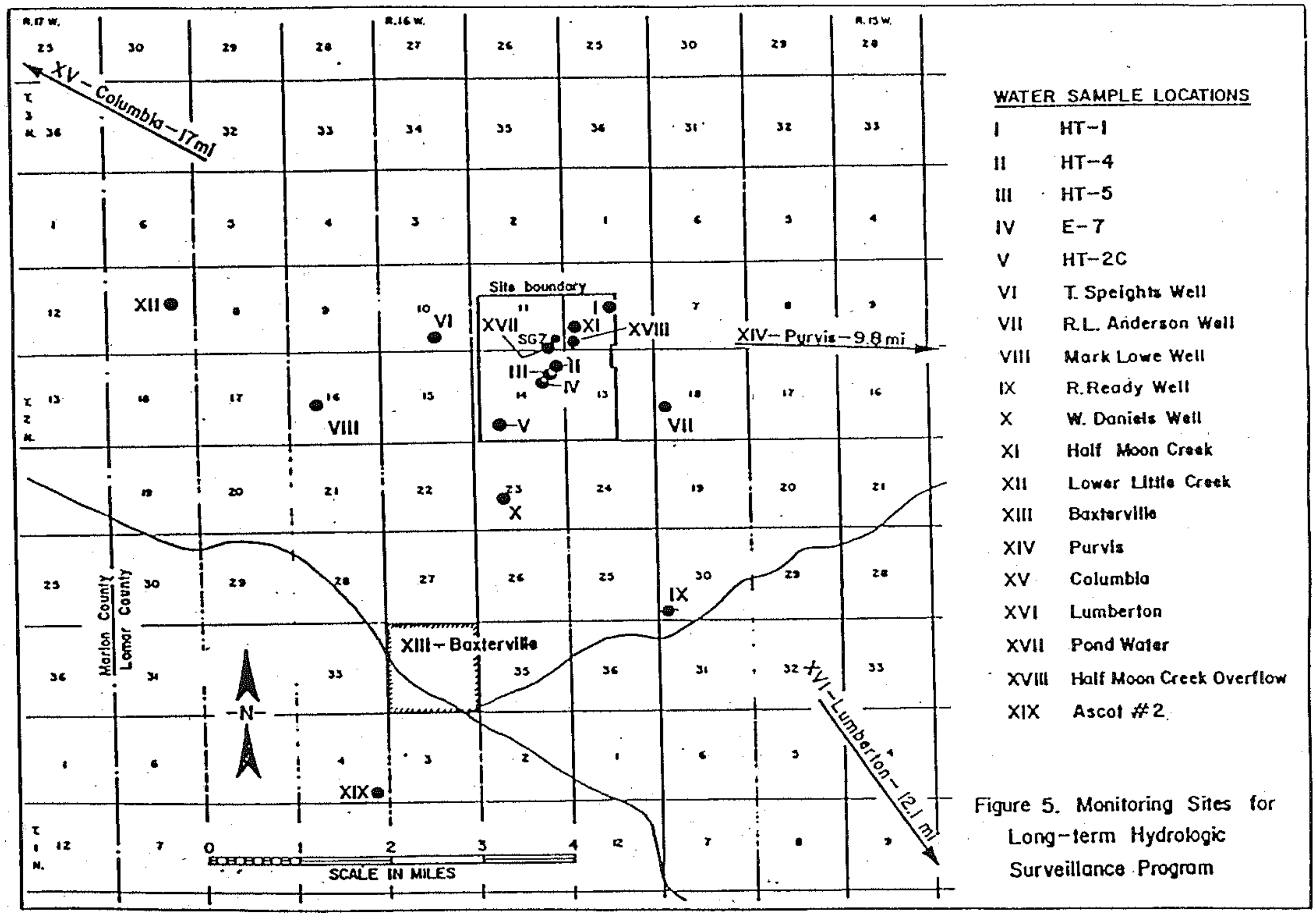


FIGURE 3.9.4. Location of Monitored Wells in 1975. Additional Wells Have Since Been Added to the Program.

At the surface ground zero (SGZ) area, the water table occurs at from 1 to 10 ft below the land surface. During times of heavy precipitation and high flow in Half Moon Creek, this shallow zone receives recharge from infiltrating precipitation and from the creek.

This shallow ground water, 1 to 10 ft below the land surface, is not potable. Total dissolved solids are high and contamination from stock and local rural plumbing systems make it unfit for human consumption.

The deeper, numbered aquifers, numbers 1, 2, and 3, in the Catahoula sandstone and limestone members of the Hattiesburg/Pascagoula formations, are areally extensive and in certain places permit commingling of waters. This hydrologic system is, however, separated by clay beds from the higher "local aquifer." Aquifer 1 supports a few domestic wells a few miles from the site. All three aquifers supply water to wells in nearby towns for municipal and industrial use.

Aquifer 4 in the sandy limestone of the Vicksburg Group is locally brackish, is at a greater depth from the surface, and has relatively low permeability. For these reasons, it is not utilized as a water source in the site vicinity. Aquifer 5 in the Eocene Cook Mountain limestone is not used as a water source because it is strongly saline.

The regional hydraulic gradient for all aquifers in the Tatum Dome area was originally to the south-southwest. Pumping, unrelated to AEC activity, has locally changed the flow direction in Aquifers 1 through 3 to the northeast. Aquifer 4 is not used and its flow direction remains unchanged to the south-southwest. Industrial injection of waste fluids from oil field operations into the saline Aquifer 5 (Cook Mountain limestone) near Baxterville since 1950 has locally reversed the hydraulic gradient in that aquifer toward the northeast. Fluid waste injections have also caused the head potential to increase markedly in Aquifer 5 in the test area since 1971.

Fenske and Humphrey[1] present a detailed description of the regional hydrogeologic picture.

In a regional sense, it is erroneous to consider individual sand beds as seen at Tatum Dome as continuous, regional aquifers. To understand the regional flow system, the Cenozoic formations from the Oligocene through the Recent should be considered although some of the Eocene formations may also be involved. All of these formations dip toward the Mississippi Embayment and toward the Gulf of Mexico. Cenozoic strata were deposited by transgressions and regressions of the Cenozoic Sea across the gulf coastal plain and into the Mississippi Embayment. The Cenozoic formations consist largely of deltaic and marginal marine clays, silts, sands, and gravels deposited during these transgressions and regressions. As the deltaic and marginal marine sands were deposited, the Mississippi Embayment and the Gulf Coast subsided so that most of these Cenozoic deposits resemble the present deposits of the Mississippi Delta. Because of the nature of the deposition, the sands are lenticular and discontinuous, migrate across stratigraphic sections, and contain clay lenses and beds.

Ground water flows from the recharge areas through the Cenozoic sands towards the Mississippi River and the Gulf of Mexico. Because of the exceedingly low relief near sea level during Cenozoic time, only a thin lense of freshwater would originally be above marine water in the Cenozoic sediments. Throughout southern Mississippi, Louisiana, Texas, and along the Gulf Coast, the updip edges of the Cenozoic sands are now a few hundred feet or more above sea level and have been truncated by erosion. They are readily available for the infiltration of precipitation to maintain the ground-water flow systems.

Over geologic time, as uplift of the Cenozoic formations occurred, the flow of fresh ground water has flushed out the salt water that formerly occupied the Cenozoic sands and moved the freshwater/saltwater interface deeper. At depths ranging from a few hundred feet towards the north to perhaps 3,000 or so feet near the Gulf of Mexico, a freshwater/saltwater interface is found within the Cenozoic sediments. The portion of the flow system towards the Mississippi River is the type of flow system found in inland regions. The deeper aquifers may contain saltwater at depth below the Mississippi River and freshwater to the east or west of the discharge area. This illustrates the circulation pattern one would expect in the Cenozoic sediments, whether along this cross section through Vicksburg or along a cross section through Hattiesburg to the gulf coast. The existence of this regional flow system requires that the Cenozoic sediments be considered hydraulically as one flow system. The identification and correlation of individual aquifers locally does not mean that these identical aquifers can be identified over greater distances and does not mean that ground water stays within these aquifers during its flow through the system. In the regional sense, a significant amount of cross-aquifer flow is required. Wells or well fields that penetrate a significant portion of the

Cenozoic sediments will, by the withdrawal of ground water, influence the circulation of water within the Cenozoic sediments. They will not only take water out of the aquifers which they penetrate, but will also influence the movement of ground water within other aquifers as well.

The following analysis of ground-water movement through the Miocene in the vicinity of Tatum Dome is based on this regional flow system analysis.

Figures 3.9.5 and 3.9.6 indicate water levels in various wells on the Tatum Dome site. Water levels were measured starting about 1961 for wells HT-1a, HT-1b, HT-2a, and HT-2b and 1963 for wells HT-4, HT-5, and HT-6. These wells are completed in Aquifers 1, 2a, 2b, and 3. These wells show a steady decline in water level of approximately 1 ft/yr (Table 3.9.1), indicating that ground water in this area is being lowered as a result of ground-water extraction. The major areas of ground-water extraction from the Miocene are shown in Figures 3.9.7 and 3.9.8. The amount of discharge at the major ground-water extraction points for 1962 and 1979 is tabulated in Table 3.9.2, which is keyed to the maps by identification numbers. To estimate where the water in the Miocene aquifers is flowing when it leaves Tatum Dome, maps were constructed on the basis of the 1962 and 1979 ground-water utilization data (Figures 3.9.7 and 3.9.8). Concepts of superpositions of sinks (ground-water extraction points) and a steady flow field were used in the construction. This method of construction assumes steady-state conditions. Figure 3.9.8 indicates the ultimate flow paths if ground-water extraction continues at the current rate. The fact that water levels are declining at an essentially constant rate at Tatum Dome (Figures 3.9.7 and 3.9.8) indicates either unsteady-state conditions or ground-water mining at the present time. The high precipitation and corresponding potential for ground-water recharge suggests that the declining water levels are due to unsteady-state conditions.

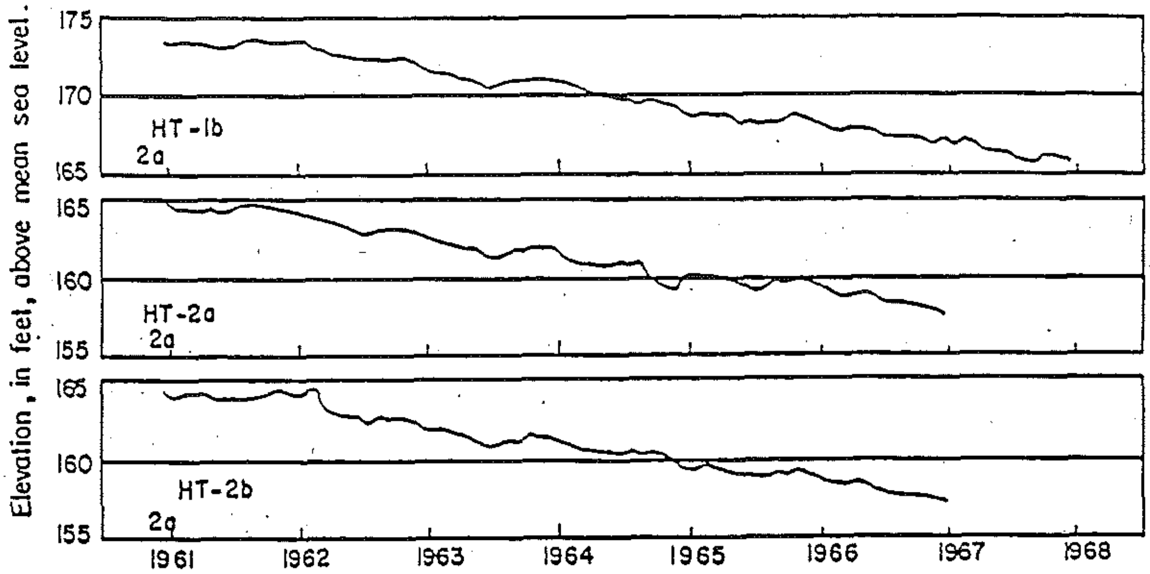


FIGURE 3.9.5 Hydrographs From Wells HT-1b, HT-2a, and HT-2b (from DOE/NVO-225).

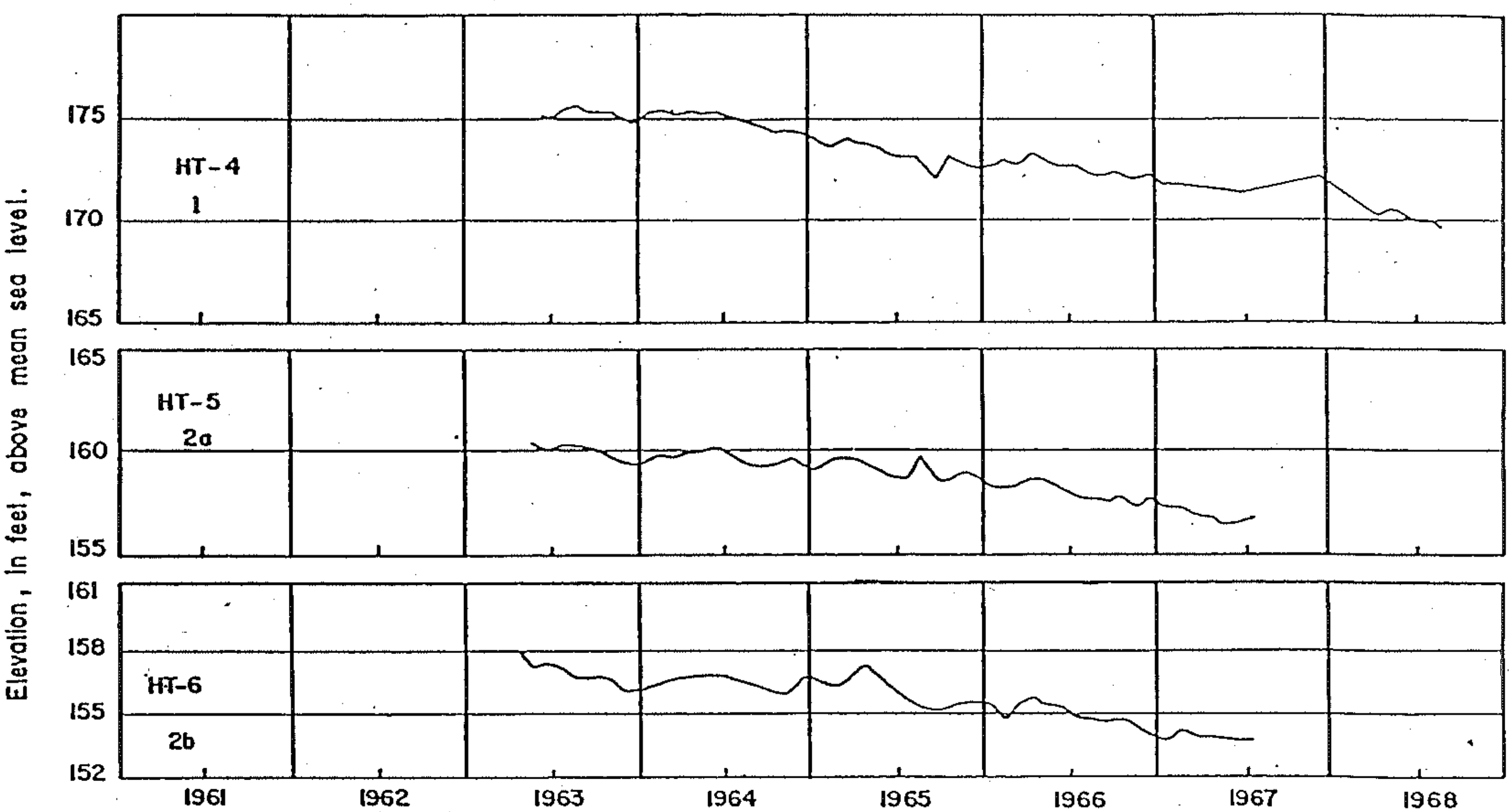
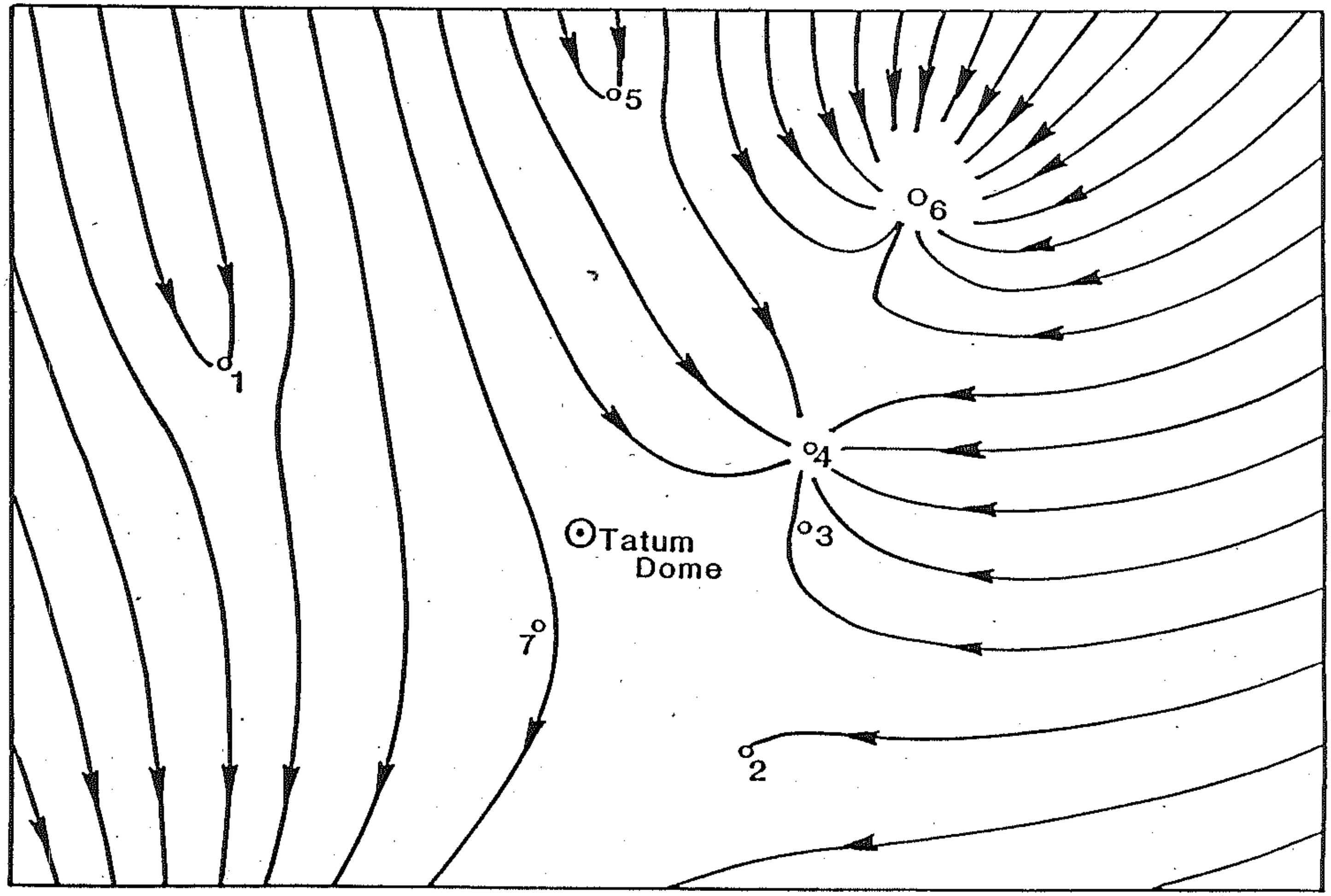


FIGURE 3.9.6. Water Level Declines in Wells HT-4, HT-5, and HT-6 (DOE/NVO-225).

TABLE 3.9.1. WATER LEVELS, SUMMER 1979 (NVO-225).

Well	Measured (ft)	Predicted* (ft)	Decline Rate ft/yr
HM-S	235.1		
HM-L	157.84		
HM-1	158.50		
HM-2a	141.04		
HM-2b	138.25		
HM-3	155.27		
HT-2c	159.11		
HT-4(1)	161.18	160.4	0.953
HT-5(2a)	142.08	141.84	1.25
HT-6(2b)		140.5	1.125
E-7	149.78		
HT-2a(2a)		142.19	1.260
HT-2b(2a)		144.09	1.145
HT-1b(2a)		142.5	1.207

* Predicted upon basis of rate of decline of static water levels from 1961 to 1968.



North is Vertical

Scale 1:500,000

FIGURE 3.9.7. Miocene Flow System in Vicinity of Tatum Dome (1962 data) (NVO-225).

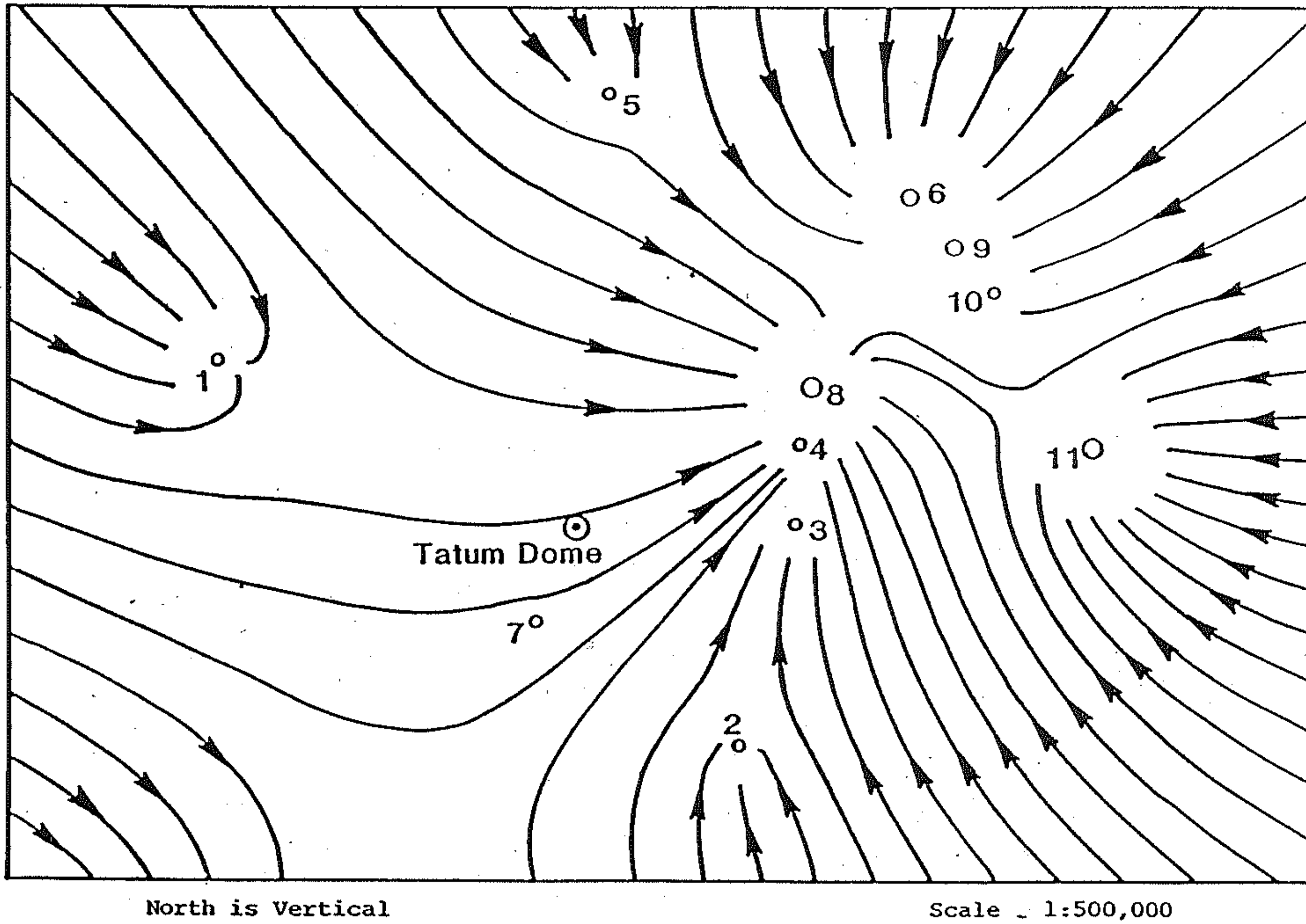


FIGURE 3.9.8. Miocene Flow System in Vicinity of Tatum Dome (1979 data) (NVO-225).

TABLE 3.9.2. DISCHARGE DATA FOR GROUND-WATER EXTRACTION POINTS IN VICINITY OF TATUM DOME.

Map Identification	Name	Discharge 1962[a]	(mgd) 1979[b]
1	Columbia	0.86	5.1
2	Lumberton	0.2	2.1
3	Purvis	0.16	1.7
4	Gulf Oil Company[c]	3.5	3.5
5	Sumrall	0.8	5.0[f]
6	Hattiesburg	6.5	16.7
7	Baxterville		.3
8	Southern Mississippi Electrical Power Association		11.5
9	Hercules Powder Co.[d]		3.6
10	Dixie Pine Products[d]		2.9
11	Camp Shelby		13.2
	Bogalusa, Louisiana[e]	8.26	26.4

[a] Data from USGS report Dribble.

[b] Data supplied by Mississippi Geologic Survey except for Bogalusa Data.

[c] This is apparently formerly Pontiac-Eastern Refining.

[d] These industries were apparently included in the Hattiesburg discharge in 1962.

[e] South of Figures 3.9.7 and 3.9.8, approximately 29 miles southwest of Lumberton.

[f] Sumrall is estimated.

The original movement of ground water was considered to be south to southwest. The gradient was estimated using the original Hattiesburg water level of 175 ft in 1907 and an estimated water level at Tatum Dome of 165 ft. Even though the 1963 data showed the water level to be 160 ft above sea level at Tatum Dome, the original water level was certainly higher. Since the flow was assumed to be south to southwest, the water level at Hattiesburg was moved on a contour to a position north to northwest of Tatum Dome and the gradient (.0002) estimated on the basis of this distance. An average transmissivity for the aquifers was calculated on the basis on the transmissivities available in the Tatum Dome area for each aquifer. The original flow field, moving uniformly to the south-southwest, was used by superposition with the sinks to construct the flow system represented on the maps, Figures 3.9.7 and 3.9.8.

On the basis of the flow system maps, the ground-water movement in the Miocene appears to be changing from a southeast to an east direction at Tatum Dome due to increased discharge towards the northeast. The gradient estimated for the flow system near Tatum Dome, along with the average hydraulic conductivities for Aquifers 1, 2a, 2b, and 3 based upon averaging available hydraulic conductivities for these aquifers in the Tatum Dome area, suggests that ground water will ultimately move at approximately 7 ft/yr in Aquifer 1; 44 ft/yr in Aquifer 2a; 16 ft/yr in Aquifer 2b; and 7 ft/yr in Aquifer 3 towards the east. However, it is probable that substantial inter-aquifer transfer of ground water occurs and that the velocities of components of flow within the aquifer are higher than the rate of ground-water movement along a flow path. Ground water will initially move southeast toward a stagnation point between Lumberton and Tatum Dome (Figure 3.9.7). The characteristic of stagnation points in hydrologic systems is that they are regions of zero to extremely low ground-water movement. Ultimately, the ground water will move toward the Gulf Oil Company wells, north of Purvis (Figure 3.9.8).

In the original hydrologic program for the Tatum Dome site in 1963, water in Aquifer 3 was found to be at a higher water level towards the southwest of Tatum Dome than towards the northeast of Tatum Dome. This is consistent with movement of water towards the east or northeast as suggested in the original study. It is also entirely consistent with the movement of ground water to the southeast as concluded in this study.

In summary, ground water in the Miocene aquifers over Tatum Dome probably moves toward the southeast at a few feet per year. The present direction of ground-water flow is controlled by the extraction of water by communities and industries. At the present time, the ground water is probably moving along a flow path that will take it into an area of extremely low to zero ground-water movement or a stagnation point. The probable location of this stagnation point is between

Lumberton and Tatum Dome. Ultimately, the ground water will move toward the Gulf Oil Company wells, north of Purvis.[1]

During the hydrologic tests of each aquifer above Tatum Dome, water levels in adjacent aquifers were monitored to establish if communication between aquifers existed locally. No obvious changes in water levels of adjacent aquifers were noted during the tests. The hydraulic head (water elevation) of each aquifer was carefully determined by multiple measurements to establish the potential for inter-aquifer flow. These heads are listed in Table 3.9.1. These wells are completed in the various aquifers. Their completion is denoted by the alpha-numeric symbol after "HM-" or in parenthesis. The potentials for inter-aquifer flow are: 1) from the Surficial Aquifer to the Local Aquifer; 2) from Aquifer 1 to the Local Aquifer and to Aquifer 2a; and 3) from Aquifer 2a and Aquifer 3 to Aquifer 2b. Aquifer 2b has the lowest head in the hydrologic system overlying Tatum Dome. In the vicinity of Tatum Dome, water from Aquifer 2b and below is not expected to enter the shallower aquifer systems.[1]

Stream flow of Half Moon Creek near Tatum Dome is estimated to range from 6,300 to 13,500 gal/min with an average flow of 7,600 gal/min. Half Moon Creek passes within 500 ft of SGZ. Half Moon Overflow, a pond 200 ft east-northeast of SGZ, has shown tritium levels above background, but below drinking water standards.[1] These areas are considered wetlands for HRS scoring.

Stream flow of Lower Little Creek, 3 miles southwest of Tatum Dome, is estimated to range from 11,200 to 44,900 gal/min with an average flow of 18,440 gal/min.

Flood information collected in the Lower Little Creek basin indicates that floods are usually of short duration and cause little damage. These waters are not believed to be used for human consumption within the area.

The climate of southeastern Mississippi is humid and semi-tropical, having an average rainfall of approximately 58 in. and average annual runoff from the streams of some 23 in. The remaining 25 in. of precipitation seeps into the ground or is dissipated by evaporation. Rainfall is distributed through the year rather evenly. October has the least rain, 2.62 in., and July the most, 6.66 in. More than 14 in. has fallen in a 24 hr period, generally coincident with late summer or autumn hurricanes. Winds in excess of 100 mph have been recorded during passage of hurricanes and tornadoes through the area. These facts indicate that flooding of low-lying terrain, significant infiltration to the ground-water system, and runoff occur. Thunderstorms are common throughout the year.[2]

The mean annual temperature is about 66°F, while the mean monthly temperature ranges from 82°F in July to 51°F in January. On the average, Tatum Dome has 106 days annually whose temperatures are equal to or greater than 90°F, and some 41 days annually whose temperatures are equal to or less than 32°F.[2]

HUMAN RECEPTORS

The area within a four-mile radius from the site boundaries is lightly settled. Single family homes within one-half mile of site boundary draw ground water. The population within a mile of the site does not likely exceed 100 persons. The small community of Baxterville (2 miles from the site boundary) maintains a public water supply serving 165 persons.[7] A census was not available from the Mississippi Division of Touristry, but it appears, based upon the water supply data, that the community is no larger than several hundred people. Purvis, 9.8 miles to the east, has a population of 2,256. Hattiesburg, at a distance of approximately 17 miles, supports a population of 40,829. Figures 3.9.1 and 3.9.4 shows the locations of these and other small communities in the general area of the site.

Water supply for persons living within a four-mile radius is derived from either the local aquifer (Pascaquola and Hattiesburg formations), Aquifer 1 or Aquifer 2. The majority of wells, including the municipal supply at Baxterville, produce from the local aquifer.[4]

ENVIRONMENTAL RECEPTORS

The Tatum Dome Test Site is located in an area of intermingled farms and forest land. The forests on the uplands are a mixture of four species of southern yellow pines. The wetter lowlands support typical southern hardwood communities. The pine stands are predominantly second growth, grown for both pulpwood and turpentine. The precise area occupied by the test site is located in a tension zone between the upland pines and lowland hardwoods. This makes the site somewhat sensitive to major environmental insults; however, due to the abundance of pine seed sources and the aggressiveness of the Tatum Lumber Company forester, the area of pine forest rapidly recovered from the relatively minor effects of AEC construction activities.

The fauna of the area, deer, fox, bobcats, opossum, raccoon, armadillo, quail, and many varieties of reptiles, have adapted to human impact over a period of years where the area has changed from forest, to brushland, to farms, and back to forest again. No adverse effects to this fauna have been observed.[3] It is not believed that critical habitats exist in the vicinity of the site.

SITE HISTORY

The Salmon Event

The Salmon event consisted of a 5.3 ± 0.5 kt yield nuclear detonation which occurred on October 22, 1964. The device was emplaced 2,710 ft below land surface in the Tatum Salt Dome.

The Sterling Event

The Sterling event consisted of a 380-ton yield nuclear detonation which occurred on December 3, 1966. The device was suspended in the 55-ft radius cavity formed by the Salmon detonation.

The Miracle Play Program

The Miracle Play Program was composed of two non-nuclear gas explosions in the Salmon/Sterling cavity. Non-nuclear events named Diode Tube and Humid Water, both with yields of approximately 315 tons, were exploded on February 2, 1969 and April 19, 1970, respectively. Oxygen and methane comprised the explosive mixture. The reaction caused by the explosions caused no radionuclides to be generated, but did produce carbon monoxide (CO) in water and caused redistribution of existing products. The temperature for a short time after the explosions was high enough to melt salt. The melting point of salt is 801°C, while the gas explosions elevated the temperature in the cavity to around 1,328°C for a short time and may thereby have released some radioactivity formerly trapped in recrystallized salt on the walls and floor of the nuclear cavity to combine with gas or fluid in the open cavity.

The Salmon nuclear explosion produced a cavity with a horizontal diameter of about 114 ft and a height of about 88 ft. Discontinuous microfractures may have occurred up to 350 ft from the working point; however, beyond 200 ft the rock is not generally microfractured. Fractures in halite, with the increased temperature produced by the nuclear detonation (gases during re-entry were 205°C) and the pressure at 2,710 ft below land surface, would heal in a short time. The Sterling nuclear explosion increased the cavity radius by about 1 ft. The Miracle Play gas explosion experiments probably did not alter the cavity, leaving a total cavity volume of about 700,000 cu ft.[2]

The cavity, with the top at a depth of 2,660 ft below the ground surface and 1,160 ft below the top of the salt dome, is contained wholly within the salt dome (see Figure 3.9.3). The cavity which was formed may, in time, close due to plastic flow.[1]

WASTE GENERATION

Both the Salmon and Sterling nuclear events were fully contained. No gaseous or particulate venting occurred. Post-shot drilling after Salmon was conducted with returns controlled by a bleed-down plant. After bleed-down plant processing, no significant concentrations of toxic gases were detected.

All high-level radioactivity at the site is believed to be confined to the melt-rubble mixture at the cavity bottom. The only source of radiologically contaminated soil or fluid on or near the land surface is from material brought to the land surface during the drillback operations or from the decontamination of tools used in the drillback operations.[2]

KNOWN RELEASES

Both the Salmon and Sterling nuclear events were fully contained. No gaseous or particulate venting occurred. Post-shot drilling after Salmon was conducted with returns controlled by a bleed-down plant. After bleed-down plant processing, no significant concentrations of toxic gases were detected.[2]

The total radioactivity at the +1 minute time after the Salmon event (1964) was estimated to be $(3 \times 10^{10}) \times (5.3 \text{ kt})$ Ci, or 15.9×10^{10} Ci. The cavity volume was measured at 700,000 ft^3.

The radioactivity produced from the Sterling event (1966) was $(3 \times 10^{10}) \times (0.380 \text{ kt})$, or 1.14×10^{10} Ci at 1 minute after detonation. The Sterling event did not significantly increase the cavity volume.

The saline Aquifer 5 has been used by oil field operators for the disposal of brine in the Baxterville area since 1950. From March to July 1965, radioactive liquid waste was disposed of through well HT-2 into Aquifer 5, the Cook Mountain limestone, in the following manner:

1. the well was acidized with 2,000 gallons of 15 percent HCL;
2. 337,900 gallons of water containing 38 Ci of beta and gamma activity and 3,253 Ci of tritium were injected;
3. 90,000 gallons of water were injected; and
4. during the final stage of injection, a surface pressure of 60 lbs/in^2 (psi) was used to inject the water at an efficient rate. The pressure decayed immediately.

Well HT-2 was plugged during June 1971 with a configuration designed to prevent communication between aquifers. A new monitoring hole, HT-2m, was drilled in June 1971, 300 ft northeast of HT-2 and between HT-2 and the emplacement site. This monitoring hole was completed by casing from the surface through Aquifer 4 and was left open through Aquifer 5.

Since completion, the water level in HT-2m has risen 75 ft, resulting in intermittent flowing from the casing at ground level. This flow was first noted in March 1972, at which time the wellhead was equipped with a tee, valve, and caps and shut in. Samples collected by the EPA Environmental Monitoring Systems Laboratory, Las Vegas, Nevada (EMSL-LV), in September 1972 were analyzed both by the EPA and the U.S. Geological Survey (USGS). The results confirmed that tritium injected into Aquifer 5 through HT-2 was present at 1,600 ft and below in HT-2m. Specific conductance was not measured on this suite of samples. On March 27, 1973, about 17,000 pCi/l of tritium and a specific conductance of 28,400 micromhos were encountered in water at 1,100 ft in HT-2m. On October 2, 1973, tritium in a concentration of approximately 9,000 pCi/l and a specific conductance of 33,500 micromhos occurred at the 600-ft level.

During the October 1973 sampling, the water in HT-2m gave off gas bubbles and as the flow increased, the water became gas cut. The gas was combustible. Shut-in gas pressure was near 21 psi. During the time that the well was shut in, the water and gas separated, which depressed the water level by about 7 ft so that the well no longer flowed.

On March 2, 1974, water containing tritium at a concentration of approximately 34,000 pCi/l and having a specific conductance of 36,000 micromhos occurred at the land surface. During the March 2, 1974 sampling, the initial flow from HT-2m was on the order of 4 gpm and the final flow rate was 22 gpm. Initial shut-in pressure was 6.5 psi. After sampling, the overnight shut-in pressure was 29.0 psi. No contaminants were found in other drill holes or in surface waters at the site.[4]

The radioactive waste that was injected through HT-2 into the saline Aquifer 5 is predicted to be transported by ground water, in above recommended concentration guidelines (RCG) concentration for tritium, about 570 ft before decay to an RCG concentration. It would reach this distance in about 75 years if the Baxterville Oil Field injection continues. If the contaminated slug was totally transferred to Aquifer 4, it would migrate about 245 ft before decaying to an RCG concentration. It would reach this distance in about 65 years. Tritium transport would not exceed these distances and tritium would never move off the site in an above RCG concentration.[1]

Site cleanup was performed in accordance with criteria furnished by the Division of Operational Safety, AEC/HQ (Table 3.9.3). Surveillance to locate and identify radiological contamination at the site was initiated during May 1970. Samples to verify the success of site cleanup were collected during January 1972.

TABLE 3.9.3. CLEANUP CRITERIA - TATUM DOME (from NVO-117).

Surface Water in excess of:	
300,000 Picocuries per Liter of Tritium	
Soil Above Ground Water (average depth 4 ft) in excess of:	
10^{-3} Microcuries per Gram	^3H
10^{-5} Microcuries per Gram	Beta Gamma
10^{-6} Microcuries per Gram	Alpha
0.2 Millirad per Hour Above Background	
Antimony-125 (^{125}Sb) was the Nuclide of Interest	

Permission to relax the cleanup criteria at two locations immediately adjacent to SGZ was obtained from AEC Headquarters. Contamination in these areas was only slightly higher than the criteria level, and the exceedingly muddy condition at and below the water table made contaminated soil very difficult to remove. The areas were backfilled with clean material to near original grade. The radioactive material was covered by from 7 to 12 ft of uncontaminated material.

There were no documented releases of non-radioactive hazardous substances at the Tatum Dome site.[5]

The cleanup was accomplished by: 1) sampling and analyzing soil, water, vegetation, and indigenous animal life from on-site work areas and contiguous off-site areas. Before cleanup, soil exceeding the cleanup criteria level of 1.0×10^{-5} µCi/g for gamma emitters (natural background is in the 10^{-6} µCi/g range) was essentially confined to six major areas (see Figure 3.9.9). These areas are identified as the E-6 decontamination pad, E-14 contaminated equipment storage pad, Bleed-down Plant, GZ, Drilling Equipment, Storage Yard, and the West Gate areas; 2) excavating and placing all contaminated soil and pumping all contaminated water and other contaminated fluids into the nuclear cavity; 3) sealing the cavity by plugging all drilled entry holes with cement; 4) transporting for disposal at the Nevada Test Site all remaining solids (including several types of material), equipment, debris, and other personal property either contaminated or suspected of being contaminated; and 5) demonstrating that the site had been decontaminated and restored so far as is practicable to provide reasonable assurance that unrestricted use of the site surface will cause no concern in respect to radiological considerations.[3]

Locations Where Cleanup Was Relaxed

1. Post-shot No. 1 Slush Pit

   Excavation in this area, approximately 230 ft south-southeast of SGZ, extended into the water table and because of the very muddy conditions that rapidly developed, it became impractical, if not impossible, to remove the contaminated liquid mud. The muddy conditions prevented actual removal and made the operation one of continual mixing.

   With the gamma concentration ($1\text{-}3 \times 10^{-5}$ µCi/g) near criteria levels (1×10^{-5} µCi/g) and considering the above condition, relief was requested and

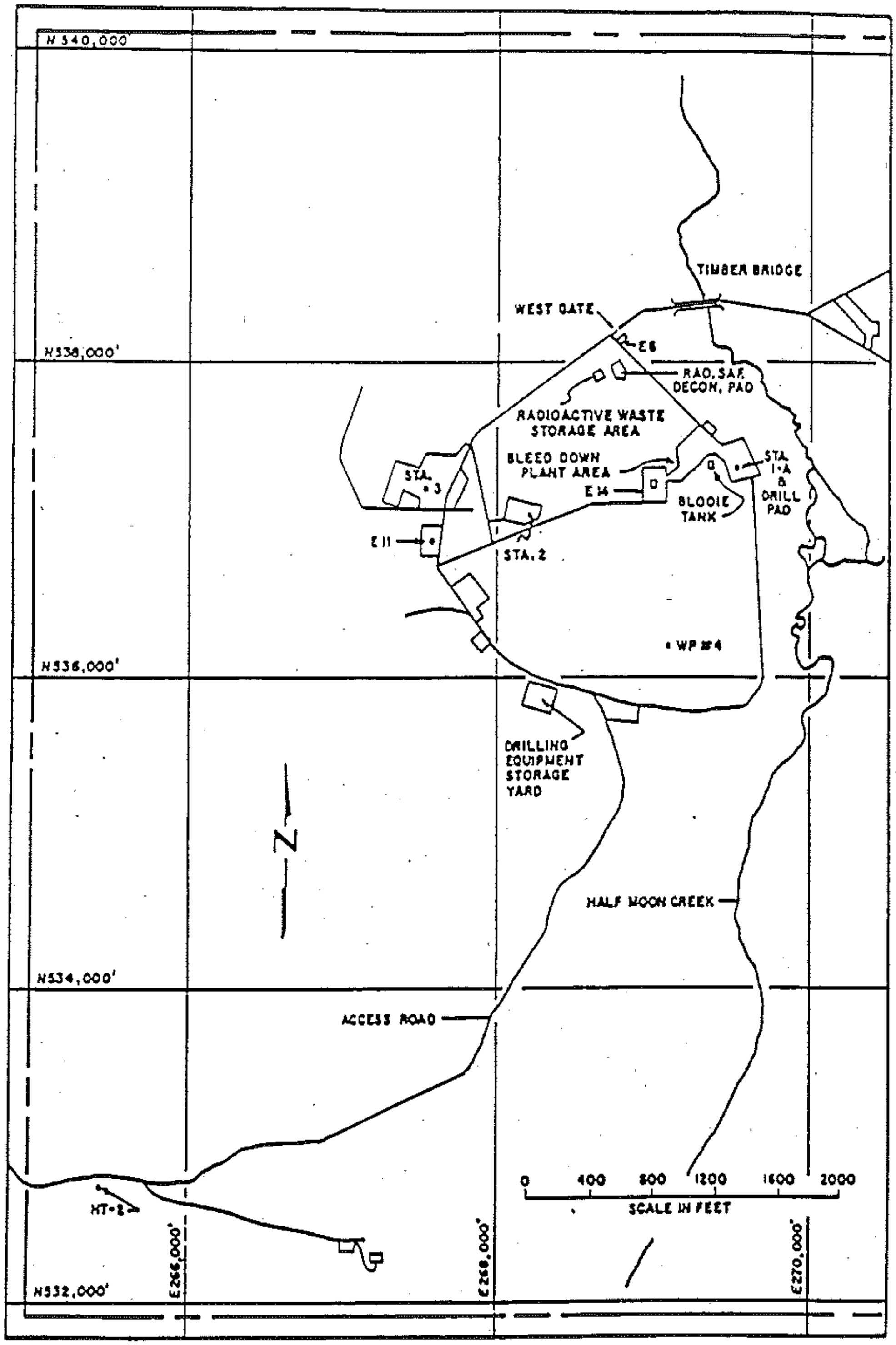


FIGURE 3.9.9. Six Areas Where Radioactivity in Soil Exceeded Criteria.

was obtained (TWX, M.B. Biles/R.E. Miller, December 17, 1971). Approval was given to backfill with clean material to near original grade. The radioactive material in the 1-3 x 10^{-5} µCi/g range was buried under approximately 7 ft of clean fill dirt.

2. Post-shot No. 1 "Mouse Hole"

   This narrow (approximately 12-in. diameter) hole, located approximately 9 ft north-northwest from SGZ, was excavated to 12 ft, the limit of the equipment used in the excavation, and penetrated the water table. To avoid a large excavation problem similar to that encountered in the slush pit, approval to backfill was requested (R.J. Catlin/D.W. Hendricks, January 14, 1972) and received.

   The hole was backfilled with uncontaminated pieces of concrete (about 4 to 6 in. in diameter), on top of which was placed a horizontal concrete slab (approximately 4 ft x 2 ft x 2 ft) and a second slab (approximately 4 ft x 2 ft x 2 ft) standing vertically. This amounted to approximately 12 ft of concrete above the bottom of the excavation. The remaining void was backfilled with clean soil and the monument slab placed on top to cover the hole.

3. Nuclear Cavity, Ground Zero

   The Station 1-A emplacement hole, Post-shot Hole No. 1, and the Post-shot Hole No. 2, all of which entered the nuclear cavity, have been plugged to the surface with concrete. Before the Station 1-A casing was plugged, approximately 10,770 cu yds of contaminated soil and 1,305,000 gallons of contaminated fluids and freshwater were disposed of into the nuclear cavity. From the recorded total volume of material, it was calculated that the top of the cavity fill would be in the vicinity of 2,705 ft below land surface. This was confirmed when the cavity fill was tagged at 2,704 ft.

   The above volumes are estimated to occupy approximately 57 percent of the available cavity volume. A concrete slab, approximately 6 ft x 14 ft x 6 in. thick, was poured to cover the top of the casing of Station 1-A and Post-shot Hole No. 1, as well as the Post-shot No. 1 "Mouse Hole."

After cleanup, soil samples were collected from the surface by augering to appropriate depths. Analytical results generally ranged from 1×10^{-5} µCi/g, ^{125}Sb down to background levels. The majority of the samples averaged about 2×10^{-6} µCi/g, ^{125}Sb for all areas except two. The Post-shot No. 1 Slush Pit at the south end of the GZ area was determined to have local spots containing levels of ^{125}Sb up to 3.0×10^{-5} µCi/g at depths of 7 to 9 ft below grade.

The Post-shot No. 1 "Mouse Hole" was also found to be above the criteria level of (1×10^{-5} µCi/g) having levels of - 3.0×10^{-3} µCi/g at 12 ft.

Portable instrument surveys of all decontaminated areas, measured at 1 cm above the ground with an instrument whose detector window was less than 7 mg/cm^2, indicated no radioactivity levels exceeding 0.05 mrad/hr.

As a result of injection of radioactive wastewater in Aquifer 5 (HT-2), contamination of Aquifer 5 (saline) has occurred.

Hole HT-2m was plugged from land surface to total depth during August 1975.

Since cleanup and decommissioning operations, tritium has been found in the shallow water table and the local aquifer. The tritium is believed to be derived from tritium in the soil from surface disposal operations and leakage along casings of wells completed in the local aquifer. A program was developed by the Physical and Life Sciences Division, NV, and concurred in by the Mississippi Board of Health, Radiological Health Division, to investigate the anomalous tritium found in soil moisture and shallow ground water in the Salmon/Sterling GZ area.

The primary objective of this program was to determine the source of the radiological contaminant. Secondarily, the program was to define the location of tritium at the various concentrations present over the project area.

The program was also to provide permanent shallow ground-water monitoring points that will provide an "early warning" system for movement of contamination in shallow ground water.

The program was conducted in the field from September 12 to 19, 1977 and from April 18 to 27, 1978.

Equipment to extract moisture from soil samples and to analyze that fluid for tritium was established and staffed by the EPA at the University of Southern Mississippi in Hattiesburg, Mississippi.

A rectangular area that overlaid Post-shot Holes 1 and 2, SGZ, and the unlined slush pond known to have contained contaminated fluids during the drillback operations was surveyed. A 25-ft grid was laid out over the rectangular area. A 50-ft grid was laid out over an area 100 ft beyond the initial rectangular area and a 100-ft grid was laid out beyond that covering the remaining GZ area not covered by swamp or dense vegetation.

Four in. diameter holes were augered to the water table on the 25-, 50-, and 100-ft grids. Additional holes were augered where analytical results indicated they were needed.

Water Table Samples

Water samples were collected from all holes that penetrated the water table upon their completion for immediate, on-site, conductivity, pH, and tritium analysis. Splits of all water samples were given to the Mississippi Division of Radiological Health.

Soil Samples

Soil samples were collected at 1-ft intervals during drilling of holes in the 25-ft grid and at 2-ft intervals in holes in the 50- and 100-ft grids. The soil moisture was extracted from these samples and analyzed for tritium. Soil samples were retained so that grain size analyses could be performed on selected zones. Samples analyzed at the project site were recounted in the EPA Las Vegas Laboratory. Analyses for other radionuclides were performed at the EPA Las Vegas Laboratory. The locations were marked and all holes were filled in when the augering program was completed. Splits of all soil samples were given to the Mississippi Division of Radiological Health.

Results From the Shallow Augered Holes[2]

The holes were augered in a reddish soil a few inches thick, in part containing well-rounded gravels up to an inch in diameter. This generally overlaid orange, red, and brown clay layers each a few inches thick. Near the water table, a very fine white unconsolidated sand occurred in some holes. In some holes, stratification was not apparent.

Holes were augered to the water table on the sample grid, outward from GZ until water samples from the holes were found to contain only background concentrations of tritium. Contour maps of the area were prepared based on tritium concentrations in ground water and on electrical conductance of the ground water. Electrical conductance is a measure of dissolved salt content. The contour map of tritium at and above 5,000 pCi/liter and the contour map of electrical conductance at and above 500 micromhos/cu cm are very similar. The source for tritium and salinity in soil moisture and ground water appear to be the same, adjacent to SGZ, and to have been acted upon by the same dispersive forces which have caused both contaminants, tritium, and salt to migrate mostly to the north and south of SGZ and to a lesser extent to the east and west.

The area contaminated by tritium at the water table is well defined. It is best described as an irregularly shaped area elongated along its north–south axis. It is approximately 1,225 ft long by 960 ft wide. SGZ is located slightly east of center of the contoured area.

Within this area, there are five locations that equal or exceed 20,000 pCi of tritium/liter. The largest covers SGZ and is roughly pyramidal in shape. The five areas combined cover approximately 87,360 ft^2, or 2 acres. Tritium concentrations in the shallow ground water varied from <300 to 560,000 pCi/liter.

Tritium concentrations in soil moisture ranged from <300 pCi/liter, considered to be natural background, on the periphery of the area sampled to 1,000,000 pCi/liter in one hole adjacent to SGZ.

Of the 171 holes that were augered during the investigative program, 167 holes encountered the water table. More than one soil sample was collected from each of 125 holes.[2]

Data derived from the analyses of these water and soil samples appears in some respects to be without pattern. In 45.3 percent of these holes, the soil moisture above the water table held a higher tritium concentration than did water below the water table. In 47.4 percent, the situation was reversed. The tritium concentration in ground water and soil moisture was the same in 7.3 percent of the holes.

In 52 percent of the holes, tritium in soil moisture increased with depth. In 24.4 percent of the holes, soil moisture from samples collected nearer the surface and at total depth contained less tritium than did the middle section. In 8.9 percent of the holes, the highest tritium levels were found in the upper part of the section. In 8.9 percent of the holes, the tritium concentration in soil moisture did not change from the top to the bottom of the hole. In 5.7 percent of the holes, the lower tritium concentrations were found in soil moisture from the midsection of the hole.

Water samples with higher tritium concentrations were analyzed for other radionuclides by gamma spectroscopy. None but naturally occurring radionuclides were observed.[2]

Based upon estimated ground-water velocities, it has been predicted that "there is no probability that tritium in the local aquifer will ever leave the site boundaries of the Tatum Dome test site."[1]

POTENTIAL FOR DIRECT CONTACT OR FIRE/EXPLOSION HAZARD

All radioactive waste at the surface facilities is at least 7 to 9 ft below land surface. All boreholes completed to the cavity have been sealed. Tritium in surface waters has not exceeded drinking water standards to date (C. Costa, personal communication EPA/EMSL). The possibility of buried radioactive material being exhumed is unlikely. The area is presently believed to be used for hunting.

POTENTIAL FOR GROUND-WATER RELEASE

Tritium has been found in Aquifer 5, the "local" aquifer, and the shallow water table. NVO-225 indicates that tritium will not migrate off-site in quantities to exceed drinking water standards due to the low velocity and radioactive decay. No drinking water wells are located on the site.

The potential migration of tritium, as well as antimony-125, appears small. Long-term hydrologic monitoring is continuing to determine if migration has occurred off-site. Figures 3.9.10, 3.9.11, and 3.9.12 show the wells currently part of the long-term hydrologic monitoring program (LTHMP). Table 3.9.4 shows the tritium levels during 1985.[6] The results show elevated tritium in several surface waters (Half Moon Creek Overflow, REECo Drainage Pit), and several monitoring wells (HM-L, HM-S, HMH-1, HMH-2, HMH-5, and HMH-11). Offsite wells have shown levels of tritium representative of background (post-1950's) tritium.[6]

The potential for off-site migration of tritium is believed low. Decay of tritium, combined with slow travel times and a routine monitoring program, signifi-

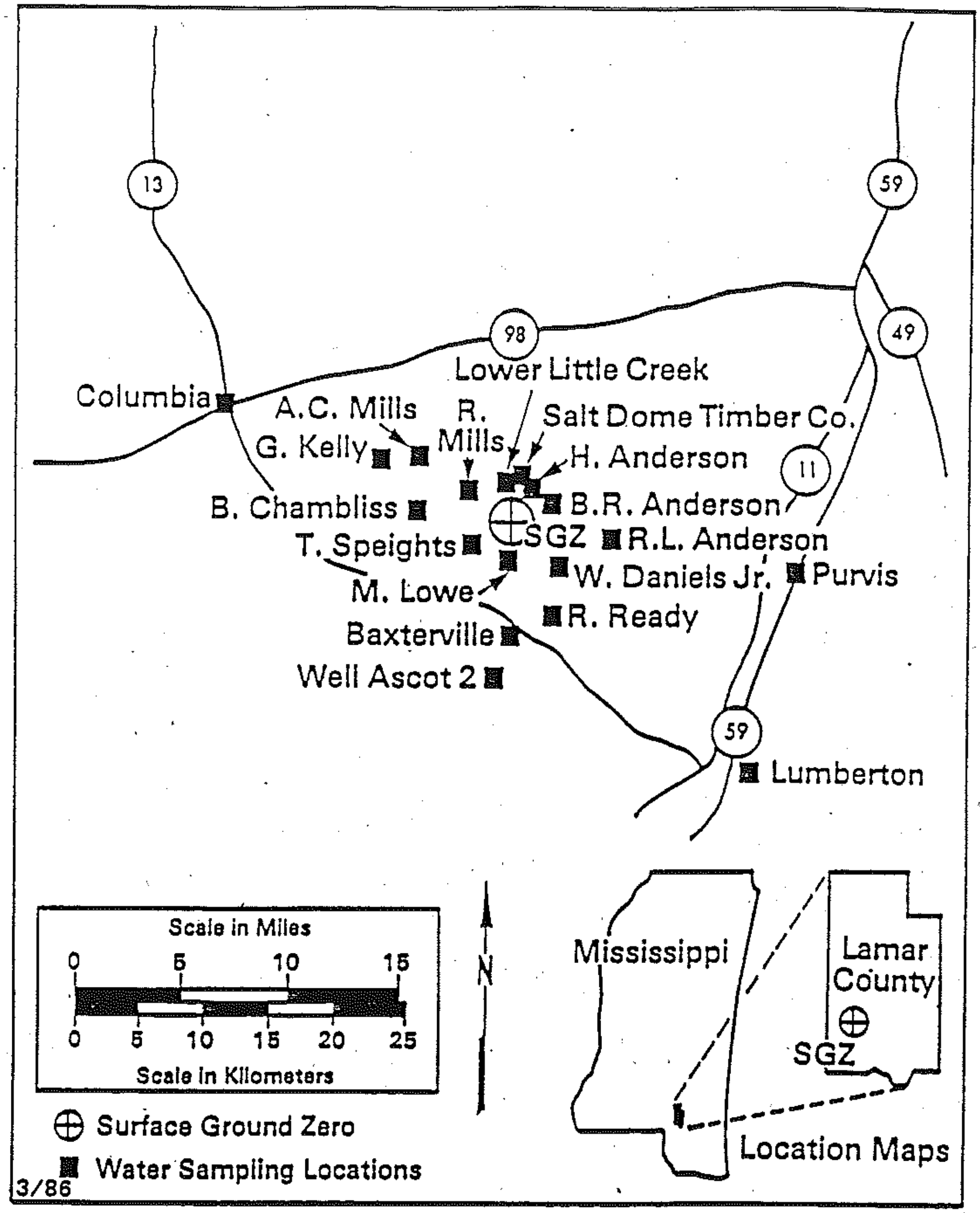


FIGURE 3.9.10. LTHMP Sampling Locations for Tatum Dome Site - Towns and Residences.

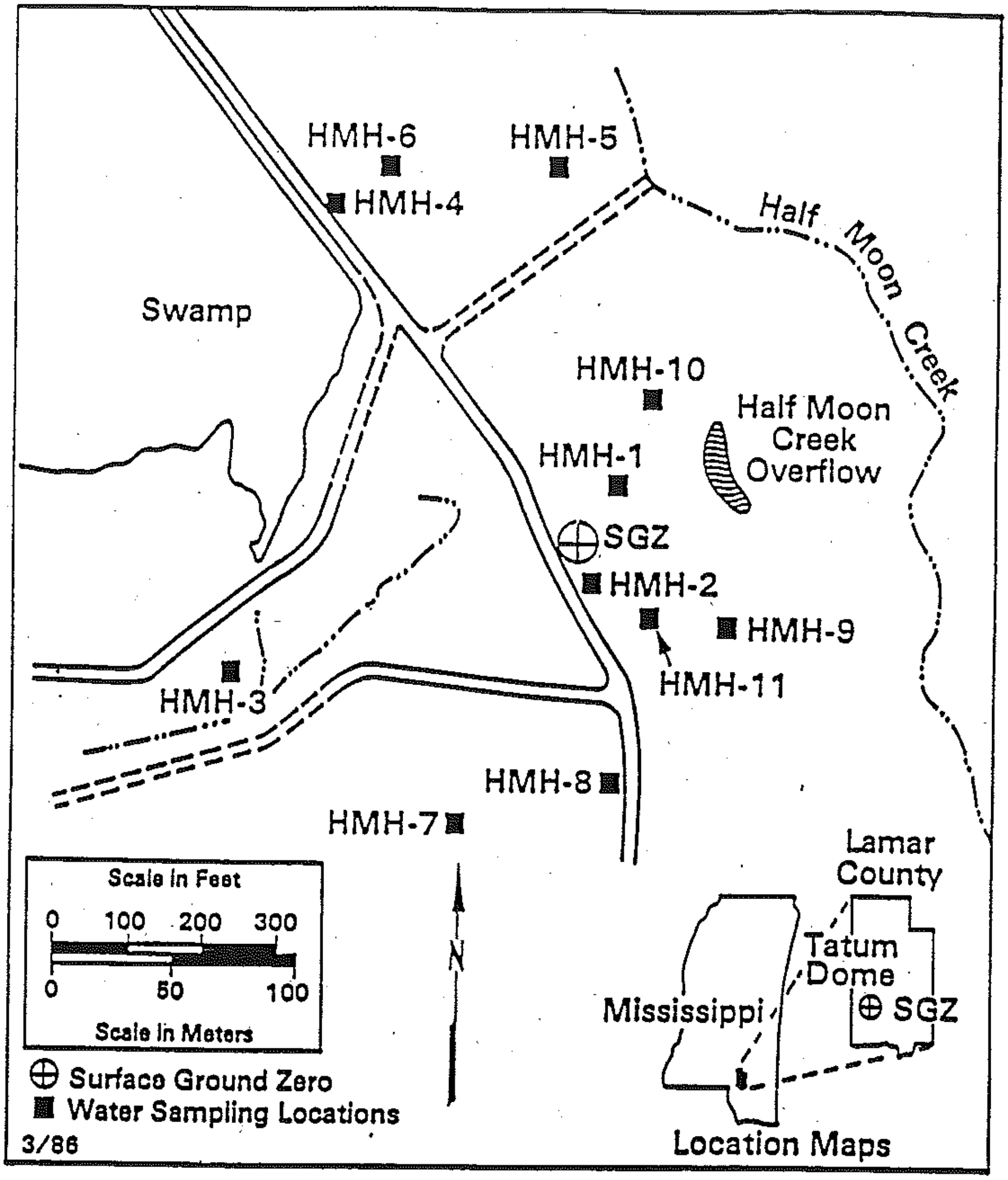


FIGURE 3.9.11. LTHMP Sampling Locations for Tatum Dome – Near GZ.

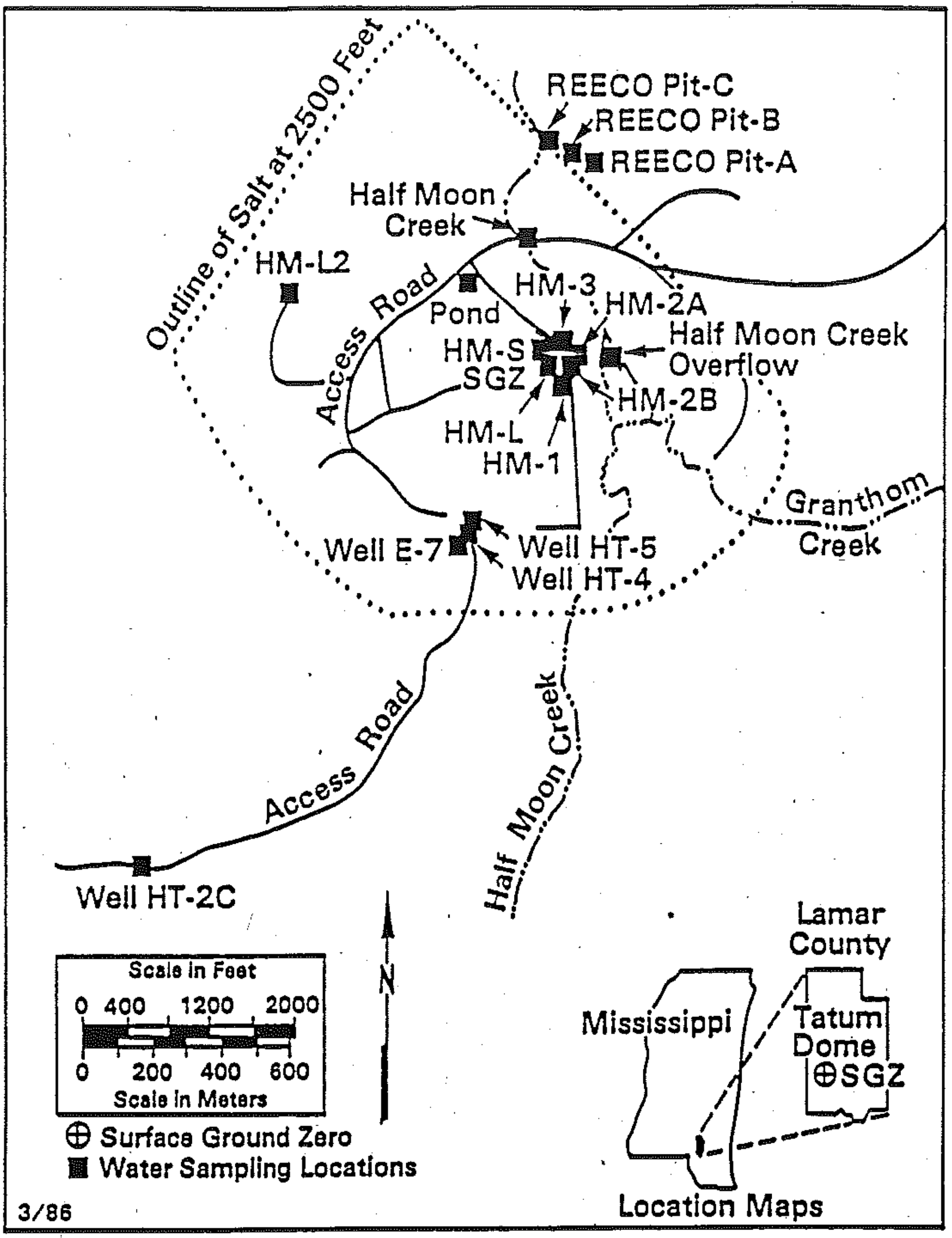


FIGURE 3.9.12. LTHMP Sampling Locations for Tatum Dome - Near Salt Dome.

TABLE 3.9.4. 1985 LTHMP WATER SAMPLES FOR TATUM DOME SITE.

Sampling Location	Collection Date 1985	Conc. ± 2 Sigma Tritium (pCI/L)	PCT of Conc. Guide
Baxterville, MS			
Half Moon Creek	04/03	36 ± 7	0.2
	04/03	3.6 ± 8.9*	0.02
Half Moon Creek Overflow	04/03	800 ± 12	4
	04/03	840 ± 12	4
Lower Little Creek	04/03	16 ± 8	0.08
	04/03	21 ± 9	0.1
Pond West of GZ	04/03	11 ± 9*	0.06
	04/03	14 ± 8	0.07
ReeCo Pit Drainage - A	04/03	62 ± 9	0.3
ReeCo Pit Drainage - B	04/03	2800 ± 200	10
ReeCo Pit Drainage - C	04/03	36 ± 9	0.2
Salt Dome Timber Co.	04/04	30 ± 9	0.2
Anderson, B.R.	04/04	42 ± 7	0.2
Anderson, H.	04/04	27 ± 7	0.1
Anderson, R.L.	04/03	34 ± 8	0.2
	04/03	42 ± 9	0.2
Chambliss, B.	04/03	−3.6 ± 8.4*	<0.01
Daniels, W., Jr.	04/03	36 ± 8	0.2
Kelly, G.	04/03	−6.9 ± 11*	<0.01
Lee, P.T.	04/04	35 ± 9	0.2
Mills, A.C.	04/03	−0.38 ± 8.1*	<0.01
Mills, R.	04/03	26 ± 8	0.1
Ready, R.	04/03	59 ± 9	0.3
Well Ascot 2	04/05	−23 ± 10*	<0.01
Well City	04/03	21 ± 8	0.1
Well E-7	04/04	−7.0 ± 12*	<0.01
Well HM-1	04/03	−14 ± 9*	<0.01
	04/03	−7.8 ± 9.4*	<0.01
Well HM-2a	04/03	−12 ± 9*	<0.01
	04/03	−13 ± 9*	<0.01
Well HM-2b	04/03	−12 ± 10*	<0.01
	04/03	−16 ± 10*	<0.01

TABLE 3.9.4. (continued).

Sampling Location	Collection Date 1985	Conc. ± 2 Sigma Tritium (pCI/L)	PCT of Conc. Guide
Baxterville, MS			
Well HM-3	04/03	−11 ± 10*	<0.01
	04/03	−19 ± 10*	<0.01
Well HM-L	04/03	1800 ± 180	9
	04/03	1400 ± 180	7
Well HM-L2	04/03	−21 ± 10*	<0.01
	04/03	66 ± 180*	0.3
Well HM-S	04/03	14000 ± 270	70
	04/03	14000 ± 270	70
Well HMH-1	04/03	18000 ± 300	90
Well HMH-2	04/03	13000 ± 270	70
Well HMH-3	04/03	81 ± 7	0.4
Well HMH-4	04/03	28 ± 7	0.1
Well HMH-5	04/03	1800 ± 200	9
Well HMH-6	04/03	99 ± 8	0.5
Well HMH-7	04/03	260 ± 10	1
Well HMH-8	04/03	34 ± 7	0.2
Well HMH-9	04/03	22 ± 7	0.1
Well HMH-10	04/03	25 ± 7	0.1
Well HMH-11	04/03	1100 ± 190	6
Well HT-2c	04/04	−4.6 ± 8.8*	<0.01
Well HT-4	04/04	−17 ± 9*	<0.01
Well HT-5	04/04	−27 ± 11*	<0.01
Well PS-3	04/05	20 ± 8	0.1
Columbia, MS			
Well 64B City	04/04	−5.0 ± 9.3*	<0.01
Lumberton, MS			
Well 2 City	04/04	−12 ± 10*	<0.01
Purvis, MS			
City Supply	04/03	−17 ± 10*	<0.01

*below detection standards

cantly reduces the possibility of off-site migration in the upper aquifers. Migration of wastes injected into Aquifer 5 is also not deemed a significant threat due to decay. Contamination of Aquifer 4 by saline waters of Aquifer 5 via monitoring wells is possible.[1]

POTENTIAL FOR SURFACE WATER RELEASE

Although surface water is ubiquitous at the site, significant contamination of surface water from contaminated soil and subsurface materials is unlikely due to dilution. Surface waters are part of the long-term hydrologic monitoring program and have not shown tritium concentrations approaching drinking water standards. Surface water is not used for municipal water supplies in the area of the site and it is believed that all private drinking water is supplied by ground water.

POTENTIAL FOR AIR RELEASE

With the plugging of all holes penetrating the cavity and the burying of hot spots, the potential for air release from either subsurface or surface activities is minimal.[3]

THREATS TO THE FOOD CHAIN OR ENVIRONMENT

Due to the depth at which radioactive materials remain on the site and the very low levels of tritium found in surface waters at the site, threats to the food chain or environment should be low. Tritium may be uptaken by plants in excess of drinking water standards, however. This could then be introduced into the human food chain through hunting of animals.

CONCLUSION AND RECOMMENDATIONS

There appears to be only a limited threat to the environment in the form of ground-water migration of tritium and possibly brine into the usable aquifers. The long-term hydrologic monitoring program undertaken by DOE, EPA, and the Mississippi Department of Health will determine if migration occurs and will develop strategies to reduce its impacts.

A preliminary HRS score has been developed for this site based upon the data presented in this Preliminary Assessment and is included in Appendix 3.9.A. The score was 20.68.

In all routing cases, the maximum score of 26 was used for waste characterization. Exact location data were not available to precisely determine distance from known ground-water contamination to nearest water supply well. A conservative estimate of 0.5 miles was used for the scoring purposes.

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APPENDIX 3.9.A
HRS WORKSHEETS
TATUM DOME SITE

FIRE AND EXPLOSION WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi- plier	Score	Max. Score	Ref. (Section)
1 Containment	(1) 3	1	1	3	7.1
2 Waste Characteristics					7.2
Direct Evidence	(0) 3	1	0	3	
Ignitability	(0) 1 2 3	1	0	3	
Reactivity	(0) 1 2 3	1	0	3	
Incompatibility	(0) 1 2 3	1	0	3	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			8	20	
3 Targets					7.3
Distance to Nearest Population	0 1 (2) 3 4 5	1	2	5	
Distance to Nearest Building	0 (1) 2 3	1	1	3	
Distance to Sensitive Environment	(0) 1 2 3	1	0	3	
Land Use	0 1 2 (3)	1	3	3	
Population Within 2-Mile Radius	0 1 (2) 3 4 5	1	2	5	
Buildings Within 2-Mile Radius	0 1 (2) 3 4 5	1	2	5	
Total Targets Score			10	24	
4 Multiply 1 x 2 x 3			80	1,440	
5 Divide line 4 by 1,440 and multiply by 100			S_{FE} = 5.56		

DIRECT CONTACT WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	8.1

If observed release is given a score of 45, proceed to line 4.

If observed release is given a score of 0, proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Accessibility	0 1 2 (3)	1	3	3	8.2
3 Containment	0 (15)	1	15	15	8.3
4 Waste Characteristics					8.4
Toxicity	0 1 2 (3)	5	15	15	
5 Targets					8.5
Population Within a 1-Mile Radius	0 (1) 2 3 4 5	4	4	20	
Distance to a Critical Habitat	(0) 1 2 3	4	0	12	
Total Targets Score			4	32	
6 If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			2,700	21,600	
7 Divide line 6 by 21,600 and multiply by 100			S_{DC} = 12.50		

GROUND WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi- plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 45	1	45	45	3.1
If observed release is given a score of 45, proceed to line 4.					
If observed release is given a score of 0, proceed to line 2.					
2 Route Characteristics					3.2
Depth to Aquifer of Concern	0 1 2 3	2		6	
Net Precipitation	0 1 2 3	1		3	
Permeability of the Unsaturated Zone	0 1 2 3	1		3	
Physical State	0 1 2 3	1		3	
Total Route Characteristics Score				15	
3 Containment	0 1 2 3	1		3	3.3
4 Waste Characteristics					3.4
Toxicity/Persistence	0 3 6 9 12 15 18	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1	8	8	
Total Waste Characteristics Score			26	26	
5 Targets					3.5
Ground Water Use	0 1 2 3	3	9	9	6
Distance to Nearest Well/Population Served	0 4 6 8 10 12 16 18 20 24 30 32 35 40	1	8	40	8
Total Targets Score			17	49	
6 If line 1 is 45, multiply 1 x 4 x 5					
If line 1 is 0, multiply 2 x 3 x 4 x 5			19,890	57,330	
7 Divide line 6 by 57,330 and multiply by 100			S_{gw} = 34.7		

SURFACE WATER ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	4.1

If observed release is given a score of 45, proceed to line 4.

If observed release is given a score of 0, proceed to line 2.

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
2 Route Characteristics					4.2
Facility Slope and Intervening Terrain	(0) 1 2 3	1	0	3	
1-yr. 24-hr. Rainfall	0 1 2 (3)	1	3	3	
Distance to Nearest Surface Water	0 1 2 (3)	2	6	6	
Physical State	0 1 2 (3)	1	3	3	
Total Route Characteristics Score			12	15	
3 Containment	0 1 2 (3)	1	3	3	4.3
4 Waste Characteristics					4.4
Toxicity/Persistence	0 3 6 9 12 15 (18)	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 (8)	1	8	8	
Total Waste Characteristics Score			26	26	
5 Targets					4.5
Surface Water Use	(0) 1 2 3	3	0	9	
Distance to a Sensitive Environment	0 1 2 (3)	2	6	6	
Population Served/ Distance to Water Intake Downstream	(0) 4 6 8 10 12 16 18 20 24 30 32 35 40	1	0	40	
Total Targets Score			6	55	
6 If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			5,616	64,350	
7 Divide line 6 by 64,350 and multiply by 100			S_{SW} = 8.72		

AIR ROUTE WORK SHEET

Rating Factor	Assigned Value (circle one)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	5.1
Date and Location:					
Sampling Protocol:					
If line 1 is 0, the $S_a = 0$. Enter on line 5. If line 1 is 45, then proceed to line 2.					
2 Waste Characteristics					5.2
Reactivity and Incompatibility	0 1 2 3	1		3	
Toxicity	0 1 2 3	3		9	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1		8	
Total Waste Characteristics Score				20	
3 Targets					5.3
Population Within 4-Mile Radius	0 9 12 15 18 21 24 27 30	1		30	
Distance to Sensitive Environment	0 1 2 3	2		6	
Land Use	0 1 2 3	1		3	
Total Targets Score				39	
4 Multiply 1 x 2 x 3				35,100	
5 Divide line 4 by 35,100 and multiply by 100		$S_a = 0$			

HRS SCORE

$S_{gw} = 34.7$

$S_{sw} = 8.72$

$S_a = 0$

$$S_m = \frac{1}{1.73}\sqrt{(34.7)^2 + (8.72)^2 + (0)^2}$$

$$S_m = 20.68$$

$S_{FE} = 5.56$

$S_{DC} = 12.50$

SECTION 3.10

COVER SHEET

NAME OF SITE: Area 13

LOCATION: Area 13 is located in southern Nevada. The size of the area is not specified, but it is centered around 115°30′ longitude and 37°11′ latitude.

DISPOSITION: Area 13 is the location of a one time safety-shot. The use of this area beyond this experiment is not available.

PRELIMINARY ASSESSMENT REPORT
AREA 13, PROJECT 57 #1

INTRODUCTION

Project 57 #1 is the name given to a "safety-shot" conducted on April 24, 1957. This test involved the non-nuclear destruction of a plutonium bearing device with chemical explosives. Its purpose was to test the safety of atomic weapons in accident situations. Most data on the area was found to be classified and/or unavailable.

OVERALL FACILITY DESCRIPTION

The size of Area 13 is not discussed in unclassified documents.

Area 13 is considered part of NTS, however, it is located on the Nellis Air Force Range North (Figure 3.10.1).

ENVIRONMENTAL SETTING

Area 13 is surrounded by the Nellis Air Force Range, which has restricted access. This site lies 4 miles to the north of Nevada Test Site which also has restricted access. No known federally listed endangered or threatened species inhabit Area 13. Gilia nyensis, which has been found in Area 13, is a species of concern and its classification may change.[2]

The closest National Monument is Death Valley National Monument. It is located 100 miles to the southwest of Area 13 (Figure 3.10.1).

HYDROLOGIC SUMMARY

Little is known of the hydrology in this basin. Three wells were drilled in the late 1950's. The well logs were not available for this report.[5]

The precipitation pattern in Nevada is principally related to topography. Stations at higher elevations generally receive more precipitation than those at lower elevations. On the valley floors, where precipitation is small, little precipitation infiltrates into the ground-water reservoirs. The greater precipitation in the mountains provides most of the recharge. Water reaches the ground-water reservoirs by seepage loss from streams on the alluvial apron and by underflow from the con-

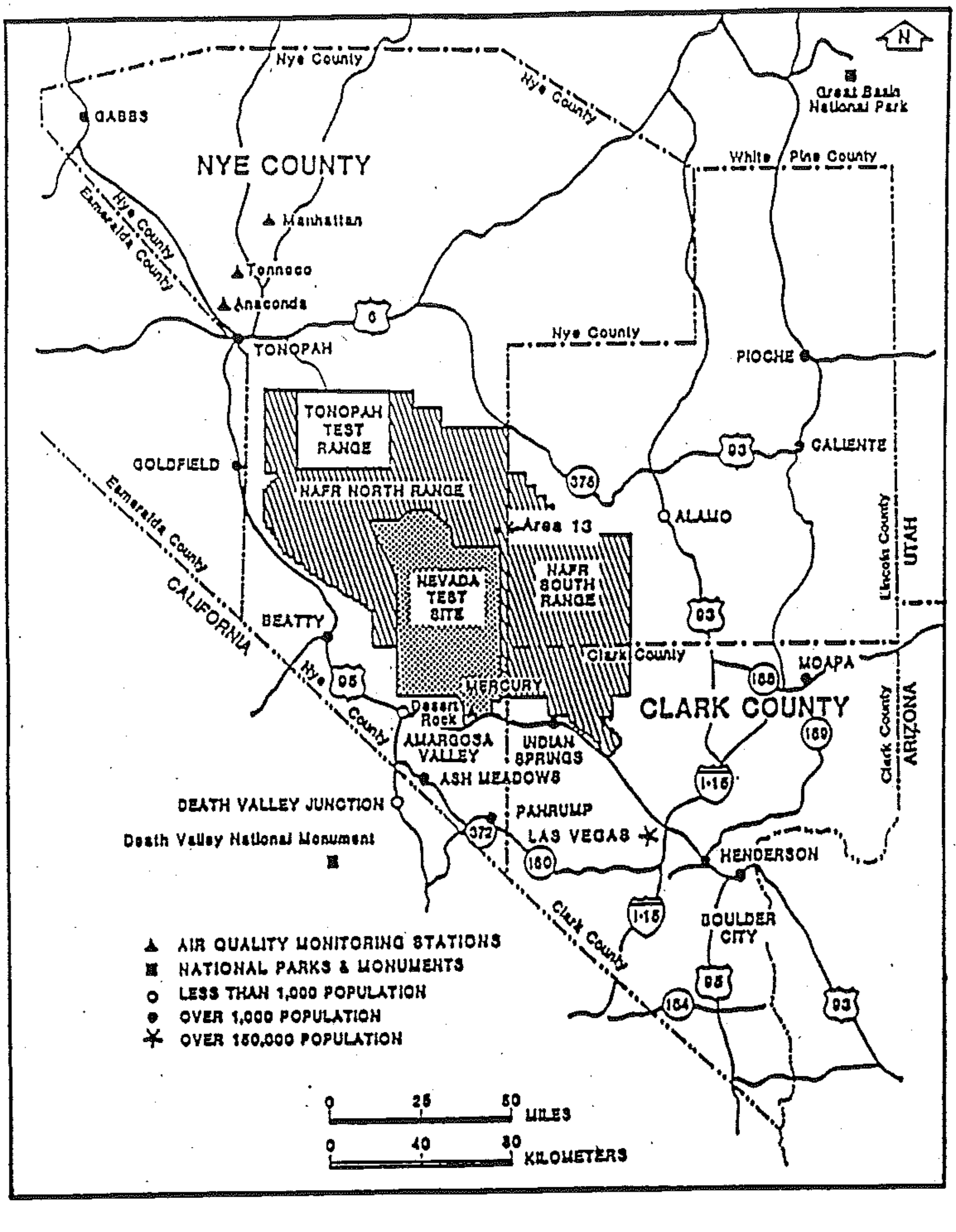


FIGURE 3.10.1. Location Map of Area 13.

solidated rocks. Most of the precipitation is evaporated before infiltration, though some temporarily adds to soil moisture at shallow depths.

There are no data available for meteorological conditions in Area 13 or Emigrant Valley which contains Area 13. However, Yucca Flat has a class 1 weather station. Table 3.10.1 presents a 10-year precipitation summary for Yucca Flat, which lies 10 miles to the southwest of Area 13.

HUMAN RECEPTORS

There are no known permanent residents within Emigrant Valley. However, significant daily use for defense-related activity may occur within a four-mile radius of Area 13.

Three known wells were drilled in Emigrant Valley. These are Watertown 1 through 3. Only one of these wells is located within 4 miles of Area 13. Watertown 3 is located about 3 miles from ground zero (GZ) of Project 57. The other two Watertown wells are located within a seven-mile radius of GZ. Data on the use of all of these wells is not available.

ENVIRONMENTAL RECEPTORS

The predominant vegetation type found in Area 13 are members from the Salt Desert Shrub community. These plant communities are found primarily in valley bottoms and include White Sage, Shadscale, Four-winged Saltbush, Barley's Greasewood. Spring Hopsage, Russian Thistle, Black Sagebrush, and Bud Sage.[2]

The predominant animal species found in an environment is largely dictated by the plant community. Table 3.10.2 shows the animal species that are expected in Area 13.[2]

WASTE GENERATION AND DISPOSAL

The amounts of plutonium and other transuranics used in Project 57 are classified information. There were no cleanup or disposal measures taken, however, experiments were conducted in Area 13 in an attempt to find the best methods to stabilize the contaminant from resuspension.[8]

KNOWN RELEASES

Off-site radiological surveys were conducted for Project 57. High volume air sampling stations were placed in various communities around the Bombing Range

TABLE 3.10.1. PRECIPITATION SUMMARY FOR YUCCA FLAT.

	Precipitation (inches)											
								Snow				
	Greatest Average	Least Monthly	Yr.	Greatest Monthly	Yr.	Least Daily	Yr.	Greatest Average	Least Monthly	Yr.	Daily	Yr.
January	0.53	4.02	1969	T	1971	1.25	1969	0.9	4.3	1962	4.3	1962
February	0.84	3.55	1969	T	1967	1.16	1969	1.9	17.4	1969	6.2	1969
March	0.29	0.60	1969	0.02	1966	0.38	1969	2.0	7.5	1969	4.5	1969
April	0.45	2.57	1965	T	1962	1.08	1965	0.7	3.0	1964	3.0	1964
May	0.24	1.62	1971	T	1970	0.86	1971	0	T	1964	T	1964
June	0.21	1.13	1969	T	1971	0.45	1969	0	0		0	
July	0.52	1.34	1966	0	1963	0.77	1969	0	0		0	
August	0.34	1.04	1965	0	1962	0.35	1971	0	0		0	
September	0.68	2.38	1969	0	1968	2.13	1969	0	0		0	
October	0.13	0.45	1969	0	1967	0.42	1969	0	T	1971	T	1971
November	0.71	3.02	1965	0	1962	1.10	1970	0.5	4.8	1964	2.3	1964
December	0.79	2.66	1965	T	1969	1.31	1965	2.3	9.9	1971	7.4	1971
ANNUAL	5.73	4.02	1969	0	1968	2.13	1969	8.3	17.4	1969	7.4	1971

TABLE 3.10.2. WILDLIFE OF AREA 13.

Predomiant	Salt Desert Shrub
Lizards	
Callisaurus draconoides (Zebra-tailed Lizard)	X
Phrynosoma platyrhinos (Desert Horned Lizard)	X
Sceloporus occidentalis (Western Fence Lizard)	X
Uta stansburiana (Side-blotched Lizard)	X
Cnemidophorus tigris (Whip-tailed Lizard)	X
Birds	
Amphispiza nevadensis (Sage Sparrow)	X
Amphispiza bilineata (Black-throated Sparrow)	X
Carpodacus mexicanus (House Finch)	X
Erimphila alpestris (Horned Lark)	X
Gymnorphinus cyanocephalus (Pinyon Jay)	X
Zenaidura macroura (Mourning Dove)	X
Mammals	
Rodents	
Microdipodops megacephalus (Dark Kangaroo Mouse)	X
Microdipodops pallidus (Pale Kangaroo Mouse)	X
Thomomys bottae (Valley Pocket Gopher)	X
Microtus longicaudus lathus (Long-tailed Meadow Mouse)	X
Rabbits	
Lepus califromicus (Jackrabbit)	X
Carnivores	
Canis latrans (Coyote)	X
Vulpes macrotis (Kit Fox)	X
Lynx rufus (Bobcat)	X
Large Mammals	
Odocoileus hemionus (Mule Deer)	X

TABLE 3.10.2. (continued).

Predomiant	Salt Desert Shrub
Antilocarpa americana (American Pronghorn)	X
Ovis canadensis (Desert Bighorn Sheep)	X
Equus caballus (Horses)	X
Equus asinus (Burros)	X

complex. From these surveys, off-site radiation was detected at the Lincoln Mine (Tempiute) which is located 25 miles to the north. The accumulated alpha activity in the air for the day of the test was 6 disintegrations/min/cu m of air (d/m/m³). One other station, Caliente, Nevada, received the accumulation of 1.05 d/m/m³ on the day of the test.[8]

In 1972, a program was developed to estimate the amounts of plutonium and americium in the soil at area 5. First a FIDLER* survey was performed. From this survey six isopleths were constructed of varying contamination levels (Figure 3.10.2). The results of this survey were used in designing a soil sampling program. The wet chemistry plutonium determination from the soil sampling program are presented in Figures 3.10.3 and 3.10.4. The FIDLER survey and the soil sample analysis were then coupled to estimate the amount of plutonium present in the top 5 cm of the soil. These estimates are presented in Table 3.10.3.[4]

POTENTIAL FOR DIRECT CONTACT OR FIRE/EXPLOSION

Figure 3.10.3 indicates that the area contaminated by Project 57 is fenced, however, available literature does not support this. Since the use of this area is unknown, the potential for direct contact cannot be made.

POTENTIAL FOR GROUND-WATER RELEASE

The GZ of Project 57 is located 5 miles to the northwest of Groom Lake. This playa lake is classified as a recharge playa.[1] Several ephemeral channels cross the contaminated area and then terminate in this playa. The potential for recharge to the ground-water system through the playa or ephemeral channels does exist.

WELLS WITHIN A FOUR-MILE RADIUS

Only one well is shown on the Groom Mine, 15′ quadrangle map. This well is 3 miles from GZ. Also shown at about 2 miles from GZ is a water tank. The current status and use of these facilities is unknown. Also located within 5 miles are the 3 Watertown wells.[5] The status and use of these wells is also unknown.

* Field instrument for the detection of low energy radiation.

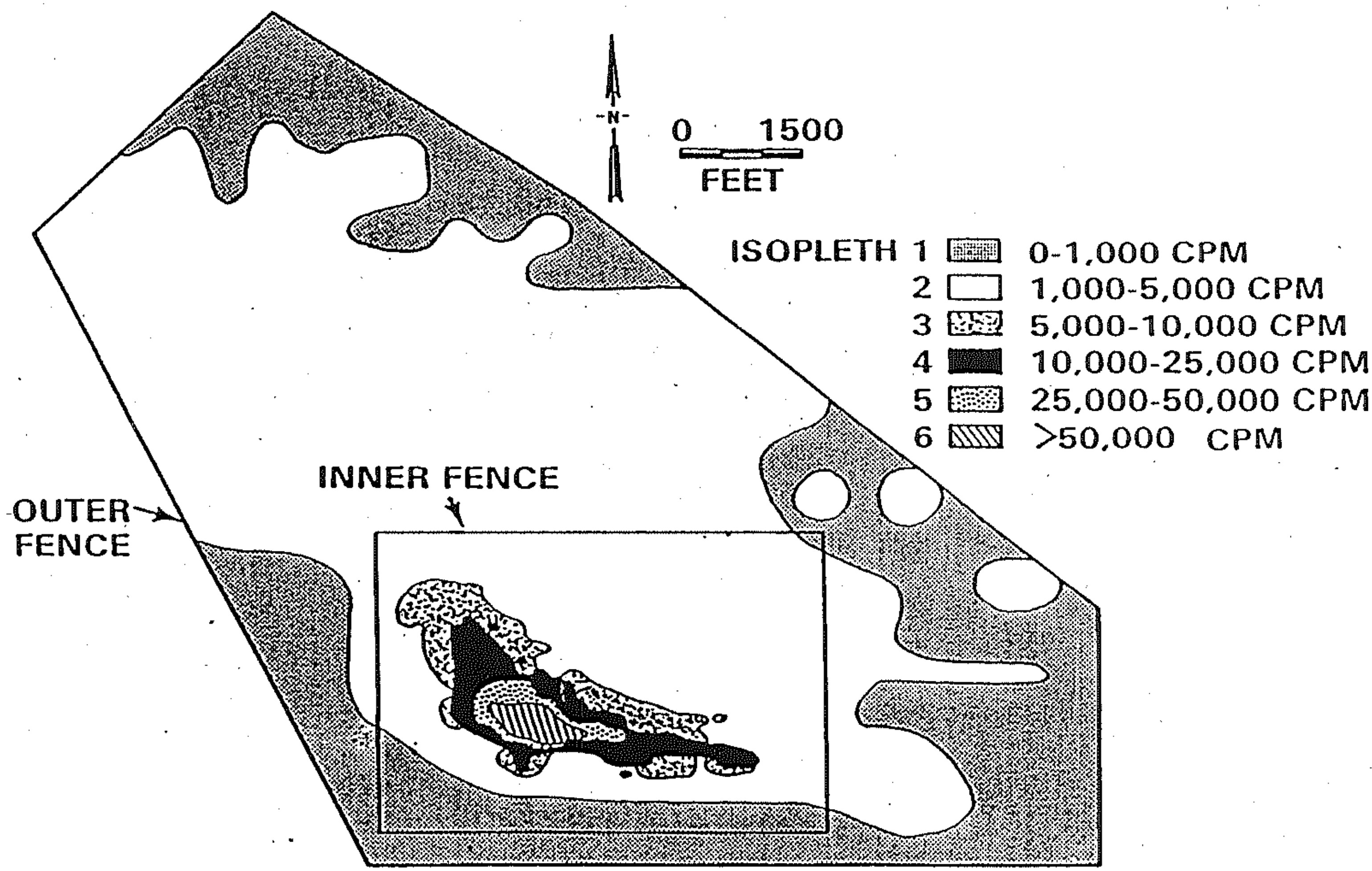


FIGURE 3.10.2. Strada used for Sampling as Determined by FIDLER Survey.

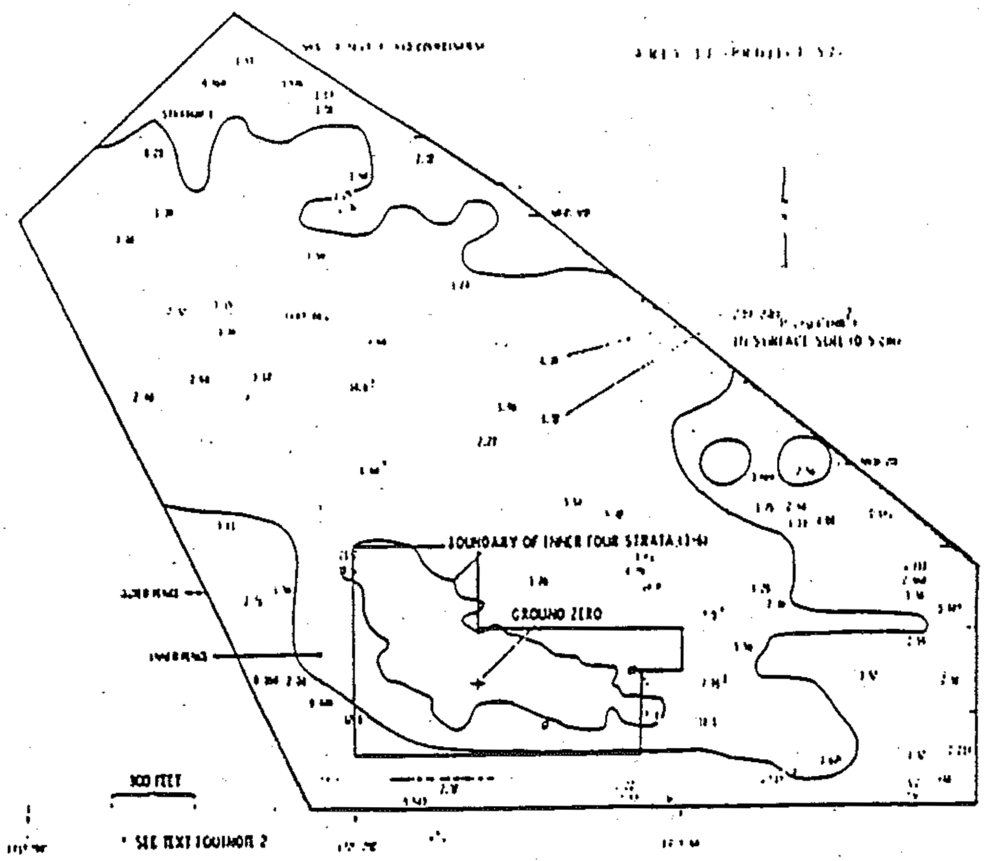
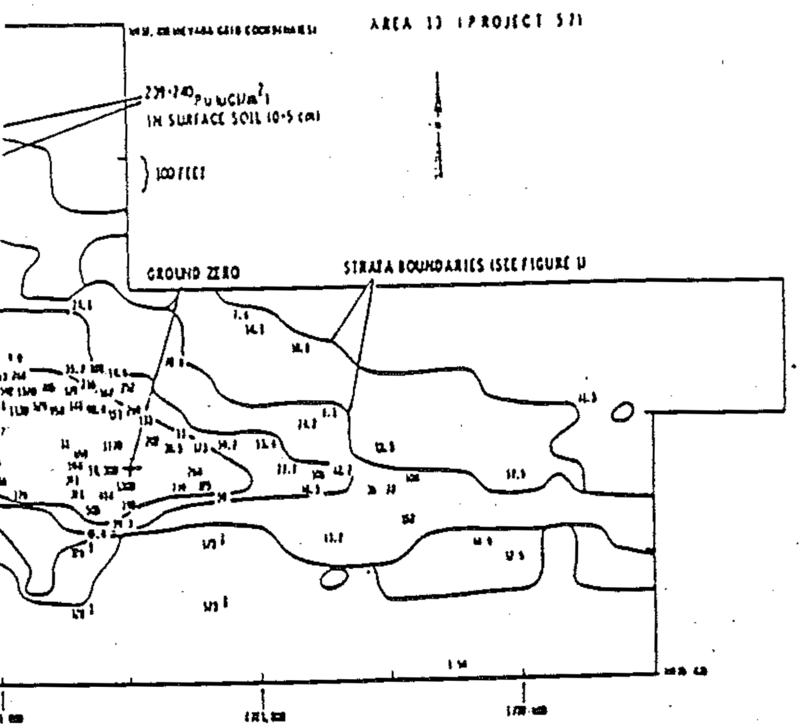


FIGURE 3.10.3. Observed ^{239,240}Pu Concentrations (µCi/m²) in Surface Soil (0–5 cm) Outside the 100 x 100 ft Grid Area at the Project 57 (Area 13) Site.



)bserved ^{239} ^{240}Pu Concentrations (µCi/m²) in Surface oil (0–5 cm) Within the 100 x 100 ft Grid Area at the roject 57 (Area 13) Site.

+ The "effective degrees of freedom" used to compare these limits was 30 (see Appendix B).

++ Prob [23 ≤ I ≤ 72] is greater than or equal to 0.95 (see Appendix B).

Page 3.10.12 is missing from this document.

POTENTIAL FOR SURFACE WATER RELEASE

The potential for surface water release would be limited to flash flooding in the ephemeral channels that traverse the contaminated area. These ephemeral channels terminate in Groom Lake.

POTENTIAL FOR AIR RELEASE

The major concern for air release of plutonium or americium is through the process of resuspension. Resuspension of these radionuclides by wind is a complex process, which is being studied at NTS. One of the more important aspects of resuspension potential is the availability of the nuclide. Although profiles at Area 13 indicate a downward migration of plutonium, a large fraction remains in the top 5 cm (Figure 3.10.5).[3]

THREATS TO FOOD CHAIN AND ENVIRONMENT

Two mechanisms are responsible for concentrations of radionuclides in vegetation. Probably the most important mechanism in the desert environment is the superficial entrapment of the radionuclide.[7] The other mechanism depends on the transport of the radionuclide through the soil profile to the root zone of the plant. The final concentration in the plant from this mechanism will be influenced by the ability of the plant to discriminate against or reject the contaminant and the mobility of that contaminant in the soil. In some cases, the daughter produced of the radioactive parent nuclide may be more soluble and hence, more available to the plant. This appears to be true for americium, which is the daughter product of plutonium.[7] The contamination can then be passed to the animal community if animals use the contaminated plant for grazing.

In the case of burrowing animals it is probable that an animal can spend its entire life within an area of relatively high plutonium concentrations. The habits of dust bathing and preening carry the nuclides into the intestinal tract. Breathing can carry radioactive particles into the lungs. Highest concentrations have been found on the pelt; material is carried into the burrow and since burrows may reach a depth of 4 ft and average 1 to 2 ft, the animal carries material to those depths. The result is a constant exposure to varying levels of radioactivity.[7]

CONCLUSION AND RECOMMENDATIONS

Due to the lack of publicly available data, an HRS score was not calculated. It is recommended that further study be initiated to determine the extent of contami-

ı of plutonium at or near
: time to flora and fauna.
'ovide valuable guidance

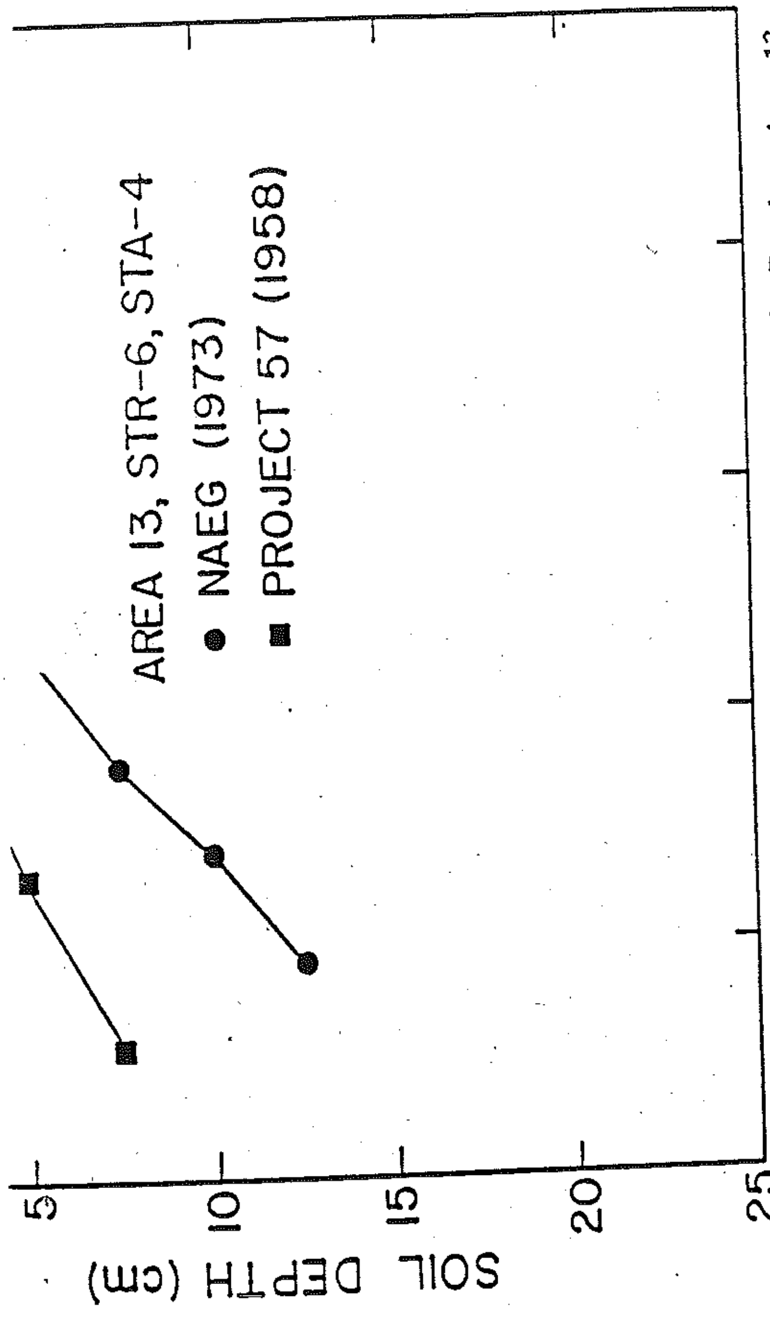


FIGURE 3.10.5. Variability of Plutonium Concentrations with Depth at Area 13.

Page 3.10.15 is missing from this document.

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