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1993 Site Environmental Report Tonopah Test Range Tonopah, Nevada

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1993 SITE ENVIRONMENTAL REPORT
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ABSTRACT

This report summarizes the environmental surveillance activities conducted by Sandia National Laboratories, the U.S. Environmental Protection Agency, and Reynolds Electrical and Engineering Company for the Tonopah Test Range operated by Sandia National Laboratories. Sandia National Laboratories' responsibility for environmental monitoring results extend to those activities performed by Sandia National Laboratories or under its direction. Results from other environmental monitoring activities are included to provide a measure of completeness in reporting. Other environmental compliance programs such as the National Environmental Policy Act of 1969, environmental permits, and environmental restoration and waste management programs are also included in this report, prepared for the U.S. Department of Energy in compliance with DOE Order 5400.1.

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ABBREVIATIONS

International System of Units Prefixes

Exponent	Prefix	Symbol	Exponent	Prefix	Symbol
10^{6}	mega	M	10^{-9}	nano	n
10^{3}	kilo	k	10^{-12}	pico	p
10^{-3}	milli	m	10^{-15}	femto	f
10^{-6}	micro	μ	10^{-18}	atto	a

Units

°C	Celsius degree
cm	centimeter
cm^2	square centimeters
cm^3	cubic centimeters
CY	calendar year
cm/yr	centimeters per year
°F	Fahrenheit degree
ft	foot
FY	fiscal year
g	gram
g/cm^3	gram per cubic centimeter
gal	gallon
hr	hour
in.	inch
in./yr	inches per year
kg	kilogram
km	kilometer
km^2	square kilometer
L	liter
m	meter
m^2	square meter
m^3	cubic meter
mi	mile
mi^2	square mile
m/s	meters per second
ppm	parts per million
sec	seconds
sec/yr	seconds per year
μm	microns
yr	year

Symbols

$>$	greater than
$<$	less than
$\geq$	greater than or equal to
$\leq$	less than or equal to
~	approximately

ABBREVIATIONS
(Continued)

Frequently Referenced Nuclide Symbols and Components

Am-241	americium-241
Be-7	beryllium-7
Cs-137	cesium-137
Pu	plutonium
Pu-238	plutonium-238
Pu-239	plutonium-239
Pu-240	plutonium-240
Pu-241	plutonium-241
Pu-242	plutonium-242
H-3	tritium
Th-232	thorium-232
U	uranium
U_{tot}	total uranium
U-238	uranium-238

Radioactivity Measurements

Ci	curie (unit of radioactivity)
Ci/g	curies per gram
Ci/yr	curies per year
mrem	millirem (unit of radiation dose)
mrem/yr	person-millirems per year
person-rem/yr	person-millirems per year
person-rem/yr	person-rem per year
pCi	picocuries
pCi/cm^2	picocuries per cubic centimeter
pCi/g	picocuries per gram
pCi/L	picocuries per liter
pCi/m^2	picocuries per square meter
R	roentgen (unit of radiation exposure)
rem	roentgen equivalent man (amount of ionizing radiation required to produce the same biological effect as 1 R of high-penetration X-rays)
$\mu g/m^2$	micrograms per square meter

Acronyms

ADM	Action Description Memorandum
AEC	U.S. Atomic Energy Commission
AIRFA	American Indian Religious Freedom Act
ALI	annual limit of intake
AR	Arkansas
ARPA	Archaeological Resources Protection Act
ASN	Air Surveillance Network
BLM	Bureau of Land Management
BOD	biochemical oxygen demand

ABBREVIATIONS (Continued)

CA	California
CAA	Clean Air Act
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CFR	Code of Federal Regulations
CG	Concentration Guide
CV	coefficient of variation
CWA	Clean Water Act
CY	calendar year
DAC	derived air concentration
DCG	U.S. Department of Energy-derived concentration guides
DOC	U.S. Department of Commerce
DOE	U.S. Department of Energy
DOE/AL	U.S. Department of Energy Albuquerque Operations Office
DOE/KAO	U.S. Department of Energy Kirtland Area Office
DOE/HQ	U.S. Department of Energy Headquarters
DOE/NV	U.S. Department of Energy Nevada Operations Office
DOI	U.S. Department of the Interior
DRI	Water Resources Center, Desert Research Institute, University of Nevada System
EA	Environmental Assessment
ECL	Environmental Checklist
EDE	effective dose equivalent
EG&G	Edgerton, Germeshausen & Grier Corporation
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
EPD	Environmental Programs Departments
ER	Environmental Restoration (Program)
ERDA	U.S. Energy Research and Development Administration
ESA	Endangered Species Act
ES&H	environment, safety and health
FIDLER	field instrument for the detection of low energy radiation
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FONSI	finding of no significant impact
FY	fiscal year
ICP	inductively coupled plasma
ICRP	International Commission on Radiological Protection
LTHMP	Long-Term Hydrologic Monitoring Program (EPA)
MDC	minimum detectable concentrations
MEI	maximally exposed individual
MSDS	Material Safety Data Sheet
MTF	memo-to-file
N/A	not applicable or not available
NAEG	Nevada Applied Ecology Group
NAFB	Nellis Air Force Base

ABBREVIATIONS (Concluded)

NDEP	Nevada Department of Environmental Protection
NEDS	Non-Violent Explosive Destruct System
NEPA	National Environmental Policy Act of 1969
NESHAP	National Emission Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NMED	New Mexico Environment Department
NPDES	National Pollutant Discharge Elimination System
NTS	Nevada Test Site
NV	Nevada
O&M	Operations and Maintenance
PA	Preliminary Assessment
PCB	polychlorinated biphenyl
PIC	pressurized ion chamber
PMS	portable monitoring station
QA	quality assurance
RCRA	Resource Conservation and Recovery Act
REECo	Reynolds Electrical and Engineering Company
SARA	Superfund Amendment and Reauthorization Act
SDWA	Safe Drinking Water Act
SHIPO	State Historic Preservation Office
SNL	Sandia National Laboratories
SNL/NM	Sandia National Laboratories/New Mexico
SNL/NV	Sandia National Laboratories/Nevada
SOP	Standard Operating Procedure
SPCC	Spill Prevention, Control, and Countermeasures
STAR	Stability Array
TA	technical area
TCLP	toxicity characteristics leaching procedure
TECR	Tonopah Electronic Combat Range
TFW	Tactical Fighter Wing
TLD	thermoluminescent dosimeter
TSCA	Toxic Substances Control Act
TSP	total suspended particulate
TSS	total suspended solids
TTR	Tonopah Test Range
USAF	U.S. Air Force
UST	underground storage tank

1.0 EXECUTIVE SUMMARY

1.1 ASSESSMENT OF RADIOLOGICAL IMPACT TO THE PUBLIC

During 1993, no radionuclides were released from the Tonopah Test Range (TTR) from typical stacks, vents, or other point sources. Based on the types of test activities, such as air drops, gun firing, ground-launched rockets, air-launched rockets, and other explosive tests, the possibility exists that small amounts of material (as part of the test component) could be released to the air or ground because of unusual circumstances (failures) during testing. There were no such failures in 1993.

A large area of transuranic surface contamination located on TTR is a potential diffuse source of airborne radionuclides through the action of wind resuspension of soil particulates. The surface contamination is the result of the three Clean Slate sites used in plutonium dispersal tests in 1963. A total of 0.25 curies per year (Ci/yr) of contaminated material was calculated to be resuspended from the three Clean Slate sites combined. The maximally exposed individual (MEI) was determined to be located at the 554 Range Squadron Operations and Maintenance (O&M) Complex located on range. The maximum effective dose equivalent (EDE) calculated for this location was 2.9 millirems per year (mrem/yr), or approximately 30 percent of the 10 mrem/yr dose limit specified by U.S. Department of Energy (DOE) orders and 40 CFR Subpart H. The off range MEI was determined to be located in the town of Goldfield. The EDE calculated for this location was 0.062 mrem, or approximately 0.6 percent of the dose limit.

This Site Environmental Report addresses only those responsibilities related to Sandia National Laboratories (SNL) activities at TTR.

1.2 OVERVIEW OF 1993 MONITORING RESULTS

1.2.1 Sandia National Laboratories Soil Sampling

Limited soil sampling was performed at TTR as part of the continuing baseline surveillance activities. Baseline sampling was performed at the Hard Target Area, Clean Slate 1, Clean Slate 3, offsite, site perimeter, and onsite. Samples collected from the Hard Target Area were analyzed for stable metals; samples collected from around Clean Slate 1 and 3 were analyzed by gamma spectroscopy and for gross alpha, gross beta, and total uranium (U_{tot}). Gross alpha, gross beta, gamma spectroscopy, U_{tot}, and stable metal analyses were performed on soil samples collected at onsite, offsite, and perimeter locations. Isotopic plutonium (Pu) analysis was performed on all samples which had detectable americium-241 (Am-241). Additional soil sampling and air monitoring was performed at TTR at the request of the Range Manager. Soil and air samples were collected in the down-wind direction of Clean Slate 1. Soil and air samples were analyzed for isotopic Pu, U_{tot}, and by gamma spectroscopy.

Soil samples collected in the vicinity of Clean Slates 1 and 3 indicate the presence of isotopic Pu and Am-241 contamination. Measurable levels of isotopic Pu and Am-241 were also detected at several additional locations on site and off site. Stable metal analysis indicates the potential contamination of several onsite locations. Air monitoring results did not indicate contamination.

1.2.2 U.S. Environmental Protection Agency (EPA) Air Surveillance Network (ASN)

The only gamma-emitting radionuclide detected on the prefilters from all four air monitoring stations (listed in Chapter 5) was beryllium-7 (Be-7), a naturally occurring spallation product formed by the interaction of cosmic radiation with atmospheric oxygen and nitrogen. The weighted average results were consistent with the area background concentrations.

1.2.3 EPA Pressurized Ion Chamber (PIC)

PIC measurements were found to be consistent with previous years' measurements and are within the normal expected fluctuation of background radiation.

1.2.4 EPA Thermoluminescent Dosimeter (TLD) Network

Due to data quality difficulties, EPA TLD data were unavailable for inclusion in this report.

1.2.5 EPA Long-Term Hydrologic Monitoring Program (LTHMP)

Analytical results for tritium in well water were reported for two well stations: Well 6, TTR; and City well, Tonopah; (see Chapter 5). All results were well below DOE-derived concentration guides.

1.2.6 Reynolds Electrical and Engineering Company (REECo) Drinking Water Sampling Program

Per regulatory statute Title 40, Code of Federal Regulations, Part 141.26 (40 CFR 141.26), drinking water on the TTR should be sampled a minimum of every 3 years (yr) for primary drinking water standards and radionuclides. In previous years, the radionuclides were sampled on a monthly basis by REECo. During 1993, Sandia National Laboratories/Nevada (SNL/NV) and DOE determined that the sampling and analysis by REECo would be discontinued. Sampling will be performed by SNL or one of its contractors at a minimum every 3 yr. Primary and secondary water standards are checked every 3 yr. When required, sampling and analytical testing for radionuclides were performed by REECo.

1.3 Summary of Permit Status

With the deactivation of the U.S. Air Force (USAF) 37th Tactical Fighter Wing (TFW) in 1992, numerous owner/operator permit changes were made. These changes were based on service area, location of equipment, and operator. During 1993, work forces at the TTR were reassigned with the result that only a small contingent of DOE/NV contractors returned to support construction activities on TTR. With this change in contractor support, the Air Quality Operating Permits for construction-related equipment or activities were transferred to DOE/NV. The transferred permits included those for the concrete batch plants, screens, crusher, and land disturbance for activities greater than 5 acres. Table 1-1 summarizes permit ownership.

DOE/NV remediation activities at the Fire Training Pit were concluded; a letter from the State acknowledged final closure of the site. This activity concluded the DOE/NV voluntary corrective-actions obligations to the State of Nevada. The Air Quality permit to construct was transferred to the USAF allowing it to proceed with planned USAF/Nellis Air Force Base (NAFB) corrective actions. These corrective actions apply to unusual occurrences related to the fuel supply system within the USAF industrial area.

Table 1-1. Summary of Permit Ownership at the Tonopah Test Range

Air Quality	Permit No.	Ownership
PetroStorage	2449	USAF
PetroStorage	2448	USAF
PetroStorage	2447	USAF
PetroStorage	2446	USAF
PetroStorage	2445	USAF
PetroStorage	1661	USAF
Batch Plant (Ross)	2229	DOE/NV
Batch Plant (Johnson)	2231	DOE/NV
Crushers	2456, 2457	DOE/NV
Screens	2455	DOE/NV
Incinerator	2450	USAF
Surface Disturbance	2844	DOE/NV
Vapor Extraction[a]	3172	USAF
Open Burn	Nonrenewal	Deactivated/DOE/NV
Public Water System		
Mancamp	NY-4068-12C	USAF
Industrial Area	NY-5001-12NC	USAF
Sandia Compound	NY-3014-12NC	DOE/Kirtland Area Office (DOE/KAO)
Tonopah Electronic Combat Range (TECR) Compound	NY-5002-12NC	USAF
National Pollutant Discharge Elimination System (NPDES)		
Sewage System	NEV20001	USAF
Hazardous Waste		
EPA Generator ID No.	NV3570090016	Deactivated/USAF
EPA Generator ID No.	NV1890011991	Activated/DOE/KAO

[a]Permit to construct.

2.0 INTRODUCTION

2.1 HISTORY AND OPERATIONS OF THE TONOPAH TEST RANGE

Sandia National Laboratories (SNL) operates the Tonopah Test Range (TTR) for the U.S. Department of Energy (DOE) nuclear ordnance programs. SNL operations at the TTR in Nevada date from 1957, when the TTR came into limited use after similar facilities at Salton Sea Test Base in California and at Yucca Flat on the Nevada Test Site (NTS) became inadequate. The TTR was used as a bombing range during World War II.

TTR was originally designed and equipped to gather raw data on aircraft-delivered inert test vehicles under U.S. Atomic Energy Commission (AEC) cognizance. Over the years, the facilities and capabilities at TTR have been expanded to accommodate tests related to the AEC (later, DOE) weapons development program. Tests conducted vary from simple tests of hardware components and systems needing only limited support to rocket launches and air drops of test vehicles requiring full range support.

The seven categories of test activities at TTR are: (1) air drops, (2) gun firings, (3) ground-launched rockets, (4) air-launched rockets, (5) explosive effects, (6) static rocket tests, and (7) earth penetrator tests. Most of these activities require a remote range for safety and security reasons. During 1993, a total of 42 tests were conducted at TTR: 24 air drop tests, 2 Davis gun tests, and 16 fly-around tests.

2.2 LOCATION AND POPULATION

TTR is located approximately 140 miles (mi) (225 kilometers [km]) northwest of Las Vegas, NV, (Figure 2-1) and covers 624 square miles (mi^2) (1616 square kilometers [km^2]) within the boundaries of the Nellis Air Force Base (NAFB) Range Complex. It is bordered on three sides by the NAFB Range Complex and on the north by sparsely populated public land administered by the Bureau of Land Management (BLM) and the U.S. Forest Service. The nearest population centers are Goldfield, population 659, located approximately 25 mi (40 km) west of TTR, and Tonopah, population 4400, located 30 mi (48 km) northwest of TTR (U.S. Department of Commerce [DOC], Bureau of the Census, 1991). The total population within a 50-mi region around TTR is 9299. This number includes a population of 1000 to account for base housing and onsite and contractor (non-SNL) personnel.

2.3 GEOLOGY AND CLIMATOLOGY

TTR is situated in a high desert and consists of broad valleys bordered by north/south-trending mountain ranges in the western part of the Basin-and-Range geophysical province. TTR lies northeast of a zone of transcurrent faulting and shear, termed the Walker Lane, and the Las Vegas Valley shear zone to the southeast (Sinnock 1982). Cactus Flat, which constitutes the basic working area of TTR, is a basin surrounded by the Cactus Range. The Cactus Range is a northwest-trending, raised structural block, one of at least five that lie along the Las Vegas Valley-Walker Lane lineaments (ERDA 1975).

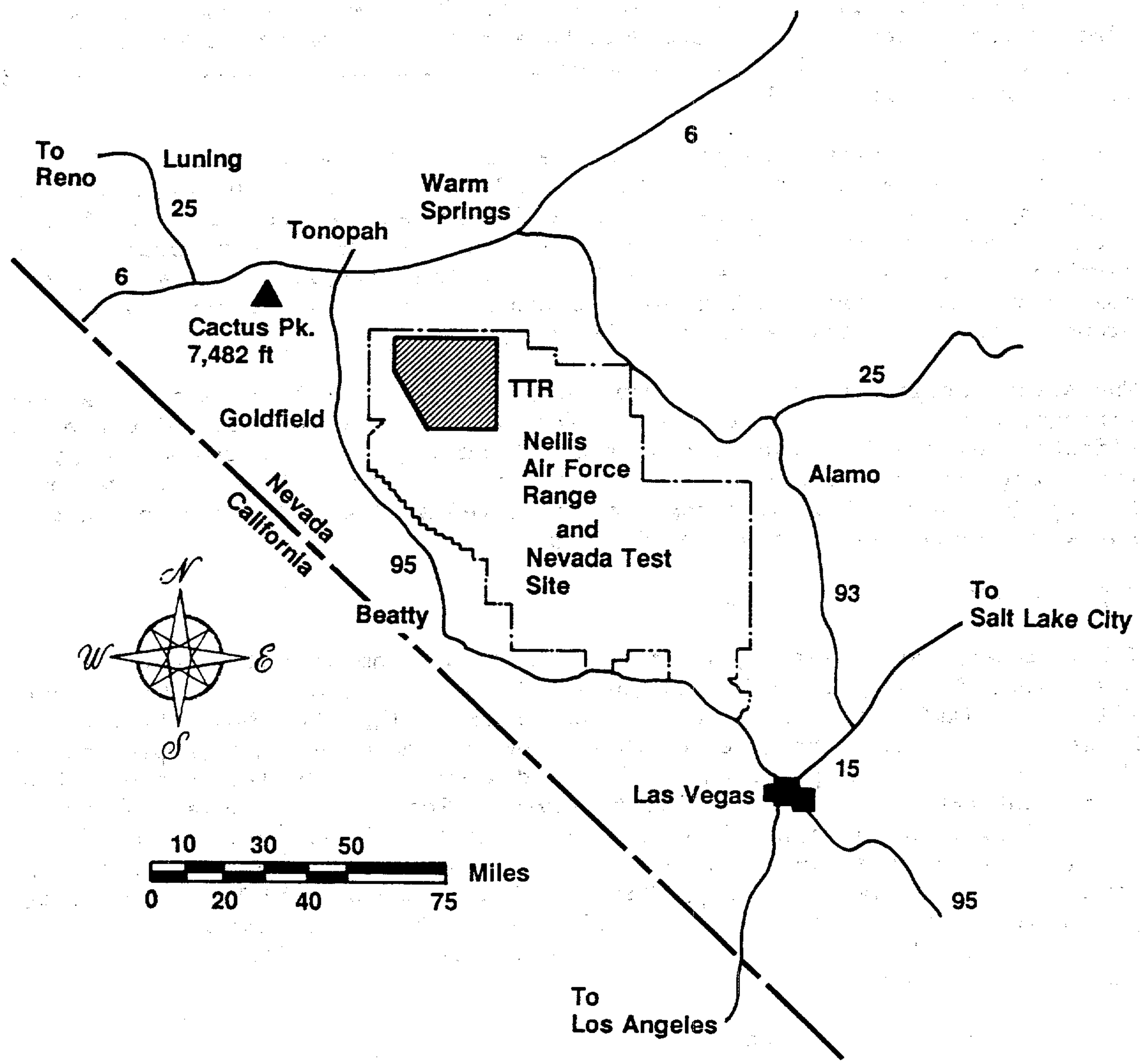

Figure 2-1. Location of Tonopah Test Range, Nevada

All the working areas of TTR lie within an area of approximately 400 mi^2. The streams in and near TTR are intermittent and end in closed basins. There are three springs within TTR: Cactus, Antelope, and Silverbow. Water from these springs does not travel far; it disappears rapidly through evaporation and infiltration and its effect on the landscape is purely local. Water used in TTR facilities comes from wells tapping underlying groundwater in alluvium derived from the surrounding mountains. Depth to water varies from 90 to 150 feet (ft) (ERDA 1975).

The climate is mild and usually dry, but, as is typical of high deserts, it is subject to large diurnal and seasonal changes in temperature, from a record high of 102 degrees Fahrenheit (°F) (38.9 degrees Celsius [°C]) to a record low of -24°F (-31.1°C) (Schaeffer 1982). Clear, sunny days with light to moderate winds are usual. Average rainfall is approximately 5 inches per year (in./yr) (12.7 centimeters per year [cm/yr]) in the valley, with most precipitation occurring in August (ERDA 1975; Schaeffer 1982). Winds are mostly from the west-northwest and from the south-southeast. Dust storms are common in the spring and dust devils are common in the summer.

Because of the temperature extremes and arid conditions at TTR, the valley in which most TTR activities occur is sparsely covered with range grasses and low shrubs (ERDA 1975; EG&G 1979a). Joshua trees grow in the foothills. Juniper trees grow in the foothills and mountains. Hundreds of wild horses graze freely throughout TTR and their exposure to TTR activities has apparently had little effect on their population and grazing habits.

2.4 PROJECT ROLLER COASTER TESTS

2.4.1 Historical Information

Project Roller Coaster included a series of four plutonium (Pu) dispersal tests (three at TTR and one at the NAFB Gunnery Range). The tests were executed in May and June of 1963. The locations of the three Project Roller Coaster tests at TTR are referred to as Clean Slates 1, 2, and 3 (Figure 2-2). Table 2-1 summarizes detailed information related to the four Project Roller Coaster sites. Through agreement with DOE's Albuquerque Operations Office (DOE/AL), DOE's Nevada Operations Office (DOE/NV) has the Environmental Restoration (ER) responsibilities for the Clean Slate sites; SNL maintains the environmental monitoring responsibilities.

2.4.2 Environmental Monitoring at Roller Coaster Areas

The initial cleanup of each Clean Slate site was conducted shortly after each test. This initial cleanup consisted of blading the test-related debris into a hole at test ground-zero. The hole and debris were then covered with dirt. A fence was then erected around each Clean Slate test area. The fences were set at approximately 1000 micrograms plutonium per square meter ($\mu g/m^2$) as determined using hand-held survey meters (Rarrick 1993). In 1973, outer fences were built. The outer fences were set at 40 picocuries plutonium per gram (pCi/g) of soil as determined using hand-held survey meters (Rarrick 1993). This survey was conducted using a field instrument for the detection of low energy radiation (FIDLER) using 61-meter (m) grids. Surface soil has been

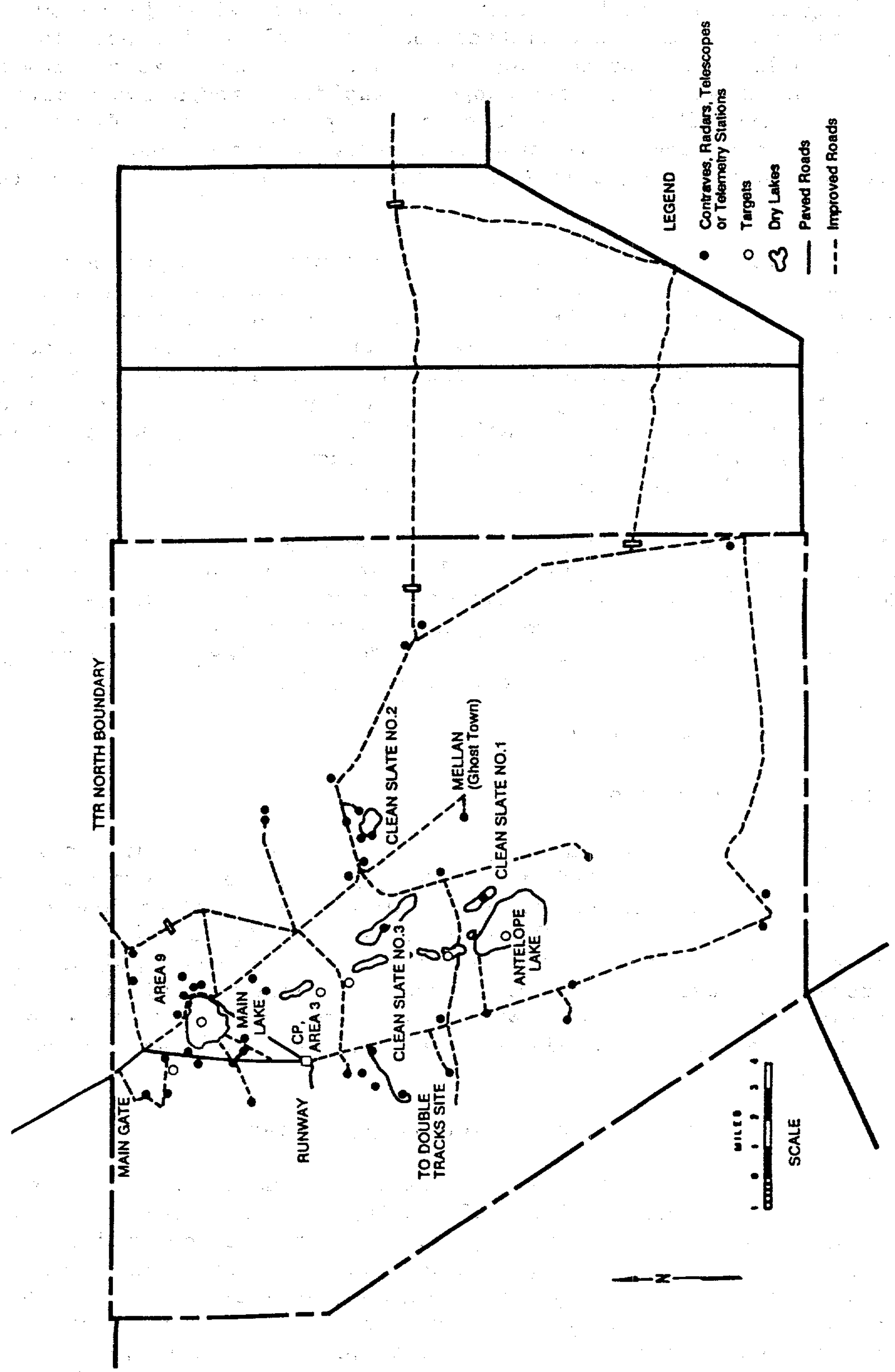

Figure 2-2. Locations of Sandia National Laboratories Facilities at the Tonopah Test Range

Table 2-1. Roller Coaster Test Information

Test	Clean Slate 1	Clean Slate 2	Clean Slate 3	Double Tracks
Date	May 25, 1963	May 31, 1963	June 9, 1963	May 15, 1963
Location	TTR	TTR	TTR	NAFB
Plutonium Inventory (curies [Ci])	5.2 ± 1.6	29 ± 6.2	30 ± 4.9	5.0 ± 1.4

Source: Annual Site Environmental Report provided by the U.S. Department of Energy Nevada Operations Office.

sampled intermittently at the Clean Slate sites. An aerial radiologic survey was performed by Edgerton, Germeshausen & Grier Corporation (EG&G) for the Nevada Applied Ecology Group (NAEG) in 1977 using the 1973 grid. The objective of the aerial survey was to determine the surficial distribution of Pu and other transuranic elements dispersed during the Project Roller Coaster tests. The aerial surveys were undertaken to supplement the FIDLER and previous soil sample measurements of americium-241 (Am-241, a plutonium-241 [Pu-241] decay product present in the Pu of the test device). Radiation isopleths showing soil activity caused by Am-241, plutonium-239 (Pu-239), and plutonium-240 (Pu-240) were drawn for each area and results were published (EG&G 1979b). This survey showed the extent of the transuranic contamination, both inside and outside of the two control fences, in the area of the Clean Slate sites. Twice yearly the test areas are examined visually to perform fence repairs. Animals that have wandered inside the area are promptly removed.

3.0 COMPLIANCE SUMMARY

3.1 COMPLIANCE STATUS

3.1.1 Regulations and Permits

Sandia National Laboratories (SNL) operates the Tonopah Test Range (TTR) in compliance with environmental and other requirements established by Federal and State statutes and regulations, Executive Orders, and U.S. Department of Energy (DOE) orders. The following paragraphs summarize the compliance status of TTR with major environmental statutes.

Comprehensive Environmental Response Compensation and Liability Act (CERCLA), Superfund Amendments and Reauthorization Act (SARA): As required under the CERCLA/SARA, Section 120(d), a Preliminary Assessment (PA) was submitted for all facilities listed on the Federal Agency Hazardous Waste Compliance docket in 1988. Several sites have been added to the list of existing sites:

- French drains within Technical Area III (TA-III)
- Old Rifle Range
- Dispersion bomblets site
- Depleted uranium impact site

TTR is not on the National Priorities list. A CERCLA site is placed on this list if the site is above a certain threshold level established by the U.S. Environmental Protection Agency (EPA).

In late 1992 and early 1993, DOE's Headquarters (DOE/HQ), Kirtland Area Office (DOE/KAO), and Nevada Operations Office (DOE/NV) agreed that DOE/NV would manage all of the DOE/KAO and DOE/NV Environmental Restoration (ER) activities at TTR. This agreement was made because TTR activities would be the first ER activities performed in the State of Nevada by the DOE, and it was felt that one field office should develop the remediation and closure plans for all sites in Nevada. During 1993, DOE/NV completed preliminary ER field investigation work at TTR, including several aerial reconnaissance flights (radiological and multispectral) and geophysical investigations. These investigations will assist in further delineating the size, type, and geological make-up of the sites and the types of potential contamination. ER activities planned for calendar year 1994 (CY 94) include further field investigations and submittal of work plans to the State of Nevada for the planned volunteer site-corrective actions.

Resource Conservation and Recovery Act (RCRA): TTR is a <90-day storage area and a large-quantity generator of hazardous waste. Hazardous chemical wastes are collected, packaged, and shipped offsite to an EPA-permitted treatment, storage and disposal facility. Standard Operating Procedures (SOPs) have been written to ensure continued compliance with RCRA. Currently, one Class II Sanitary Landfill is in operation on TTR. This unit is cooperatively used by all organizations on TTR. SNL also manages five underground storage tanks (USTs) on TTR.

Clean Air Act (CAA): TTR is regulated by the CAA and the Nevada Air Quality Regulations, published in the Nevada Revised Statutes, Title 40, Public Health and Safety, Chapter 445. In 1993, the State of Nevada issued the following CAA permits and transferred ownership to the identified organizations:

- Six aboveground storage tanks--U.S. Air Force (USAF)
- Two concrete batch plants--DOE/NV
- Vapor extraction unit--USAF
- Incinerator--USAF
- Disturbance land use greater than 5 acres--DOE/NV
- Crusher/screen--DOE/NV

The Nevada Department of Environmental Protection (NDEP) performed an air quality audit in the first and third quarters of 1993. There were no significant findings.

DOE/NV currently holds six air quality permits for TTR. DOE/NV acquired these permits during 1993 (issued December 1993). The change of ownership was required since DOE/NV contractors' activities on TTR required them to use the equipment on a regular basis. Air emissions in 1993 were in compliance with applicable permits. A National Emission Standards for Hazardous Air Pollutants (NESHAP) annual report was prepared for CY 1993.

Clean Water Act (CWA): TTR is regulated by CWA and Nevada Water Pollution and Sanitary Waste Systems regulations. The sewage systems in TA-III, the main industrial area, are connected to the USAF facultative sewage lagoon facility. An automatic effluent monitoring system was installed within TA-III for random-basis sampling of hazardous material contaminants before connection to the USAF facility. This monitoring system was operated once during 1993 for a 3-day composite sampling. Due to the low population at TTR, the flow is not sufficient to activate sampling equipment. Samples are obtained on a quarterly basis by Sandia National Laboratories/Nevada (SNL/NV). The sampling technique used for the low flow is grab sampling.

The remote locations on TTR are serviced by septic tank systems. These septic systems are maintained by the TTR facilities group. The 13 septic tanks disconnected within TA-III will require further testing to assure that no hazardous constituents are present before disposing of the waste and closing the tanks in conformance with State of Nevada regulations. The State of Nevada does not have a permitting process for septic tanks. A list transmitted to the State of Nevada Public Health Service through the DOE/NV in June 1992 updated the status of all septic tank systems on TTR.

Safe Drinking Water Act (SDWA): TTR is regulated by the SDWA and Nevada Public Water Supply and Public Water Systems regulations. Drinking water for SNL operations at TTR is provided by a well permitted by the State of Nevada in compliance with the Public Water Supply Standards. Activities include monthly bacteriological sampling and a site sampling plan for the system. In November 1992, the State of Nevada passed regulatory requirements for a certified water distribution operator for community systems. Presently, three of the support contractor staff for SNL are certified with the American Well Association and will be grandfathered into the State certification program. The State of

Nevada Water Resources Division codified regulations requiring a Water Conservation Plan for permitted water systems and major water users in Nevada. The Water Conservation Plan for the TTR was completed in July 1992, submitted to the DOE/NV, and transmitted to the State of Nevada Water Resource Division.

Toxic Substances Control Act (TSCA): All transformers on TTR owned by DOE/KAO were sampled and analyzed during CY 1993. This information was consolidated into a Sandia National Laboratories/New Mexico (SNL/NM) data base and into the SNL/NV inventory data base. None of the samples contained more than 50 parts per billion of polychlorinated biphenyls (PCBs).

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA): EPA-registered pesticides are applied at SNL facilities. These pesticides are applied by an EPA-certified applicator. SNL retains records of the quantities and types of pesticides that are used as well as Material Safety Data Sheets (MSDSs) for each pesticide.

Endangered Species Act (ESA): The DOE must comply with the ESA when planning Federal actions or major construction activities. The key provision of the ESA for Federal activities is Section 7, Consultation, which states that Federal agencies must consult with the U.S. Fish and Wildlife Service to ensure that any agency actions are "not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species." There has not been a recent environmental assessment to detail the current situation in regard to sensitive species, though a number are known to occur in the area (ERDA 1975). SNL assists the DOE in complying with the ESA at TTR.

Cultural Resources Acts: TTR holds responsibilities for cultural resources management, including those responsibilities applicable under the National Historic Preservation Act (NHPA), the Archaeological Resources Protection Act (ARPA), and the American Indian Religious Freedom Act (AIRFA). SNL integrates cultural resources management into the National Environmental Policy Act of 1969 (NEPA) Program. It is DOE's policy that NEPA review is required for all DOE actions potentially affecting the environment; thus, even actions that are categorically excludable are reviewed for impacts on cultural resources, among other things. (See Section 4.5 for further information on NEPA activities.)

Executive Orders: Executive Order 11988, Floodplain Management, and Executive Order 11990, Protection of Wetlands, require evaluation of the potential effects of actions taken in floodplains and wetlands. There are no floodplains or wetlands at TTR.

3.1.2 1993 Audits

The DOE Albuquerque Operations Office (DOE/AL), NDEP and SNL conducted the following audits in 1993:

- NDEP, Familiarization Visit (April 1993)
- NDEP Air Quality Inspection and Inventory (June and September 1993)
- Nevada Department of Health Protection (June and September 1993)

- DOE/AL Environmental Programs Departments (EPD) RCRA Appraisal (August 1993)
- DOE/AL and DOE/KAO Industrial Hygiene (October 1993)
- DOE/AL and DOE/KAO Transportation (November 1993)

No DOE/HQ audits were performed at TTR in 1993.

3.2 CURRENT ISSUES AND ACTIONS FOR THE TONOPAH TEST RANGE

3.2.1 Septic Tanks/Sewage Line

Septic tanks were sampled during fiscal year 1990 (FY 90) by the facility group. The septic tank sampling procedure met Federal and State requirements. Since the time of the sampling, Federal and State regulations have imposed more stringent testing parameters, including requiring toxicity characteristics leaching procedure (TCLP) analytical testing. To assure that SNL is characterizing and managing the tanks to the most stringent rule and that the correct determination of waste characteristics are made, the sludge will be reanalyzed from 1993 through 1995. This sampling will be performed during ER activities.

3.2.2 Underground Storage Tanks

The SNL UST program for TTR has implemented the Warren Rogers program for monitoring USTs for leaks (Warren Rogers Associates, Inc. 1992). This program is a statistical calculation from the daily inventories of fuels. During 1993, the Warren Rogers program indicated erratic readings from the tanks at the fueling station. It was determined that the erratic readings were due to the manifold connecting the tanks, infrequent use, and temperature variations at TTR. SNL/NV entered into an agreement with USAF to use its fueling facility for all SNL/NV activities for an indefinite time. The tanks in TA-III and TA-IX are scheduled for closure during CY 94 because the downsizing of the SNL/NV operations has made it more cost effective to join the USAF fuels program.

3.2.3 Waste Minimization Program

An informal waste minimization program is practiced at TTR. The activities include the following:

- Solvent recycling
- Fuel recycling
- Oil recycling
- Antifreeze recycling
- Tire recycling
- Lead acid battery recycling

In addition, most hazardous waste is recycled through an alternate fuels program (e.g., fuels for a Part B-permitted cement kiln). Due to the remote location of TTR, the cost-effectiveness of recycling other items such as paper is being evaluated.

3.3 ENVIRONMENTAL PERMITS

As part of the DOE complex, the SNL-operated TTR is committed to full compliance with all applicable environmental laws and regulations and to protection of the environment. TTR is regulated by Federal laws and State of Nevada regulations for the applicable activities. (See Table B-1 in Appendix B for the State regulations and the corresponding activities.)

The permit application and registration of SNL activities at TTR were administered by SNL/NV contractor support through 1993. There are a total of 13 air permits (8 permits owned by the USAF, 5 by the DOE/NV), 4 public water system permits (1 owned by the DOE/KAO, 3 by the USAF), 1 National Pollutant Discharge Elimination System (NPDES) permit for the sewage lagoon facility (owned by the USAF), and 1 EPA identification number for chemical hazardous waste on TTR (owned by the DOE/KAO). The State of Nevada has initiated the storm water permit program. The State will not be making determinations or permitting until CY 94. TTR has no waters of the United States within its boundaries. Thus, following best management practices, the SNL activities on TTR may be permitted by SNL itself. Detailed permit listings with expiration dates, issuance agencies, and responsible parties are included in Table B-2 of Appendix B. TTR was in full compliance with all permit requirements for CY 93.

4.0 OTHER ENVIRONMENTAL COMPLIANCE PROGRAMS

4.1 SPILL PREVENTION CONTROL AND COUNTERMEASURE PLAN

The Spill Prevention Control and Countermeasure (SPCC) Plan for the Tonopah Test Range (TTR) was completed by Sandia National Laboratories (SNL) in 1990 (SNL 1990). This plan was prepared in accordance with Title 40, Code of Federal Regulations, Part 112 (40 CFR 112). The SPCC Plan for SNL at TTR documents 29 locations for secondary containment upgrade, including transformers, above-ground storage tanks, and three bulk storage areas. Construction of the secondary containment areas was completed in fiscal year 1993 (FY 93).

4.2 UNDERGROUND STORAGE TANKS

Underground storage tanks (USTs) at TTR are managed in accordance with the Nevada Department of Environmental Protection (NDEP) and Federal regulations. SNL had four USTs tested for tank tightness by an offsite contractor in October 1992. No leaks or malfunctioning tanks were detected. All USTs located at TTR are registered with the NDEP (Table 4-1). SNL also implemented the Warren Rogers tank-tightness testing program, which statistically tracks the volumes of fuel maintained in the tanks (Warren Rogers Associates, Inc. 1992).

Table 4-1. 1993 Underground Storage Tank Survey

Tank No.	Capacity	Contents	Year Installed
0359-1	10,000	Unleaded gas	1983
0359-2	10,000	Unleaded gas	1983
0359-3	10,000	Diesel	1983
0359-4	10,000	Diesel	1983
0958-1	1,000	Diesel	1966

4.3 WASTE MANAGEMENT PROGRAMS

4.3.1 Chemical and Hazardous Waste Management

Chemical wastes generated by SNL activities at TTR during calendar year 1993 (CY 93) were managed by Reynolds Electrical and Engineering Company (REECo), the facilities support contractor.

Waste types and quantities that were transported and disposed of offsite at a permitted treatment and storage facility during 1993 included the following:

Waste Characteristic	Waste Identification Code	Quantity
Ignitable chemical waste	D001	9010 kilograms (kg)
Corrosive chemical waste	D002	495 kg
Reactive chemical waste	D003	165 kg
Lead chemical waste	D008, D006, D007, D011	2265 kg
Waste containing mercury	D009	6 kg
Spent halogenated solvents	F001	209 liters (L)
Spent nonhalogenated solvents	F003	3971 L
Waste 1,1,1 Trichloroethane	U226	30 kg

Waste transported offsite for recycling or alternative fuel use consisted of the following:

Waste Type	Code	Quantity
Motor oil	N/A	17,600 kg

The above listed wastes were shipped to the following facilities for disposal or recycling:

- ENSCO (El Dorado, AR)
- Safety Kleen Corporation (Los Angeles, CA)

4.4 ENVIRONMENTAL RESTORATION PROGRAM

The Environmental Restoration (ER) Program is a phased U.S. Department of Energy (DOE) program to identify, assess, and correct past spill, release, or disposal sites at all DOE Albuquerque Operations Office (DOE/AL) facilities including the SNL-operated TTR. The method parallels the U.S. Environmental Protection Agency (EPA) Comprehensive Environmental Response Compensation and Liability Act (CERCLA) program to identify, characterize, and clean up inactive release sites. Table 4-2 lists the ER Program sites at TTR that DOE/AL is responsible for. DOE's Nevada Operations Office (DOE/NV) is responsible for the three Clean Slate sites.

4.5 1993 NATIONAL ENVIRONMENTAL POLICY ACT COMPLIANCE ACTIVITIES AND DOCUMENTATION

4.5.1 Background

The National Environmental Policy Act of 1969 (NEPA), the nation's most comprehensive legislative and public policy statement on environmental protection, applies to all agencies of the Federal government. Executive and DOE orders, DOE guidance, and DOE regulations apply NEPA and NEPA-related activities to SNL.

The Council on Environmental Quality (CEQ) was created in the Executive Office of the President under the authority of NEPA. CEQ regulations were formally adopted by DOE in August 1979 (10 CFR 1021). DOE NEPA guidelines were last

Table 4-2. Environmental Restoration Program Sites at the Tonopah Test Range

ER Program Task	ER Program Site No.	Site Name
AL-SA-15 (TTR Technical Area III [TA-III])	118	TA-III Underground Diesel Tank
	119	TA-III Landfills
	120	Fire Training Area
	121	Waste Oil Sumps, Building 360
	122	TA-III Septic Tanks and Leach Fields
	123	Photography Shop French Drains
	134	Heavy Duty Shop Floor Drains
AL-SA-16 (TTR TA-IX)	124	High-Explosive Disposal Area
	125	TA-IX Landfills
	126	Mobile Photographic Laboratory
AL-SA-17 (TTR Test Areas)	127	Non-Violent Explosive Destruct System (NEDS) Site
	128	Antelope Lake
	129	Cactus Springs
	130	Roller Coaster Radioactive Decontamination
	131	Sanitary Sewage System and Lagoons

published in full in the *Federal Register* on December 15, 1987. On April 24, 1992, DOE codified its existing rule of compliance with NEPA (10 CFR 1021). The proposed rule incorporates certain policy initiatives instituted by the Secretary of Energy.

Although only DOE has the authority to make decisions regarding the appropriate level of NEPA documentation, SNL assists DOE by drafting appropriate documentation, such as Environmental Checklists (ECLs), Action Description Memoranda (ADMs), and Environmental Assessments (EAs) for DOE approval. Such environmental documents serve as vehicles for assessing potential environmental impacts of proposed Federal actions and disclosing Federal activities.

At SNL, Department 7258 (Risk Management/NEPA) carries out various NEPA-related activities, including consulting and training line-organization personnel in NEPA compliance, coordinating document preparation, maintaining a corporate NEPA document file, and reviewing NEPA documents before submittal to DOE. These responsibilities are documented in the SNL NEPA program (SNL 1991).

4.5.2 Compliance

Following the Secretary of Energy's February 5, 1990, National Environmental Policy Act Notice (SEN-15-90) with directives intended to bring DOE into full compliance with NEPA, an Environmental Safety and Health Bulletin was issued to all SNL employees to enhance understanding of SNL NEPA compliance responsibilities. Subsequently, several group meetings were held, including visits to remote sites, such as Livermore, CA, and Tonopah, NV, to better communicate SNL's NEPA responsibilities and enhance NEPA compliance.

At TTR, NEPA compliance is a joint effort by SNL with DOE/NV and the Desert Research Institute (DRI). DRI and EG&G prepare archaeological and biological surveys and reports. Final reports are submitted to SNL and DOE/NV for transmittal to the State of Nevada State Historic Preservation Office (SHIPO) for review and decision making.

4.5.3 Environmental Checklist

An ECL serves to document the use of a categorical exclusion (a category of actions for which neither an EA or an Environmental Impact Statement [EIS] is required).

4.5.4 Action Description Memorandum

An ADM is a document containing a concise description of a proposed action and a brief discussion of relevant potential environmental issues. DOE uses ADMs to determine the appropriate level of NEPA documentation for proposed actions. In the past, ADMs were also used to document categorical exclusions and to support memo-to-file (MTF) reviews.

The MTF was a unique DOE mechanism established in 1980 to justify not preparing EAs on insignificant actions that had not yet been added to the DOE published list of categorical exclusions. This procedure was followed because the categorical exclusions list was not well defined. The MTF system to exclude actions that are clearly insignificant, but not specifically categorically excluded from detailed NEPA documentation, ended on September 30, 1990. At present, actions that are not categorically excluded or covered in approved NEPA documents require preparation of EAs or EISs.

4.5.5 Environmental Assessment

An EA is intended to be a "concise public document" which provides sufficient evidence and analysis to determine whether to prepare an EIS or a finding of no significant impact (FONSI). The EA also aids in the compliance with NEPA when no EIS is required and facilitates preparation of an EIS when one is necessary. The ADMs and EAs written or approved in 1993 and their approval status are listed in Table 4-3.

Figure 4-1 describes the sequence for creating and reviewing NEPA documents.

Table 4-3. Action Description Memoranda, Environmental Assessments, and Approval Status for the Tonopah Test Range in 1993

Title	Memo to DOE	DOE Approval Letter
Installation of Propane Lines		Categorical Exclusion
Installation of Water Tanks		Categorical Exclusion
Development of Communication Station and Road		Categorical Exclusion

4.6 OVERVIEW OF NON-SNL ENVIRONMENTAL MONITORING PROGRAMS AT TTR

The TTR landowner is the Bureau of Land Management (BLM). The U.S. Air Force (USAF) maintains a use permit with BLM that is renewed every 5 years (yr). BLM must approve any new construction, such as roads. SNL's responsibilities for environmental monitoring extend to those environmental monitoring activities performed by SNL or under its direction. Other agencies and contractors perform environmental monitoring activities at TTR under memoranda of understanding with DOE. These other agencies include the following:

- U.S. Environmental Protection Agency: The EPA Environmental Monitoring Systems Laboratory in Las Vegas, NV, under an interagency agreement with DOE, monitors background radiation at TTR as part of its Offsite Radiation Monitoring Program. Reports of the monitoring are issued to DOE/NV on both a quarterly and annual basis.

- Water Resources Center, Desert Research Institute, University of Nevada System: The Water Resources Center, Desert Research Institute, University of Nevada System (DRI) is under contract with DOE to provide services that include public information activities and radiation monitoring support.

  DRI provides and trains station managers to run EPA community monitoring stations at such remote locations as Tonopah and Goldfield. These managers generally are local science teachers. The EPA laboratory in Las Vegas, NV, provides equipment and performs the analysis and reporting. DRI also provides external quality assurance (QA) on field measurements taken by EPA at community monitoring stations. Selected locations are monitored concurrently by DRI with a portable monitoring station (PMS) and thermoluminescent dosimeters (TLDs). EPA monitor results are compared to DRI results. The analysis for PMS samples are done by REECo.

  The QA results that summarize EPA and DRI data at the selected locations are reported annually by DRI. DRI also does other monitoring, primarily hydrological, for DOE as requested. This may include evaluating environmental impacts due to road construction. Monitoring conducted by DRI is included in Section 5.1 of the EPA Monitoring Program.

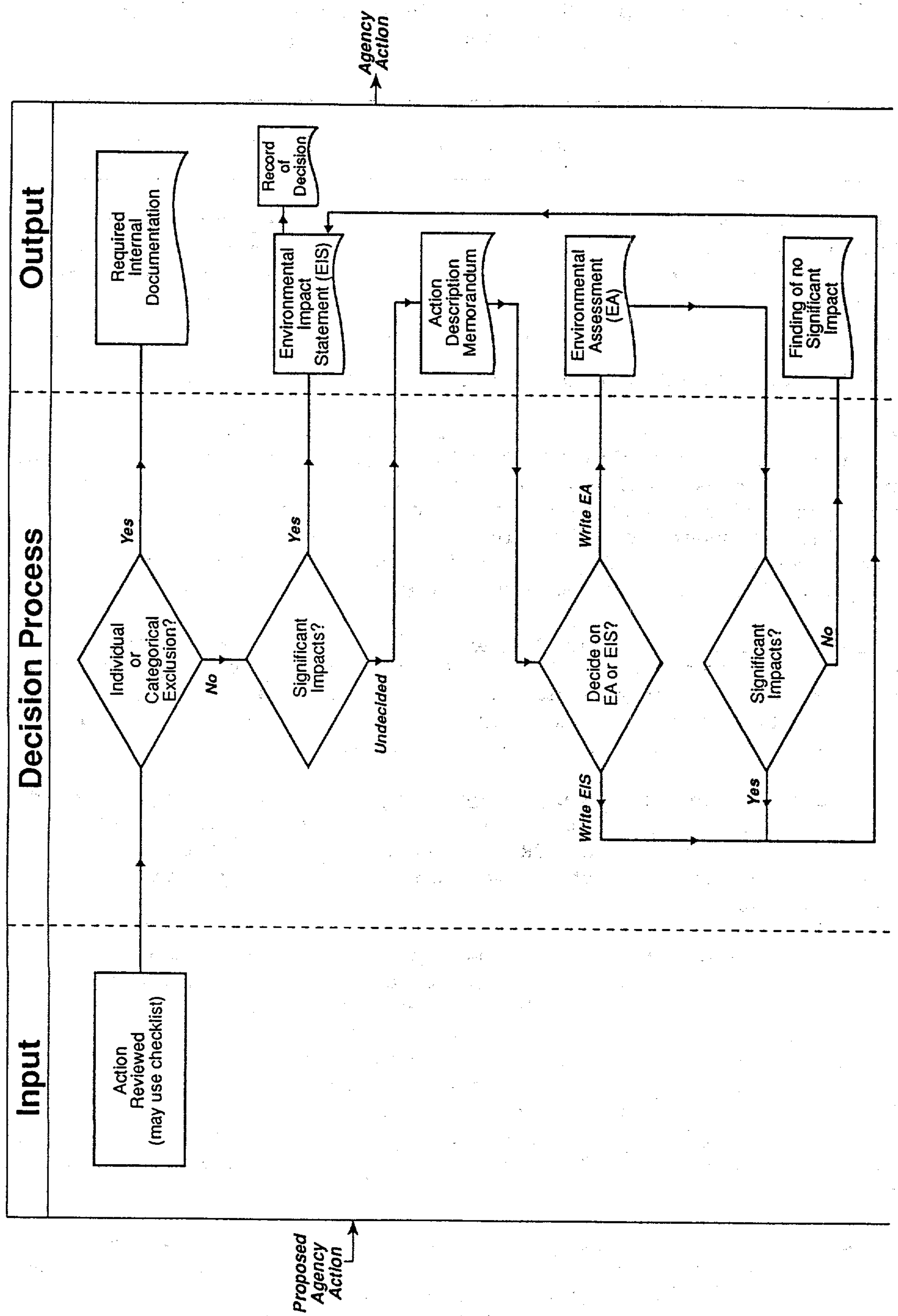

Figure 4-1. Sequence for Creating and Reviewing National Environmental Policy Act Documents

- Reynolds Electrical and Engineering Company: REECo/Nevada Test Site (NTS), as part of its TTR support activities, also performs environmental monitoring activities at TTR. These activities include water monitoring and obtaining permits in compliance with EPA and State of Nevada regulations.

  Until 1984, the radiological analysis results for TTR wells were published by REECo in the annual NTS environmental monitoring report. Starting in 1986, data for TTR Well 6 in the Control Point area (as well as information on other TTR wells) and relevant permit information have been forwarded to SNL so that these data can be reported in the annual TTR Site Environmental Report published by SNL (Millard and West 1987, 1988; Millard et al. 1989; Hwang et al. 1990, 1991; Howard and Culp 1992, 1993).

  REECo performs hazardous waste manifesting for offsite disposal of hazardous wastes at EPA-approved facilities.

- Edgerton, Germeshausen & Grier Corporation (EG&G) Energy Measurements Group: The EG&G Energy Measurements Group, under contract to the Nevada Applied Ecology Group (NAEG), did an aerial radiological survey of the TTR Clean Slate areas in 1977. A report was published in 1979 (EG&G 1979b).

  EG&G also published a report in 1979 on the status of endangered plant species at TTR (EG&G 1979a).

  EG&G performed additional aerial radiological surveys of SNL areas in the third and fourth quarters of CY 93. This work was in conjunction with ER activities.

Other agencies also prepare reports that may include information on TTR. These reports have been described in Volumes 1 through 4 of the Sandia National Laboratories/Nevada Environmental Compliance Summary Report (TTR 1992). They are available from the respective agencies. Reports which are prepared on a regular basis include the following:

- Annual Permits/Registration Certificates for Sandia National Laboratories/Nevada

- Offsite Monitoring Report-Nevada Test Site and Other Test Areas, Quarterly Report--EPA, Dose Assessment Branch, Nuclear Radiation Assessment Division

- Environmental Monitoring Report: Radiation Monitoring Around United States Nuclear Test Areas, Calendar Year Report--EPA, Dose Assessment Branch, Nuclear Radiation Assessment Division (also published as part of the NTS Annual Site Environmental Report)

- Community Radiation Monitoring Program, Annual Report--DRI, University of Nevada System

4.7 1993 REPORTABLE RELEASES

TTR had one reportable spill of petroleum hydrocarbons in 1993. The affected soil was cleaned up and disposed of in an approved manner. During 1993, the State of Nevada codified new rules for petroleum hydrocarbon releases reporting. These rules increase the reportable quantity to any amount greater than 25 gallons (or 3 cubic yards).

5.0 ENVIRONMENTAL SURVEILLANCE AT THE TONOPAH TEST RANGE IN 1993

5.1 1993 SANDIA NATIONAL LABORATORIES ENVIRONMENTAL SURVEILLANCE

5.1.1 Baseline Activities

In June 1993, Sandia National Laboratories' (SNL) Environmental Protection Department II (7575) Environmental Surveillance Program staff collected soil samples at the Tonopah Test Range (TTR). Limited air monitoring samples were collected from June to August 1993. An objective of these sampling activities was to supplement the baseline data collected in 1992 (SNL 1992a). The baseline surveillance efforts were designed to determine existing environmental contamination conditions at TTR and to provide information required to site long-term, routine, environmental surveillance locations.

Due to limited resources, the sampling locations, number of samples, and analyses performed were prioritized based on the following: (1) contaminants believed to be present, (2) contamination considered readily dispersible by environmental factors (e.g., wind or rain), and (3) areas with the greatest potential for impacts to workers and the environment. Limited soil samples were collected in the following areas in 1993 as part of the baseline study: Hard Target Area, Clean Slate 1, Clean Slate 3, Range Operations Center, various onsite locations, and offsite locations. Offsite locations represent areas unaffected or unrelated to site activities. Onsite samples can then be compared to the conditions that exist in areas unrelated to range operations. Air monitoring samples were collected near the Range Operations Center and in the vicinity of Clean Slates 1 and 2. All samples collected in 1993 were from areas of uncontrolled access outside the controlled areas.

Environmental thermoluminescent dosimeters (TLDs) are used to measure gamma radiation. Based on information available in 1993, environmental TLDs were placed at various locations on site, at the site perimeter, and off site in early January 1994. TLDs will be exchanged each calendar quarter, and all information will be included in future Site Environmental Reports. While the siting of TLDs is based on currently available information, these locations may be moved as additional information becomes available, or additional locations may be added as needed.

5.1.2 Additional Activities

During 1993, Edgerton, Germeshausen & Grier Corporation (EG&G) Energy Measurements Group performed an aerial radiological survey of a portion of TTR. The survey measured the terrestrial gamma radiation at the site to determine the levels of natural and man-made radiation. The helicopter used in this survey was outfitted with two detector pods and was flown at approximately 150 feet (ft) above the survey area. Preliminary results of the completed activities have been provided in the form of a site map showing approximately 40 picocuries per gram (pCi/g) transuranic contours. The aerial survey was initially funded by the U.S. Department of Energy's Nevada Operations Office

(DOE/NV). Due to costs and budget restrictions, a final document presenting the results of the aerial survey is not expected. If any pertinent information from this survey becomes available, it will be included in the 1994 Site Environmental Report for TTR.

In November 1993, Department 7575 was requested by Range Operations (Department 2719) to collect soil and air samples from three distinct areas downwind of Clean Slate 1. Soil samples were collected from the Mellan Airstrip, the Tin Building Area, and the Bridge Area. PM-10 and total suspended particulate (TSP) air filter samples were collected from the Mellan Airstrip area during landing events. Samples were collected to assess the existing contaminant source term and to determine the level of restricted access (if any) for these three areas where Range activities were scheduled.

5.1.3 Sample Collection and Analysis

Soil samples were gathered in accordance with *Environmental Sampling Procedure* (SNL 1992b), the activity-specific environment, safety and health (ES&H) Standard Operating Procedure (SOP). In cases of replicate sampling, only the first sample collected (sample A) was used in summary calculations to avoid skewing summary data toward replicate sample data. The results of replicate sampling may be found in Appendix A, Table A-1, for the baseline sampling, and Table A-2, for the special request sampling around the Mellan Airstrip, the Tin Building, and the Bridge Area.

Eighty-two soil samples were collected at TTR as part of the baseline activities: 6 from the Hard Target Area, 4 from the Range Operations Center, 21 from Clean Slate 1, 20 from Clean Slate 3, 15 from various locations on the TTR site (e.g., potential TLD locations, air monitoring locations), and 16 from offsite background locations.

All samples collected from the Hard Target Area were qualitatively analyzed for 20 metals by the inductively coupled plasma (ICP) method. Samples collected from the offsite locations, the Operations Center, and various onsite locations were analyzed for ICP metals, gross alpha, gross beta, total uranium (U_{tot}), and gamma spectroscopy. Samples collected at Clean Slate 1 and Clean Slate 3 were analyzed for gross alpha, gross beta, and U_{tot}, and analyzed by gamma spectroscopy.

Only the gamma spectroscopy results for americium-241 (Am-241) and cesium-137 (Cs-137) are included in this report. Americium-241 is a decay product of plutonium-241 (Pu-241); thus the presence of Am-241 infers the presence of Pu-241. Plutonium-241 is a common impurity in weapons-grade plutonium (Pu), the source of Pu-241. Plutonium analysis was performed on the subset of samples with measurable Am-241 concentrations as determined by the analytical laboratory.

PM-10 air monitoring samples were collected at two locations on TTR as part of the baseline activities. PM-10 monitors sample air particulates of 10 microns (μm) or less. This size particulate is considered respirable. Ten samples were collected from the Main Well location near the Range Operations Center and nine samples were collected from location STA-14, in the vicinity of Clean

Slates 1 and 2. Samples were gathered in accordance with TOP-94-07 (Culp 1994). All samples were analyzed for gross alpha and gross beta and analyzed by gamma spectroscopy.

For the requested sampling in the downwind area of Clean Slate 1, 87 soil samples were collected: 33 from around the Mellan Airstrip, 28 from around the Tin Building, and 26 from around the Bridge Area. All samples were analyzed for isotopic plutonium and U_{tot}, and by gamma spectroscopy. In addition, 12 air samples were collected from the vicinity of the Mellan Airstrip. Air filters were analyzed for isotopic Pu and U_{tot}.

5.2 1993 SNL RADIOLOGICAL SURVEILLANCE RESULTS

5.2.1 Baseline Soil Sampling

Figures A-1 through A-5 of Appendix A show the sample locations. Tables A-3 through A-8 of Appendix A list the individual sample results for the baseline-related soil sampling.

5.2.2 Offsite Baseline Soil Sampling

Table 5-1 summarizes the data for the 14 offsite locations (see Figure A-1 and Table A-3). Two sample locations (B-1 and B-2) were found to contain measurable amounts of Am-241. The follow-up isotopic Pu analysis confirmed the presence of Pu in the samples. These offsite data are believed to be representative of the ambient radionuclide concentrations for the area surrounding TTR. All offsite locations will be sampled again in 1994.

5.2.3 Onsite Baseline Soil Sampling

<u>Site Perimeter</u>: TTR is bordered on the east, west, and south by Nellis Air Force Base (NAFB) and to the north by Bureau of Land Management (BLM) land withdraw. Four perimeter locations were sampled and the data are summarized in Table 5-1 (see also Figure A-2 and Table A-4). Gross alpha, gross beta, U_{tot}, Am-241, and Cs-137 concentrations for perimeter locations T-6, T-8, and T-12 were found to be indistinguishable from offsite results. Gross alpha, gross beta, U_{tot}, and Cs-137 concentrations for location T-11 were also found to be indistinguishable from offsite results. At location T-11, Am-241 and isotopic Pu concentrations were found in concentrations approximating the analytical detection limit for the analyses and consistent with those offsite locations with measurable isotopic Pu and Am-241.

<u>Range Operations Center</u>: Table 5-1 contains summary results for the four sample locations around the Range Operations Center (Figure A-3 and Table A-5). Gross alpha, gross beta, U_{tot}, Cs-137, and Am-241 concentrations appear to be consistent with previous years' results and consistent with the results of those samples collected from offsite locations.

<u>Clean Slate 1</u>: Table 5-1 contains summary results for the 18 sample locations around Clean Slate 1 (see also Figure A-4 and Table A-6). Gross beta, Cs-137, and U_{tot} concentrations in soil collected at Clean Slate 1 appear to be consistent with soils collected off site and do not indicate gross contamination

Table 5-1. Summary Data for Soil Samples Collected at the Tonopah Test Range in 1993

Location	Number of Samples/ Transuranic Analyses[a]	Gross Alpha (pCi/g)			Gross Beta (pCi/g)			Pu-239,240 (pCi/g)			Pu-238 (pCi/g)			Am-241 (pCi/g)			U_{tot} (pCi/g)			Cs-137 (pCi/g)		
		Mean (CV)[b]	Std.	Range	Mean (CV)[b]	Std.	Range	Mean (CV)[b]	Std.	Range	Mean (CV)[b]	Std.	Range	Mean (CV)[b]	Std.	Range	Mean (CV)[b]	Std.	Range	Mean (CV)[b]	Std.	Range
Off Site	14/2	18 (28)	5	7 to 28	39 (13)	5	28 to 46	0.15 (34)	0.05	0.11 to 0.18	0.12 (59)	0.07	0.7 to 0.17	0.00 (-)	0.00	0.00 to 0.00	2.6 (23)	0.6	1.5 to 3.7	0.52 (54)	0.28	0.17 to 1.00
Site Perimeter	4/1	16 (23)	4	12 to 19	42 (5.0)	2	39 to 44	0.06	0.04[c]	-- to 0.06	0.12 (-)	0.05[c]	-- to 0.12	0.15	0.07[c]	-- to 0.15	1.9 (49)	0.9	0.5 to 2.4	0.40 (63)	0.26	0.07 to 0.56
Range Operations Center	4/0	20 (25)	5	14 to 25	40 (7.5)	3	39 to 45	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.2 (50)	0.6	0.7 to 2.0	0.46 (8.7)	0.04	0.41 to 0.50
Clean Slate 1	18/18	66 (130)	83	14 to 320	46 (15)	7	29 to 56	30 (220)	66	0.46 to 280	0.25 (190)	0.48	-0.04 to 2.10	4.1 (120)	5.1	0.10 to 14	2.75 (11)	0.29	1.9 to 3.1	0.71 (41)	0.29	0.26 to 1.1
Clean Slate 3	19/19	54 (69)	37	13 to 150	44 (11)	5	34 to 52	42 (200)	86	0.27 to 380	0.26 (220)	0.57	-0.11 to 2.4	2.7 (110)	3.0	0.11 to 12	3.0 (13)	0.4	2.2 to 3.4	0.58 (31)	0.18	0.22 to 1.00
Various On Site	11/4	20 (10)	2	18 to 23	43 (11)	4	35 to 50	0.44 (100)	0.46	0.06 to 1.1	0.25 (110)	0.27	0.02 to 0.54	0.16 (54)	0.09	0.08 to 0.28	1.3 (85)	1.1	0.6 to 4.0	0.32 (66)	0.21	0.0 to 0.63

[a]Number of samples in which analyses for isotopic Pu and Am-241 were performed.
[b]Coefficient of Variation = (standard deviation ÷ mean) x 100.
[c]±95% confidence level, counting error.
N/A means no analysis performed.

of beta-emitting radionuclides, U_{tot}, or Cs-137. The low coefficient of variations (CVs) indicate good reproducibility in the measurements and apparent uniform distribution in the sampled area.

Gross alpha concentrations were found to be elevated when compared to offsite results. The CV and range of values reveal considerable variation in the data, indicating that gross alpha contamination is not uniformly distributed in the area around Clean Slate 1. All samples collected at Clean Slate 1 were found to contain isotopic Pu and Am-241 in concentrations greater than the respective analytical detection limit. The CVs and the range of isotopic Pu and Am-241 values indicate a considerable variation in the sampled media and the nonuniform distribution of these radionuclides in the vicinity of Clean Slate 1.

<u>Clean Slate 3</u>: Table 5-1 contains summary results for the 19 sample locations around Clean Slate 3 (see Figure A-5 and Table A-7). Gross beta, Cs-137, and U_{tot} concentrations from soil collected at Clean Slate 3 appear to be consistent with soils collected off site and do not indicate gross contamination of beta emitting radionuclides, U_{tot}, or Cs-137. The low CVs indicate good reproducibility in the measurements and apparent uniform distribution in the sampled area.

Gross alpha concentrations were found to be elevated when compared to background. The CV and range of values reveal considerable variation in the data, indicating that gross alpha contamination is not uniformly distributed in the area around Clean Slate 3. All samples collected at Clean Slate 3 were found to contain isotopic Pu and Am-241 in concentrations greater than the respective analytical detection limit. The CVs and the range of isotopic Pu and Am-241 values indicates a considerable variation in the sampled media and the nonuniform distribution of these radionuclides in the vicinity of Clean Slate 3.

In general, transuranic concentrations decreased as the distance from the source increased in the downwind direction. The results of this limited soil sampling at Clean Slates 1 and 3 compare favorably with the results of the aerial radiologic survey performed in 1977 (EG&G 1979b).

The transuranic material associated with the original Clean Slate tests contained varying amounts of Pu-238, -239, and -240, and Am-241. Because these radionuclides are alpha emitting, the elevated gross alpha measurements are due, at least in part, to the elevated concentrations of these radionuclides at these sites. The abundance of Pu-241 in the original Clean Slate tests material is small relative to the other radionuclides which were present. Pu-241 is a beta-emitting radionuclide. Its concentration relative to the naturally occurring gross beta concentration is small. Considering the normal, or expected, variation in gross beta measurements, the contribution by Pu-241 would be small and may go unnoticed in the gross beta measurement.

<u>Various Onsite Locations</u>: Eleven samples were collected from various locations on site. The data are summarized in Table 5-1 (see also Figure A-2 and Table A-8). Gross alpha, gross beta, U_{tot}, and Cs-137 concentrations for locations

OP3-1, OP3-2, STA14-1, T-1, T-4, T-5, and T-10 were found to be indistinguishable from offsite concentrations. Results from locations D-1, T-2, T-3, and T-7 were found to be indistinguishable from offsite results for gross alpha, gross beta, U_{tot} and Cs-137. Locations D-1, T-2, and T-3 were found to contain measurable concentrations of isotopic Pu and Am-241. These locations are in areas suspected of containing transuranic contamination. Location T-7 contained isotopic Pu and Am-241 in concentrations approximating the detection limit for the various analyses and similar to measurable offsite concentrations.

5.2.4 Baseline Air Sampling

Tables A-9 and A-10 of Appendix A list the individual sample results from the limited baseline PM-10 air sampling at the Main Well and STA-14, respectively. The Main Well was chosen due to its location in the general vicinity of the Range Operations Center where the majority of SNL personnel work. STA-14 was chosen due to its location between Clean Slate 1 and Clean Slate 2. This location is in the predominant wind direction from the potential sources of contamination (Clean Slates 1 and 2) toward the occupied areas of TTR.

All samples were analyzed for gross alpha and gross beta, and by gamma spectroscopy. The limited samples collected closest to the Clean Slate sites (STA-14) appear to be consistent with those collected near the Range Operations Center (Main Well). Both data sets also appear to be consistent with the 1993 EPA Air Surveillance Network Results (Table 5-6) for the towns of Goldfield and Tonopah along with the EPA results for TTR, collected from the Range Operations Center.

5.2.5 Results of Environmental Radiological Sampling at the Mellan Airstrip, Tin Building, and Bridge Area

The general areas around the Mellan Airstrip, Tin Building, and Bridge Area are either known or suspected to be contaminated with transuranic radionuclides related to the original test conducted at Clean Slate 1 (EG&G 1979b). Figures A-6 through A-9 of Appendix A show the sample locations. Tables A-11 through A-16 of Appendix A list individual sample results. At all sampled locations, U_{tot} concentrations were found to be indistinguishable from concentrations in offsite soils.

<u>Mellan Airstrip</u>: Thirty soil samples were collected from around the Mellan Airstrip (see Figure A-6 and Table A-11). The sampling emphasized the east/west runway that is used for airplane landings and takeoffs. Samples were also collected from the north/south runway closest to the area of known contamination. The data are summarized in Table 5-2. The majority of soil samples were found to have Pu-238, -239, and -240, and Am-241 in concentrations greater than the analytical detection limit and greater than the concentrations in offsite samples.

PM-10 and TSP air samplers were co-located at six locations around the Mellan Airstrip along the east/west runway and at the main well near the Operations Center. The Main Well location was used as a reference location (see Figure A-7 and Table A-12). The PM-10 samples air particulates that are 10 μm or less

Table 5-2. Summary of Radiological Analysis Data for Soil Samples Collected from Mellan Airstrip, Tin Building, and Bridge Area

Location	Number of samples	Pu-239, 240 (pCi/g)			Pu-238 (pCi/g)			Am-241 (pCi/g)			U_{tot} (μg/g)		
		Mean (CV)[a]	Std.	Range	Mean (CV)[a]	Std.	Range	Mean (CV)[a]	Std.	Range	Mean (CV)[a]	Std.	Range
Mellan Airstrip	30	0.59 (130)	0.78	-0.02 to 4.5	0.06 (130)	0.08	-0.02 to 0.30	0.10 (100)	0.10	-0.0 to 0.42	2.54 (17)	0.43	1.7 to 3.2
Tin Building (total)	26												
Road	12	0.39 (330)	1.3	-0.02 to 4.4	0.02 (150)	0.03	-0.04 to 0.04	0.05 (340)	0.17	-0.00 to 0.60	3.2 (13)	0.40	2.7 to 3.8
Disturbed	7	9.3 (160)	15	0.59 to 40	0.08 (150)	0.12	-0.02 to 0.31	1.4 (100)	1.4	0.15 to 3.1	3.0 (12)	0.37	2.4 to 3.4
Undisturbed	7	79 (92)	73	14. to 230	0.68 (74)	0.50	0.23 to 1.7	4.6 (61)	2.8	2.2 to 10	3.2 (16)	0.5	2.2 to 4.0
Bridge Area	24	0.06 (450)	0.27	-0.07 to 1.3	0.02 (300)	0.06	-0.07 to 0.11	0.05 (400)	0.20	-0.00 to 1.0	3.3 (12)	0.38	2.6 to 4.1

[a]Coefficient of Variation = (standard deviation ÷ mean) x 100.

in diameter. The TSP samples the total suspended particulates in the air. Samplers were turned on prior to a landing/take-off event and turned off as soon as practicable after the event. Sampling was designed to evaluate the resuspension of contaminated material. Due to the short duration of sampling, all material collected by the samplers was conservatively assumed to have been contained in one liter of air. This is conservative because the actual volume of air sampled is believed to be greater than one liter.

Air monitoring results indicated that no air samples approach the U.S. Environmental Protection Agency (EPA) annual limit of intake (ALI) or derived air concentration (DAC) for the respective radionuclides. Because this is a conservative way of determining the amount of material that is resuspended, the actual air concentration of contaminated material due to landing/take-off activities is expected to be less.

<u>Tin Building</u>: Due to the variety of conditions at the Tin Building area, three distinct areas were sampled: the dirt road, the disturbed area, and the undisturbed area (see Figure A-8 and Tables A-13, -14, and -15). A total of 26 soil samples were collected: 12 from the dirt road, 7 from the disturbed area, and 7 from the undisturbed area. The data are summarized in Table 5-2. The dirt road provides access to the Tin Building from the Mellan Airstrip road. It appears to have been built-up and compacted during construction of the Tin Building and contains the lowest transuranic activity concentrations in the Tin Building area. The majority of the samples collected from the dirt road have transuranic activity less than the associated analytical detection limit.

The area around the Tin Building appears to have been disturbed during the construction of the building. The soil disturbance probably was related to the use of heavy equipment in the construction of the building or in the recontouring of the soils after construction. The transuranic concentrations appear to be greater than those in the dirt road area. The majority of the activities are greater than the analytical detection limits and are much greater than the transuranic concentrations found offsite.

The soil samples collected from the undisturbed area around the Tin Building appear to have been minimally impacted by the construction of the Tin Building. The transuranic concentrations in this area are the greatest of the three areas sampled in the Tin Building area.

The difference in the transuranic concentrations for these three sub-areas of the Tin Building area show the effect of unintentional "mixing" of the soil. The original test at Clean Slate 1 is believed to have deposited the transuranics on the soil surface. Through construction-related activities this surficially contaminated material has been mixed with lower "clean" layers of soil. This has had the effect of lowering the contamination through dilution. The samples collected from the undisturbed locations would appear to be the best indication of the transuranic concentrations for the entire Tin Building area prior to the activities related to building construction.

<u>Bridge Area</u>: Twenty-four soil samples were collected from the Bridge Area. The data are summarized in Table 5-2 (see also Figure A-9 and Table A-16). Due to construction-related activities at the time of sampling, the area around the

Bridge was extensively disturbed. The majority of the samples were found to be less than the analytical detection limits. The low activities are believed to be related to the previously described unintentional "mixing" related to construction activities.

5.3 1993 SNL NON-RADIOLOGICAL SURVEILLANCE RESULTS

The Environmental Surveillance Program was enhanced to include analysis of soil samples for total metals. Samples were classified as onsite and offsite. Onsite samples were collected from the Hard Target Area, the Range Operations Center, and various locations on the TTR site. Offsite samples were collected outside TTR in the surrounding community in areas not expected to be influenced by activities conducted on TTR. Soil samples were analyzed using the ICP method. Soil samples were analyzed for the following elements: aluminum, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, silica, silver, sodium, strontium, titanium, vanadium and zinc. Analytical data are shown in Appendix C. Comparison of onsite and offsite samples will help to determine if TTR activities have contributed to the deposition of metals. If TTR activities do contribute to metal contamination, then comparison of samples from the same locations over time will provide an indication of potential contaminant migration or the addition of contaminants.

5.3.1 Baseline Soil Sampling

Tables C-1, C-2, C-3, and C-4 in Appendix C list the concentrations of metals in soil samples collected from onsite and offsite locations. The results are summarized in Table 5-3. Figures A-2, A-3, and A-1 show the sample locations. Statistically, the concentration means for some elements could be shown to be significantly higher for onsite samples than for offsite samples at the 95% confidence level. The Hard Target samples had concentration means for chromium and lead which were higher than the corresponding offsite means. The silica concentration was also higher, but silica is of minor importance. The highest concentration of chromium in a Hard Target sample was 45 parts per million (ppm), well above the community high of 21 ppm. The highest concentration of lead in a Hard Target sample was 160 ppm, while the offsite high concentration of lead was 33 ppm. There were no element concentration means at the various onsite locations which were higher than the corresponding means in the offsite samples and which were statistically significant. The concentration means for beryllium, cobalt, iron, aluminum, and potassium in the Operations Center samples were significantly higher than the corresponding means for community samples. The elevations in concentration for beryllium and cobalt, although statistically significant, were small. As indicated in Table 5-3, the concentration means for a number of elements (iron, vanadium, and zinc) were lower in some onsite samples than in the community samples.

5.4 ENVIRONMENTAL PERSPECTIVE

It is generally accepted that once Pu comes in contact with soil in the environment, it becomes firmly attached to the host particle. Previous studies (Tamura 1974, 1975, 1976) of soil samples from safety-shot areas at the Nevada Test Site (NTS) showed Pu particle-size association was primarily with coarse

Table 5-3. Metals Concentration Summary of Onsite and Offsite Soil Samples

	Metal Concentration Mean (ppm)			
	Onsite			
	Hard Target	Clean Slate	Operations Center	Offsite
Aluminum	7,317	9,338	12,316*	8,544
Barium	122	129	153	193
Beryllium	0.500	0.504	0.583*	0.5
Cadmium	0.5	0.5	0.5	0.6
Calcium	13,704	5,185	16,000	12,537
Chromium	28*	11.99	9	11
Cobalt	3.9	3.42	5*	3.3
Copper	10.6	6.36	10	8.8
Iron	7,767	9,369	11,917*	9,862
Lead	84.3*	10	13	14
Magnesium	3,000	3,161	4,467	3,737
Manganese	278	350	352	362
Nickel	7	5	6	6
Potassium	3,550	3,261	4,167*	3,025

Table 5-3. Metals Concentration Summary of Onsite and Offsite Soil Samples (Concluded)

	Metal Concentration Mean (ppm)			
	Onsite			
	Hard Target	Clean Slate	Operations Center	Offsite
Silica	493*	428	315	333
Silver	0.5	0.5	0.5	14*
Sodium	1,010	399	539	584
Strontium	91	50	91	81
Titanium	288	329	493	379
Vanadium	13	16.9	23	23
Zinc	11	24	25	44*

* = Statistically above offsite at the 95% confidence level.

silts (50 to 20 μm) and fine sands (125 to 50 μm). Whereas the inhalation of fine sizes (<7 μm diameter at 1 gram per cubic centimeter [g/cm^3] density) is considered most hazardous (Tamura 1976), the coarser soil particles should not be ignored with regard to environmental transport, as these particle sizes are readily subjected to movement by wind (Leavitt 1980). Leavitt (1976) studied five safety-shot areas in Nevada and reported that the wind had a dominant influence on the surface texture of the desert soil by depositing soil fines around the base of brush or vegetation. Another study (Tamura 1977) discussed the occurrence of sandy mounds formed under desert shrubbery. These mounds were formed by the filtering action of the desert vegetation in intercepting saltation and creeping particles. The vegetation intercepts the material being moved through the environment by wind. This study and additional studies found that in Pu-contaminated areas, the Pu activity levels were higher in the desert mounds than in the contiguous desert pavement. This demonstrates the effect of wind erosion in dispersal of contaminated material. The Tamura (1977) study also discussed evidence of Pu migration downward into the soil profile.

Evidence of water erosion has been observed within the outer control fence at Clean Slate 2. The erosive effects of water may pose another mechanism for transport of the contaminated material. Essington and Fowler (1976) observed the ability of Pu to migrate to deeper layers of soil with time. Vertical transport of contaminants into the soil column may allow greater exposure of roots and a potential for root uptake of contaminants by the plants. Soil profiles from the safety-shot areas at TTR indicate a decrease in the Pu-to-Am ratio with depth (Romney et al. 1975), suggesting greater vertical movement of Am-241 relative to Pu-239 and -240. This same report also stated that there is evidence showing that Am is much more readily available to plants through roots than is Pu. Gilbert et al. (1975) stated that erosive processes and penetration into the soil would eventually flatten out peak contaminant concentrations and that there was a need for long-term hazard evaluation in order to evaluate the change in contaminant concentrations over time at the safety-shot areas.

5.5 1993 U.S. ENVIRONMENTAL PROTECTION AGENCY MONITORING AT THE TONOPAH TEST RANGE

5.5.1 Background

The EPA does routine monitoring around the NTS and near the TTR. The monitoring includes TLDs and pressurized ion chamber (PIC) measurements to detect gamma radiation; air monitoring to measure noble gases, tritium (H-3), and other radionuclides; and water monitoring primarily to measure radionuclides. Routine sample results are reported on a quarterly basis to DOE/NV and are summarized in Tables 5-4 and 5-5. A detailed description of the EPA monitoring procedures, equipment, quality assurance (QA), and detection limits can be found in the annual *Offsite Environmental Monitoring Report* published by the EPA (Grossman et al. 1986).

5.5.2 Location

The EPA has a monitoring station located at the TTR Control Point (Station 3) adjacent to the medical aid station. Water samples are collected at TTR Well 6. These are the only two onsite monitoring stations at TTR.

For comparative purposes, the remainder of this section presents results of air, water, and dosimetry analyses for Goldfield, NV, which is the closest populated area, and Tonopah, NV, which is the next nearest populated area. Results for Las Vegas, NV, are for water only. Goldfield is approximately 25 miles (mi) (40 kilometers [km]) west of TTR; Tonopah is 30 mi (48 km) northwest of TTR; and Las Vegas is 140 mi (225 km) southeast of TTR.

5.5.3 Soil Sampling

The EPA has not performed soil sampling on a routine basis at TTR, though it has performed soil sampling and radiation surveys in the past (Bliss and Parr 1980).

5.5.4 External Radiation

The EPA measures external radiation using TLDs and PICs. EPA TLDs are located in the communities of Tonopah, Clark Station, and Goldfield, and at TTR. Due

Table 5-4. Summary of 1993 U.S. Environmental Protection Agency Pressurized Ion Chamber Data[a]

Location	1993 Quarter	Average Exposure Rate[b]	
		µrem/hr ± 1 Sigma	mrem/Qtr
Goldfield, NV	1	14.7 ± 0.4	32.1 ± 0.9
	2	15.0 ± 0.1	32.8 ± 0.2
	3	15.0 ± 0.1	32.8 ± 0.2
	4	15.2 ± 0.4	33.2 ± 0.9
Tonopah, NV	1	16.6 ± 0.6	36.2 ± 1.3
	2	17.0 ± 0.1	37.1 ± 0.2
	3	17.8 ± 0.2	38.9 ± 0.4
	4	17.5 ± 0.4	38.2 ± 0.9

[a]Source: EPA 1993.
[b]The values presented here are gross results including background exposure values.

Table 5-5. Summary of 1993 Groundwater Analytical Results for the U.S. Environmental Protection Agency Long-Term Hydrologic Monitoring Program

Sample Location	1993 Collection Date	H-3 picocuries per liter (pCi/L)	2 Sigma
Clark Station, NV	02/02	0.41	3.5
Well 6 TTR	03/01	-48	276
	08/12	-0.92	3.0
	08/12	-1.9	2.8
Tonopah, NV	03/01	-48	276
City Well	09/15	-0.53	3.1
	09/15	1.1	2.7

Source: EPA 1993.

to data-quality difficulties, EPA TLD data was unavailable for inclusion in this report.

Reuter-Stokes PICs are located at the Goldfield and Tonopah community monitoring stations. Quarterly summary data for Goldfield and Tonopah are provided in Table 5-4.

5.5.5 Water

TTR is included in EPA's Long-Term Hydrologic Monitoring Program (LTHMP) (EPA 1990). The EPA established LTHMP to monitor water sources in the general area where nuclear tests have been conducted to determine if nuclear-test-related radioactivity is present in nearby communities. In this program, TTR is considered a nearby community of the NTS (location of the tests). Samples were collected on a semiannual basis by EPA until 1984, but are now collected monthly. Monthly sample analysis includes a gamma spectral analysis, suspended solids, pH, temperature, and conductivity. Tritium analysis is done semiannually. When the conventional analysis yields H-3 concentrations ≤700 picocuries/liter (pCi/L), a reanalysis is performed using a H-3-enrichment analysis technique (minimum detectable concentrations [MDC] = 9 pCi/L). Gross alpha and gross beta analyses are not performed on the routine samples. A detailed analysis including isotopic U and alpha count is only performed for initial samples at new sample locations.

Two 3.8-liter (L) (1-gallon [gal]) samples are collected monthly. One sample is filtered and acidified. Two 0.47-L (1-pint) samples are collected for the H-3 analysis, one of which is stored for a year as a backup sample.

Tritium concentrations reported by the EPA for TTR Well 6 were compared with the Tonopah City well results (Table 5-5). No unexpected gamma-emitting radionuclides were detected; therefore, only H-3 values are reported. The H-3 concentrations observed were consistent with previous years' data. All values are well below the DOE H-3 concentration guide of 20,000 pCi/L. Future measurements at this monitoring location will be evaluated to determine whether this value is representative or anomalous.

5.5.6 Air Monitoring

A continuous particulate air monitoring station is located at TTR as part of the EPA Air Surveillance Network (ASN). Air filters are changed weekly, then analyzed by gamma spectrometry. This EPA network also includes a station at Goldfield and at Tonopah (Table 5-6). Beryllium-7 (Be-7), a naturally occurring radionuclide, is generally the only nuclide detected by gamma spectrometry.

5.6 1993 Reynolds Electrical and Engineering Company (REECo) Monitoring Program

5.6.1 Background

Traditionally, Reynolds Electrical and Engineering Company's (REECo) NTS environmental monitoring activities at TTR are limited to water monitoring and

Table 5-6. Summary of 1993 U.S. Environmental Protection Agency Air Surveillance Network Results

Sample Location	1993 Quarter	Average Concentration (pCi/m^3 ± 1 standard deviation)[a]		
		Gross Alpha	Gross Beta	Be-7
TTR, NV	1	4.8E-4 ± 5.4E-4(13)	1.1E-2 ± 4.5E-3(13)	0.29 ± 0.18[b] (1)
	2	5.4E-5 ± 2.3E-3(13)	8.6E-3 ± 4.7E-3(13)	0.24 ± 0.07 (3)
	3	1.0E-3 ± 6.9E-4(13)	1.7E-2 ± 3.4E-3(13)	0.28 ± 0.10 (3)
	4	1.1E-3 ± 4.5E-4(12)	2.0E-2 ± 5.9E-3(12)	--
Goldfield, NV	1	2.4E-4 ± 4.2E-4(14)	1.2E-4 ± 6.5E-3(14)	0.28 ± 0.06 (2)
	2	6.2E-4 ± 3.4E-4(13)	1.3E-2 ± 2.7E-3(13)	0.39 ± 0.11 (3)
	3	7.6E-4 ± 5.4E-4(13)	1.7E-2 ± 3.6E-3(13)	0.32 ± 0.07 (3)
	4	9.4E-4 ± 3.8E-4(14)	2.1E-2 ± 5.4E-3(14)	0.33 ± 0.04 (3)
Tonopah, NV	1	6.7E-4 ± 4.7E-4(13)	1.2E-2 ± 6.0E-3(13)	0.46 ± 0.19[b] (1)
	2	5.5E-4 ± 4.6E-4(13)	1.3E-2 ± 3.5E-3(13)	0.31 ± 0.01 (2)
	3	5.6E-4 ± 3.7E-4(13)	1.6E-2 ± 3.9E-3(13)	0.31 ± 0.08 (5)
	4	1.1E-3 ± 5.9E-4(13)	2.2E-2 ± 6.7E-3(13)	0.39 ± 0.11 (6)

[a] Number of weeks sampled is in parentheses for gross alpha and gross beta; number of weeks detected is in parentheses for Be-7.
[b] Individual measurements with units of pCi/m^3 ± 2 σ counting error.

obtaining permits in compliance with EPA regulations. Environmental compliance permits for TTR include those for potable water supply, sewage, and air quality. These permits are updated annually or as necessary. The current permit listing is in Table B-2 of Appendix B.

Water samples are collected monthly as required by the Safe Drinking Water Act (SDWA) and the State of Nevada Public Water Supply and Public Water System Regulation NAC 445.370-445-420. Plans for sampling frequency and location have been developed in the TTR Sampling Site Plan (REECo 1991a). This document has been reviewed and approved by State of Nevada Bureau of Health Services. Table 5-7 summarizes water sampling of the public water systems at the TTR, listing the frequency and type of analysis and results. Wastewater is sampled quarterly by the United States Air Force (USAF) at the headwater end of the lagoon (see Table 5-8).

In addition, REECo meets two other annual requirements: the Superfund Amendment and Reauthorization Act (SARA), Title III (the Emergency Planning and Community Right-to-Know Act [EPCRA]), reporting requirements for all TTR activities and the State of Nevada Extremely Hazardous Material reporting requirements.

5.6.2 Water

The Environmental Health Services Section of REECo is responsible for collecting samples at TTR. Water samples for bacteriological testing are collected from the Well 6 distribution system that services the Central Point and Technical Area III (TA-III). In addition, Well 6 is sampled by the EPA for a radiological analysis survey for the LTHMP. Sampling sites are based on the TTR Sampling Site Plan for compliance with the SDWA.

Well 6's permit is renewed annually by the State of Nevada Bureau of Health Protection Services. Permit updates are obtained annually by the U.S. Department of Energy's Kirtland Area Office (DOE/KAO) and copies are forwarded to Sandia National Laboratories/Nevada (SNL/NV) for inclusion in the annual TTR Site Environmental Report.

Following guidelines in the REECo Monitoring Procedure Manual (REECo 1987), samples are collected for bacteriological and radiological analysis to comply with the SDWA.

Bacteriological samples are collected monthly in preserved-sample bottles obtained from the state-certified laboratory. REECo transports the samples to the laboratory in Las Vegas, Nevada, following chain-of-custody procedures. All analyses meet the requirements of the total coliform rule.

5.6.3 Sewage System

Sewage from SNL facilities at TA-III of TTR goes to the USAF sewage lagoon. The permit was held by DOE/NV through July 1992 when it was transferred to the USAF Nellis Air Force Base (NAFB) Range Complex. Because of widespread locations in remote areas, sewage goes into septic tanks and associated drain fields. These discharges fall primarily under the statutory authority of the

Table 5-7. Summary of 1993 SNL/NV Public Water Systems Sampling at the Tonopah Test Range

Public Water System	Frequency/Analysis	Results
Site 6 (2 samples)[a]	Monthly/Coliform	Negative

[a]TTR well number 6.

Table 5-8. Summary of 1993 SNL/NV Wastewater Sampling Program

Location	Number of Samples	Frequency	Analyses	Analytical Laboratory
Sample Station TA-III	2	Quarterly	Priority Pollutants Radiochemistry	IT Corp.

Clean Water Act (CWA) and SDWA (as amended). These discharges are regulated under Nevada Administrative Code, Chapters 444-445, and are administered by the State of Nevada, Bureau of Health Protection Services, and the Nevada Department of Environmental Protection (NDEP). The wastewater samples from head works and sewage lagoons are analyzed quarterly for biochemical oxygen demand (BODs) and total suspended solids (TSS). The quarterly discharge monitoring reports are prepared and submitted to DOE for review and transmittal to NDEP. (All data are summarized in the NTS yearly site environmental report [REECo 1991b].)

5.7 ASSESSMENT OF POTENTIAL DOSE TO THE PUBLIC

The three Clean Slate sites are considered a potential source of airborne radioactive contamination through the process of wind resuspension of the transuranic contaminated surface soils associated with each site. A radiation dose was calculated based on the resuspension of this material. The dose assessment was performed for onsite and offsite receptors where non-SNL personnel abide or reside. Four different onsite receptor locations were evaluated as suspected locations of the maximally exposed individual (MEI). The concept of "onsite receptors" is conservatively assumed to include members of the military, military contractors, and other non-SNL personnel who work at locations on TTR but over whom SNL has little or no operational control. This definition is believed to be consistent with current DOE guidance. In addition to onsite receptors, four offsite receptor locations were evaluated. All dose calculation results presented in this section were performed using the EPA CAP-88 computer code (EPA 1991). A summary of the data, calculations, and supporting documentation is provided in Appendix D of this report. The detailed methodology and supplemental data used to calculate the radiological doses is provided in Appendix E of this report.

5.7.1 Receptor Locations

For determination of potential dose to the public, receptor locations were divided into onsite and offsite. The TTR onsite receptor locations consist of Onsite Housing, Airport, South Perimeter, and the 554 Range Squadron Operations and Maintenance (O&M) Complex (Figure 5-1). The TTR offsite region includes a distinct population of seasonal workers and permanent residents. These two sets of public receptors are shown in Figure 5-2. The first zone shows the permanent public-receptor zone and the second zone shows the seasonal public-receptor zone. The potential dose to an offsite receptor was determined for hypothetical individuals who reside in the towns of Goldfield, Tonopah, and Warm Springs, and at the east entrance to NAFB/TTR (Figure 5-2).

5.7.2 Meteorological Data

Meteorological data for the TTR area are derived from the joint frequency distribution table for the Tonopah Airport located about 65 km north of TTR (EPA 1991). Although the meteorological measurements were taken north of TTR, wind patterns are not believed to be appreciably different due to the geographic similarities of these locations.

5.7.3 Release Sources

During 1993, no radiological point-source releases occurred as a result of TTR operations. The potential releases associated with the Clean Slate sites occur as a result of the wind resuspension of soil particulates (fugitive dust) contaminated with transuranic radionuclides. The 1977 EG&G aerial radiological survey of Clean Slates 1, 2, and 3 documented the level of residual surface soil activity in the form of radiation isopleths showing the soil activity of Am-241, Pu-239, and Pu-240 (EG&G 1979b). The study concluded that the contaminated area associated with the Clean Slate sites is approximately 22.5 million square meters.

The annual diffuse source term associated with the Clean Slate sites was calculated using a wind resuspension model which calculates the rate at which soil particulates become airborne. This model uses site specific information (e.g., wind speed, wind direction, and contaminant source term) whenever appropriate.

A release of 0.25 curies per year (Ci/yr) of total activity (Pu-238, -239, -240, -241, and -242, and Am-241) was calculated as the resuspended source term associated with the Clean Slate sites. This resuspended source term is for particulate matter which is 10 μm or less in diameter, and is assumed to be entirely respirable. A more detailed description of the source term determination is included in Appendix E.

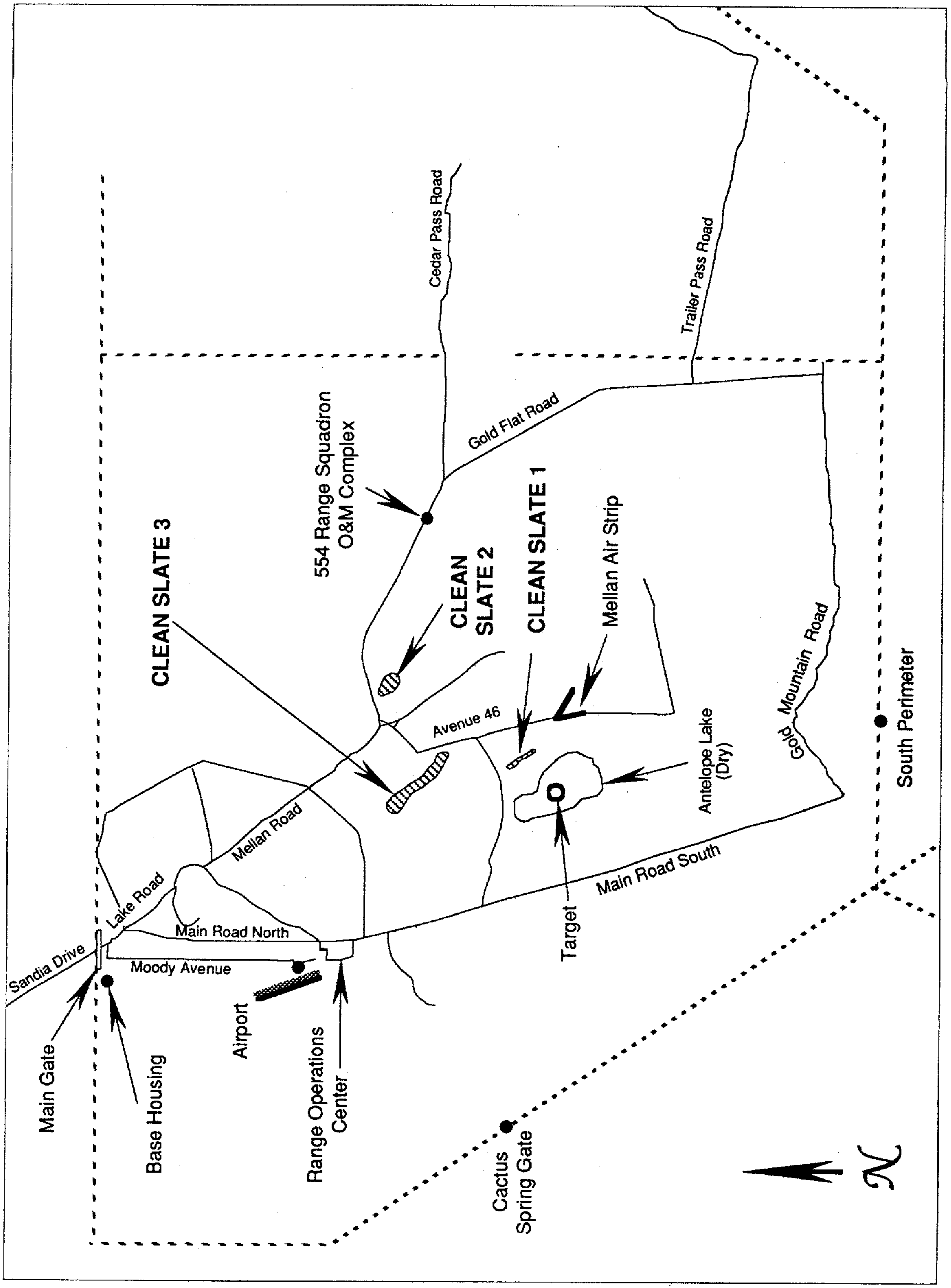

Figure 5-1. Onsite Receptor Locations

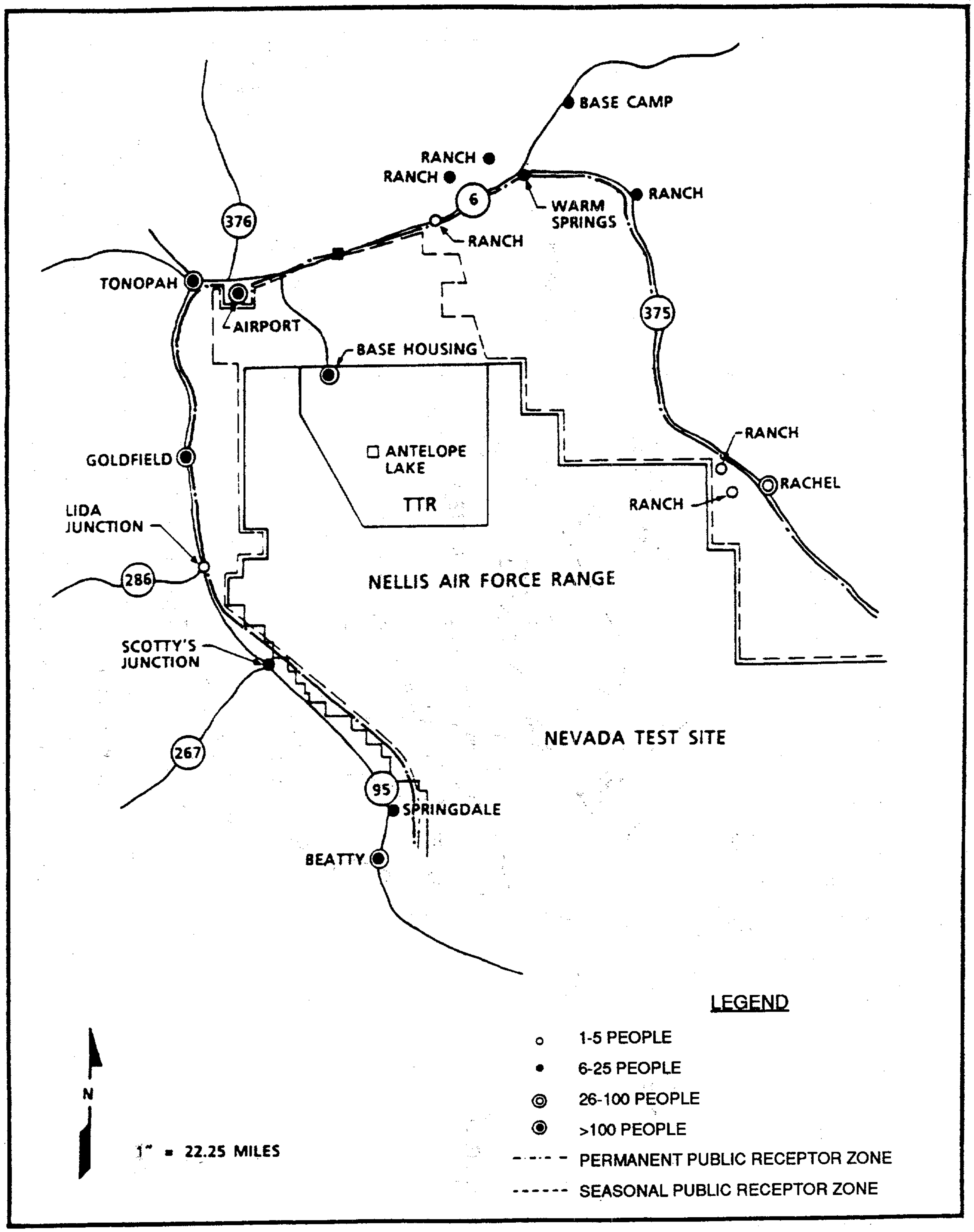

Figure 5-2. Public Receptor Zone Around the Tonopah Test Range

5.7.4 Radiological Dose Assessment

The diffuse emissions associated with the Clean Slate sites were the focal point of the overall dose assessment. The calculated annual release was used to calculate a regional population dose of 0.00038 person-millirems per year (person-mrem/yr). An MEI dose of 2.9 millirems per year (mrem/yr) was calculated for the 554th Range Squadron O&M Complex receptor location. The potential doses to individuals residing in the towns of Goldfield, Tonopah, and Warm Springs, and at the east entrance of NAFB/TTR were calculated to be 0.062 mrem/yr, 0.045 mrem/yr, 0.013 mrem/yr, and 0.050 mrem/yr. A summary description of the dose assessment is included in Appendix D; a more detailed description is found in Appendix E.

6.0 REFERENCES

Bliss and Parr 1980: Bliss, W. A., and R. A. Parr, "Plutonium in Soil Around the Nevada Test Site (Draft Report)," EMSL-LV-0539-xx, Environmental Monitoring Systems Laboratory, Las Vegas, NV (1980).

Culp 1994: Culp, T., "Department 7575 Technical Operating Procedure for Validation and Analysis of Environmental Surveillance Data," TOP-94-07, Sandia National Laboratories, Albuquerque, NM (1994).

DOC 1991: U.S. Department of Commerce, Bureau of the Census, "1990 United States Census--Preliminary Report," DOC, U.S. Government Printing Office, Washington, DC (1991).

EG&G 1979a: Edgerton, Germeshausen & Grier Corporation, "Status of Endangered and Threatened Species on Test Range - A Survey," EGG-1183-2387, EG&G, Las Vegas, NV (1979).

EG&G 1979b: Edgerton, Germeshausen & Grier Corporation, "An Aerial Radiological Survey of Clean Slates 1, 2, and 3, and Double Track, Test Range," EGG-1183-1737, Energy Measurement Group, EG&G, Las Vegas, NV (1979).

EPA 1991: U.S. Environmental Protection Agency, "CAP-88, Clean Air Act Assessment Package," Radiation Shielding Information Center, CCC-542, Oak Ridge, TN (1991).

EPA 1993: U.S. Environmental Protection Agency, 1993 Data for the Pressurized Ion Chamber and Analytical Results for the EPA Long-Term Hydrologic Monitoring Program, EPA, Las Vegas, NV (1993).

ERDA 1975: U.S. Energy Research and Development Administration, "Environmental Assessment, Tonopah Test Range," EIA/MA/76-2, ERDA (1975).

Essington and Fowler 1976: Essington, E. H., and, E. B. Fowler, 'Distribution of Transuranic Nuclides in Soils: A Review,' in "Transuranics in Natural Environments," Report NVO-178 (1976).

Gilbert et al. 1975: Gilbert, R. O., et al., 'Statistical Analysis of $^{239-240}Pu$ and ^{241}Am Contamination of Soil and Vegetation on NAEG Study Sites,' in "The Radioecology of Plutonium and Other Transuranics in Desert Environments," Report NVO-153, Battelle Memorial Institute, Pacific Northwest Laboratory, Richland, WA (1975).

Grossman et al. 1986: Grossman, R. F., S. C. Black, R. E. Dye, D. D. Smith, D. J. Thome, A. A. Mullen, and the Nuclear Radiation Assessment Division, "Offsite Environmental Monitoring Report, Radiation Monitoring Around the United States Nuclear Test Areas, Calendar Year 1985," EPA-600/4-86-022, DOE/DP/0539-055, U.S. Environmental Protection Agency, Las Vegas, NV (1986).

Howard and Culp 1992: Howard, D., and T. Culp, "1991 Environmental Monitoring Report, Tonopah Test Range, Tonopah, Nevada," SAND92-0938, Sandia National Laboratories, Albuquerque, NM (1992).

Howard and Culp 1993: Howard, D., and T. Culp, "1992 Environmental Monitoring Report, Tonopah Test Range, Tonopah, Nevada," SAND93-1449, Sandia National Laboratories, Albuquerque, NM (1993).

Hwang et al. 1990: Hwang, S., J. Phelan, T. Wolff, G. Yeager, D. Dionne, and G. West, "1989 Environmental Monitoring Report, Tonopah Test Range, Tonopah, Nevada," SAND90-0302, Sandia National Laboratories, Albuquerque, NM (1990).

Hwang et al. 1991: Hwang, S., J. Phelan, T. Wolff, G. Yeager, D. Dionne, G. West, and C. Girard, "1990 Environmental Monitoring Report, Tonopah Test Range, Tonopah, Nevada," SAND91-0593, Sandia National Laboratories, Albuquerque, NM (1991).

Leavitt 1976: Leavitt, V., 'Soil Surveys of Five Plutonium-Contaminated Areas on the Test Range Complex in Nevada,' in "Nevada Applied Ecology Group Procedures Handbook for Environmental Transuranics," Report NVO-166, National Environmental Research Center, Las Vegas, NV (1976).

Leavitt 1980: Leavitt, V., "Soil Profiles of Mounds on Plutonium-Contaminated Areas of the Nevada Test Range Complex," Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Las Vegas, NV (1980).

Millard and West 1987: Millard, G. C., and G. L. West, "1986 Environmental Monitoring Report, Tonopah Test Range, Tonopah, Nevada," SAND87-0605, Sandia National Laboratories, Albuquerque, NM (1987).

Millard and West 1988: Millard, G. C., and G. L. West, "1987 Environmental Monitoring Report, Sandia National Laboratories, Tonopah Test Range, Tonopah, Nevada," SAND88-0698, Sandia National Laboratories, Albuquerque, NM (1988).

Millard et al. 1989: Millard, G., R. Hamilton, J. Phelan, and G. West, "1988 Environmental Monitoring Report, Tonopah Test Range, Tonopah, Nevada," SAND89-1367, Sandia National Laboratories, Albuquerque, NM (1989).

Rarrick 1993: Rarrick, H., Personal communication (February 2, 1993).

REECo 1987: Reynolds Electrical and Engineering Company, "M-14 Environmental Surveillance Program, Sampling and Analysis, January 1987 Update in REECo Standard Procedures Manual," RE-1002, REECo, Las Vegas, NV (1987).

REECo 1991a: Reynolds Electrical and Engineering Company, "Tonopah Test Range Sampling Site Plan," REECo, Las Vegas, NV (1991).

REECo 1991b: Reynolds Electrical and Engineering Company, "The U.S. DOE Nevada Field Office Annual Site Environmental Report," Vol. 1 and 2, S. C. Black, A. R. Latham, and Y. E. Townsend (ed.), DOE/NV 10630-33, prepared for the U.S. Department of Energy by REECo, Las Vegas, NV (1991).

Romney et al. 1975: Romney, E. M., et al., '$^{239-240}$Pu and ^{241}Am Contamination of Vegetation in Aged Plutonium Fallout Areas,' in "The Radioecology of Plutonium and Other Transuranics in Desert Environments," Report NVO-153, Laboratory of Nuclear Medicine and Radiation Biology, University of California, Los Angeles, CA (1975).

Schaeffer 1982: Schaeffer, J. R., "Climatology of the Tonopah Test Range, 1967," SC-M-68-522, Sandia National Laboratories, Albuquerque, NM (1982).

Secretary of Energy, 1990. "National Environmental Policy Act Notice," SEN-15-90, February 5, 1990.

SEN-15-90, see Secretary of Energy.

Sinnock 1982: Sinnock, S., "Geology of the Nevada Test Site and Nearby Areas - Southern Nevada," SAND82-2207, Sandia National Laboratories, Albuquerque, NM (1982).

SNL 1990: Sandia National Laboratories, "Spill Prevention Control and Countermeasure (SPCC) Plan," Plan 90-11, Sandia National Laboratories, Albuquerque, NM (1990).

SNL 1991: Sandia National Laboratories, "National Environmental Policy Act (NEPA) Program," PG470110, Sandia National Laboratories, Albuquerque, NM (1991).

SNL 1992a: Sandia National Laboratories, "Environmental Monitoring Plan for the Tonopah Test Range, Nevada," Sandia National Laboratories, Albuquerque, NM (1992).

SNL 1992b: Sandia National Laboratories, "Environmental Sampling Procedure," Activity-Specific Environment, Safety and Health Standard Operating Procedure, SP471991, Albuquerque, NM (November 19, 1992).

State of Nevada Air Quality Regulations, Revised Statutes, Title 40, "Public Health and Safety," Chapter 445.

State of Nevada Public Water Supply and Public Water System Regulations, Title 40, "Public Health and Safety," Chapter 445.

TTR 1992: Tonopah Test Range, "Environmental Monitoring Reports, Tonopah Test Range," Volumes 1 through 4, TTR, Tonopah, NV (1992).

Tamura 1974: Tamura, T., 'The Dynamics of Plutonium in Desert Environments. Nevada Applied Ecology Group Report,' in "Distribution and Characterization of Plutonium in Soils from Nevada Test Site," Report NVO-142 (1974).

Tamura 1975: Tamura, T., 'Characterization of Plutonium in Surface Soils from Area 13 of the Nevada Test Site,' in "The Radioecology of Plutonium and Other Transuranics in Desert Environments," Report NVO-153, Oak Ridge National Laboratory, Environmental Sciences Division, Oak Ridge, TN (1975).

Tamura 1976: Tamura, T., 'Plutonium Association in Soils,' in "Transuranics in Natural Environments," Report NVO-178, Oak Ridge National Laboratory, Environmental Sciences Division, Oak Ridge, TN (1976).

Tamura 1977: Tamura, T., 'Plutonium Distribution in a Desert Pavement Desert Mound,' in "Environmental Plutonium on the Nevada Test Site and Environs," Report NVO-171, Oak Ridge National Laboratory, Environmental Sciences Division, Oak Ridge, TN (1977).

Warren Rogers Associates, Inc. 1992: "Statistical Inventory Reconciliation Analysis (SIRA)," Middletown, RI: Crain Communications, Inc. (1992).

ACTS

American Indian Religious Freedom Act (AIRFA) of 1978, as amended. Title 42 U.S.C. 1996.

Archaeological Resources Protection Act (ARPA) of 1979, Public Law 96-95, as amended by Public Law 100-588.

Clean Air Act (CAA) of 1955, as amended. Title 42 U.S.C. 7401.

Clean Water Act (CWA) of 1948, (Federal Water Pollution Control Act), as amended. Title 33 U.S.C. 1251.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended. Title 40 U.S.C. 9601.

Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) (Enacted by Public Law 99-499, October 17, 1986; 42 U.S.C. 11001 et seq.).

Endangered Species Act (ESA) of 1973, as amended. Title 16 U.S.C. 1531.

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended. Title 7 U.S.C. 136.

National Environmental Policy Act (NEPA) of 1969, as amended. Title 42 U.S.C. 4341.

National Historic Preservation Act (NHPA) of 1966, as amended. Title 16 U.S.C. 470.

Resource Conservation and Recovery Act (RCRA) of 1976. Public Law 94-580, 1976, 90 Statute 2795.

Safe Drinking Water Act (SDWA) of 1974, as amended. Title 42 U.S.C. §300f et seq.

Superfund Amendments and Reauthorization Act (SARA) of 1986. Title III, Section 313, "Toxic Chemical Release Reporting."

Toxic Substances Control Act (TSCA) of 1976. Title 15 U.S.C. 2601.

CODE OF FEDERAL REGULATIONS

10 CFR 1021, 1992. "National Environmental Policy Act Implementing Procedures," as revised April 24, 1992.

40 CFR 61, 1973. "National Emission Standards for Hazardous Air Pollutants (NESHAP)," including 1985, Subpart H. "National Emission Standards for Emissions of Radionuclide Other Than Radon From Department of Energy Facilities," as amended.

40 CFR 112, 1973. "Oil Pollution Prevention," as amended March 26, 1976.

40 CFR 141.26, 1992. "Monitoring Frequency for Radioactivity in Community Water Systems" (Revision 6, September 15, 1992).

ORDERS

DOE 1990: U.S. Department of Energy, "Radiation Protection of the Public and the Environment," DOE Order 5400.5, DOE, Washington, DC (February 8, 1990, change 2, January 7, 1993).

DOE 1988: U.S. Department of Energy, "General Environmental Protection Program," DOE Order 5400.1, DOE, Washington, DC (1988, change 1, June 21, 1990).

Executive Order 11988, Floodplain Management (Signed May 24, 1977; 42 FR 26951, 3 CFR, 1977 Comp., p. 117; Amended by Executive Order 12148, July 20, 1979; 44 FR 43239, 3 CFR, 1979 Comp., p. 412).

Executive Order 11990, Protection of Wetlands (Signed May 24, 1977; 42 FR 26961, 3 CFR, 1977 Comp., p. 121).

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APPENDIX A

RADIOLOGICAL SOIL SAMPLING LOCATIONS AND RESULTS

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Table A-1. Results of Replicate Sampling from Baseline-Related Soil Sampling, 1993

Location	Number of Samples	Gross Alpha (pCi/g) mean	Gross Alpha std	Gross Alpha (CV)	Gross Beta (pCi/g) mean	Gross Beta std	Gross Beta (CV)	Pu-239,240 (pCi/g) mean	Pu-239,240 std	Pu-239,240 (CV)	Pu-238 (pCi/g) mean	Pu-238 std	Pu-238 (CV)	Am-241 (pCi/g) mean	Am-241 std	Am-241 (CV)	U_{tot} (ug/g) mean	U_{tot} std	U_{tot} (CV)	Cs-137 (pCi/g) mean	Cs-137 std	Cs-137 (CV)
B-10	3	10	3	(26)	28	1	(3.6)	N/A	N/A		N/A	N/A		N/A	N/A		2.1	0.5	23	0.16	0.07	(44)
CS-1-17	3	16	2	(10)	51	6	(11)	0.38	0.17	(44)	-0.04	0.01	(13)	0.23	0.15	(64)	2.7	0.23	(8.4)	0.36	0.01	(1.6)
CS3-11	3	200	260	(130)	36	19	(54)	22	6	(27)	0.28	0.31	(110)	1.9	0.4	(18)	3.0	0.2	(5.0)	0.54 ±	0.08	(16)

Note: CV is the coefficient of variation, a measure of relative error, where CV = (standard deviation ÷ mean) x 100. N/A means no analysis was performed.

Table A-2. Results of Replicate Sampling from Special Sampling at the Mellan Airstrip Area, Tin Building Area, and Bridge Area, 1993

Location	Number of Samples	Pu-239,240 (pCi/g) mean	Pu-239,240 (pCi/g) (CV)	Pu-239,240 (pCi/g) std	Pu-238 (pCi/g) mean	Pu-238 (pCi/g) (CV)	Pu-238 (pCi/g) std	Am-241 (pCi/g) mean	Am-241 (pCi/g) (CV)	Am-241 (pCi/g) std	U_{tot} (ug/g) mean	U_{tot} (ug/g) (CV)	U_{tot} (ug/g) std
AG-100	3	0.38	(130)	0.51	0.12	(140)	0.17	0.14	(28)	0.04	2.5	(80)	2
C-200	3	100	(110)	110	0.74	(110)	0.83	2.9	(28)	0.8	3.2	(7.8)	0.2
BR-4	3	0.3	(200)	0.6	0.05	(140)	0.07	0.02	(200)	0.04	3.3	(15)	0.5

Note: CV is the coefficient of variation, a measure of relative error, where CV = (standard deviation ÷ mean) x 100.

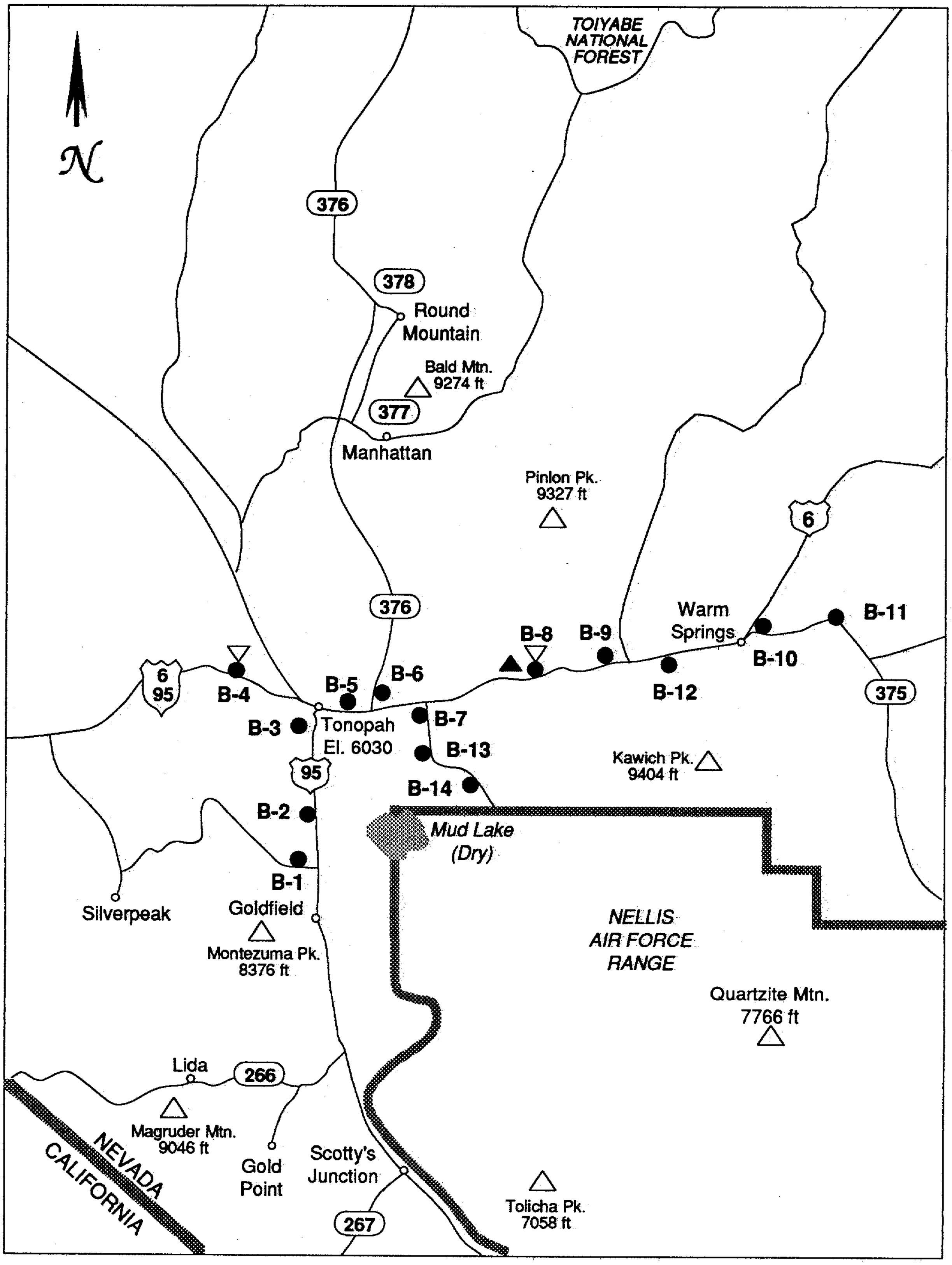


Figure A-1. Offsite Soil Sampling Locations

Table A-3. Results of Offsite Soil Sampling

Sample Location	Gross Alpha[a] (pCi/g)		Gross Beta[a] (pCi/g)		Pu-239, -240[a] (pCi/g)		Pu-238[a] (pCi/g)		Pu Total[b] (pCi/g)	Pu Error[b] (pCi/g)	Am-241[a] (pCi/g)		U_{tot} (ug/g)	Cs-137[a] (pCi/g)	
B-1	20.00	7.00	42.00	7.00	0.11	0.07	0.07	0.06	0.18	0.13	0.00	0.06	3.1	0.85	0.08
B-2	17.00	7.00	34.00	7.00	0.18	0.06	0.17	0.06	0.35	0.12	0.00	0.06	2.3	0.32	0.07
B-3	22.00	9.00	44.00	6.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.9	1.00	0.1
B-4	17.00	8.00	39.00	6.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.9	0.44	0.06
B-5	20.00	9.00	45.00	7.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.7	0.91	0.08
B-6	13.00	8.00	39.00	6.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.5	0.73	0.12
B-7	20.00	8.00	38.00	6.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.7	0.51	0.07
B-8	15.00	8.00	38.00	6.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.4	0.26	2
B-9	25.00	9.00	46.00	6.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.4	0.66	0.07
B-10 A[c]	7.00	7.00	28.00	6.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.7	0.23	0.05
B-11	14.00	7.00	34.00	6.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.5	0.54	0.07
B-12	28.00	9.00	46.00	6.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.6	0.47	0.08
B-13	16.00	7.00	35.00	6.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.4	0.19	0.06
B-14	22.00	8.00	36.00	6.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.6	0.17	0.05

[a]Individual value $\pm$ variability of the radioactive disintegration process (counting error) at the 95% confidence level (1.96 sigma).
[b]Summation of individual values and associated uncertainties.
[c]"A" denotes the sample of record at a triplicate sample location.
Note: N/A means no analysis performed.

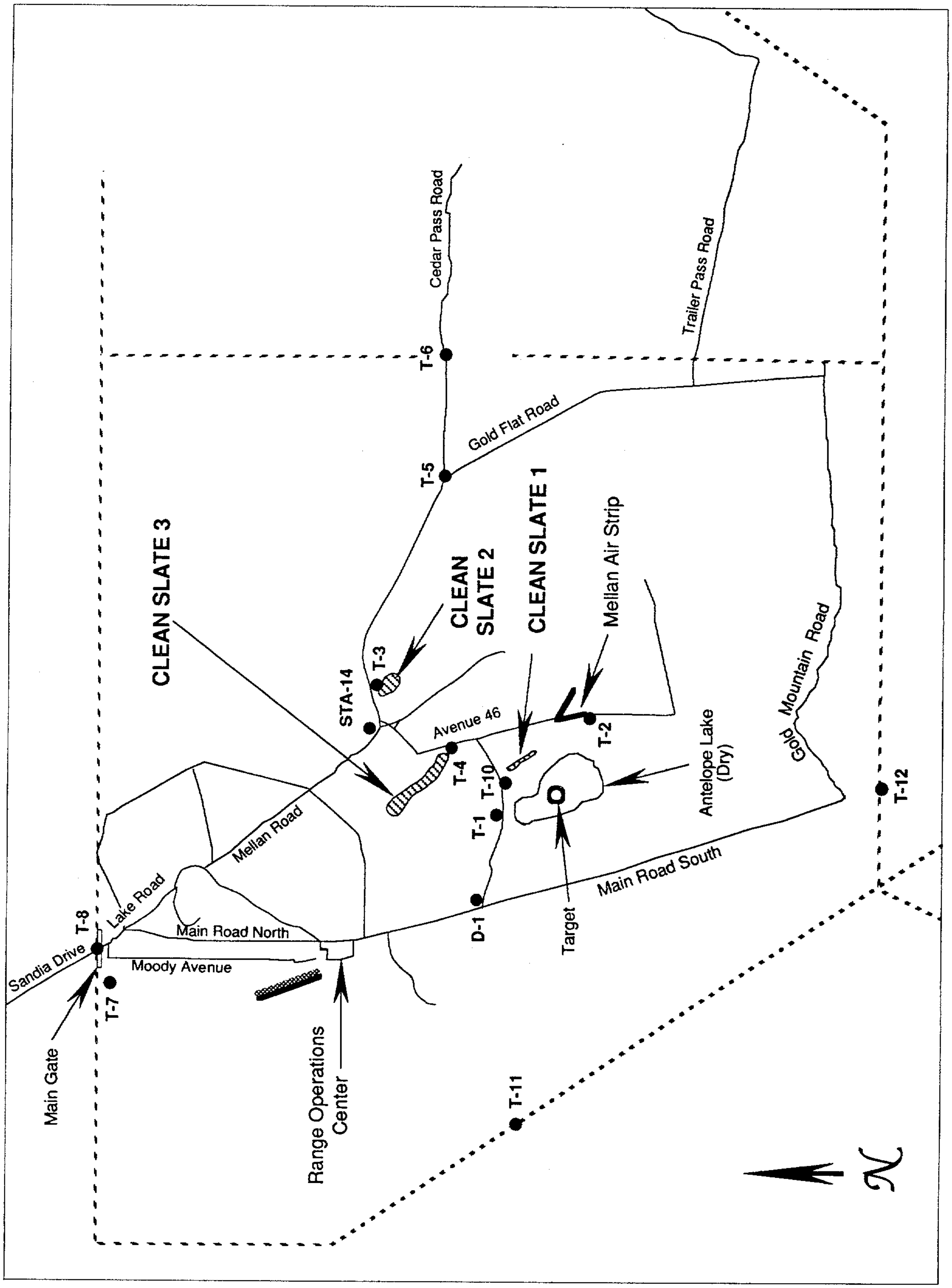


Figure A-2. Perimeter and Onsite Soil Sampling Locations

Table A-4. Results of Site Perimeter Soil Sampling

Sample Location	Gross Alpha[a] (pCi/g)		Gross Beta[a] (pCi/g)		Pu-239, -240[a] (pCi/g)		Pu-238[a] (pCi/g)		Pu Total[b] (pCi/g)	Pu Error[b] (pCi/g)	Am-241[a] (pCi/g)		U_{tot} (ug/g)	Cs-137[a] (pCi/g)	
T-6	13	6	39	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.50	0.64	0.07
T-8	12	7	44	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.20	0.07	0.04
T-11	18	8	41	6	0.06	0.04	0.12	0.05	0.18	0.09	0.15	0.07	2.30	0.34	0.05
T-12	19	8	42	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.40	0.56	0.06

[a]Individual value ± variability of the radioactive disintegration process (counting error) at the 95% confidence level (1.96 sigma).
Note: N/A means no analysis performed.
[b]Summation of individual values and associated uncertainties.

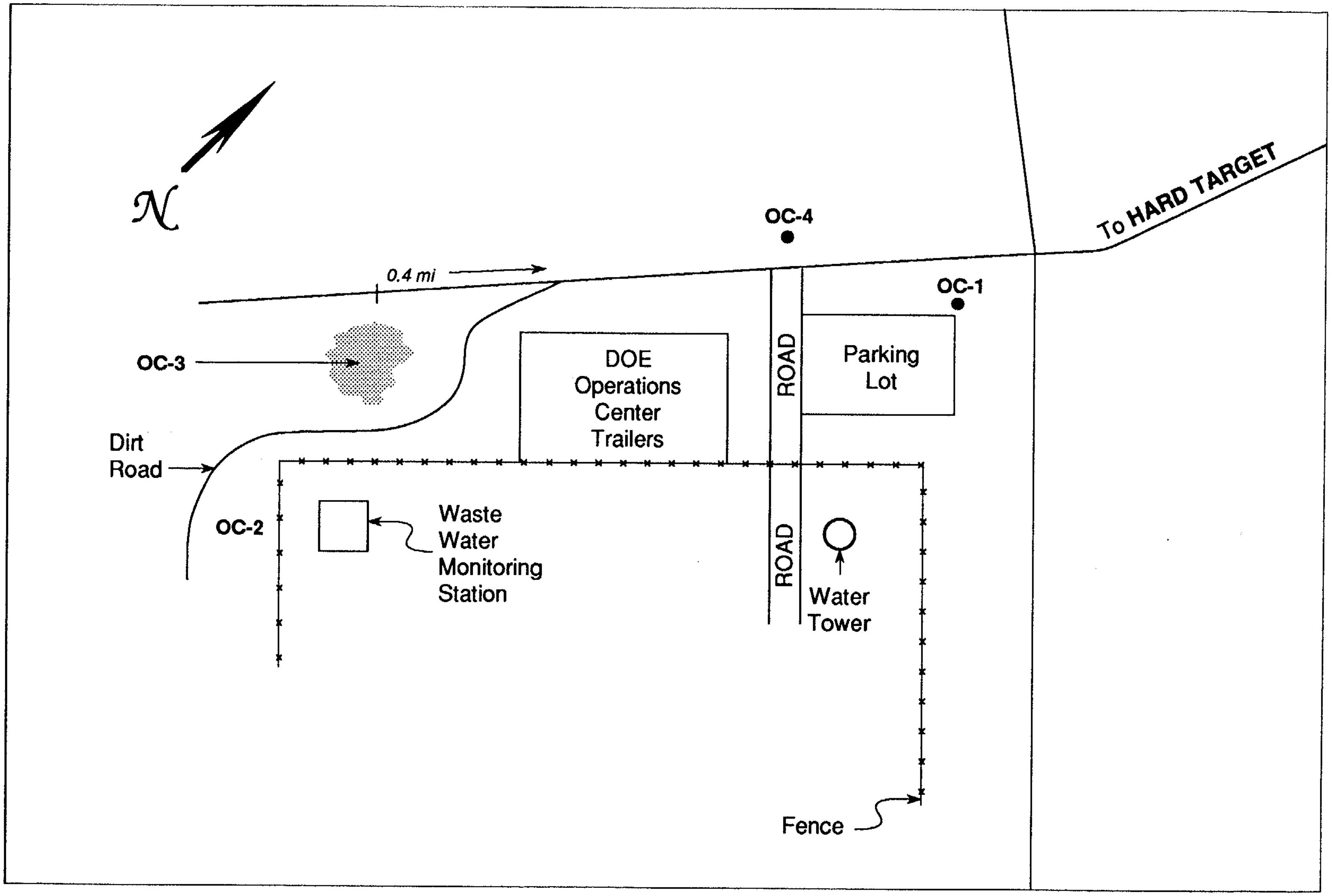
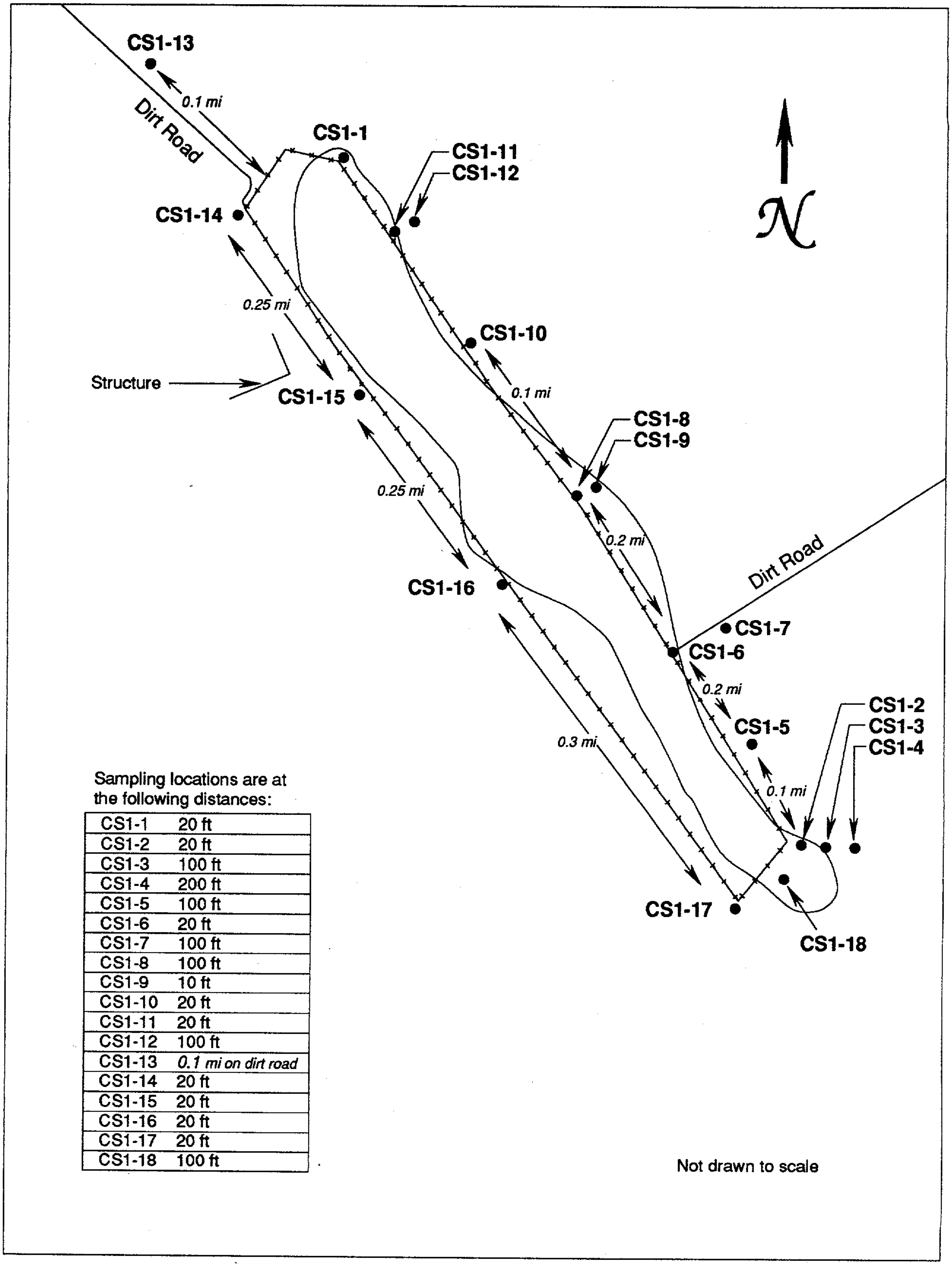


Figure A-3. Soil Sampling Locations around the Range Operations Center

Table A-5. Results of Soil Sampling Around the Range Operations Center

Sample Location	Gross Alpha[a] (pCi/g)		Gross Beta[a] (pCi/g)		U_{tot} (ug/g)	Cs-137[a] (pCi/g)	
OC1	18	6	39	6	0.7	0.50	0.06
OC2	25	6	39	6	2.0	0.45	0.07
OC3	25	6	45	6	1.2	0.41	0.06
OC4	14	5	39	6	0.7	0.48	0.07

[a]Individual value ± variability of the radioactive disintegration process (counting error) at the 95% confidence level (1.96 sigma).



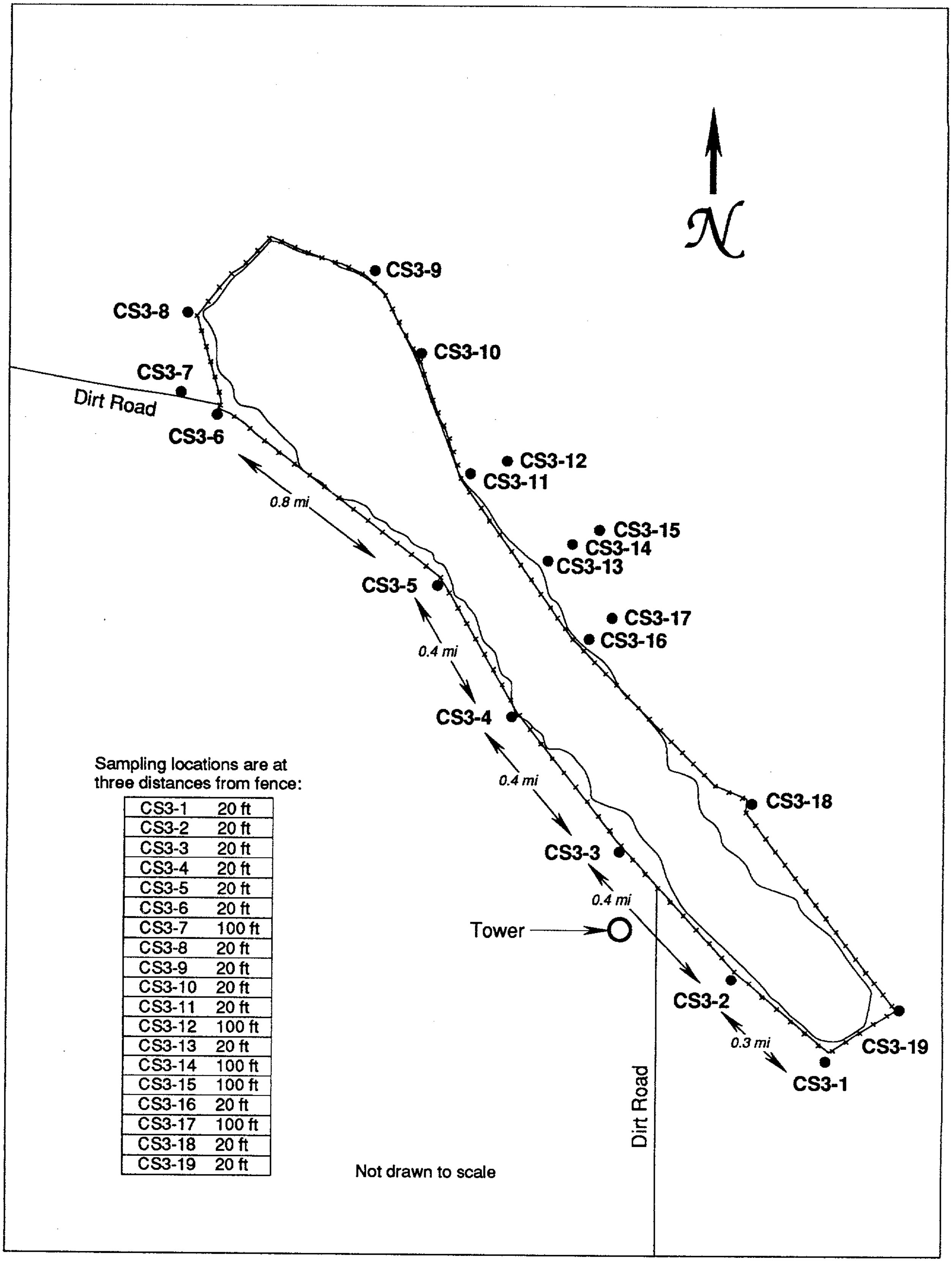
CS1-1	20 ft
CS1-2	20 ft
CS1-3	100 ft
CS1-4	200 ft
CS1-5	100 ft
CS1-6	20 ft
CS1-7	100 ft
CS1-8	100 ft
CS1-9	10 ft
CS1-10	20 ft
CS1-11	20 ft
CS1-12	100 ft
CS1-13	*0.1 mi on dirt road*
CS1-14	20 ft
CS1-15	20 ft
CS1-16	20 ft
CS1-17	20 ft
CS1-18	100 ft

Figure A-4. Soil Sampling Locations Around Clean Slate 1

Table A-6. Results of Soil Sampling Around Clean Slate 1

Sample Location	Gross Alpha[a] (pCi/g)		Gross Beta[a] (pCi/g)		Pu-239, -240[a] (pCi/g)		Pu-238[a] (pCi/g)		Pu Total (pCi/g)	Pu Error[b] (pCi/g)	Am-241[a] (pCi/g)		U_{tot} (ug/g)	Cs-137[a] (pCi/g)	
CS 1-1	230	20.00	32	6.00	280.00	10.00	2.10	0.50	282.10	10.50	13.00	1.00	2.90	0.79	0.08
CS 1-2	150	20.00	37	6.00	46.00	2.00	0.19	0.13	46.19	2.13	14.00	1.00	2.70	0.74	0.09
CS 1-3	23	21.00	50	38.00	71.00	2.00	0.27	0.17	71.27	2.17	11.00	1.00	2.70	0.83	0.08
CS 1-4	30	10.00	47	6.00	28.00	2.00	0.36	0.20	28.36	2.20	3.20	0.10	2.80	0.80	0.08
CS 1-5	39	11.00	52	7.00	50.00	2.00	0.42	0.20	50.42	2.20	3.90	0.20	3.00	0.47	0.07
CS 1-6	41	10.00	42	7.00	2.00	0.40	0.07	0.13	2.07	0.53	0.68	0.10	3.10	0.35	0.07
CS 1-7	53	11.00	44	6.00	16.00	1.00	0.23	0.15	16.23	1.15	9.40	0.40	3.10	0.26	0.06
CS 1-8	52	11.00	53	7.00	2.20	0.30	0.19	0.13	2.39	0.43	0.87	0.11	2.50	0.91	0.08
CS 1-9	41	11.00	45	7.00	4.10	0.60	0.05	0.11	4.15	0.71	0.75	0.11	2.50	0.86	0.07
CS 1-10	26	7.00	49	7.00	3.80	0.40	0.01	0.07	3.81	0.47	0.84	0.12	2.70	0.61	0.09
CS 1-11	19	6.00	44	7.00	1.50	0.20	0.04	0.06	1.54	0.26	0.53	0.10	2.90	1.10	0.90
CS 1-12	320	20.00	29	6.00	17.00	1.00	0.10	0.08	17.10	1.08	1.70	0.10	3.00	0.60	0.08
CS 1-13	46	9.00	56	7.00	14.00	1.00	0.15	0.13	14.15	1.13	1.00	0.10	3.00	0.68	0.08
CS 1-14	22	7.00	54	7.00	0.46	0.16	0.08	0.10	0.54	0.26	0.10	0.04	2.80	1.50	0.10
CS 1-15	22	7.00	48	7.00	1.10	0.20	0.01	0.06	1.11	0.26	0.56	0.11	2.50	0.71	0.08
CS 1-16	20	7.00	51	7.00	0.74	0.19	-0.04	0.06	0.70	0.25	0.52	0.09	1.90	0.66	0.07
CS 1-17A[c]	14	6.00	47	8.00	0.54	0.18	-0.05	0.05	0.49	0.23	0.37	0.09	2.60	0.36	0.07
CS 1-18	31	8.00	47	7.00	12.00	1.00	0.24	0.06	12.24	1.06	12.00	1.00	2.80	0.51	0.07

[a]Individual value ± variability of the radioactive disintegration process (counting error) at the 95% confidence level (1.96 sigma).
[b]Summation of individual values and associated uncertainties.
[c]"A" denotes the sample of record at a triplicate sample location.



CS3-1	20 ft
CS3-2	20 ft
CS3-3	20 ft
CS3-4	20 ft
CS3-5	20 ft
CS3-6	20 ft
CS3-7	100 ft
CS3-8	20 ft
CS3-9	20 ft
CS3-10	20 ft
CS3-11	20 ft
CS3-12	100 ft
CS3-13	20 ft
CS3-14	100 ft
CS3-15	100 ft
CS3-16	20 ft
CS3-17	100 ft
CS3-18	20 ft
CS3-19	20 ft

Figure A-5. Soil Sampling Locations Around Clean Slate 3

Table A-7. Results of Soil Sampling Around Clean Slate 3

Sample Location	Gross Alpha[a] (pCi/g)		Gross Beta[a] (pCi/g)		Pu-239, -240[a] (pCi/g)		Pu-238[a] (pCi/g)		Pu Total (pCi/g)	Pu Error[b] (pCi/g)	Am-241[a] (pCi/g)		U_{tot} (ug/g)	Cs-137[a] (pCi/g)	
CS 3-1	47	11.00	45	7.00	18.00	1.00	0.18	0.17	18.18	1.17	4.20	0.20	3.00	0.47	0.06
CS 3-2	150	20.00	41	6.00	10.00	1.00	0.00	0.09	10.00	1.09	4.20	0.20	3.10	0.59	0.08
CS 3-3	56	12.00	37	6.00	54.00	2.00	0.36	0.20	54.36	2.20	2.90	0.20	3.10	0.76	0.07
CS 3-4	61	12.00	44	6.00	13.00	1.00	-0.02	0.08	12.98	1.08	2.60	0.20	3.30	0.68	0.09
CS 3-5	34	9.00	50	7.00	0.93	0.28	-0.05	0.06	0.88	0.34	0.36	0.09	3.40	0.48	0.07
CS 3-6	26	9.00	34	6.00	0.27	0.17	-0.05	0.06	0.22	0.23	0.12	0.06	3.00	0.37	0.07
CS 3-7	13	6.00	39	6.00	1.00	0.30	0.26	0.16	1.26	0.46	0.11	0.05	2.50	0.22	0.05
CS 3-8	28	8.00	44	6.00	1.40	0.10	0.05	0.10	1.45	0.20	0.22	0.06	2.90	0.37	0.06
CS 3-9	49	11.00	48	6.00	380.00	10.00	2.40	0.40	382.40	10.40	1.80	0.10	2.30	0.57	0.06
CS 3-10	36	9.00	52	6.00	5.90	0.90	-0.11	0.16	5.79	1.06	0.30	0.07	3.10	0.61	0.07
CS 3-11A[c]	45	10.00	50	6.00	24.00	2.00	0.22	0.23	24.22	2.23	2.10	0.10	3.20	0.51	0.07
CS 3-12	37	9.00	45	6.00	16.00	1.00	-0.02	0.16	15.98	1.16	4.30	0.20	3.00	1.00	0.10
CS 3-13	88	14.00	46	6.00	44.00	2.00	0.35	0.22	44.35	2.22	6.80	0.30	3.00	0.51	0.07
CS 3-14	37	9.00	43	6.00	3.20	0.60	-0.11	0.15	3.09	0.75	1.40	0.10	3.00	0.60	0.07
CS 3-15	27	9.00	45	6.00	2.00	0.40	0.00	0.09	2.00	0.49	0.26	0.06	2.70	0.71	0.08
CS 3-16	140	20.00	38	6.00	160.00	10.00	1.20	0.50	161.20	10.50	12.00	1.00	3.20	0.65	0.07
CS 3-17	94	15.00	34	6.00	54.00	2.00	0.25	0.16	54.25	2.16	6.20	0.30	3.00	0.62	0.07
CS 3-18	29	9.00	47	6.00	2.30	0.40	0.08	0.12	2.38	0.52	0.41	0.07	2.20	0.82	0.11
CS 3-19	22	9.00	47	7.00	3.50	0.60	0.01	0.10	3.51	0.70	0.47	0.09	3.30	0.51	0.07

[a]Individual value ± variability of the radioactive disintegration process (counting error) at the 95% confidence level (1.96 sigma)
[b]Summation of individual values and associated uncertainties
[c]"A" denotes the sample of record at a triplicate sample location.

Table A-8. Results of Soil Sampling at Various Locations on the Tonopah Test Range

Sample Location	Gross Alpha (pCi/g)		Gross Beta (pCi/g)		Pu-239, -240 (pCi/g)		Pu-238 (pCi/g)		Pu Total (pCi/g)[a]	Pu Error (pCi/g)[a]	Am-241 (pCi/g)		U_{tot} (ug/g)	Cs-137 (pCi/g)	
D-1	21	8	35	6	1.10	0.20	0.02	0.05	1.12	0.25	0.28	0.08	1.40	0.09	0.05
OP3-1	18	5	42	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.80	0.14	0.05
OP3-2	18	6	47	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.60	0.37	0.07
STA14-1	23	6	43	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.70	0.13	0.05
T-1	18	6	41	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.70	0.32	0.06
T-2	19	6	47	6	0.18	0.41	0.42	0.35	0.60	0.76	0.15	0.05	1.00	0.55	0.07
T-3	20	6	46	6	0.41	0.44	0.54	0.37	0.95	0.81	0.12	0.05	0.90	0.29	0.06
T-4	22	6	50	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.80	0.63	0.08
T-5	22	6	40	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.60	0.42	0.07
T-7	18	8	40	6	0.06	0.05	0.02	0.05	0.08	0.10	0.08	0.04	3.00	0.00	0.05
T-10	22	8	38	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.00	0.57	0.08

[a]Individual value ± variability of the radioactive disintegration process (counting error) at the 95% confidence level (1.96 sigma)
[b]Summation of individual values and associated uncertainties.
Note: N/A means no analysis performed.

Table A-9. Results of PM-10 Air Sampling at the Main Well[a]

Collection Date	Concentration (pCi/m³ ± 2 Standard Deviations)			
	Gross Alpha	Gross Beta	K-40	Be-7
06/17/93	0.004 ± 0.002	0.03 ± 0.01	0.11 ± 0.10	0.36 ± 0.20
06/23/93	0.005 ± 0.003	0.03 ± 0.01	N/A	0.48 ± 0.23
06/30/93	0.002 ± 0.002	0.03 ± 0.01	0.14 ± 0.12	0.45 ± 0.17
07/21/93	0.006 ± 0.002	0.03 ± 0.01	N/A	0.34 ± 0.16
07/28/93	0.003 ± 0.003	0.04 ± 0.01	N/A	0.13 ± 0.16
08/05/93	0.005 ± 0.003	0.03 ± 0.01	N/A	0.20 ± 0.15
08/18/93	0.002 ± 0.002	0.03 ± 0.01	N/A	0.38 ± 0.11
08/25/93	0.002 ± 0.002	0.04 ± 0.01	N/A	0.26 ± 0.08
08/26/93	0.002 ± 0.002	0.04 ± 0.01	N/A	0.19 ± 0.08
08/27/93	0.001 ± 0.002	0.04 ± 0.01	N/A	0.24 ± 0.09

[a]Sample collection duration approximately 24 hrs/sample.
Note: N/A means no analysis performed.

Table A-10. Results of PM-10 Air Sampling at STA-14[a]

Collection Date	Concentration (pCi/m^3 ± 2 Standard Deviations)			
	Gross Alpha	Gross Beta	K-40	Be-7
06/16/93	0.004 ± 0.002	0.03 ± 0.01	0.12 ± 0.12	0.42 ± 0.18
06/23/93	0.003 ± 0.002	0.03 ± 0.01	N/A	N/A
06/30/93	0.005 ± 0.003	0.04 ± 0.01	N/A	0.46 ± 0.16
07/21/93	0.005 ± 0.003	0.03 ± 0.01	N/A	0.32 ± 0.11
07/28/93	0.004 ± 0.003	0.03 ± 0.01	N/A	N/A
08/18/93	0.002 ± 0.002	0.03 ± 0.01	0.17 ± 0.13	0.28 ± 0.09
08/25/93	0.004 ± 0.002	0.04 ± 0.01	0.13 ± 0.11	0.17 ± 0.12
08/26/93	0.003 ± 0.002	0.04 ± 0.01	N/A	0.24 ± 0.09
08/27/93	0.003 ± 0.002	0.01 ± 0.01	N/A	0.22 ± 0.07

[a]Sample collection duration approximately 24 hrs/sample.
Note: N/A means no analysis performed.

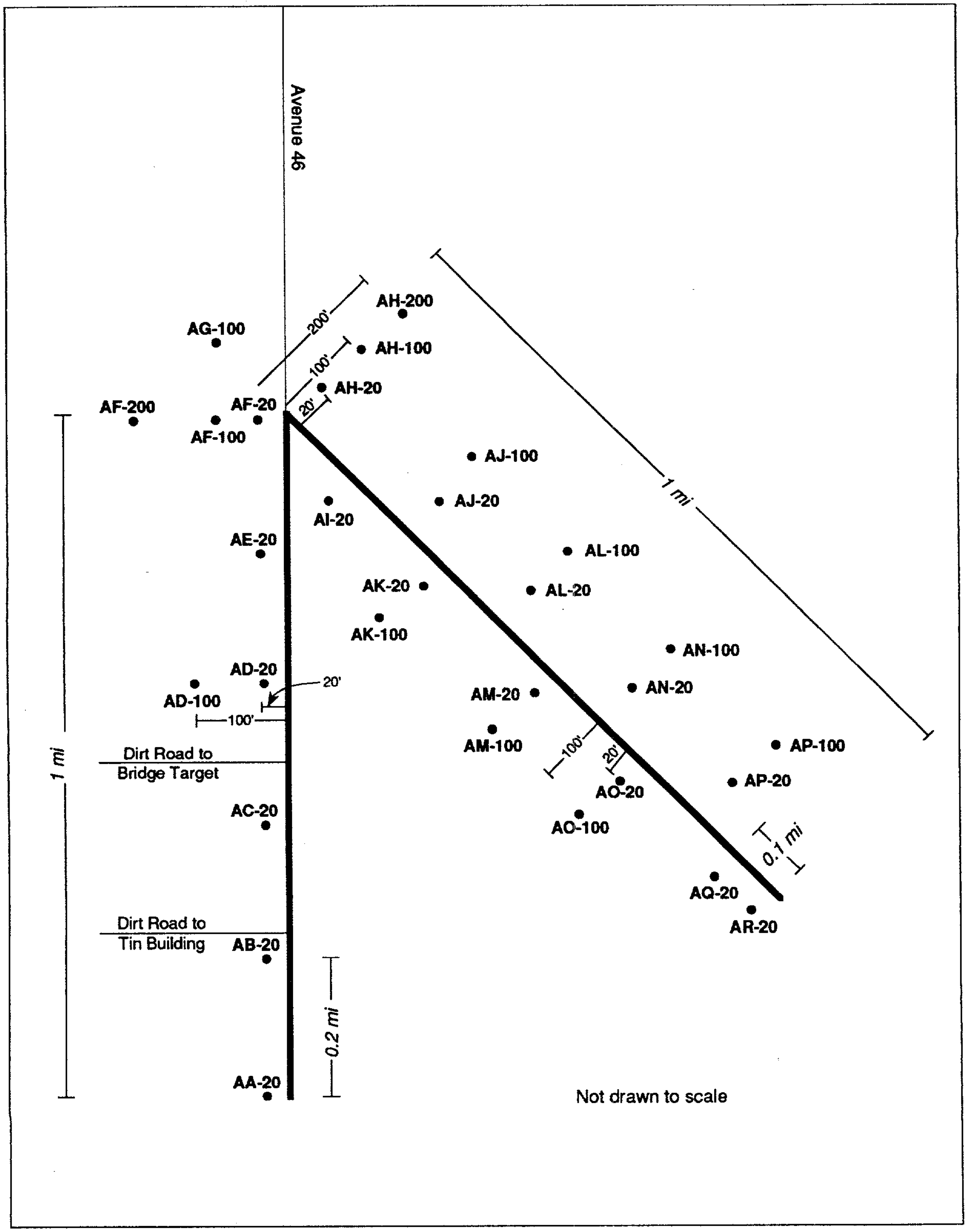


Figure A-6. Soil Sampling Locations Around the Mellan Airstrip

Table A-11. Results of Soil Sampling Around the Mellan Airstrip

Location	Pu-239, -240[a] (pCi/g)		Pu-238[a] (pCi/g)		Total Pu[b] (pCi/g)		Am-241[a] (pCi/g)		U Total
AA20	0.44	0.15	0.03	0.07	0.47	0.22	0.31	0.38	2.2
AB20	0.13	0.08	0.15	0.1	0.28	0.18	0.00	0.07	3.3
AC20	0.07	0.06	0.03	0.06	0.10	0.12	0.17	0.07	2.3
AD20	0.17	0.09	0.04	0.07	0.21	0.16	0.00	0.05	1.8
AD100	0.15	0.08	0.16	0.09	0.31	0.17	0.00	0.07	2.3
AE20	0.12	0.07	0.1	0.08	0.22	0.15	0.10	0.04	2.3
AF20	0.00	0.02	-0.02	0.04	-0.02	0.06	0.00	0.07	3.0
AF100	0.86	0.18	0.03	0.06	0.89	0.24	0.09	0.07	3.0
AF200	0.39	0.14	-0.01	0.05	0.38	0.19	0.05	0.03	2.8
AG100A[c]	0.59	0.16	0.30	0.12	0.89	0.28	0.18	0.06	2.2
AH100	0.46	0.24	0.01	0.05	0.47	0.29	0.00	0.07	2.7
AH20	-0.02	0.03	-0.02	0.03	-0.04	0.06	0.00	0.05	3.0
AH200	0.24	0.11	0.04	0.06	0.28	0.17	0.00	0.05	2.4
AI100	0.59	0.16	0.11	0.08	0.70	0.24	0.07	0.05	2.6
AI20	0.81	0.19	0.09	0.07	0.90	0.26	0.42	0.09	3.2
AJ100	0.29	0.15	0.03	0.06	0.32	0.21	0.13	0.06	2.8
AJ20	0.56	0.20	0.04	0.14	0.60	0.34	0.00	0.05	2.0
AK100	0.21	0.09	-0.02	0.07	0.19	0.16	0.13	0.06	1.8
AK20	0.41	0.13	-0.01	0.06	0.40	0.19	0.30	0.07	3.0
AL100	0.70	0.18	-0.03	0.06	0.67	0.24	0.16	0.05	2.3
AL20	0.38	0.12	-0.03	0.06	0.35	0.18	0.05	0.03	3.0
AM100	0.41	0.13	0.09	0.09	0.50	0.22	0.08	0.05	2.7
AM20	0.47	0.14	0.02	0.07	0.49	0.21	0.10	0.04	2.3
AN100	0.97	0.23	0.20	0.13	1.17	0.36	0.00	0.07	3.1
AN20	0.63	0.17	0.13	0.11	0.76	0.28	0.13	0.07	2.1
AO100	0.43	0.12	-0.01	0.06	0.42	0.18	0.00	0.05	2.6
AP100	1.40	0.20	0.09	0.08	1.49	0.28	0.17	0.04	2.4
AP20	4.50	0.50	0.19	0.12	4.69	0.62	0.13	0.06	2.4
AQ20	0.31	0.12	0.10	0.08	0.41	0.20	0.16	0.06	2.4
AR20	0.49	0.15	0.02	0.05	0.51	0.20	0.10	0.05	3.1

[a]Individual value ± variability of the radioactive disintegration process (counting error) at the 95% confidence level (1.96 sigma).
[b]Summation of individual values and associated uncertainties.
[c]"A" denotes the sample of record at a triplicate sample location.

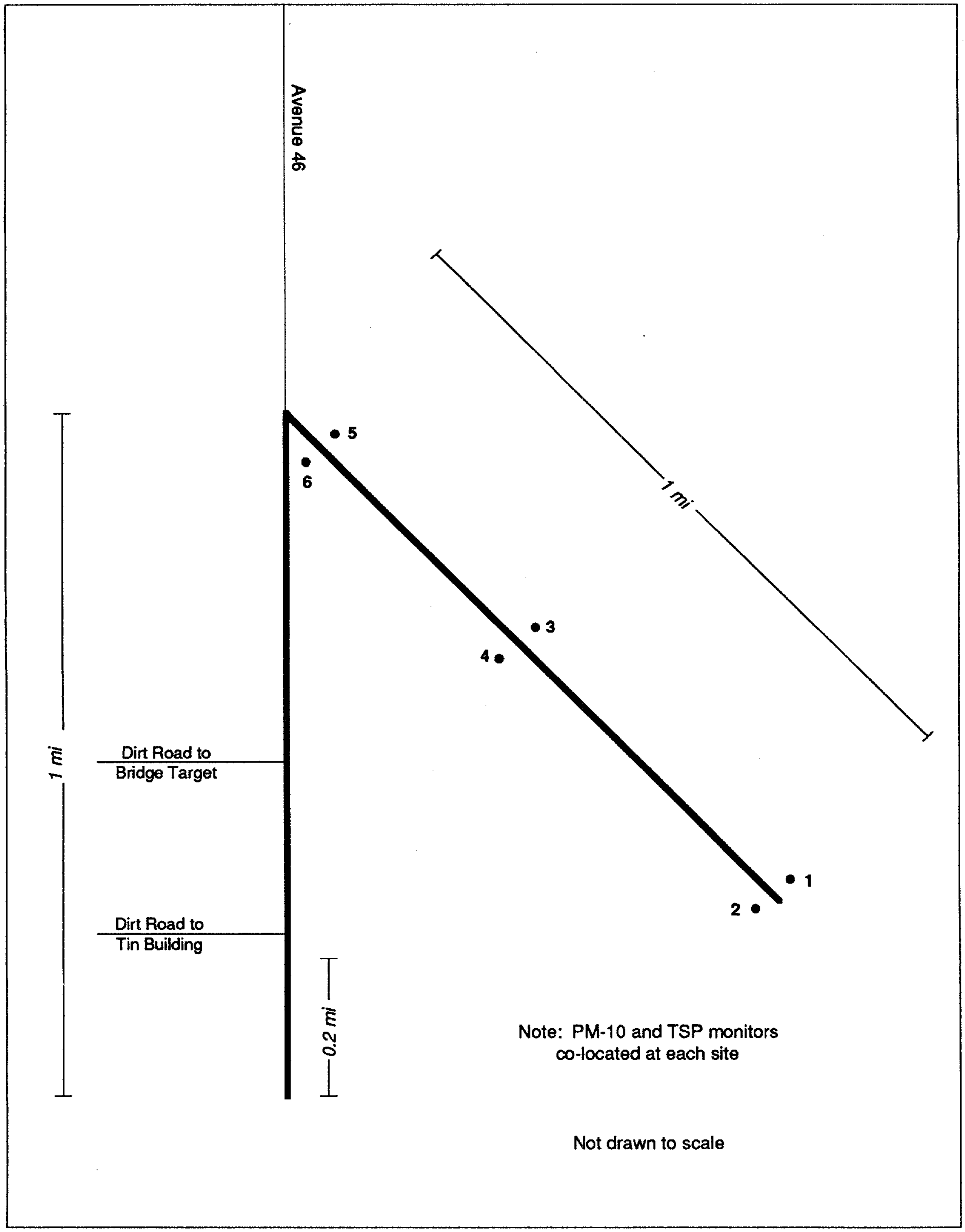


Figure A-7. Air Monitoring Locations at the Mellan Airstrip

Table A-12. Results of Air Monitoring at the Mellan Airstrip

Location	1		2		3	
Monitor Type	PM-10	TSP	PM-10	TSP	PM-10	TSP
Pu-239,240 (pCi/l)[a]	-0.01 ± 0.15	0.05 ± 0.18	-0.06 ± 0.16	-0.02 ± 0.16	-0.08 ± 0.13	-0.11 ± 0.13
Pu-238 (pCi/l)[a]	-0.06 ± 0.20	-0.05 ± 0.20	0.12 ± 0.29	0.21 ± 0.27	0.01 ± 0.22	-0.03 ± 0.24
U Total (mg/l)[a]	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Location	4		5		6	
Monitor Type	PM-10	TSP	PM-10	TSP	PM-10	TSP
Pu-239,240 (pCi/l)[a]	-0.10 ± 0.14	0.03 ± 0.17	-0.02 ± 0.16	-0.03 ± 0.15	-0.03 ± 0.05	0.04 ± 0.10
Pu-238 (pCi/l)[a]	-0.04 ± 0.23	0.26 ± 0.28	0.01 ± 0.22	0.03 ± 0.24	0.23 ± 0.28	0.21 ± 0.24
U Total (mg/l)[a]	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Location	Main Well	
Monitor Type	PM-10	TSP
Pu-239,240 (pCi/l)[a]	0.04 ± 0.09	0.00 ± 0.07
Pu-238 (pCi/l)[a]	0.08 ± 0.18	0.25 ± 0.22
U Total (mg/l)[a]	<0.005	<0.005

[a]Conservatively assumes 1 l of air sampled. Measured value ± 95% confidence interval (counting error).

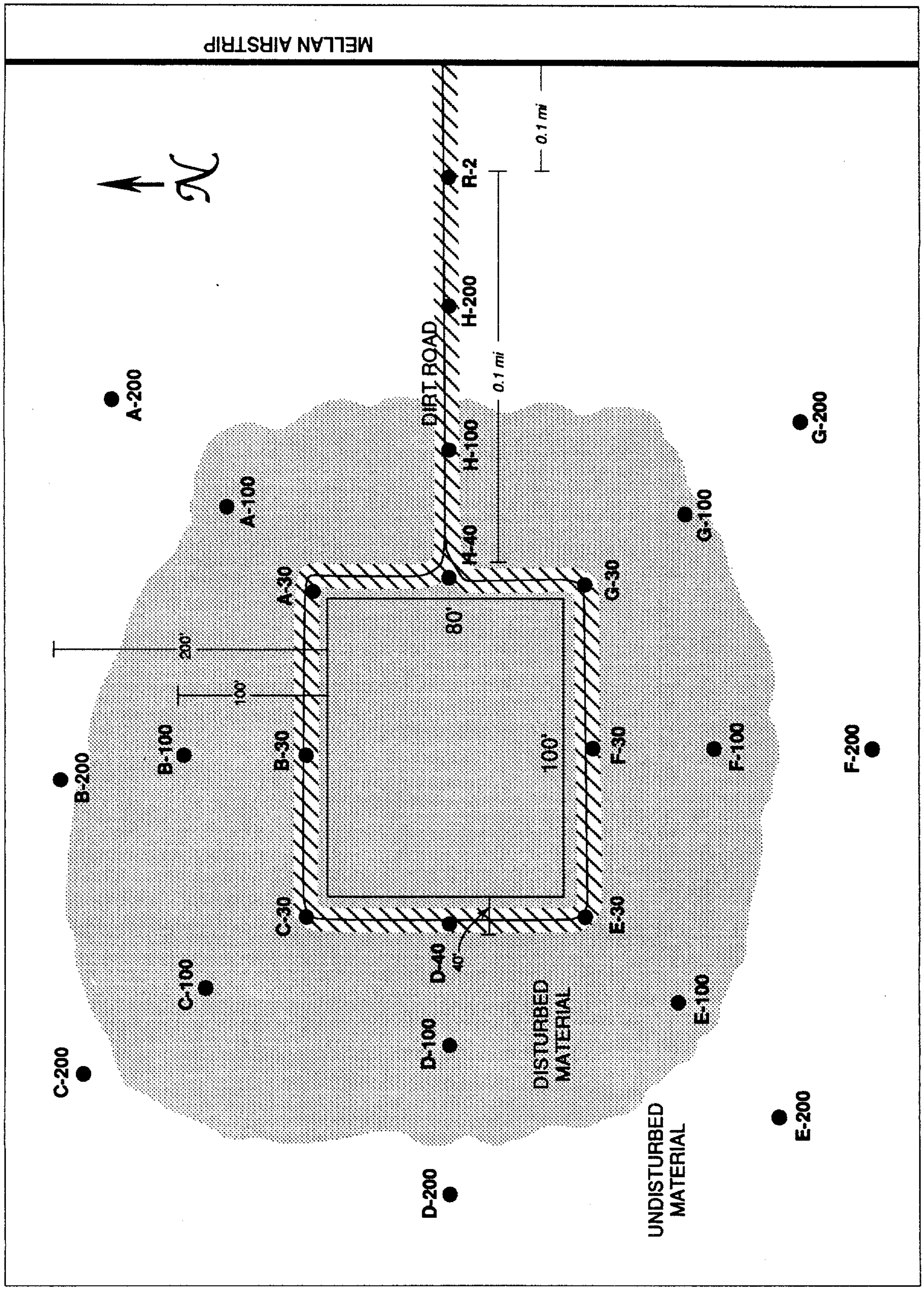


Figure A-8. Soil Sampling Locations Around the Tin Building

Table A-13. Results of Soil Sampling on the Dirt Road at the Tin Building

Location	Pu-239, -240[a] (pCi/g)		Pu-238[a] (pCi/g)		Total Pu[b] (pCi/g)		Am-241[a] (pCi/g)		U_{tot} (μg/g)
A-30	0.01	0.02	-0.02	0.02	-0.01	0.04	0.00	0.06	2.7
B-30	0.07	0.06	0.07	0.06	0.14	0.12	0.00	0.06	3.3
C-30	0.07	0.07	0.03	0.06	0.10	0.13	0.00	0.06	3.5
D-40	-0.01	0.07	-0.03	0.09	-0.04	0.16	0.00	0.04	2.7
E-30	4.40	0.40	-0.02	0.09	4.38	0.49	0.60	0.11	3.3
F-30	-0.02	0.07	-0.04	0.09	-0.06	0.16	0.00	0.06	3.8
G-30	0.12	0.06	0.04	0.05	0.16	0.11	0.00	0.04	3.4
H-40	0.00	0.01	-0.02	0.02	-0.02	0.03	0.00	0.04	3.2
H-100	0.02	0.03	0.02	0.05	0.04	0.08	0.00	0.07	3.8
H-200	0.03	0.03	-0.01	0.03	0.02	0.06	0.00	0.04	2.6
R-1	0.00	0.01	0.01	0.04	0.01	0.05	0.05	0.04	3.1
R-2	0.02	0.03	0.01	0.04	0.03	0.07	0.00	0.06	3.4

[a] Individual value ± variability of the radioactive disintegration process (counting error) at the 95% confidence level (1.96 sigma).
[b] Summation of individual values and associated uncertainties.

Table A-14. Results of Soil Sampling in the Disturbed Area at the Tin Building

Location	Pu-239, -240[a] (pCi/g)		Pu-238[a] (pCi/g)		Total Pu[b] (pCi/g)		Am-241[a] (pCi/g)		U_{tot} (μg/g)
A-100	3.00	0.40	0.03	0.05	3.03	-0.45	0.19	0.06	2.7
B-100	4.80	0.50	0.04	0.05	4.84	0.55	2.60	0.20	2.4
C-100	0.08	0.07	0.01	0.03	0.09	0.10	0.00	0.04	3.2
D-100	0.59	0.16	-0.02	0.09	0.57	0.25	0.15	0.08	3.2
E-100	50.00	1.00	0.46	0.16	50.46	1.16	7.80	0.40	3.2
F-100	40.00	1.00	0.31	0.14	40.31	1.14	2.10	0.10	3.1
G-100	7.40	0.60	0.12	0.08	7.52	0.68	3.10	0.20	3.4

[a]Individual value ± variability of the radioactive disintegration process (counting error) at the 95% confidence level (1.96 sigma).
[b]Summation of individual values and associated uncertainties.

Table A-15. Results of Soil Sampling in the Undisturbed Area at the Tin Building

	Pu-239, -240[a] (pCi/g)		Pu-238[a] (pCi/g)		Total Pu[b] (pCi/g)		Am-241[a] (pCi/g)		U_{tot} (µg/g)
A-200	100.00	10.00	0.94	0.39	100.94	10.39	2.20	0.10	4.0
B-200	14.00	1.00	0.44	0.15	14.44	1.15	2.90	0.20	2.8
C-200A[c]	230.00	10.00	1.70	0.20	231.70	10.20	3.00	0.20	3.2
D-200	74.00	2.00	0.48	0.16	74.48	2.16	10.00	1.00	2.9
E-200	22.00	1.00	0.32	0.16	22.32	1.16	5.90	0.30	3.3
F-200	43.00	1.00	0.28	0.15	43.28	1.15	5.50	0.30	3.5
G-200	68.00	2.00	0.57	0.21	68.57	2.21	2.40	0.20	2.2

[a]Individual value ± variability of the radioactive disintegration process (counting error) at the 95% confidence level (1.96 sigma).
[b]Summation of individual values and associated uncertainties.
[c]"A" denotes the sample of record at a triplicate sample location.

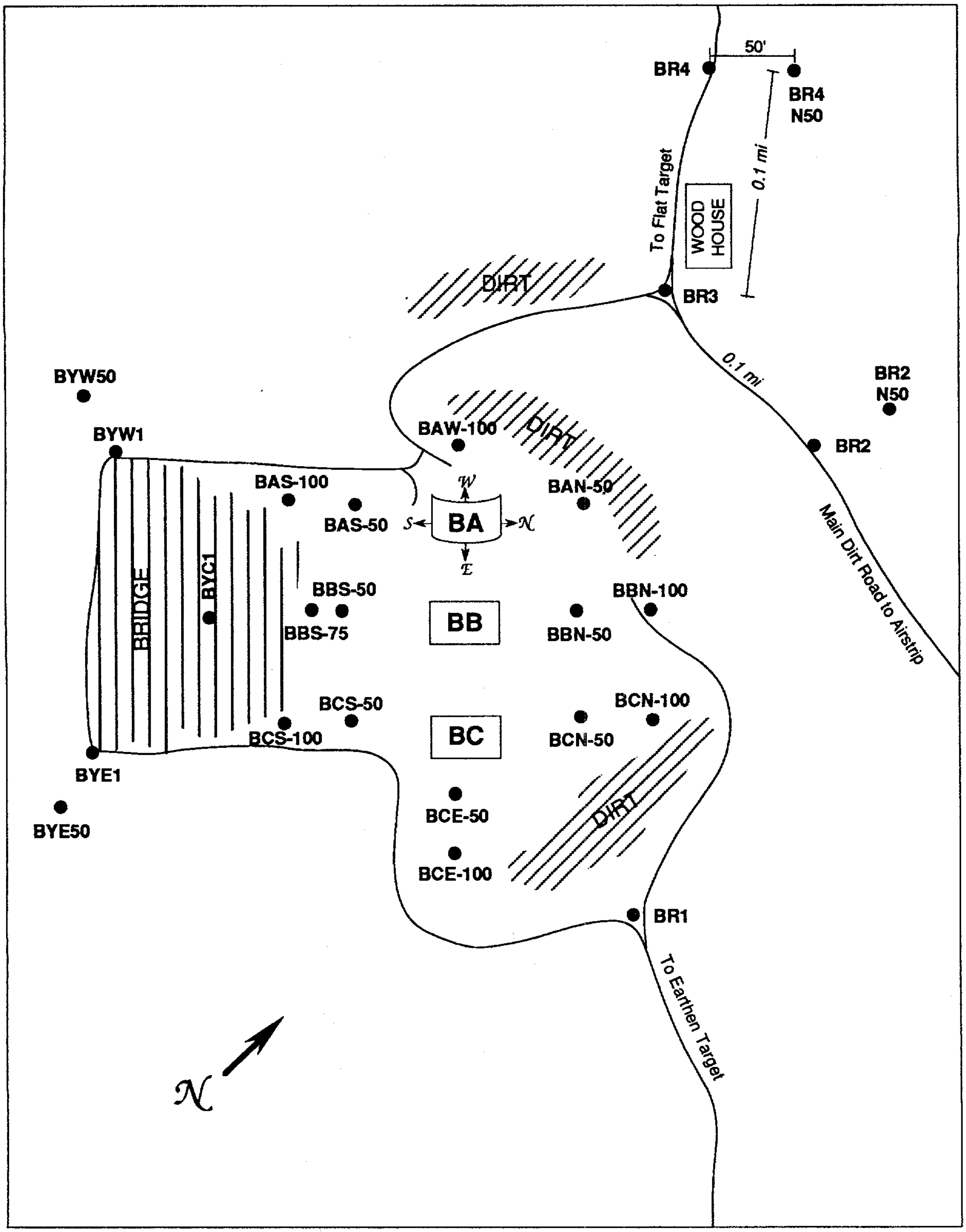


Figure A-9. Soil Sampling Locations Around the Bridge Area

Table A-16. Results of Soil Sampling at the Bridge Area

Location	Pu-239, -240[a] (pCi/g)		Pu-238[a] (pCi/g)		Total Pu[b] (pCi/g)		Am-241[a] (pCi/g)		U_{tot} (μg/g)
BAS50	-0.02	0.03	0.07	0.07	0.08	0.17	0.00	0.04	3.1
BAS100	0.19	0.10	-0.05	0.06	0.24	0.11	0.00	0.06	3.6
BAW40	0.04	0.06	0.08	0.06	0.18	0.20	0.07	0.05	2.7
BAW50	-0.02	0.03	0.06	0.06	0.07	0.15	0.07	0.04	3.1
BBN50	-0.01	0.04	0.01	0.04	0.04	0.09	0.00	0.06	3.4
BBN100	0.08	0.07	0.12	0.08	0.27	0.27	0.00	0.04	3.4
BBS50	-0.01	0.04	0.05	0.06	0.08	0.15	0.00	0.06	2.6
BBS75	-0.02	0.03	0.07	0.07	0.08	0.17	0.00	0.04	3.0
BCE50	-0.07	0.08	0.00	0.09	0.01	0.17	0.00	0.04	3.2
BCE100	0.05	0.10	-0.04	0.07	0.11	0.13	0.09	0.06	4.0
BCN50	-0.04	0.09	0.02	0.10	0.07	0.21	0.00	0.06	3.6
BCN100	0.11	0.12	-0.05	0.07	0.18	0.14	0.00	0.04	3.0
BCS50	0.04	0.05	0.14	0.07	0.23	0.26	0.00	0.06	3.2
BR1	1.30	0.30	-0.04	0.08	1.56	0.34	1.00	0.10	3.5
BR2	0.02	0.03	-0.02	0.04	0.03	0.05	0.00	0.06	3.5
BR2N50	0.02	0.02	-0.01	0.05	0.03	0.06	0.00	0.04	2.9
BR3	0.02	0.02	-0.01	0.04	0.03	0.05	0.00	0.04	3.1
BR4A[c]	0.00	0.01	0.07	0.10	0.08	0.18	0.07	0.04	2.8
BR4N50	0.03	0.03	0.03	0.05	0.09	0.11	0.00	0.04	3.3
BYC1	-0.06	0.08	0.08	0.11	0.10	0.27	0.00	0.06	4.1
BYE1	-0.02	0.09	0.01	0.10	0.08	0.20	0.00	0.06	3.3
BYE50	-0.02	0.08	0.00	0.09	0.06	0.17	0.00	0.04	3.8
BYW1	-0.06	0.07	-0.05	0.08	-0.04	0.10	0.00	0.06	3.7
BYW50	-0.07	0.08	-0.07	0.09	-0.06	0.10	0.00	0.04	3.5

[a] Individual value ± variability of the radioactive disintegration process (counting error) at the 95% confidence level (1.96 sigma).
[b] Summation of individual values and associated uncertainties.
[c] "A" denotes the sample of record at a triplicate sample location.

APPENDIX B

STATE OF NEVADA REGULATIONS AND PERMIT LISTINGS

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B-1	State of Nevada Regulations Applicable to the Tonopah Test Range	B-5
B-2	Tonopah Test Range Permits and Registrations	B-7

Table B-1. State of Nevada Regulations Applicable to the Tonopah Test Range

Regulation	Applicable Activity
<u>Nevada Wildlife Regulations</u> Nevada Revised Statute, Title 45, Chapter 501. NRS 501.010-501.243 Wildlife Regulations NAC 504.510-504.550	- Diversion of surface drainage channels - Clearing, leveling, and grading of site - Road construction - Highway improvement - Installation of water lines - Installation of water reservoirs - Installation of fuel storage tanks - Construction of sanitary landfill - Construction of explosives bunkers
<u>Nevada Air Quality Regulations</u> Nevada Revised Statutes, Title 40, Public Health and Safety, Chapter 445. NRS 445.401-445.601 NAC 445.430-445.995	- Diversion of surface drainage channels - Clearing, leveling, and grading of site - Road construction - Highway improvement - Installation of water lines - Installation of water reservoirs - Installation of fuel storage tanks - Construction of sanitary landfill - Construction of explosives bunkers - Construction of support buildings - Incinerator - Diesel-powered emergency generator
<u>Nevada Water Pollution</u> Nevada Revised Statutes, Title 40, Public Health and Safety, Chapter 445. NRS 445.131-445.354 NAC 445.070-445.194	- Construction of operation of Control Regulations sewage treatment plant - Disposal of drilling fluids - Water treatment plant
<u>Nevada Regulations Solid Waste Management</u> Nevada Revised Statutes, Title 40, Public Health and Safety, Chapter 444. NRS 444.510-444.610 Regulations Governing Solid Waste Management	- Clearing, leveling, and grading of site - Construction of support buildings - Construction and operation of sanitary landfill - Daily sanitary wastes - Disposal of sewage sludge

Table B-1. State of Nevada Regulations Applicable to the Tonopah Test Range (Concluded)

Regulation	Applicable Activity
<u>Nevada Regulations Governing Individual Sewage Systems</u> Nevada Revised Statutes, Title 40, Public Health and Safety, Chapter 444. NRS 444.650 NAC 444.750-444.840	- Construction of sewage collection systems
<u>Nevada Public Water Supply and Public Water Systems Regulations</u> Nevada Revised Statutes, Title 40, Public Health and Safety, Chapter 445. NRS 445.030 NAC 445.370-445.420	- Installation of water lines - Installation of water reservoirs
<u>Nevada Water Resources</u> Nevada Revised Statutes, Underground Water and Wells, Chapters 533 and 534. NRS 534.010-534.190 Regulations for Drilling Wells	- Installation of water lines - Installation of water reservoirs
<u>Radiation Control</u> Nevada Revised Statutes, Title 40, Public Health and Safety, Chapter 459. NRS 459.010-459.290 Nevada Regulations for Radiation Control	- Use of radioactive sources

Table B-2. Tonopah Test Range Permits and Registration

	Type of Activity	Permit Expiration Date	Report to Agency Due by	Comments
Air Quality[a]				
1.	Petro Storage JP-4	03/26/97		State of NV to USAF Permit #2449
2.	Petro Storage JP-4	03/26/97		State of NV to USAF Permit #2448
3.	Petro Storage JP-4	03/26/97		State of NV to USAF Permit #2447
4.	Petro Storage JP-4	03/26/97		State of NV to USAF Permit #2446
5.	Petro Storage Diesel #1	03/26/97		State of NV to USAF Permit #2445
6.	Petro Storage Diesel #1	09/15/93 (in process of being renewed)		State of NV to USAF Permit #1661
7.	Large Batch Plant (Ross)	02/12/96	04/15/93[b]	State of NV to DOE/NV Permit #2229
8.	Small Batch Plant (S.C. Johnson)	02/19/96	04/15/93[b]	State of NV to DOE/NV Permit #2231
9.	Crusher Cedarapids Mdl #2416		04/15/93[b]	State of NV to DOE/NV Permit to Operate #2456
10.	Crusher Cedarapids Mdl #1524		04/15/93[b]	State of NV to DOE/NV Permit to Operate #2457
11.	Screen Cedarapids Mdl #2416		04/15/93[b]	State of NV to DOE/NV Permit to Operate #2455

[a]Air Quality Activities 1 to 6 apply to the surface tanks in Technical Area X (Industrial Area).
[b]Annual Summary Report transmitted through the DOE/NV/EPD Office to Nevada Division of Environmental Protection.

Table B-2. Tonopah Test Range Permits and Registration (Continued)

	Type of Activity	Permit Expiration Date	Report to Agency Due by	Comments
12.	Surface Disturbance	09/15/98	04/15/93[b]	State of NV to DOE/KAO Air Quality Permit #2844
13.	Incinerator (MDL 500CA)	03/26/98	04/15/93[b]	State of NV to USAF Permit #2450
14.	Vapor Extraction			State of NV to USAF Air Quality Permit #3172, Permit to Construct
Water Systems				
1.	Mancamp Area Well 1A BLM Well	09/30/93	Monthly	State of NV to USAF Permit #NY-4068-12C
2.	Industrial Area Well 3A Well 3B Well EH-2	09/30/93	Monthly	State of NV to USAF Permit #NY-5001-12NC
3.	SNL Compound Well 6	09/30/93	Monthly	State of NV to DOE/KAO Permit #NY-3014-12NC
4.	TECR (O&M) Well	09/30/93	Monthly	State of NV to USAF Permit #NY-5002-12NC

[a]Air Quality Activities 1 to 6 apply to the surface tanks in Technical Area X (Industrial Area).
[b]Annual Summary Report transmitted through the DOE/NV/EPD Office to Nevada Division of Environmental Protection.
[c]NPDES permit renewal application has been transmitted to the State. The State is presently renewing the application and design modification. Expected renewal date is unknown.

Table B-2. Tonopah Test Range Permits and Registration (Concluded)

Type of Activity	Permit Expiration Date	Report to Agency Due by	Comments
Sewage System			
1. TIADS Mancamp Industrial Area	08/20/92[c]	Quarterly	State of NV to USAF Permit #NEV20001
Hazardous Waste			
1. EPA Waste ID Number TTR	N/A	Yearly	EPA to DOE/KAO EPA I.D. #NV1890011991

[a]Air Quality Activities 1 to 6 apply to the surface tanks in Technical Area X (Industrial Area).
[b]Annual Summary Report transmitted through the DOE/NV/EPD Office to Nevada Division of Environmental Protection.
[c]NPDES permit renewal application has been transmitted to the State. The State is presently renewing the application and design modification. Expected renewal date is unknown.

APPENDIX C

NON-RADIOLOGICAL ANALYTICAL DATA

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C-1 Concentrations (ppm) of Metals in TTR Soil Samples for Hard Target Area, June 1993 . . . . C-5
C-2 Concentrations (ppm) of Metals in TTR Soil Samples for the Clean Slate Area, June 1993 . . . . C-6
C-3 Concentrations (ppm) of Metals in TTR Soil Samples for the Operations Center, June 1993 . . . . C-8
C-4 Concentrations (ppm) of Metals in Offsite Soil Samples, June 1993 . . . . C-9

Table C-1. Concentrations (ppm) of Metals in TTR Soil Samples for Hard Target Area, June 1993

Location	Aluminum	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium
HTS20	8100	130	0.5	0.5	13000	35	3	7.9	8300	110	3000
HTSW20	5700	120	0.5	0.5	9700	19	2.6	7.7	6200	39	2500
HTNW20	6900	120	0.5	0.5	18000	22	2.9	10	7300	69	3000
HTNE20	10000	140	0.5	0.5	15000	10	4.1	10	9900	18	4000
HTE20	7500	120	0.5	0.5	14000	34	7.4	12	7900	110	2900
HTSE20	5700	100	0.5	0.5	13000	45	3	16	7000	160	2600

Location	Manganese	Nickel	Potassium	Silica	Silver	Sodium	Strontium	Titanium	Vanadium	Zinc
HTS20	280	9	3800	410	0.5	820	88	310	14	10
HTSW20	280	4	3200	620	0.5	860	69	280	11	10
HTNW20	240	4	3500	480	0.5	2400	110	270	13	10
HTNE20	360	5	4200	420	0.5	650	110	360	17	11
HTE20	280	14	3400	480	0.5	620	80	290	14	16
HTSE20	230	4	3200	550	0.5	710	89	220	11	10

Table C-2. Concentrations (ppm) of Metals in TTR Soil Samples for the Clean Slate Area, June 1993

Location	Aluminum	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium
T-1	15000	220	0.06	0.5	18000	8	6.1	8.7	14000	8	6400
T-2	10000	120	0.5	0.5	3300	9	2.7	5.1	8400	8	2800
T-3	10000	110	0.5	0.5	3600	9.3	3	5.9	8600	7	3000
T-4	9400	120	0.5	0.5	3400	7.3	3.1	6.3	9000	8	3200
T-5	11000	100	0.5	0.5	4700	9.4	3.1	5.9	8600	10	3000
T-6	8200	150	0.5	0.5	6900	7.9	3.4	5.6	8800	10	3600
T-7	7500	140	0.5	0.5	9400	14	2	4.2	6900	7	2300
T-8	5300	82	0.5	0.5	1800	14	1.5	3.2	5300	6	1400
T10	8700	120	0.5	0.5	3700	14	3	5.1	7900	11	2900
T-11	8000	74	0.8	0.5	3100	20	4.3	13	9600	16	2200
T-12	9200	140	0.6	0.5	6400	16	3.6	6	9900	14	3200
STA14A	8100	160	0.5	0.5	5700	12	2.5	6.9	8800	13	2700
D1	11000	140	0.6	0.5	5600	15	6.2	6.9	16000	14	4400

Table C-2. Concentrations (ppm) of Metals in TTR Soil Samples for the Clean Slate Area, June 1993 (Concluded)

Location	Manganese	Nickel	Potassium	Silica	Silver	Sodium	Strontium	Titanium	Vanadium	Zinc
T-1	470	6	4100	280	0.5	860	130	320	26	18
T-2	280	5	3700	560	0.5	330	40	350	14	10
T-3	330	4	3500	870	0.5	370	42	390	13	10
T-4	460	5	3200	700	0.5	290	36	410	14	10
T-5	340	5	4100	260	0.5	390	44	370	14	10
T-6	340	4	3200	570	0.5	280	50	300	15	10
T-7	180	3	2800	280	0.5	460	61	280	15	25
T-8	120	2	2100	180	0.5	270	23	220	10	23
T10	410	3	3200	290	0.5	570	38	350	15	28
T-11	530	7	2600	340	0.5	270	30	190	20	58
T-12	450	5	3500	230	0.5	440	46	340	19	39
STA14A	250	6	2900	700	0.5	290	44	400	15	30
D1	390	6	3500	300	0.5	370	66	360	30	43

Table C-3. Concentrations (ppm) of Metals in TTR Soil Samples for the Operations Center, June 1993

Location	Aluminum	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium
OP3-2	11000	130	0.5	0.5	20000	13	3.5	5.9	10000	8	3800
OP3-1	11000	130	0.5	0.5	19000	12	4	10	12000	22	3200
OC-4	8900	160	0.5	0.5	10000	8.3	3.9	6.6	9500	10	3200
OC-1	10000	160	0.5	0.5	13000	7.3	4.4	7	11000	9	3700
OC-3	15000	160	0.8	0.5	17000	9.1	5.8	13	14000	14	6100
OC-2	18000	180	0.7	0.5	17000	7.2	6	15	15000	16	6800

Location	Manganese	Nickel	Potassium	Silica	Silver	Sodium	Strontium	Titanium	Vanadium	Zinc
OP3-2	280	4	3800	180	0.5	510	73	390	21	10
OP3-1	340	4	3900	330	0.5	640	110	330	22	51
OC-4	290	5	3000	320	0.5	550	72	490	22	10
OC-1	330	5	3200	360	0.5	610	79	530	23	10
OC-3	420	9	5300	370	0.5	430	99	580	24	32
OC-2	450	10	5800	330	0.5	491	110	638	27	39

Table C-4. Concentrations (ppm) of Metals in Offsite Soil Samples, June 1993

Location	Aluminum	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium
B1	10000	180	0.6	2.2	13000	17	5.6	25	13000	19	4200
B2	11000	150	0.5	0.5	10000	13	5.1	9.4	14000	15	3400
B3	8000	110	0.5	0.5	14000	11	3.6	12	9400	20	3700
B4	7700	120	0.5	0.5	7300	14	2.7	10	8600	15	3700
B5	9600	180	0.5	0.5	20000	11	3.7	14	10000	10	4300
B6	10000	230	0.5	0.5	14000	12	3.3	11	9400	16	3500
B7	10000	170	0.5	0.5	5700	11	3.6	7.7	11000	16	3400
B8	7300	160	0.5	0.5	3100	10	2.4	5	9300	12	1900
B9	9700	160	0.5	0.5	2300	7.9	2.9	5.9	10000	13	2200
B10A	5500	390	0.5	0.9	34000	21	3.3	11	9800	33	7300
B10B	6200	460	0.5	0.6	38000	13	3.2	8.9	10000	14	8600
B10C	8400	160	0.5	0.5	12000	9.7	3.7	4.7	9900	7	3200
B11	9800	180	0.5	0.5	13000	12	4.1	4.9	12000	8	3400
B12	7300	160	0.5	0.5	5700	6.5	2.8	5.1	7300	9	2600
B13	10000	170	0.5	0.5	6000	6.5	2.3	4	7800	6	2600
B14	6200	110	0.5	0.5	2500	7.4	1.6	3.7	6300	5	1800

Table C-4. Concentrations (ppm) of Metals in Offsite Soil Samples, June 1993 (Concluded)

Location	Manganese	Nickel	Potassium	Silica	Silver	Sodium	Strontium	Titanium	Vanadium	Zinc
B1	460	8	2800	220	0.5	620	82	600	30	57
B2	330	6	2000	190	0.5	900	110	710	41	39
B3	610	6	3400	430	14	1600	60	340	20	54
B4	300	5	2500	330	1.2	360	44	310	17	41
B5	430	6	3000	370	0.5	590	120	430	25	54
B6	300	6	3800	330	0.5	660	160	420	23	42
B7	490	5	4300	330	0.7	420	49	240	17	55
B8	300	3	3000	390	0.5	320	47	270	14	30
B9	290	4	2300	310	0.5	310	30	510	21	65
B10A	220	17	2000	420	0.5	240	86	170	33	85
B10B	270	13	2100	410	0.5	220	93	200	32	62
B10C	450	4	2600	340	0.5	830	110	520	26	26
B11	470	6	2800	260	0.5	970	120	630	33	27
B12	510	4	3800	370	0.5	840	42	220	12	35
B13	220	4	4900	280	0.5	260	110	270	15	22
B14	140	3	3100	350	0.5	210	35	220	11	17

APPENDIX D

1993 RADIOLOGICAL DOSE CALCULATIONS FOR SANDIA NATIONAL LABORATORIES, NEVADA

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SUMMARY

Operations at Sandia National Laboratories/Nevada (SNL/NV) at the Tonopah Test Range (TTR) resulted in no planned radiological releases during 1993. Other releases from SNL/NV included a diffuse plutonium source from the three Clean Slate areas due to wind resuspension of near-surface plutonium-contaminated soil particulates. The total area of contamination was estimated to exceed 15 million square meters (m^2). Soil contamination was documented in an aerial survey program in 1977. Surface contamination levels were generally found to be below 400 picocuries per gram (pCi/g) alpha activity. Hot spot areas ranged up to 43000 pCi/g alpha activity. Recent onsite soil contamination measurements confirm the presence of significant levels of alpha activity in the surface soil. An annual diffuse source term of 0.25 curies (Ci) of alpha-plutonium was calculated for the cumulative release from all Clean Slate sites.

The diffuse release resulted in a maximally exposed individual (MEI) dose of 2.9 millirem per year (mrem/yr) at the Air Force 554th Range Squadron Operations and Maintenance (O&M) Complex located on site 9.8 kilometers (km) east of the closest Clean Slate site (Clean Slate 2). A population dose of 0.00038 person-millirem per year (person-mrem/yr) was calculated for the local residents. Both doses were attributable to inhalation of plutonium-contaminated dust.

D.1 INTRODUCTION

This appendix provides a summary of the data, calculations, and supporting documentation for assessing the potential radiological dose resulting from activities and environmental conditions at TTR. Included in this appendix is a detailed summary of the radionuclide releases at SNL/NV for calendar year 1993, as well as a description of relevant release parameters. A description is given of the models used in the dose assessment, including the CAP88-PC computer code and the wind resuspension model. In addition, the MEI radiological dose calculation and the population dose to regional residents are discussed. Diffuse sources, which constitute the only 1993 radionuclide releases, and their contributions to the overall dose are presented.

Supplemental calculational methodologies and data relevant to the environmental assessments presented here are contained in this document as Appendix E, *Supplemental 1993 Dose Assessment Data for SNL, Nevada Facilities*.

D.2 POINT RADIOLOGICAL SOURCES

SNL/NV does not currently have any facilities or other stack emission points that generate airborne radionuclide releases.

D.3 DIFFUSE RADIOLOGICAL SOURCES

Experiments conducted at SNL/NV occasionally involve small amounts of radioactive material from destructive testing experiments. During testing, materials can be dispersed over a broad area at the test site and can be subsequently incorporated into the surface soil. A potential airborne source of radionuclides is possible through the wind resuspension of surface soil material. Such potential sources are small and the resulting radiological exposures are expected to be well below applicable exposure limits.

During the early 1960s, three dispersal tests involving plutonium were conducted at SNL/NV. The three Clean Slate sites received the most significant levels of surface radiological contamination. A total of about 64 Ci of plutonium (Pu) is estimated to be contained in the near-surface soil of the fenced area. Radiation isopleths showing soil activity of americium-241 (Am-241), plutonium-239 (Pu-239), and plutonium-240 (Pu-240) were drawn for these sites (EG&G 1979). The Clean Slate sites pose a source of airborne alpha activity through wind resuspension of surface soils. Future plans include onsite air monitoring of the on range receptor to better estimate the diffuse source from contaminated soils. Current air monitoring performed by the U.S. Environmental Protection Agency (EPA) at public locations on the perimeter of SNL/NV shows no elevated air concentrations of plutonium.

D.4 AIR EMISSION DATA

D.4.1 Radiological Releases During 1993

During 1993, the only source of airborne radionuclides at TTR was a diffuse source of plutonium as a result of wind resuspension of surface soil particulates. The annual diffuse source term was calculated using a wind resuspension model which calculates the rate at which soil particulates become airborne. The wind resuspension model utilizes an empirical relation (DOE 1984) that predicts rates of resuspension as a function of the wind speed. Using site-specific meteorological data, radionuclide source terms were calculated separately for each wind direction sector from soil contamination data (EG&G 1979) and wind speed characteristics. A detailed description of the wind resuspension model is contained in this document as Appendix E, *Supplemental 1993 Dose Assessment Data for SNL, Nevada, Facilities*.

During 1993, a total of 0.25 Ci of alpha-activity plutonium (i.e., 0.013 Ci plutonium-238 [Pu-238], 0.19 Ci Pu-239, 0.043 Ci Pu-240, 5.8×10^{-6} Ci plutonium-242 [Pu-242], and 0.0032 Ci Am-241) was calcu-lated as the diffuse source term from all three Clean Slate sites. The diffuse source was calculated for particulate matter which is 10 microns (μm) or less in diameter, and is assumed to be entirely respirable.

D.4.2 Environmental Surveillance Program

The EPA conducts routine monitoring at TTR. A continuous particulate air monitoring station is located at TTR as part of the EPA Air Surveillance Network. This network also includes stations at Goldfield and Tonopah. Air filters are changed weekly and analyzed by gamma spectroscopy. Beryllium-7 (Be-7), a naturally occurring radionuclide, is generally the only radionuclide detected by gamma spectroscopy.

In addition to air monitoring, the EPA also conducts water sampling and analysis. Monthly sample analyses include a gamma spectral analysis, suspended solids, pH, temperature, and conductivity. Sandia National Laboratories (SNL) is currently conducting environmental surveillance baseline soil sampling along with limited air monitoring.

D.5 DOSE ASSESSMENT

During 1993, the diffuse source of plutonium from the three Clean Slate sites described in Section D.4.1 of this Appendix is the only quantifiable release from SNL/NV facilities. A dose assessment was performed for this release. The dose assessment was conducted for four nearby onsite receptors located around the Clean Slate sites. Additionally, the dose assessment included offsite receptors located much farther away, near the towns of Goldfield, Tonopah, and Warm Springs, and at the East Nellis Air Force Base (NAFB)/TTR entrance.

The CAP88-PC computer code (EPA 1991) was used for all dose assessments. Using CAP88-PC, an MEI dose calculation was performed for the diffuse release. The calculated doses were the cumulative doses contributed by all three Clean Slate sites. An effective dose equivalent of 2.9 mrem/yr was calculated for an MEI located 9.8 km east of the Clean Slate 2 site. A regional population dose of 0.00038 person-mrem/yr was calculated for the 6008 persons living within an 80-km radius of the geographic center of TTR.

REFERENCES

DOE 1984: U.S. Department of Energy, "Atmospheric Science and Power Production," DOE/TIC-27601 (DE840055177), Technical Information Center, Office of Scientific and Technical Information, U.S. Dept. of Commerce, Springfield VA.

EG&G 1979: Edgerton, Germeschausen, & Grier Corporation, "An Aerial Radiological Survey of Clean Slates 1, 2, and 3, and Double Track, Tonopah Test Range," EGG-1183-1737, Energy Measurement Group, EG&G, Las Vegas, NV.

EPA 1991: U.S. Environmental Protection Agency, "CAP-88, Clean Air Act Assessment Package," Radiation Shielding Information Center, CCC-542, Oak Ridge, TN (1991).

APPENDIX E

SUPPLEMENTAL 1993 DOSE ASSESSMENT DATA FOR SNL, NEVADA, FACILITIES

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E.1 INTRODUCTION

This appendix details the methodology and supplemental data used to calculate radiological dose resulting from activities and environmental conditions existing at the Tonopah Test Range (TTR). Appendix D provides a summary of the dose results and calculational methods that are presented in more detail here.

The CAP88-PC code (EPA 1991) requires large amounts of data to calculate annual doses. Required site-specific information includes the location of receptors that can potentially be exposed during the year, demographic data, and meteorological data. Receptor data include the distance and direction of receptors relative to locations of radionuclide releases. Since the dose to a given receptor is the cumulative contribution from all emission sources, a maximally exposed receptor location must be determined by calculating doses to several locations surrounding the source region. Therefore, several potential maximum receptor locations are studied. Demographic data include population, dairy cattle, beef cattle, and food crop information that have been specially formulated into a CAP88-PC grid system. Meteorological data include harmonic and true-averaged wind speeds in each of sixteen wind direction sectors used by CAP88-PC. Additionally, the meteorological data include the frequency occurrence of the six Pasquill atmospheric stability classes (segregated into the sixteen wind direction sectors) and the frequency occurrence of each of the sixteen wind directions. Those supplemental data are presented in this document.

Dose assessment at Sandia National Laboratories/Nevada (SNL/NV) utilizes the CAP88-PC computer code, approved by the U.S. Environmental Protection Agency (EPA). CAP88-PC will not calculate the annual source terms which must be known in order to calculate annual radiological doses. During 1993, no radionuclides were released from TTR from typical stack, vents, or other point sources. However, a large area of surface contamination was calculated to produce a diffuse source of airborne radionuclides through the action of wind resuspension of soil particulates. The surface contamination is the result of three plutonium dispersal tests conducted in 1963 where residual plutonium is still present in the surface soil. The methodology for estimating the diffuse source term is presented in Section E.6, The Wind Resuspension Model.

E.2 RECEPTOR LOCATIONS

E.2.1 Offsite Receptors

Figure E-1 depicts the zone of offsite receptors around TTR. The TTR zone of offsite receptors includes a distinct population of seasonal residents and workers. Therefore, two sets of offsite receptor groups are indicated in Figure E-1: a zone of permanent offsite receptors and a zone of seasonal (semipermanent) public receptors. To the west of TTR and Nellis Air Force Base (NAFB) Range Complex, permanent residents are found mainly along Highway 95 and as much as three miles east of the highway near Goldfield. However, a zone of seasonal offsite receptors (mainly miners) extends as far as seven miles east of Highway 95. To the northeast, the offsite receptors are mainly along or north of Highway 6, with the exception of the Tonopah Airport, which protrudes several miles south of the highway. To the east and northeast, the permanent offsite receptors are primarily along the paved road, with a few exceptions near Rachel,

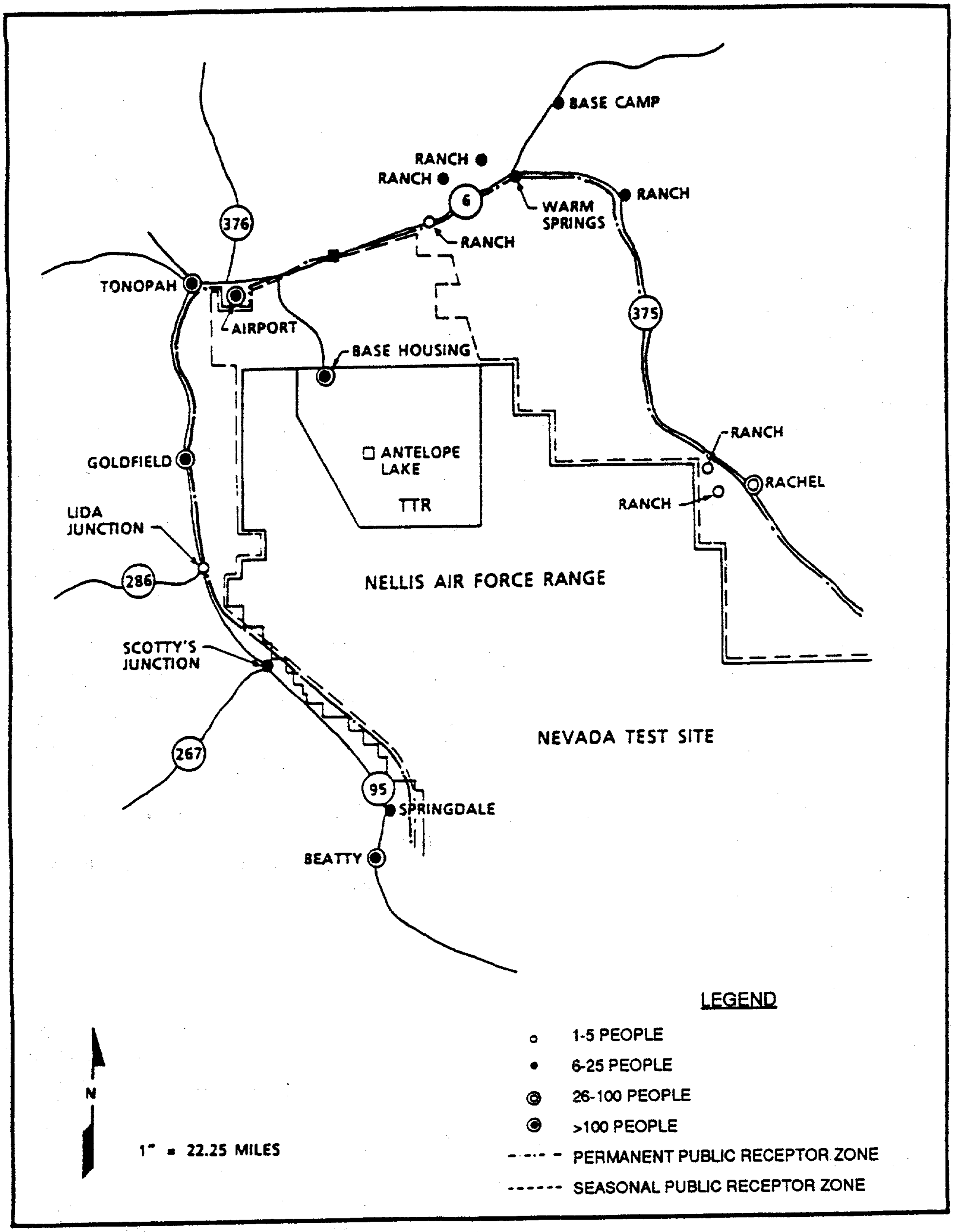

Figure E-1. Offsite Receptor Zone Around Tonopah Test Range where a few ranches are found west of the highway up to the eastern boundary of NAFB Range. However, a significant seasonal population of ranchers inhabits the area northwest of TTR during late spring, summer, and early fall. During winter months, winter ranching camps are established south of Highway 6 in the Stone Cabin Valley area. Summer ranchers are found up to the NAFB Range boundary during warmer months. Miners are also present during warmer months in the central Kawich Ranges. The zone of seasonal offsite receptors makes a substantial incursion toward the TTR in this area. To the south, no offsite receptors were found due to the restricted areas in the Nevada Test Site. Table E-1 summarizes the closest offsite receptors around SNL/NV.

In addition to the zone of offsite receptors surrounding SNL/NV summarized in Table E-1, four other specific offsite receptor locations are assessed: the towns of Tonopah (51 kilometers [km] northwest of TTR), Goldfield (39 km west), and Warm Springs (66 km northeast), and the east NAFB/TTR entrance (64 km east).

E.2.2 Onsite Receptors

In addition to the offsite receptor locations, several receptors are located onsite as shown in Figure E-2. The concept of "onsite receptor" is conservatively assumed to include members of the military, military contractors, and other non-Sandia National Laboratories (SNL) personnel who work at locations on TTR and over whom SNL has little or no operational control. This definition is believed to be consistent with current U.S. Department of Energy (DOE) guidance. Table E-2 summarizes the distances and directions of the onsite locations relative to the three Clean Slate sites.

The Clean Slate sites have the appearance of elongated rectangles rather than circles. The CAP88-PC model allows for circular source region configurations only. Consequently, each Clean Slate area was subdivided into two component areas which more closely approximate a circular configuration. Based on the effective diameter of each resulting subdivision and the relative distances to receptor locations, it was judged that additional subdivision into smaller component areas was not necessary. Each subdivision is modelled as an independent source possessing its own unique distances and directions from its geographic center to receptor locations as summarized in Table E-2. The radiological dose assessed for a Clean Slate site is the sum of the two component doses from its subdivisions.

E.3 RADIOLOGICAL DOSE ASSESSMENTS

During 1993, no radiological point-source releases occurred as a result of SNL/NV operations. Diffuse sources of radionuclides were examined in detail. The Clean Slate 1, 2, and 3 sites contain elevated levels of plutonium in the surface soil as a result of plutonium dispersal testing that was conducted in 1963. In 1977, Edgerton, Germeshausen & Grier Corporation (EG&G) conducted an extensive measurement program to document the levels of residual surface soil activity (EG&G 1979). The study concluded that the soil contamination ranged from about 300 to 80,000 picocuries per gram (pCi/g) of alpha-plutonium activity (i.e., a

Table E-1. Distances to Offsite Receptors Around Tonopah Test Range

Direction Toward Receptor	Permanent Receptors (km)	Seasonal Receptors (km)
N	35.0	27.0
NNW	33.4	33.4
NW	33.4	33.4
WNW	41.4	41.0
W	48.5	37.5
WSW	47.7	39.0
SW	56.3	44.5
SSW	63.6	63.8
S	74.5	74.8
SSE	>100.0	>100.0
SE	>100.0	78.0
ESE	65.2	65.2
E	58.9	29.4
ENE	57.3	23.9
NE	48.8	18.5
NNE	36.1	20.0

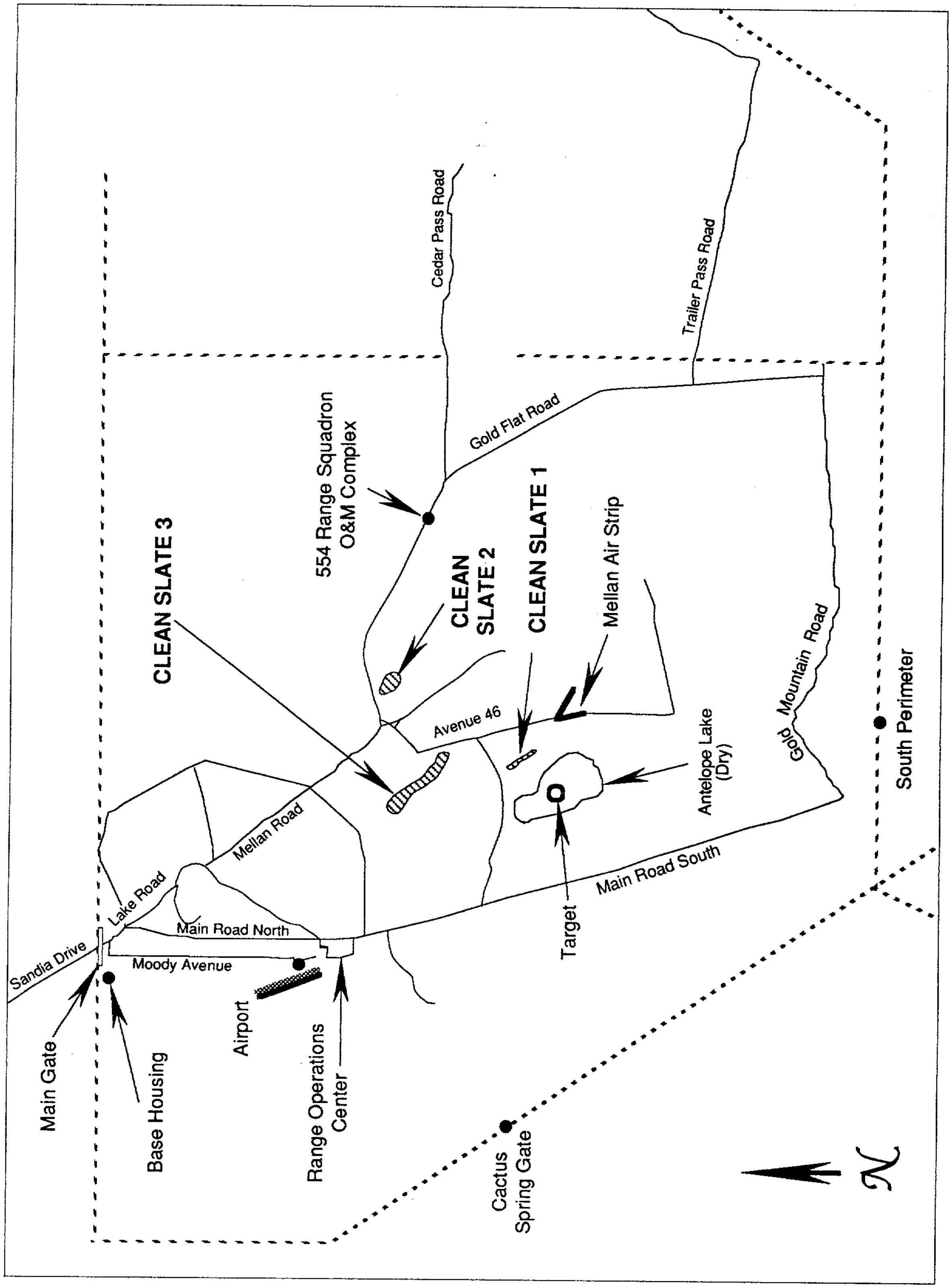

Figure E-2. Onsite Receptor Locations

Table E-2. Distance (km) and Direction to Onsite Receptor Locations at Tonopah Test Range

Receptor[1]	Base Housing	Airport	South Perimeter	554th Range Squadron O&M Complex
<u>Clean Slate 1</u>				
1a	22.3 NNW	13.8 NW	18.2 S	14.6 ENE
1b	24.1 NNW	15.6 NW	16.5 S	14.0 ENE
<u>Clean Slate 2</u>				
2a	19.7 NW	14.3 WNW	24.0 S	10.5 E
2b	21.1 NW	15.5 WNW	24.0 S	9.8 E
<u>Clean Slate 3</u>				
3a	16.3 NNW	8.9 WNW	24.1 S	16.6 E
3b	20.1 NNW	12.6 NW	21.0 S	13.7 E

[1]Clean Slate sites have been subdivided into two smaller areas for modeling purposes.

mixture of five isotopes of plutonium and americium-241 (Am-241) which collectively is called alpha-plutonium). The contamination was about 15 million square meters (m^2) in area. The majority of the Clean Slate areas contain surface contamination less than about 400 pCi/g. Limited soil sampling has been performed in the vicinity of the Clean Slate sites as part of the SNL Environmental Surveillance Program. Results of the soil sampling confirm the results of the 1977 EG&G study.

The potential releases from the Clean Slate sites occur as a result of the wind resuspension of soil particulates (fugitive dust) contaminated with plutonium. A total annual release (i.e., the sum of the sixteen directional releases) of 0.25 curies per year (Ci/yr) of alpha-plutonium was calculated to occur from all three Clean Slate sites combined. The diffuse source is composed of PM-10 particulates (i.e., particulates less than 10 microns [μm] in diameter) and has the potential to disperse downwind to receptor locations.

A detailed dose calculation was conducted for four onsite receptor locations and is presented later in this Appendix. Individual doses were calculated for the four onsite receptors using the CAP88-PC code (EPA 1991). The maximally exposed individual (MEI) dose was 2.9 millirems per year (mrem/yr) and occurred at the Air Force 554th Range Squadron Operations and Maintenance (O&M) Complex located on the east side of TTR. The dose was due primarily to the inhalation of plutonium-239 (Pu-239). A detailed presentation of the wind resuspension and dose assessment is presented later in Section E.6, The Wind Resuspension Model.

In addition to the onsite doses, individual doses were calculated using the CAP88-PC code for selected offsite receptor locations described earlier. Because the distances are relatively large between the source and receptor, the doses were calculated using a single cumulative source term of 0.25 curies (Ci) alpha-plutonium representing the sum of all sixteen diffuse sources (one in each direction) presented in Table E-27. The individual doses calculated for the towns of Tonopah, Goldfield, and Warm Springs, and the east NAFB/TTR entrance are 0.045 mrem/yr, 0.062 mrem/yr, 0.013 mrem/yr, and 0.050 mrem/yr, respectively.

A regional population dose was calculated using the CAP88-PC code. Data for the resident population of 6008 persons within an 80-km radius of TTR were placed into the CAP 88-PC 16-sector, 5-ring grid for the analysis. The population data were figured from the 1990 census and are presented in Section E.5, Demographic Data. The source term used was 0.25 Ci/yr alpha-plutonium consistent with the calculations performed for the offsite receptors. The population was conservatively assumed to obtain all of its food supply locally. Using the 0.25 Ci/yr source term, the resulting population dose was calculated to be 0.00038 person-millirem per year (person-mrem/yr) due primarily from inhalation of Pu-239.

E.4 METEOROLOGICAL DATA

Meteorological data for the SNL/NV area are derived from the joint frequency distribution table for the Tonopah, Nevada, Airport located about 65 km north of TTR (DOC 1978). These data, which comprise over 14,598 hourly meteorological observations of wind direction, wind speed, and stability class (inferred from wind and solar insolence data) form a normalized distribution from which all wind and stability-frequency-of-occurrence data are derived. The four-year data collection period, 1961-1964, was selected by the National Climatic Center, Ashville, South Carolina, as the best for application of the Stability Array (STAR) data program, which generates stability class data from conventional meteorological measurements. Although the data are from about 65 km north of TTR, wind patterns should not be appreciably different due to geographic similarities between these locations. The STAR data file for Tonopah was not contained in the CAP88-PC computer code; it was entered into a supplemental data file from where it was selected from the CAP88-PC user menu. Table E-3 summarizes the harmonic and arithmetic average wind speeds used by the CAP88-PC code for the dose assessment. Table E-3 also contains the frequency occurrence of wind directions. Table E-4 summarizes the frequency of occurrence of Pasquill stability classes. Other meteorological data used in the CAP88-PC code are summarized in Table E-5.

E.5 DEMOGRAPHIC DATA

Demographic data include population, beef cattle, dairy cattle, and the area of food crop harvesting. Although the CAP88-PC code will calculate demographic data for the Tonopah area based on statewide demographic averages, these data are available on a per-county basis and were calculated and input to CAP88-PC to give more accurate quantities within the 80 CAP-88 analysis zones (16 wind direction sectors subtended by 5 concentric, equally spaced rings to 80 km [50 miles]). This was done by calculating the demographic data density for each county and by assuming a uniform distribution. The densities were then multiplied by the area of each county falling into each zone. Some zones were occupied by as many as four counties. Once the area of each county within a given zone was tabulated, the areas were multiplied by the appropriate density for the county, and the demographic data was summed over the contributing counties. The contributions from each county were summed within each grid to yield the total population. The 1990 population data for the study area were taken from DOC 1991a and 1991b. Agricultural data were taken from DOA 1988. A complete listing of the gridded demographic data and a detailed description of the methodology used to derive them are provided in this Appendix. The SNL/NV CAP88-PC grid was centered on Antelope Lake in the center of TTR and is provided for calculating the regional population dose only.

In general, county densities for population, beef cattle, dairy cattle, and food crops were calculated as the quotient of the most recent county data and the county land area. For example, dividing the number of residents in Nye County, Nevada (11,790), by its area (18,155 mi^2.) yields a population density of 0.65 people per square mile. This concept is applied to beef and dairy cattle and food crops. However, for counties with significant population centers, the population of the urban centers was subtracted from the county population. The resulting population density was, therefore, a rural population density. The population centers were later added to CAP88-PC zones (EPA 1991), in addition to the rural population in the zone, on a case-by-case basis.

Table E-3. Average Wind Speeds

	Pasquill Stability Class							
Dir	A	B	C	D	E	F	G	Frequency
Harmonic Average								
N	0.988	1.487	4.200	6.840	3.495	1.193	0.000	0.108
NNW	1.066	1.486	3.671	5.762	3.564	1.130	0.000	0.050
NW	1.120	1.230	2.728	4.903	3.239	1.154	0.000	0.050
WNW	0.956	1.138	2.486	4.564	3.545	1.197	0.000	0.017
W	1.083	0.987	2.174	3.896	3.469	1.062	0.000	0.032
WSW	1.140	1.082	2.732	6.491	3.779	1.026	0.000	0.014
SW	1.120	1.039	2.663	6.771	3.722	1.298	0.000	0.062
SSW	0.983	1.071	2.320	6.790	3.914	1.404	0.000	0.077
S	0.983	1.037	2.082	6.366	4.032	1.489	0.000	0.216
SSE	0.000	0.988	2.261	6.441	4.077	1.469	0.000	0.086
SE	1.356	1.074	2.568	6.098	3.965	1.418	0.000	0.068
ESE	1.356	1.230	2.146	6.109	3.689	1.224	0.000	0.017
E	0.011	1.085	2.000	5.841	3.694	1.167	0.000	0.026
ENE	0.983	1.226	4.784	6.545	3.720	1.204	0.000	0.020
NE	1.083	1.386	5.023	7.016	3.851	1.300	0.000	0.074
NNE	1.356	1.537	5.599	7.838	3.731	1.410	0.000	0.081
Arithmetic Average								
N	1.334	2.417	5.938	8.260	3.727	1.681	0.0000	
NNW	1.482	2.358	4.925	6.911	3.789	1.588	0.0000	
NW	1.572	1.950	3.763	5.986	3.472	1.624	0.0000	
WNW	1.268	1.755	3.456	6.250	3.773	1.686	0.0000	
W	1.510	1.452	3.177	5.443	3.703	1.475	0.0000	
WSW	1.603	1.737	3.930	7.638	3.969	1.410	0.0000	
SW	1.572	1.641	3.823	7.925	3.923	1.815	0.0000	
SSW	1.326	1.699	3.532	8.001	4.071	1.930	0.0000	
S	1.326	1.542	3.155	7.501	4.155	2.011	0.0000	
SSE	0.000	1.461	3.268	7.490	4.186	1.992	0.0000	
SE	1.880	1.662	3.727	7.376	4.108	1.945	0.0000	
ESE	1.880	1.999	3.653	7.299	3.896	1.722	0.0000	
E	1.380	1.758	3.838	6.894	3.900	1.643	0.0000	
ENE	1.326	1.725	6.550	7.606	3.921	1.695	0.0000	
NE	1.510	2.356	7.185	7.973	4.024	1.817	0.0000	
NNE	1.880	2.537	7.475	8.743	3.931	1.936	0.0000	

Source: STAR data file for Tonopah, Nevada (DOC 1978). Wind directions are toward the indicated direction.

Table E-4. Frequency of Stability Classes

	Pasquill Stability Class						
Dir	A	B	C	D	E	F	G
N	0.0059	0.0884	0.2002	0.5766	0.0719	0.0570	0.0000
NNW	0.0141	0.1606	0.2890	0.3941	0.0656	0.0767	0.0000
NW	0.0179	0.2831	0.2640	0.2729	0.0617	0.1005	0.0000
WNW	0.0334	0.3742	0.2389	0.1612	0.0484	0.1439	0.0000
W	0.0121	0.2791	0.2554	0.1618	0.0828	0.2088	0.0000
WSW	0.0183	0.1833	0.2001	0.3111	0.0751	0.2121	0.0000
SW	0.0073	0.0787	0.1235	0.5124	0.0951	0.1830	0.0000
SSW	0.0051	0.0551	0.0687	0.5100	0.1790	0.1821	0.0000
S	0.0012	0.0198	0.0431	0.4936	0.2662	0.1761	0.0000
SSE	0.0000	0.0109	0.0309	0.5169	0.2761	0.1652	0.0000
SE	0.0019	0.0262	0.0488	0.4511	0.2475	0.2245	0.0000
ESE	0.0076	0.0516	0.0849	0.4359	0.1681	0.2519	0.0000
E	0.0271	0.0557	0.0942	0.4030	0.1727	0.2474	0.0000
ENE	0.0064	0.0337	0.0917	0.5951	0.1581	0.1150	0.0000
NE	0.0053	0.0270	0.1166	0.6776	0.0996	0.0739	0.0000
NNE	0.0016	0.0314	0.1512	0.7103	0.0620	0.0434	0.0000
Tot.	0.0062	0.0736	0.1194	0.4988	0.1596	0.1423	0.0000

Source: STAR data file for Tonopah, Nevada (DOC 1978).

Table E-5. Additional Weather Information

Data	Value
Average air temperature*	7°C
Annual precipitation*	12.5 cm/y
Mixing height†	2370 m

* Source: SNL 1991.
† Source: Slade 1968.

Table E-6 shows the urban centers for the Tonopah area. Also shown are the CAP88-PC grid locations so that the urban centers could be added to the rural population for the zone. An N/A in the grid location means that the population of the urban center was subtracted from the county population before figuring the county population density. However, the urban center was located outside the CAP88-PC grid and was not added back to any zone. Table E-7 shows the resulting rural population density by county for the Tonopah area. Tables E-8 through E-12 show the same kind of information as Table E-7 for the beef cattle, dairy cattle, and food crop densities by county for the Tonopah area.

Table E-13 shows the calculation of the rural populations for each CAP88-PC zone for the Tonopah area. In particular, it shows the land area of each county that contributes to the zone. Urban center populations are added back to Table E-13 values before input to the CAP88-PC data input file. Tables E-14, E-15, and E-16 summarize the calculation of the same kind of information as Table E-13 for beef cattle, dairy cattle, and food crops per zone, respectively, for the Tonopah area.

E.6 THE WIND RESUSPENSION MODEL

The Clean Slate sites at TTR are a potential diffuse source of radionuclides. Small amounts of plutonium were calculated to be released from TTR as fugitive dust originating from near-surface plutonium-contaminated soil through the action of wind pick-up and suspension. This phenomenon, known as wind resuspension, gives rise to an areal source rate release. This section describes the wind resuspension model used in the 1993 dose assessment to estimate the annual release of fugitive dust containing radionuclides at TTR.

E.6.1 Wind Resuspension Equation

Processes of wind resuspension are related to the process where ambient wind speed becomes increasingly greater as wind speed increases. The ability of the wind to resuspend surface particulate matter is calculated from the resuspension rate:

$$Q = S * C_A$$

where

Q = radionuclide source rate (pCi/cm^2/sec),
S = resuspension rate (1/sec), and
C_A = surface contamination (pCi/cm^2).

The resuspension rate, S, is a strong function of the wind speed. Figure E-3 displays a graph of the variation of resuspension rate versus wind speed. The chart is compiled for soil particles that range in size from about 1 to 10 μm in diameter and shows that the resuspension rate varies over many orders of magnitude as the wind varies from 1 to 20 m/s. Figure E-3 also shows the average resuspension rate for each of the six STAR wind speed categories.

Table E-6. Urban Centers by County for the Tonopah Area

County	City	Urban Population*	Sector	Ring
Esmeralda	Goldfield	659	5	3
Lincoln	None			
Nye	Beatty	1,652	N/A	N/A
	Tonopah	3,680	3	4
Total		5,991		

* Source: DOC 1991a, 1991b.
Note: N/A means not applicable.

Table E-7. Rural Population Density by County for the Tonopah Area

County	County Area* (mi^2)	Total Population†	Urban Population	Net Population	Rural Population Density (pop./mi^2)
Esmeralda	3,587	1,344	659	685	0.19
Lincoln	10,635	3,775	0	3,775	0.36
Nye	18,155	17,781	5,332	12,449	0.69

* Source: BOC 1983.
† Source: DOC 1991a, 1991b.

Table E-8. Beef Cattle Density by County for the Tonopah Area*

County	Total Beef Cattle†	County Area (mi^2)†	NTS Area Exclusion‡ (mi^2)	Beef Cattle Density ($head/mi^2$)
Esmeralda	12,000	3,587	0.0	3.34
Lincoln	19,000	10,635	0.0	1.79
Nye	23,000	18,155	4,181	1.65§
Nevada Test Site	0	N/A	N/A	0.00

* Source: DOA 1988.
† Source: BOC 1983.
‡ Includes the Nevada Test Site, Tonopah Test Range, Air Force test sites, and other restricted federal land.
§ Excluding NTS area.
Note: N/A means not applicable.

Table E-9. Number of Dairy Cattle by County for the Tonopah Area

County	Number Farms*	Percent Farms	Number of Dairy Cattle†
Elko	272	25.2	280
Esmeralda	29	2.7	30
Eureka	83	7.7	85
Humboldt	175	16.2	180
Lander	57	5.3	59
Lincoln	79	7.3	81
Mineral	32	3.0	33
Nye	118	10.9	121
Pershing	107	9.9	110
Storey	4	0.4	4
White Pine	124	11.5	127
Totals	1,080	100	1,110‡

* Source: BOC 1983.
† Derived from Column 3 (Percent Farms) and total number of dairy cattle (1,110). Numbers are rounded to nearest whole unit.
‡ Total of 1,110 dairy cattle for the counties listed. Source: DOA 1988.

Table E-10. Dairy Cattle Density by County for the Tonopah Area

County	Total Dairy Cattle*	County Area (mi^2)*	NTS Area Exclusion† (mi^2)	Dairy Cattle Density (head/mi^2)
Esmeralda	30	3,587	0.0	0.0084
Lincoln	81	10,635	0.0	0.0076
Nye	121	18,155	4,181	0.0087
Nevada Test Site	0	N/A	N/A	0.0

* Source: BOC 1983.
† Includes the Nevada Test Site, Tonopah Test Range, Air Force test sites, and other restricted federal land.
Note: N/A means not applicable.

Table E-11. Acres of Food Crops by County for the Tonopah Area

County	Number Farms*	Percent Farms†	Total Food Crops‡ (acres)
Esmeralda	29	1.2	386
Lincoln	79	3.3	1,063
Nye	118	4.9	1,578
Nevada Test Site	0	0.0	0

* Source: BOC 1983.
† Total farms in Nevada is 2,399.
‡ Source: U.S. Department of Agriculture 1988. Barley was not included because the vast majority of barley grown (>90%) goes for animal feed (Source: Personnel communications between Nevada Agricultural Statistics Service and LATA, Los Alamos.).

Table E-12. Food Crop Density by County for the Tonopah Area

County	Food Crops (acres)	Area* (mi^2)	NTS Area Exclusion† (mi^2)	Food Crop Density (ac/mi^2)	Food Crop Density (m^2/mi^2)
Esmeralda	386	3,587	0	0.11	445
Lincoln	1,063	10,635	0	0.10	405
Nye	1,578	18,155	4,181	0.11	445
Nevada Test Site	0	N/A	N/A	0.0	0

* Source: BOC 1983.
† Includes the Nevada Test Site, Tonopah Test Range, Air Force test sites, and other restricted federal land.
Note: N/A means not applicable.

Table E-13. Tonopah Rural Populations by Sector and Ring

SECTOR	RING	DIVISION	PARTIAL AREA (SQ MI)	POP DENSITY (PER SQ MI)	RURAL POP	TOTAL POP
N	1	NEV TEST SITE	19.63	0.00	0.	0.
	2	NYE	58.80	0.65	38.	38.
	3	NYE	117.84	0.65	77.	77.
	4	NYE	137.52	0.65	89.	89.
	5	NYE	176.16	0.65	115.	115.
NNW	1	NEV TEST SITE	19.63	0.00	0.	0.
	2	NEV TEST SITE	4.80	0.00	0.	
		NYE	54.00	0.65	35.	35.
	3	NYE	117.84	0.65	77.	77.
	4	NYE	137.52	0.65	89.	89.
	5	NYE	176.16	0.65	115.	115.
NW	1	NEV TEST SITE	19.63	0.00	0.	0.
	2	NEV TEST SITE	24.00	0.00	0.	
		NYE	34.80	0.65	23.	23.
	3	ESMERALDA	31.20	0.19	6.	
		NYE	86.64	0.65	56.	62.
	4	NYE	52.80	0.65	34.	
		ESMERALDA	84.72	0.19	16.	50.
	5	NYE	72.00	0.65	47.	
		ESMERALDA	104.16	0.19	20.	67.
WNW	1	NEV TEST SITE	19.63	0.00	0.	0.
	2	NEV TEST SITE	24.00	0.00	0.	
		ESMERALDA	2.40	0.19	0.	
		NYE	32.40	0.65	21.	22.
	3	NYE	7.20	0.65	5.	
		ESMERALDA	110.64	0.19	21.	26.
	4	ESMERALDA	137.52	0.19	26.	26.
	5	ESMERALDA	176.16	0.19	33.	33.

Table E-13. Tonopah Rural Populations by Sector and Ring (Continued)

W	1	NEV TEST SITE	19.63	0.00	0.	0.
	2	NEV TEST SITE	16.80	0.00	0.	
		ESMERALDA	7.20	0.19	1.	
		NYE	34.80	0.65	23.	24.
	3	ESMERALDA	117.84	0.19	22.	22.
	4	ESMERALDA	137.52	0.19	26.	26.
	5	ESMERALDA	176.16	0.19	33.	33.
WSW	1	NEV TEST SITE	19.63	0.00	0.	0.
	2	NEV TEST SITE	19.20	0.00	0.	
		ESMERALDA	2.40	0.19	0.	
		NYE	37.20	0.65	24.	25.
	3	ESMERALDA	117.84	0.19	22.	22.
	4	ESMERALDA	137.52	0.19	26.	26.
	5	ESMERALDA	176.16	0.19	33.	33.
SW	1	NEV TEST SITE	19.63	0.00	0.	0.
	2	NYE	9.60	0.65	6.	
		NEV TEST SITE	49.20	0.00	0.	6.
	3	NEV TEST SITE	16.80	0.00	0.	
		ESMERALDA	101.04	0.19	19.	19.
	4	ESMERALDA	132.72	0.19	25.	
		NYE	4.80	0.65	3.	28.
	5	ESMERALDA	176.16	0.19	33.	33.
SSW	1	NEV TEST SITE	19.63	0.00	0.	0.
	2	NEV TEST SITE	58.80	0.00	0.	0.
	3	NYE	9.60	0.65	6.	
		NEV TEST SITE	108.24	0.00	0.	6.
	4	NEV TEST SITE	14.40	0.00	0.	
		ESMERALDA	24.00	0.19	5.	
		NYE	99.12	0.65	64.	69.
	5	ESMERALDA	91.20	0.19	17.	
		NYE	84.96	0.65	55.	73.

Table E-13. Tonopah Rural Populations by Sector and Ring (Continued)

S	1	NEV TEST SITE	19.63	0.00	0.	0.
	2	NEV TEST SITE	58.80	0.00	0.	0.
	3	NEV TEST SITE	117.84	0.00	0.	0.
	4	NYE	16.80	0.65	11.	
		NEV TEST SITE	120.72	0.00	0.	11.
	5	NEV TEST SITE	31.20	0.00	0.	
		NYE	144.96	0.65	94.	94.
SSE	1	NEV TEST SITE	19.63	0.00	0.	0.
	2	NEV TEST SITE	58.80	0.00	0.	0.
	3	NEV TEST SITE	117.84	0.00	0.	0.
	4	NEV TEST SITE	137.52	0.00	0.	0.
	5	NEV TEST SITE	171.36	0.00	0.	
		NYE	4.80	0.65	3.	3.
SE	1	NEV TEST SITE	19.63	0.00	0.	0.
	2	NEV TEST SITE	58.80	0.00	0.	0.
	3	NEV TEST SITE	117.84	0.00	0.	0.
	4	NEV TEST SITE	137.52	0.00	0.	0.
	5	NEV TEST SITE	176.16	0.00	0.	0.
ESE	1	NEV TEST SITE	19.63	0.00	0.	0.
	2	NEV TEST SITE	58.80	0.00	0.	0.
	3	NEV TEST SITE	117.84	0.00	0.	0.
	4	NEV TEST SITE	137.52	0.00	0.	0.
	5	NEV TEST SITE	176.16	0.00	0.	0.

Table E-13. Tonopah Rural Populations by Sector and Ring (Concluded)

E	1	NEV TEST SITE	19.63	0.00	0.	0.
	2	NEV TEST SITE	58.80	0.00	0.	0.
	3	NEV TEST SITE	110.64	0.00	0.	
		NYE	7.20	0.65	5.	5.
	4	NEV TEST SITE	33.60	0.00	0.	
		NYE	103.92	0.65	68.	68.
	5	LINCOLN	9.60	0.36	3.	
		NEV TEST SITE	48.00	0.00	0.	
		NYE	118.56	0.65	77.	81.
ENE	1	NEV TEST SITE	19.63	0.00	0.	0.
	2	NEV TEST SITE	58.80	0.00	0.	0.
	3	NYE	38.40	0.65	25.	
		NEV TEST SITE	79.44	0.00	0.	25.
	4	NYE	137.52	0.65	89.	89.
	5	LINCOLN	2.40	0.36	1.	
		NYE	173.76	0.65	113.	114.
NE	1	NEV TEST SITE	19.63	0.00	0.	0.
	2	NYE	4.80	0.65	3.	
		NEV TEST SITE	54.00	0.00	0.	3.
	3	NYE	26.40	0.65	17.	
		NEV TEST SITE	91.44	0.00	0.	17.
	4	NEV TEST SITE	2.40	0.00	0.	
		NYE	135.12	0.65	88.	88.
	5	NYE	176.16	0.65	115.	115.
NNE	1	NEV TEST SITE	19.63	0.00	0.	0.
	2	NEV TEST SITE	7.20	0.00	0.	
		NYE	51.60	0.65	34.	34.
	3	NEV TEST SITE	9.60	0.00	0.	
		NYE	108.24	0.65	70.	70.
	4	NYE	137.52	0.65	89.	89.
	5	NYE	176.16	0.65	115.	115.

Table E-14. Tonopah Beef Cattle by Sector and Ring

SECTOR	RING	DIVISION	PARTIAL AREA (SQ MI)	BEEF CATTLE (PER SQ MI)	NUM IN CO	TOTAL
N	1	TEST SITE	19.63	0.00	0.	0.
	2	NYE	24.00	1.65	40.	
		TEST SITE	34.80	0.00	0.	40.
	3	NYE	117.84	1.65	194.	194.
	4	NYE	137.52	1.65	227.	227.
	5	NYE	176.16	1.65	291.	291.
NNW	1	TEST SITE	19.63	0.00	0.	0.
	2	NYE	14.40	1.65	24.	
		TEST SITE	44.40	0.00	0.	24.
	3	NYE	117.84	1.65	194.	194.
	4	NYE	137.52	1.65	227.	227.
	5	NYE	176.16	1.65	291.	291.
NW	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	38.40	0.00	0.	
		NYE	79.44	1.65	131.	131.
	4	ESMERALDA	38.40	3.34	128.	
		ESMERALDA	99.12	3.34	331.	459.
	5	NYE	81.60	1.65	135.	
		ESMERALDA	94.56	3.34	316.	450.
WNW	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	33.60	0.00	0.	
		ESMERALDA	16.80	3.34	56.	
		NYE	67.44	1.65	111.	167.
	4	NYE	4.80	1.65	8.	
		ESMERALDA	132.72	3.34	443.	451.
	5	ESMERALDA	176.16	3.34	588.	588.

Table E-14. Tonopah Beef Cattle by Sector and Ring (Continued)

W	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	19.20	0.00	0.	
		NYE	38.40	1.65	63.	
		ESMERALDA	60.24	3.34	201.	265.
	4	ESMERALDA	137.52	3.34	459.	459.
	5	ESMERALDA	176.16	3.34	588.	588.
WSW	1	TEST SITE	19.63	0.00	0.	0.
	2	NYE	2.40	1.65	4.	
		TEST SITE	56.40	0.00	0.	4.
	3	TEST SITE	36.00	0.00	0.	
		ESMERALDA	19.20	3.34	64.	
		NYE	62.64	1.65	103.	167.
	4	NYE	4.80	1.65	8.	
		ESMERALDA	132.72	3.34	443.	451.
	5	ESMERALDA	176.16	3.34	588.	588.
SW	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	NYE	31.20	1.65	51.	
		TEST SITE	86.64	0.00	0.	51.
	4	ESMERALDA	48.00	3.34	160.	
		NYE	89.52	1.65	148.	308.
	5	NYE	21.60	1.65	36.	
		ESMERALDA	154.56	3.34	516.	552.
SSW	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	NYE	9.60	1.65	16.	
		TEST SITE	108.24	0.00	0.	16.
	4	TEST SITE	33.60	0.00	0.	
		NYE	103.92	1.65	171.	171.
	5	ESMERALDA	4.80	3.34	16.	
		NYE	171.36	1.65	283.	299.

Table E-14. Tonopah Beef Cattle by Sector and Ring (Continued)

S	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	117.84	0.00	0.	0.
	4	NYE	28.80	1.65	48.	
		TEST SITE	89.04	0.00	0.	48.
	5	TEST SITE	72.00	0.00	0.	
		NYE	104.16	1.65	172.	172.
SSE	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	117.84	0.00	0.	0.
	4	TEST SITE	137.52	0.00	0.	0.
	5	TEST SITE	176.16	0.00	0.	0.
SE	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	117.84	0.00	0.	0.
	4	TEST SITE	137.52	0.00	0.	0.
	5	TEST SITE	164.16	0.00	0.	
		NYE	9.60	1.65	16.	16.
ESE	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	117.84	0.00	0.	0.
	4	TEST SITE	137.52	0.00	0.	0.
	5	NYE	74.40	1.65	123.	
		LINCOLN	60.00	1.79	107.	
		TEST SITE	41.76	0.00	0.	230.

Table E-14. Tonopah Beef Cattle by Sector and Ring (Concluded)

E	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	110.64	0.00	0.	
		NYE	7.20	1.65	12.	12.
	4	NYE	21.60	1.65	36.	
		TEST SITE	115.92	0.00	0.	36.
	5	LINCOLN	176.16	1.79	315.	315.
ENE	1	TEST SITE	19.63	0.00	0.	0.
	2	NYE	2.40	1.65	4.	
		TEST SITE	56.40	0.00	0.	4.
	3	TEST SITE	9.60	0.00	0.	
		NYE	108.24	1.65	179.	179.
	4	NYE	137.52	1.65	227.	227.
	5	NYE	43.20	1.65	71.	
		LINCOLN	132.96	1.79	238.	309.
NE	1	TEST SITE	19.63	0.00	0.	0.
	2	NYE	12.00	1.65	20.	
		TEST SITE	46.80	0.00	0.	20.
	3	TEST SITE	4.80	0.00	0.	
		NYE	113.04	1.65	187.	187.
	4	NYE	137.52	1.65	227.	227.
	5	LINCOLN	7.20	1.79	13.	
		NYE	168.96	1.65	279.	292.
NNE	1	TEST SITE	19.63	0.00	0.	0.
	2	NYE	26.40	1.65	44.	
		TEST SITE	32.40	0.00	0.	44.
	3	NYE	117.84	1.65	194.	194.
	4	NYE	137.52	1.65	227.	227.
	5	NYE	176.16	1.65	291.	291.

Table E-15. Tonopah Dairy Cattle by Sector and Ring

SECTOR	RING	DIVISION	PARTIAL AREA (SQ MI)	DAIR CATTLE (PER SQ MI)	NUM IN CO	TOTAL
N	1	TEST SITE	19.63	0.00	0.	0.
	2	NYE	24.00	0.01	0.	
		TEST SITE	34.80	0.00	0.	0.
	3	NYE	117.84	0.01	1.	1.
	4	NYE	137.52	0.01	1.	1.
	5	NYE	176.16	0.01	2.	2.
NNW	1	TEST SITE	19.63	0.00	0.	0.
	2	NYE	14.40	0.01	0.	
		TEST SITE	44.40	0.00	0.	0.
	3	NYE	117.84	0.01	1.	1.
	4	NYE	137.52	0.01	1.	1.
	5	NYE	176.16	0.01	2.	2.
NW	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	38.40	0.00	0.	
		NYE	79.44	0.01	1.	1.
	4	ESMERALDA	38.40	0.01	0.	
		ESMERALDA	99.12	0.01	1.	1.
	5	NYE	81.60	0.01	1.	
		ESMERALDA	94.56	0.01	1.	2.
WNW	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	33.60	0.00	0.	
		ESMERALDA	16.80	0.01	0.	
		NYE	67.44	0.01	1.	1.
	4	NYE	4.80	0.01	0.	
		ESMERALDA	132.72	0.01	1.	1.
	5	ESMERALDA	176.16	0.01	1.	1.

Table E-15. Tonopah Dairy Cattle by Sector and Ring (Continued)

W	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	19.20	0.00	0.	
		NYE	38.40	0.01	0.	
		ESMERALDA	60.24	0.01	1.	1.
	4	ESMERALDA	137.52	0.01	1.	1.
	5	ESMERALDA	176.16	0.01	1.	1.
WSW	1	TEST SITE	19.63	0.00	0.	0.
	2	NYE	2.40	0.01	0.	
		TEST SITE	56.40	0.00	0.	0.
	3	TEST SITE	36.00	0.00	0.	
		ESMERALDA	19.20	0.01	0.	
		NYE	62.64	0.01	1.	1.
	4	NYE	4.80	0.01	0.	
		ESMERALDA	132.72	0.01	1.	1.
	5	ESMERALDA	176.16	0.01	1.	1.
SW	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	NYE	31.20	0.01	0.	
		TEST SITE	86.64	0.00	0.	0.
	4	ESMERALDA	48.00	0.01	0.	
		NYE	89.52	0.01	1.	1.
	5	NYE	21.60	0.01	0.	
		ESMERALDA	154.56	0.01	1.	1.
SSW	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	NYE	9.60	0.01	0.	
		TEST SITE	108.24	0.00	0.	0.
	4	TEST SITE	33.60	0.00	0.	
		NYE	103.92	0.01	1.	1.
	5	ESMERALDA	4.80	0.01	0.	
		NYE	171.36	0.01	1.	2.

Table E-15. Tonopah Dairy Cattle by Sector and Ring (Continued)

S	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	117.84	0.00	0.	0.
	4	NYE	28.80	0.01	0.	
		TEST SITE	89.04	0.00	0.	0.
	5	TEST SITE	72.00	0.00	0.	
		NYE	104.16	0.01	1.	1.
SSE	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	117.84	0.00	0.	0.
	4	TEST SITE	137.52	0.00	0.	0.
	5	TEST SITE	176.16	0.00	0.	0.
SE	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	117.84	0.00	0.	0.
	4	TEST SITE	137.52	0.00	0.	0.
	5	TEST SITE	164.16	0.00	0.	
		NYE	9.60	0.01	0.	0.
ESE	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	117.84	0.00	0.	0.
	4	TEST SITE	137.52	0.00	0.	0.
	5	NYE	74.40	0.01	1.	
		LINCOLN	60.00	0.01	0.	
		TEST SITE	41.76	0.00	0.	1.

Table E-15. Tonopah Dairy Cattle by Sector and Ring (Concluded)

E	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	110.64	0.00	0.	
		NYE	7.20	0.01	0.	0.
	4	NYE	21.60	0.01	0.	
		TEST SITE	115.92	0.00	0.	0.
	5	LINCOLN	176.16	0.01	1.	1.
ENE	1	TEST SITE	19.63	0.00	0.	0.
	2	NYE	2.40	0.01	0.	
		TEST SITE	56.40	0.00	0.	0.
	3	TEST SITE	9.60	0.00	0.	
		NYE	108.24	0.01	1.	1.
	4	NYE	137.52	0.01	1.	1.
	5	NYE	43.20	0.01	0.	
		LINCOLN	132.96	0.01	1.	1.
NE	1	TEST SITE	19.63	0.00	0.	0.
	2	NYE	12.00	0.01	0.	
		TEST SITE	46.80	0.00	0.	0.
	3	TEST SITE	4.80	0.00	0.	
		NYE	113.04	0.01	1.	1.
	4	NYE	137.52	0.01	1.	1.
	5	LINCOLN	7.20	0.01	0.	
		NYE	168.96	0.01	1.	2.
NNE	1	TEST SITE	19.63	0.00	0.	0.
	2	NYE	26.40	0.01	0.	
		TEST SITE	32.40	0.00	0.	0.
	3	NYE	117.84	0.01	1.	1.
	4	NYE	137.52	0.01	1.	1.
	5	NYE	176.16	0.01	2.	2.

Table E-16. Tonopah Food Crops by Sector and Ring

SECTOR	RING	DIVISION	PARTIAL AREA (SQ MI)	BEEF CATTLE (M2/SQ MI)	NUM IN CO (SQ M)	TOTAL (SQ M)
N	1	TEST SITE	19.63	0.00	0.	0.
	2	NYE	24.00	445.00	10680.	
		TEST SITE	34.80	0.00	0.	10680.
	3	NYE	117.84	445.00	52439.	52439.
	4	NYE	137.52	445.00	61196.	61196.
	5	NYE	176.16	445.00	78391.	78391.
NNW	1	TEST SITE	19.63	0.00	0.	0.
	2	NYE	14.40	445.00	6408.	
		TEST SITE	44.40	0.00	0.	6408.
	3	NYE	117.84	445.00	52439.	52439.
	4	NYE	137.52	445.00	61196.	61196.
	5	NYE	176.16	445.00	78391.	78391.
NW	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	38.40	0.00	0.	
		NYE	79.44	445.00	35351.	35351.
	4	ESMERALDA	38.40	445.00	17088.	
		ESMERALDA	99.12	445.00	44108.	61196.
	5	NYE	81.60	445.00	36312.	
		ESMERALDA	94.56	445.00	42079.	78391.
WNW	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	33.60	0.00	0.	
		ESMERALDA	16.80	445.00	7476.	
		NYE	67.44	445.00	30011.	37487.
	4	NYE	4.80	445.00	2136.	
		ESMERALDA	132.72	445.00	59060.	61196.
	5	ESMERALDA	176.16	445.00	78391.	78391.

Table E-16. Tonopah Food Crops by Sector and Ring (Continued)

W	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	19.20	0.00	0.	
		NYE	38.40	445.00	17088.	
		ESMERALDA	60.24	445.00	26807.	43895.
	4	ESMERALDA	137.52	445.00	61196.	61196.
	5	ESMERALDA	176.16	445.00	78391.	78391.
WSW	1	TEST SITE	19.63	0.00	0.	0.
	2	NYE	2.40	445.00	1068.	
		TEST SITE	56.40	0.00	0.	1068.
	3	TEST SITE	36.00	0.00	0.	
		ESMERALDA	19.20	445.00	8544.	
		NYE	62.64	445.00	27875.	36419.
	4	NYE	4.80	445.00	2136.	
		ESMERALDA	132.72	445.00	59060.	61196.
	5	ESMERALDA	176.16	445.00	78391.	78391.
SW	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	NYE	31.20	445.00	13884.	
		TEST SITE	86.64	0.00	0.	13884.
	4	ESMERALDA	48.00	445.00	21360.	
		NYE	89.52	445.00	39836.	61196.
	5	NYE	21.60	445.00	9612.	
		ESMERALDA	154.56	445.00	68779.	78391.
SSW	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	NYE	9.60	445.00	4272.	
		TEST SITE	108.24	0.00	0.	4272.
	4	TEST SITE	33.60	0.00	0.	
		NYE	103.92	445.00	46244.	46244.
	5	ESMERALDA	4.80	445.00	2136.	
		NYE	171.36	445.00	76255.	78391.

Table E-16. Tonopah Food Crops by Sector and Ring (Continued)

S	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	117.84	0.00	0.	0.
	4	NYE	28.80	445.00	12816.	
		TEST SITE	89.04	0.00	0.	12816.
	5	TEST SITE	72.00	0.00	0.	
		NYE	104.16	445.00	46351.	46351.
SSE	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	117.84	0.00	0.	0.
	4	TEST SITE	137.52	0.00	0.	0.
	5	TEST SITE	176.16	0.00	0.	0.
SE	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	117.84	0.00	0.	0.
	4	TEST SITE	137.52	0.00	0.	0.
	5	TEST SITE	164.16	0.00	0.	
		NYE	9.60	445.00	4272.	4272.
ESE	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	117.84	0.00	0.	0.
	4	TEST SITE	137.52	0.00	0.	0.
	5	NYE	74.40	445.00	33108.	
		LINCOLN	60.00	405.00	24300.	
		TEST SITE	41.76	0.00	0.	57408.

Table E-16. Tonopah Food Crops by Sector and Ring (Concluded)

E	1	TEST SITE	19.63	0.00	0.	0.
	2	TEST SITE	58.80	0.00	0.	0.
	3	TEST SITE	110.64	0.00	0.	
		NYE	7.20	445.00	3204.	3204.
	4	NYE	21.60	445.00	9612.	
		TEST SITE	115.92	0.00	0.	9612.
	5	LINCOLN	176.16	405.00	71345.	71345.
ENE	1	TEST SITE	19.63	0.00	0.	0.
	2	NYE	2.40	445.00	1068.	
		TEST SITE	56.40	0.00	0.	1068.
	3	TEST SITE	9.60	0.00	0.	
		NYE	108.24	445.00	48167.	48167.
	4	NYE	137.52	445.00	61196.	61196.
	5	NYE	43.20	445.00	19224.	
		LINCOLN	132.96	405.00	53849.	73073.
NE	1	TEST SITE	19.63	0.00	0.	0.
	2	NYE	12.00	445.00	5340.	
		TEST SITE	46.80	0.00	0.	5340.
	3	TEST SITE	4.80	0.00	0.	
		NYE	113.04	445.00	50303.	50303.
	4	NYE	137.52	445.00	61196.	61196.
	5	LINCOLN	7.20	405.00	2916.	
		NYE	168.96	445.00	75187.	78103.
NNE	1	TEST SITE	19.63	0.00	0.	0.
	2	NYE	26.40	445.00	11748.	
		TEST SITE	32.40	0.00	0.	11748.
	3	NYE	117.84	445.00	52439.	52439.
	4	NYE	137.52	445.00	61196.	61196.
	5	NYE	176.16	445.00	78391.	78391.

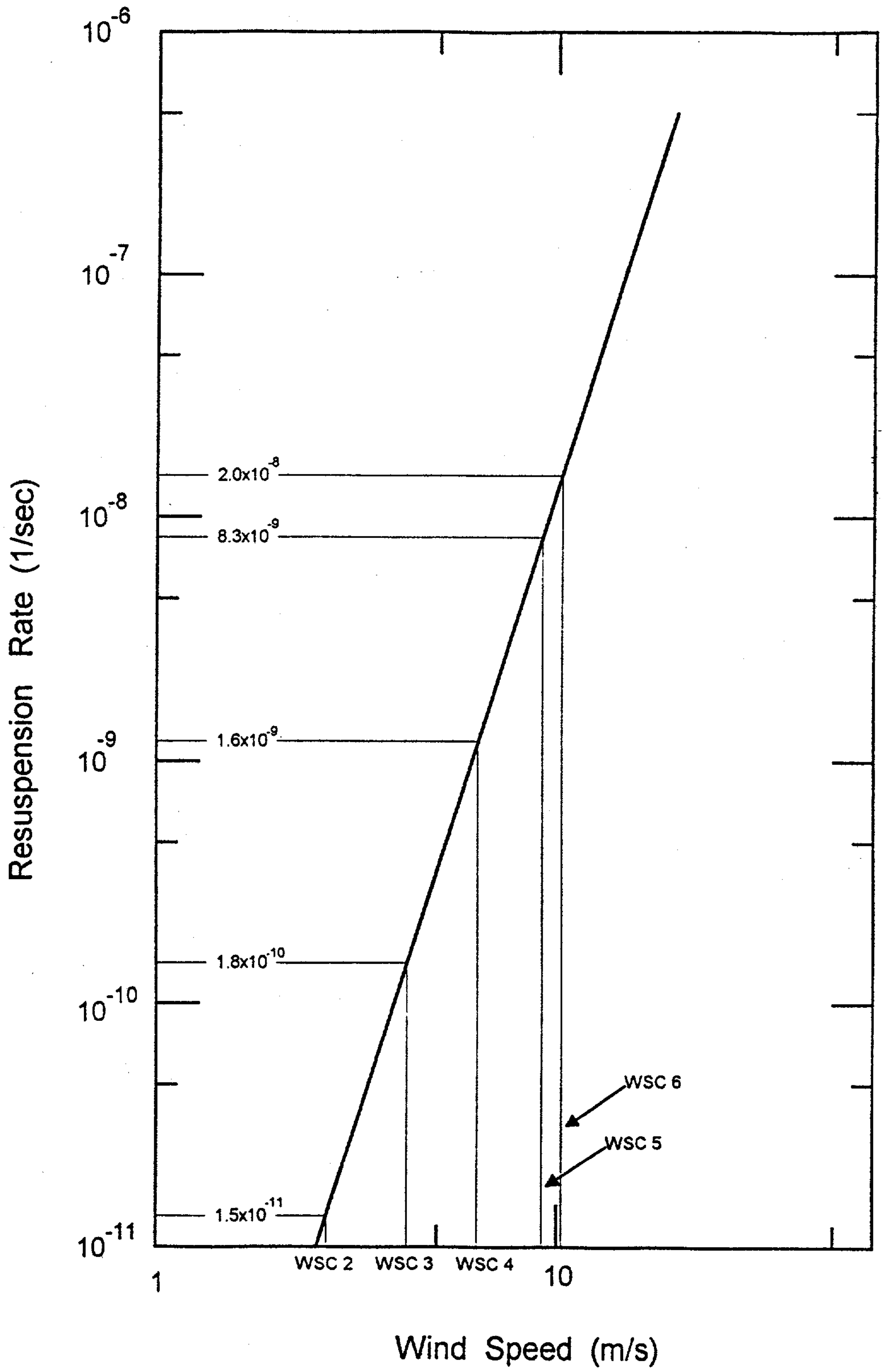

Figure E-3. Resuspension Rate vs Wind Speed

Since the resuspension rate is a strong function of wind speed, the annual rate of dust resuspension is a function of the wind direction which, in general, exhibits wind speed characteristics that vary with the wind direction. Accordingly, a directionally dependent rate of resuspension can be calculated from the wind data and resuspension rate curve presented in Figure E-3.

Table E-17 summarizes the calculation of the directionally dependent resuspension rates for the sixteen wind direction sectors using STAR data for Tonopah, Nevada. As shown in Table E-17, the frequency of occurrence of each STAR wind speed category (directionally dependent) is multiplied by the representative resuspension rate for the wind speed class (taken from Figure E-3). The weighted resuspension rates are then summed to yield the average resuspension rate in each direction. From Table E-17, it can be seen that the weighted-average resuspension rate varies from a maximum of 2.0×10^{-9} 1/sec in the N sector to a minimum of 1.8×10^{-10} 1/sec in the SW sector. The variation of resuspension rate is a factor of about 11 and is due to the variation in wind speed (as measured by the frequency occurrence of the wind speed classes) in each sector as reported in STAR data.

E.6.2 Surface Contamination at TTR

Figure E-2 shows the locations and relative sizes of the three contaminated areas at TTR. The level of contamination was measured in a 1974 study (EG&G 1979) using remote sensing FIDLER detectors mounted on low-flying aircraft. The analysis presented in the EG&G study reported volumetric levels of plutonium-238 (Pu-238), plutonium-240 (Pu-240), and Am-241 calculated from direct measurements of the Am-241 gamma emission signature. The study presented the results as graphical two-dimensional plots of alpha soil contamination with as many as 13 discrete isopleths representing increasing levels of contamination. No information is provided in the EG&G study which describes the actual depth of material contamination.

Average levels of contamination were calculated in this dose assessment by area-weighting the levels of contamination reported in the EG&G study. The areas of each isopleth were measured and multiplied by its representative average contamination level. Tables E-18 through E-23 summarize the tabulation of the area-weighting analysis. Each site was subdivided into two smaller areas for calculational accuracy. The smaller areas allow a more representative distance to be used between the source region and receptor, as well as allow the smaller areas to more accurately represent a point source. The subdivided areas were modelled as independent sources and later summed to yield a cumulative source term.

Table E-17. Directional Resuspension Rates

Wind Direction	Wind Speed[1] Class (kt)	Resuspension[2] Rate (1/s)	Fraction Contribution	Weighted Res. Rate (1/s)
N	1-3	0.0	.140	0.0
	4-6	$1.5x10^{-11}$	.20	$3.0x10^{-12}$
	7-10	$1.8x10^{-10}$	.32	$5.8x10^{-11}$
	11-16	$1.6x10^{-9}$	.22	$3.5x10^{-5}$
	17-21	$8.3x10^{-9}$	.075	$6.2x10^{-10}$
	>21	$2.0x10^{-8}$	.049	$9.8x10^{-10}$
	Total			$2.0x10^{-9}$
NNW	1-3	0.0	.18	0.0
	4-6	$1.5x10^{-11}$	.22	$3.3x10^{-12}$
	7-10	$1.8x10^{-10}$	.31	$5.6x10^{-11}$
	11-16	$1.6x10^{-9}$	.19	$3.0x10^{-10}$
	17-21	$8.3x10^{-9}$	.081	$6.7x10^{-10}$
	>21	$2.0x10^{-8}$	.019	$3.8x10^{-10}$
	Total			$1.4x10^{-9}$
NW	1-3	0.0	.18	0.0
	4-6	$1.5x10^{-11}$	.24	$3.6x10^{-12}$
	7-10	$1.8x10^{-10}$	.30	$5.4x10^{-11}$
	11-16	$1.6x10^{-9}$	.20	$3.2x10^{-10}$
	17-21	$8.3x10^{-9}$	.061	$5.1x10^{-10}$
	>21	$2.0x10^{-8}$	.015	$3.0x10^{-10}$
	Total			$1.2x10^{-9}$
WNW	1-3	0.0	.23	0.0
	4-6	$1.5x10^{-11}$	.30	$4.5x10^{-12}$
	7-10	$1.8x10^{-10}$	.29	$5.2x10^{-11}$
	11-16	$1.6x10^{-9}$	.13	$2.1x10^{-10}$
	17-21	$8.3x10^{-9}$	.045	$3.7x10^{-10}$
	>21	$2.0x10^{-8}$	.0087	$1.7x10^{-10}$
	Total			$8.1x10^{-10}$
W	1-3	0.0	.22	0.0
	4-6	$1.5x10^{-11}$	.35	$5.3x10^{-12}$
	7-10	$1.8x10^{-10}$	.30	$5.4x10^{-11}$
	11-16	$1.6x10^{-9}$	.12	$1.9x10^{-10}$
	17-21	$8.3x10^{-9}$	.011	$9.1x10^{-11}$
	>21	$2.0x10^{-8}$	.0028	$5.6x10^{-11}$
	Total			$4.0x10^{-10}$

Table E-17. Directional Resuspension Rates (Continued)

Wind Direction	Wind Speed[1] Class (kt)	Resuspension[2] Rate (1/s)	Fraction Contribution	Weighted Res. Rate (1/s)
WSW	1-3	0.0	.28	0.0
	4-6	$1.5x10^{-11}$	.41	$6.2x10^{-12}$
	7-10	$1.8x10^{-10}$	.23	$4.1x10^{-11}$
	11-16	$1.6x10^{-9}$	.071	$1.1x10^{-11}$
	17-21	$8.3x10^{-9}$	.0050	$4.2x10^{-11}$
	>21	$2.0x10^{-8}$	0.0	0.0
	Total			$2.0x10^{-10}$
SW	1-3	0.0	.26	0.0
	4-6	$1.5x10^{-11}$	.36	$5.4x10^{-12}$
	7-10	$1.8x10^{-10}$	.32	$5.8x10^{-11}$
	11-16	$1.6x10^{-9}$	.055	$8.8x10^{-11}$
	17-21	$8.3x10^{-9}$	.0035	$2.9x10^{-11}$
	>21	$2.0x10^{-8}$	0.0	0.0
	Total			$1.8x10^{-10}$
SSW	1-3	0.0	.15	0.0
	4-6	$1.5x10^{-11}$	.30	$4.5x10^{-12}$
	7-10	$1.8x10^{-10}$	.46	$8.3x10^{-11}$
	11-16	$1.6x10^{-9}$	.086	$1.4x10^{-10}$
	17-21	$8.3x10^{-9}$	.0084	$7.0x10^{-11}$
	>21	$2.0x10^{-8}$	0.0	0.0
	Total			$3.0x10^{-10}$
S	1-3	0.0	.16	0.0
	4-6	$1.5x10^{-11}$	.34	$5.1x10^{-12}$
	7-10	$1.8x10^{-10}$	.41	$7.4x10^{-11}$
	11-16	$1.6x10^{-9}$	.081	$1.3x10^{-10}$
	17-21	$8.3x10^{-9}$	.016	$1.3x10^{-10}$
	>21	$2.0x10^{-8}$	.00088	$1.8x10^{-11}$
	Total			$3.6x10^{-10}$
SSE	1-3	0.0	.16	0.0
	4-6	$1.5x10^{-11}$	.29	$4.4x10^{-12}$
	7-10	$1.8x10^{-10}$	.39	$7.0x10^{-11}$
	11-16	$1.6x10^{-9}$	.13	$2.1x10^{-10}$
	17-21	$8.3x10^{-9}$	.029	$2.4x10^{-10}$
	>21	$2.0x10^{-8}$	.0046	$9.2x10^{-11}$
	Total			$6.2x10^{-10}$
SE	1-3	0.0	.13	0.0
	4-6	$1.5x10^{-11}$	.25	$3.8x10^{-12}$
	7-10	$1.8x10^{-10}$	.39	$7.0x10^{-11}$
	11-16	$1.6x10^{-9}$	.18	$2.9x10^{-10}$
	17-21	$8.3x10^{-9}$	.045	$3.7x10^{-10}$
	>21	$2.0x10^{-8}$	.011	$2.2x10^{-10}$
	Total			$9.5x10^{-10}$

Table E-17. Directional Resuspension Rates (Concluded)

Wind Direction	Wind Speed[1] Class (kt)	Resuspension[2] Rate (1/s)	Fraction Contribution	Weighted Res. Rate (1/s)
ESE	1-3	0.0	.12	0.0
	4-6	$1.5x10^{-11}$	.20	$3.0x10^{-12}$
	7-10	$1.8x10^{-10}$	.31	$5.6x10^{-11}$
	11-16	$1.6x10^{-9}$	.27	$4.3x10^{-10}$
	17-21	$8.3x10^{-9}$	.088	$7.3x10^{-10}$
	>21	$2.0x10^{-8}$	.018	$3.6x10^{-10}$
	Total			$1.6x10^{-9}$
E	1-3	0.0	.15	0.0
	4-6	$1.5x10^{-11}$	.21	$3.2x10^{-12}$
	7-10	$1.8x10^{-10}$	.32	$5.8x10^{-11}$
	11-16	$1.6x10^{-9}$	.25	$4.0x10^{-10}$
	17-21	$8.3x10^{-9}$	.066	$5.5x10^{-10}$
	>21	$2.0x10^{-8}$	.011	$2.2x10^{-10}$
	Total			$1.2x10^{-9}$
ENE	1-3	0.0	.22	0.0
	4-6	$1.5x10^{-11}$	.30	$4.5x10^{-12}$
	7-10	$1.8x10^{-10}$	.35	$6.3x10^{-11}$
	11-16	$1.6x10^{-9}$	.11	$1.8x10^{-10}$
	17-21	$8.3x10^{-9}$	.02	$1.7x10^{-10}$
	>21	$2.0x10^{-8}$	.0030	$6.0x10^{-11}$
	Total			$4.8x10^{-10}$
NE	1-3	0.0	.20	0.0
	4-6	$1.5x10^{-11}$	.24	$3.6x10^{-12}$
	7-10	$1.8x10^{-10}$	.35	$6.3x10^{-11}$
	11-16	$1.6x10^{-9}$	.17	$2.7x10^{-10}$
	17-21	$8.3x10^{-9}$	.031	$2.6x10^{-10}$
	>21	$2.0x10^{-8}$	.0070	$1.4x10^{-10}$
	Total			$7.3x10^{-10}$
NNE	1-3	0.0	.12	0.0
	4-6	$1.5x10^{-11}$	.20	$3.0x10^{-12}$
	7-10	$1.8x10^{-10}$	.39	$7.0x10^{-11}$
	11-16	$1.6x10^{-9}$	.24	$3.8x10^{-10}$
	17-21	$8.3x10^{-9}$	.049	$4.1x10^{-10}$
	>21	$2.0x10^{-8}$	.0045	$9.0x10^{-11}$
	Total			$9.5x10^{-10}$

[1]Source: STAR data for Tonopah, Nevada (DOC 1978).
[2]Source: Figure E-3.

Table E-18. Average Surface Contamination of the Clean Slate 1a Site[1]

Isopleth	Area[2] (m^2)	Weighting Factor	Contamination Level[2] (pCi/g)	Weighted Contribution (pCi/g)
A	7.7×10^5	.90	328	295
B	1.9×10^4	.022	820	18
C	1.4×10^4	.017	1220	21
D	1.4×10^4	.017	1820	31
E	1.8×10^4	.021	2640	55
F	9.6×10^3	.011	3790	42
G	6.2×10^3	.0073	5530	40
H	3.7×10^3	.0043	8220	35
I	1.9×10^3	.0023	12200	28
Total	8.5×10^5	1.00		5.65×10^2

[1]Alpha contamination from Pu-239, Pu-240, and Am-241.
[2]Calculated from data presented in EG&G 1979.

Table E-19. Average Surface Contamination of the Clean Slate 1b Site[1]

Isopleth	Area[2] (m^2)	Weighting Factor	Contamination Level[2] (pCi/g)	Weighted Contribution (pCi/g)
A	9.6×10^5	.91	328	298
B	5.1×10^4	.049	820	40
C	4.1×10^4	.039	1220	48
D	6.6×10^3	.0062	1820	11
E	1.1×10^3	.0011	2640	3
Total	1.05×10^6	1.01		4.0×10^2

[1]Alpha contamination from Pu-239, Pu-240, and Am-241.
[2]Calculated from data presented in EG&G 1979.

Table E-20. Average Surface Contamination of the Clean Slate 2a Site[1]

Isopleth	Area[2] (m^2)	Weighting Factor	Contamination Level[2] (pCi/g)	Weighted Contribution (pCi/g)
A	$1.2x10^6$	.80	256	205
B	$5.2x10^4$	.035	641	22
C	$3.6x10^4$	.024	950	23
D	$2.6x10^4$	.017	1420	24
E	$2.6x10^4$	.017	2050	35
F	$3.4x10^4$	.023	3130	72
G	$3.9x10^4$	.026	4300	112
H	$4.3x10^4$	.029	6400	186
I	$2.0x10^4$	.013	9440	123
J	$1.6x10^4$	.011	14100	155
K	$1.9x10^4$	.013	20500	267
L	$2.5x10^2$	$1.7x10^{-4}$	29500	5
M	$6.6x10^3$	$4.4x10^{-3}$	43000	189
Total	$1.5x10^6$	1.01		1418

[1]Alpha contamination from Pu-239, Pu-240, and Am-241.
[2]Calculated from data presented in EG&G 1979.

Table E-21. Average Surface Contamination of the Clean Slate 2b Site[1]

Isopleth	Area[2] (m^2)	Weighting Factor	Contamination Level[2] (pCi/g)	Weighted Contribution (pCi/g)
A	$6.4x10^5$	.653	256	167
B	$9.8x10^4$	.10	641	64
C	$1.4x10^5$	.143	950	136
D	$5.9x10^4$	.06	1420	85
E	$2.7x10^4$	.028	2050	57
F	$9.7x10^3$	.0099	3130	31
G	$1.0x10^4$	.010	4300	43
Total	$9.8x10^5$	1.00		583

[1]Alpha contamination from Pu-239, Pu-240, and Am-241.
[2]Calculated from data presented in EG&G 1979.

Table E-22. Average Surface Contamination of the Clean Slate 3a Site[1]

Isopleth	Area[2] (m^2)	Weighting Factor	Contamination Level[2] (pCi/g)	Weighted Contribution (pCi/g)
A	$2.3x10^6$	.41	220	90
B	$9.6x10^5$	.17	552	94
C	$7.1x10^5$	.13	818	106
D	$8.4x10^5$	.15	1220	183
E	$4.6x10^5$	.082	1780	146
F	$3.3x10^5$	.059	2550	150
G	$9.3x10^2$	.00017	3720	0.6
H	$9.6x10^3$	.0017	5530	9
Total	$5.6x10^6$	1.00		779

[1]Alpha contamination from Pu-239, Pu-240, and Am-241.
[2]Calculated from data presented in EG&G 1979.

Table E-23. Average Surface Contamination of the Clean Slate 3b Site[1]

Isopleth	Area[2] (m^2)	Weighting Factor	Contamination Level[2] (pCi/g)	Weighted Contribution (pCi/g)
A	$4.4x10^6$	.89	220	196
B	$2.9x10^5$	.058	552	32
C	$1.6x10^5$	.032	818	26
D	$9.5x10^4$	.019	1220	23
Total	$4.95x10^6$	.999		277

[1]Alpha contamination from Pu-239, Pu-240, and Am-241.
[2]Calculated from data presented in EG&G 1979.

E.6.3 Correction for Pu-238

The plutonium used in the Clean Slate tests is assumed to be a weapons-grade mixture originating from DOE's Rocky Flats Plant near Denver. Nearly all the plutonium at TTR comes from Rocky Flats with the exception of that which is used as thermal sources and is composed only of the Pu-238 isotope. As such, additional radionuclides, known to be present in all Rocky Flats plutonium, must be accounted for. Table E-24 summarizes the isotopic constituents found in new Rocky Flats-grade plutonium. The plutonium isotopes reported in the EG&G study include Pu-239, Pu-240, and Am-241. Pu-238 was not included as a contaminant in the EG&G study and must be added into the surface contamination. The relative contribution from plutonium-242 (Pu-242) is so small that it may be ignored. The beta/gamma activity of plutonium-241 (Pu-241) does not contribute to the alpha activity; however, its contribution to the ingrowth of Am-241 will be considered in the next section. To account for Pu-238, the combined contributions from Pu-239, Pu-240, and Am-241 were calculated from Table E-24 as a 0.0711 curies per gram (Ci/g) mixture. The Pu-238 contribution to the total mixture is 0.0050 Ci/g.

Since the half-life of Pu-238 is 87.8 years, a significant amount of decay has occurred since the material was deposited in 1963. A decay fraction of 0.784 was calculated for the 31 years of decay since deposition so that the residual Pu-238 activity is only 0.00392 Ci/g. This is about 6% of the total alpha activity. The half-lives of Pu-239, Pu-240, and Am-241 are long relative to the length of time since initial deposition. As such, they display no appreciable decay. An increase of 6% is therefore added to the total alpha surface contamination reported in the EG&G study.

Table E-24. Composition of Rocky Flats Plutonium[1]

Isotope	Mode of Decay	Activity[2] (Ci/g mixture)
Pu-238	alpha	0.0050
Pu-239	alpha	0.0576
Pu-240	alpha	0.0129
Pu-241[2]	beta/gamma	0.336
Pu-242	alpha	1.20×10^{-6}
Am-241	alpha	0.00060

[1]Source: Rockwell International 1985.
[2]Activity is alpha activity except for Pu-241 which is beta/gamma.

E.6.4 Correction for the Ingrowth of Am-241

Am-241 grows into Rocky Flats plutonium because of the presence of the short-lived Pu-241 constituent. The EG&G study conducted in 1977 accounted for the Am-241 present at that time. During the 17 years since the study was conducted, more Am-241 has been formed from the decay of Pu-241. To correct for this, the combined alpha activity from Pu-239, Pu-240, and Am-241 are summed for 1977 and 1994 based on the radiological decay of the parent Pu-241. Table E-25 summarizes the Am-241 ingrowth calculation and shows 0.0032 Ci/g (3.8%) increase in alpha activity. A correction factor of 3.8% will be applied to the 1977 results to correct for the additional ingrowth of Am-241. This correction is applied independent of and in addition to any other corrections.

E.6.5 Correction for Elevated Surface Contamination

The EG&G study presented soil contamination results as an average through the top 5 cm of soil. The study also stated that the actual contamination was greatest at the topmost surface, exhibiting an exponential decrease in contamination with increasing distance from the surface. Since the contamination used in the resuspension model was the topmost contamination, a correction factor was applied to estimate the surface contamination from the average through the top 5 cm of soil.

The generic equation giving the contamination as a function of depth below the surface is

$$C = C_0 * \exp(-kz)$$

where
C = the contamination level as a function of depth (pCi/g),
C_0 = the contamination at the surface where z=0 (pCi/g),
k = exponential rate constant (1/m), and
z = depth below the surface.

The average contamination was calculated from the integral of the above expression evaluated over the averaging distance as

$$\langle C \rangle = \frac{1}{D} * \int C_0 * \exp(-kz)\, dz$$

where
$\langle C \rangle$ = the average contamination as a function of depth (pCi/g), and
D = the averaging depth (m).

All other parameters are as defined above. When integrated and evaluated between the surface (z=0) and the averaging depth (z=D=5 cm), the above expression becomes

$$\langle C \rangle = -C_0 * \frac{[1-\exp(-kD)]}{kD}$$

The exponential rate constant, k, was found from the first equation by imposing the conditions that 99% of the contamination lay above the 5 cm depth (i.e.,

Table E-25. Activity Concentrations of Contamination at Various Times

		Activity (Ci/g)		
		1963[1] (t = 0 yr)	1977[2] (t = 14 yr)	1994[3] (t = 31 yr)
Pu-238		0.0050	0.0045	0.0039
Pu-239		0.0576	0.0576	0.0576
Pu-240		0.0129	0.0129	0.0129
Pu-241		0.336	0.172	0.0759
Pu-242		1.2E-6	1.2E-6	1.2E-6
Am-241	Original	0.00060	0.00060	0.00060
	Ingrowth	0.0	0.0055	0.0087
Total Am-241		0.00060	0.0061	0.0093
Total Pu-239, Pu-240, and Am-241		0.0711	0.0766	0.0798

[1]Assumed mixture of new Rocky Flats grade plutonium.
[2]Assumed mixture at the time of the EG&G Aerial Survey corrected for ingrowth and decay.
[3]Assumed mixture in 1994 corrected for ingrowth and decay.

D=5 cm), as implied from the EG&G study. Substituting $C=.01C_0$ and D=0.05 m (5 cm) into the first equation yielded $k=92.1\ m^{-1}$. Substituting the value of k into the last equation together with the other known parameters, it was found that the surface contamination, C_0 , is equal to 4.65 times the average through the 0.05 m (5 cm) depth.

E.6.6 Correction for Radioactive Decay and Ingrowth

The EG&G study in 1977 accounted for the Am-241, Pu-239, and Pu-240 present at that time. Previous sections of this Appendix described correcting for the Pu-238 that was also present in the initial mixture but not reported in the EG&G study. During the 17 years since that study was conducted, Am-241 has increased and Pu-241 has decreased due to the radioactive decay of Pu-241 into Am-241. The radionuclide abundance has been decay-corrected to make it current. Table E-25 summarizes the radionuclide abundance corrected for decay and Am-241 ingrowth from the time of deposition in 1963. The Pu-238 radionuclide present in all weapons plutonium has been added to the isotope list and is included in Table E-25.

E.6.7 Corrected Surface Contamination Levels

The correction/conversion factors as discussed in preceding sections were needed in order to use the data presented in the EG&G study in a dose assessment analysis. The first correction factor resulted in a 6% increase which accounts for the lack of a Pu-238 component in the original contamination considered in the study. The second correction factor resulted in a 3.8% increase in the total alpha activity due to the ingrowth of Am-241 during the 17 years since the 1977 study was conducted. The third factor is a conversion factor which converted average contamination through a depth to a surface contamination needed for modeling purposes. The surface conversion factor resulted in an increase of 465%, implying that the surface contamination is 4.65 times greater than the average through the depth. The cumulative correction factor is 5.12 (4.65 x 1.06 x 1.038). Table E-26 summarizes the corrected average contaminations for the subdivided Clean State sites.

E.6.8 Volumetric to Areal Conversion

The contamination level is expressed in volumetric units of picocuries per gram (pCi/g). For the resuspension model, the contamination was converted to units of picocuries per square meter (pCi/m²). This was accomplished using the conversion equation

$$C_A = C_V * \rho * L * 10^6$$

where
C_A = the areal contamination (pCi/m²),
C_V = the volumetric contamination (pCi/g),
ρ = the soil density (g/cm³),
L = the skin depth (m), and
10^6= conversion from cm³ to m³.

A soil density of 0.9 g/cm³ is a representative value of the average soil density at TTR. A skin depth of $2.0x10^{-4}$ m is used (NRC 1983). Table E-26 summarizes the corrected/converted areal surface contamination for each of the Clean Slate subdivisions.

Table E-26. Corrected Surface Contamination Levels at the Clean Slate Sites

Site	Area (m²)	EG&G study Contamination[1] (pCi/g)	Corrected Contamination (pCi/g)	Conversion to Areal Contamin. (pCi/m²)
Clean Slate 1a	$8.5x10^5$	570	2950	$5.3x10^5$
Clean Slate 1b	$1.1x10^6$	400	2070	$3.7x10^5$
Clean Slate 2a	$1.5x10^6$	1420	7360	$1.3x10^6$
Clean Stale 2b	$9.8x10^5$	583	3020	$5.4x10^5$
Clean Slate 3a	$5.6x10^6$	779	4040	$7.3x10^5$
Clean Slate 3b	$5.0x10^6$	277	1430	$2.6x10^5$

[1]Average contamination across site subdivision. Source: Tables E-18 through E-23.

E.6.9 Diffuse Source Terms from the Clean Slate Sites

The diffuse source term was calculated from the directionally dependent resuspension rates summarized in Table E-17 and the average corrected surface contamination presented in Table E-26. The annual source term in a given direction is calculated as

$$Q = S * C_A * A * T$$

where

Q = annual source term (pCi),
S = directionally dependent resuspension rate from Table E-17 (1/sec),
C_A = average corrected surface contamination converted to aerial contamination from Table E-26 (pCi/m^2),
A = area of contamination from Tables E-18 through E-23 (m^2), and
T = duration of release (sec).

The duration of release, T, is the percentage of time that the wind blows in a given direction. It is calculated as the frequency of wind direction times $3.15x10^7$ seconds/yr. Table E-27 summarizes the calculation of the directionally dependent source term. The diffuse source term from all Clean Slate sites varies from a maximum of 0.028 Ci/yr toward the north to a minimum of 0.00044 Ci/yr toward the west-southwest. A total annual release of 0.25 Ci is estimated for the combined Clean Slate sites. The releases presented in Table E-27 are total alpha activity that includes a mixture of plutonium and americium isotopes. Table E-28 is used to calculate the percentage of each isotope included in the source term such that the alpha activity equals the total activity shown in Table E-27.

Table E-27. Diffuse Source Term for the Clean Slate Sites

Wind Direction	Resuspension Rate (1/sec)	Wind Dir. Frequency Occurrence	Clean Slate Site No.	Area (m^2)	Avg. Surface Contamin. (pCi/m^2)	Source Term (pCi/yr)
N	$2.0x10^{-9}$	.088	1a	$8.5x10^5$	$5.3x10^5$	$2.5x10^9$
			1b	$1.1x10^6$	$3.7x10^5$	$2.3x10^9$
			2a	$1.5x10^6$	$1.3x10^6$	$1.1x10^{10}$
			2b	$9.8x10^5$	$5.4x10^5$	$2.9x10^9$
			3a	$5.6x10^6$	$7.3x10^5$	$2.3x10^{10}$
			3b	$5.0x10^6$	$2.6x10^5$	$7.2x10^9$
			Total			$4.5x10^{10}$
NNW	$1.4x10^{-9}$	.062	1a	$8.5x10^5$	$5.3x10^5$	$1.2x10^9$
			1b	$1.1x10^6$	$3.7x10^5$	$1.1x10^9$
			2a	$1.5x10^6$	$1.3x10^6$	$5.3x10^9$
			2b	$9.8x10^5$	$5.4x10^5$	$1.4x10^9$
			3a	$5.6x10^6$	$7.3x10^5$	$1.1x10^{10}$
			3b	$5.0x10^6$	$2.6x10^5$	$3.6x10^9$
			Total			$2.4x10^{10}$
NW	$1.2x10^{-9}$	.045	1a	$8.5x10^5$	$5.3x10^5$	$7.7x10^8$
			1b	$1.1x10^6$	$3.7x10^5$	$6.9x10^8$
			2a	$1.5x10^6$	$1.3x10^6$	$3.3x10^9$
			2b	$9.8x10^5$	$5.4x10^5$	$9.0x10^8$
			3a	$5.6x10^6$	$7.3x10^5$	$7.0x10^9$
			3b	$5.0x10^6$	$2.6x10^5$	$2.2x10^9$
			Total			$1.5x10^{10}$
WNW	$8.1x10^{-10}$	.031	1a	$8.5x10^5$	$5.3x10^5$	$7.7x10^8$
			1b	$1.1x10^6$	$3.7x10^5$	$6.9x10^8$
			2a	$1.5x10^6$	$1.3x10^6$	$9.5x10^8$
			2b	$9.8x10^5$	$5.4x10^5$	$9.0x10^8$
			3a	$5.6x10^6$	$7.3x10^5$	$3.2x10^9$
			3b	$5.0x10^6$	$2.6x10^5$	$2.2x10^9$
			Total			$8.7x10^9$
W	$4.0x10^{-10}$	.024	1a	$8.5x10^5$	$5.3x10^5$	$1.4x10^8$
			1b	$1.1x10^6$	$3.7x10^5$	$2.2x10^8$
			2a	$1.5x10^6$	$1.3x10^6$	$1.1x10^9$
			2b	$9.8x10^5$	$5.4x10^5$	$2.9x10^8$
			3a	$5.6x10^6$	$7.3x10^5$	$1.2x10^9$
			3b	$5.0x10^6$	$2.6x10^5$	$7.1x10^8$
			Total			$3.7x10^9$

Table E-27. Diffuse Source Term for the Clean Slate Sites (Continued)

Wind Direction	Resuspension Rate (1/sec)	Wind Dir. Frequency Occurrence	Clean Slate Site No.	Area (m^2)	Avg. Surface Contamin. (pCi/m^2)	Source Term[1] (pCi/yr)
WSW	$2.0x10^{-10}$	.014	1a	$8.5x10^5$	$5.3x10^5$	$4.0x10^7$
			1b	$1.1x10^6$	$3.7x10^5$	$3.6x10^7$
			2a	$1.5x10^6$	$1.3x10^6$	$1.7x10^8$
			2b	$9.8x10^5$	$5.4x10^5$	$4.7x10^7$
			3a	$5.6x10^6$	$7.3x10^5$	$3.6x10^8$
			3b	$5.0x10^6$	$2.6x10^5$	$1.1x10^8$
			Total			$1.1x10^9$
SW	$1.8x10^{-10}$	.020	1a	$8.5x10^5$	$5.3x10^5$	$5.1x10^7$
			1b	$1.1x10^6$	$3.7x10^5$	$4.6x10^7$
			2a	$1.5x10^6$	$1.3x10^6$	$2.2x10^8$
			2b	$9.8x10^5$	$5.4x10^5$	$6.0x10^7$
			3a	$5.6x10^6$	$7.3x10^5$	$4.6x10^8$
			3b	$5.0x10^6$	$2.6x10^5$	$1.5x10^8$
			Total			$9.9x10^8$
SSW	$3.0x10^{-10}$	.058	1a	$8.5x10^5$	$5.3x10^5$	$2.5x10^8$
			1b	$1.1x10^6$	$3.7x10^5$	$2.2x10^8$
			2a	$1.5x10^6$	$1.3x10^6$	$1.1x10^9$
			2b	$9.8x10^5$	$5.4x10^5$	$2.9x10^8$
			3a	$5.6x10^6$	$7.3x10^5$	$2.2x10^9$
			3b	$5.0x10^6$	$2.6x10^5$	$7.1x10^8$
			Total			$4.8x10^9$
S	$3.6x10^{-10}$	.162	1a	$8.5x10^5$	$5.3x10^5$	$8.3x10^8$
			1b	$1.1x10^6$	$3.7x10^5$	$7.5x10^8$
			2a	$1.5x10^6$	$1.3x10^6$	$3.6x10^9$
			2b	$9.8x10^5$	$5.4x10^5$	$9.7x10^8$
			3a	$5.6x10^6$	$7.3x10^5$	$7.5x10^9$
			3b	$5.0x10^6$	$2.6x10^5$	$2.4x10^9$
			Total			$1.6x10^{10}$
SSE	$6.2x10^{-10}$	.148	1a	$8.5x10^5$	$5.3x10^5$	$1.3x10^9$
			1b	$1.1x10^6$	$3.7x10^5$	$1.2x10^9$
			2a	$1.5x10^6$	$1.3x10^6$	$5.6x10^9$
			2b	$9.8x10^5$	$5.4x10^5$	$1.5x10^9$
			3a	$5.6x10^6$	$7.3x10^5$	$12x10^{10}$
			3b	$5.0x10^6$	$2.6x10^5$	$3.8x10^9$
			Total			$2.5x10^{10}$

Table E-27. Diffuse Source Term for the Clean Slate Sites (Continued)

Wind Direction	Resuspension Rate (1/sec)	Wind Dir. Frequency Occurrence	Clean Slate Site No.	Area (m^2)	Avg. Surface Contamin. (pCi/m^2)	Source Term[1] (pCi/yr)
SE	9.5×10^{-10}	.107	1a	8.5×10^{5}	5.3×10^{5}	1.4×10^{9}
			1b	1.1×10^{6}	3.7×10^{5}	1.3×10^{9}
			2a	1.5×10^{6}	1.3×10^{6}	6.2×10^{9}
			2b	9.8×10^{5}	5.4×10^{5}	1.7×10^{9}
			3a	5.6×10^{6}	7.3×10^{5}	1.3×10^{10}
			3b	5.0×10^{6}	2.6×10^{5}	4.2×10^{9}
			Total			2.8×10^{10}
ESE	1.6×10^{-9}	.103	1a	8.5×10^{5}	5.3×10^{5}	2.3×10^{9}
			1b	1.1×10^{6}	3.7×10^{5}	2.1×10^{9}
			2a	1.5×10^{6}	1.3×10^{6}	1.0×10^{10}
			2b	9.8×10^{5}	5.4×10^{5}	2.7×10^{9}
			3a	5.6×10^{6}	7.3×10^{5}	2.1×10^{10}
			3b	5.0×10^{6}	2.6×10^{5}	6.7×10^{9}
			Total			4.5×10^{10}
E	1.2×10^{-9}	.065	1a	8.5×10^{5}	5.3×10^{5}	1.1×10^{9}
			1b	1.1×10^{6}	3.7×10^{5}	1.0×10^{9}
			2a	1.5×10^{6}	1.3×10^{6}	4.9×10^{9}
			2b	9.8×10^{5}	5.4×10^{5}	1.3×10^{9}
			3a	5.6×10^{6}	7.3×10^{5}	1.0×10^{10}
			3b	5.0×10^{6}	2.6×10^{5}	3.2×10^{9}
			Total			2.2×10^{10}
ENE	4.8×10^{-10}	.023	1a	8.5×10^{5}	5.3×10^{5}	1.6×10^{8}
			1b	1.1×10^{6}	3.7×10^{5}	1.4×10^{8}
			2a	1.5×10^{6}	1.3×10^{6}	6.8×10^{8}
			2b	9.8×10^{5}	5.4×10^{5}	1.8×10^{8}
			3a	5.6×10^{6}	7.3×10^{5}	1.4×10^{9}
			3b	5.0×10^{6}	2.6×10^{5}	4.5×10^{8}
			Total			3.0×10^{9}
NE	7.3×10^{-10}	.020	1a	8.5×10^{5}	5.3×10^{5}	2.0×10^{8}
			1b	1.1×10^{6}	3.7×10^{5}	1.9×10^{8}
			2a	1.5×10^{6}	1.3×10^{6}	9.0×10^{8}
			2b	9.8×10^{5}	5.4×10^{5}	2.4×10^{8}
			3a	5.6×10^{6}	7.3×10^{5}	1.9×10^{9}
			3b	5.0×10^{6}	2.6×10^{5}	6.0×10^{8}
			Total			4.0×10^{9}

Table E-27. Diffuse Source Term for Clean Slate Sites (Concluded)

Wind Direction	Resuspension Rate (1/sec)	Wind Dir. Frequency Occurrence	Clean Slate Site No.	Area (m^2)	Avg. Surface Contamin. (pCi/m^2)	Source Term[1] (pCi/yr)
NNE	$9.5x10^{-10}$	.031	1a	$8.5x10^5$	$5.3x10^5$	$4.3x10^8$
			1b	$1.1x10^6$	$3.7x10^5$	$3.8x10^8$
			2a	$1.5x10^6$	$1.3x10^6$	$1.8x10^9$
			2b	$9.8x10^5$	$5.4x10^5$	$4.9x10^8$
			3a	$5.6x10^6$	$7.3x10^5$	$3.8x10^9$
			3b	$5.0x10^6$	$2.6x10^5$	$1.2x10^9$
			Total			$8.1x10^9$
Total From All Wind Directions						$2.5x10^{11}$

Table E-28. Activity in 1.0 Ci of Alpha-Plutonium

Isotope	Ci/g Mixture[1]	Activity Fraction	Activity (Ci) in 1.0 alpha-Curie[2]
Pu-238	.0039	.0244	.0466
Pu-239	.0576	.360	.688
Pu-240	.0129	.0808	.154
Pu-241	.0759	.475	-[2]
Pu-242	1.2×10^{-6}	$7.5x10^{-6}$	1.4×10^{-5}
Am-241	.0093	.0583	.111
Total	.1600	1.0	1.0

[1]Mixture is based on a 31-year decay time up to 1994. Source: Table E-25, 1994 activity.
[2]Total alpha activity is normalized to 1.0 Ci (excludes Pu-241 beta/gamma activity).

E.6.10 Individual Dose Assessment

The potential releases from the Clean Slate sites occur as a result of the wind resuspension of soil particulates (fugitive dust) contaminated with plutonium. A total annual release of 0.25 Ci/yr of alpha-plutonium was calculated to occur from all three Clean Slate sites combined. The diffuse source is composed of PM-10 particulates less than 10 μm in diameter and therefore have the potential to disperse downwind to receptor locations. It is assumed that all suspended particulates are respirable; therefore, the dose is a conservatively high estimate.

Table E-27 summarizes the directionally dependent annual source terms calculated for the Clean Slate sites. The contribution from each diffuse source released toward a given onsite receptor using Table E-27 was tabulated in Table E-29 based on the direction from the source to the onsite receptor (Table E-2). The greatest source term disperses toward the N and ESE sectors with an annual release of 0.045 Ci. Individual doses were calculated for the four onsite receptors shown in Table E-2. Source terms presented in Table E-29 were input to the CAP88-PC code along with the distances shown in Table E-2. Because of the directional nature of the source terms, the CAP88-PC input data set was constructed in a special manner to accommodate the variable source term. The data set had all wind direction frequencies set to a value of 1.00 for each of the sixteen wind sectors. This has the effect of "sending" the entire source to each sector. Additionally, the source term used in the CAP88-PC code was set to a value of 1.0 Ci of alpha-plutonium broken down into its component isotopes (see Table E-28). Also, receptor distances from each Clean Slate site to each receptor location (Table E-2) were input. The resulting individual dose for a given onsite receptor was calculated as the CAP88-PC dose at the appropriate sector and downwind distance, multiplied by the actual source term released into the sector.

Contributing doses were then summed to yield a cumulative dose from all diffuse sources. Table E-30 summarizes the component and cumulative doses calculated using the CAP88-PC code for TTR onsite receptors. The doses ranged from 0.25 mrem/yr to 2.9 mrem/yr at the 554th Range Squadron O&M Complex. Exposure is primarily due to inhalation of Pu-239.

E.7 CONCLUSIONS

No point-source radiological releases occurred from SNL/NV during 1993. Diffuse-source releases were calculated for the Clean Slate sites using a wind resuspension model and carefully selected supporting data. The resuspension model calculated in diffuse releases that are directionally dependent and different for each wind direction sector. A cumulative annual release of 0.25 Ci/yr of alpha-plutonium (including Am-241) was calculated for all three Clean Slate sites. The diffuse sources were used to calculate a regional population dose of 0.38 person-rem/yr and a maximally exposed individual onsite dose of 2.9 mrem/yr at the Air Force 554th Range Squadron O&M Complex located on the east side of TTR. The offsite location of maximum dose was found to be 0.062 mrem/yr at the town of Goldfield. The primary pathway of exposure was through inhalation of contaminated dust. Pu-239 was responsible for the majority of the dose. Although Pu-241 is the radionuclide of greatest activity, as seen in Table E-28,

Table E-29. Source Terms (Ci/yr) Toward Onsite Receptor Locations[1]

Receptor	CS-1a	CS-1b	CS-2a	CS-2b	CS-3a	CS-3b	Total
Base Housing	.0020	.0019	.0056	.0015	.051	.0061	.068
Airport	.0013	.0012	.0013	.0013	.0010	.0037	.0098
South Perimeter	.0014	.0013	.0061	.0016	.0013	.0041	.0016
554th Range Squadron O&M Complex	.0019	.00020	.017	.0022	.0017	.0544	.077

[1]Total alpha-plutonium including Am-241.

Table E-30. Individual Doses (mrem/yr) to TTR Onsite Receptors

Receptor	CS-1a	CS-1b	CS-2a	CS-2b	CS-3a	CS-3b	Total
Base Housing	.024	.020	.078	.020	.12	.061	.32
Airport	.031	.024	.041	.034	.081	.037	.25
South Perimeter	.058	.060	.016	.046	.13	.041	.50
554th Range Squadron O&M Complex	.054	.0073	.83	.12	.046	1.84	2.90

it is a beta-gamma emitter and does not pose as great a risk on a per curie basis as the other alpha emitters such as Pu-239.

The diffuse source term derivation was the focal point of the overall dose assessment. A number of modeling methodologies and supporting data were employed in the assessment. Table E-31 summarizes the key components and references that were used in the diffuse source term derivation.

Table E-31. Summary of Diffuse Source Modeling Methods and Supporting Data.

Model/Data	Reference Location
Wind Resuspension Model (used for modeling fugitive PM-10 in an Undisturbed Desert Regime)	DOE 1984
Wind Data	STAR data for Tonopah, Nevada DOC 1984
Soil Contamination	
Initial Data	EG&G 1977
Correction for Pu-238	Rockwell International 1985
Correction for Ingrowth of Am-241	Calculated from radiological decay
Correction for Surface Contamination from the Average through the Top 5 cm	Calculated from assumptions given in EG&G 1977
Size of Contaminated Areas	EG&G 1977, calculated from contour figures
Isotopic Composition of Plutonium	Rockwell International 1985
Conversion from Volumetric to Areal Contamination	Skin depth given by NRC 1984
Receptor Locations	SNL/NM
Dose Calculation	EPA 1992

REFERENCES

BOC 1983: U.S. Bureau of Census, "County and City Data Book," U.S. Government Printing Office (1983).

Culp and Howard 1992: Culp, T., and Howard, D., "1992 Environmental Monitoring Report, Tonopah Test Range, Tonopah, Nevada," SAND93-1449, Sandia National Laboratories, Albuquerque, NM.

DOA 1988: U.S. Department of Agriculture, "New Mexico Agricultural Statistics," P.O. Box 1809, Las Cruces, NM, 88004 (1988).

DOC 1978: U.S. Department of Commerce, "NOAA (National Oceanic and Atmospheric Administration) Environmental Data Service, Monthly and Annual Wind Distribution by Pasquill Stability Classes, STAR Program, Tonopah, NV," National Climatic Center (NCC) Federal Building, Ashville, NC (1978).

DOC 1991a: U.S. Department of Commerce, Bureau of the Census, "1990 United States Census–Preliminary Report," DOC, Denver, Colorado regional office (1991).

DOC 1991b: U.S. Department of Commerce, Bureau of the Census, "1990 United States Census–Preliminary Report," Seattle, Washington, regional office (1991).

DOE 1984: U.S. Department of Energy, "Atmospheric Science and Power Production," DOE/TIC-27601 (DE840055177), Technical Information Center, Office of Scientific and Technical Information, U.S. Department of Commerce, Springfield, VA (1984).

EG&G 1979: Edgerton, Germeschausen, and Grier Corporation, "An Aerial Radiological Survey of Clean Slates 1, 2, and 3, and Double Track, Tonopah Test Range," EGG-1183-1737, Energy Measurement Group, EG&G, Las Vegas, NV (1979).

EPA 1989: U.S. Environmental Protection Agency, "National Emission Standards for Hazardous Air Pollutants (NESHAP)," Code of Federal Regulations, Protection of the Environment, Title 40, Part 61 (December 1989).

EPA 1991: U.S. Environmental Protection Agency, "CAP-88, Clean Air Act Assessment Package," Radiation Shielding Information Center, CCC-542, Oak Ridge, Tennessee.

NRC 1983: U.S. Nuclear Regulatory Commission, "Radiological Assessment," NUREG/CR-3332, ORNL-5968, Division of Systems Integration, Office of Nuclear Reactor Regulation, Washington, DC (1983).

REFERENCES
(concluded)

Rockwell International 1985: Rockwell International, "Rocky Flats Risk Assessment Guide," Internal Report, North American Space Operations, Rocky Flats Plant, CO (1985).

Slade 1968: Slade, D. H., ed., "Meteorology and Atomic Energy," U.S. Atomic Energy Commission/Division of Reactor Development and Technology (July 1968).

SNL 1991: Sandia National Laboratories, "1990 Environmental Monitoring Report, Sandia National Laboratories," Sandia National Laboratories, Tonopah, NV (May 1991).

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