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RADIOLOGICAL DOSE CALCULATIONS AND SUPPLEMENTAL DOSE ASSESSMENT DATA FOR NESHAP COMPLIANCE FOR SNL, NEVADA FACILITIES

1996

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EXECUTIVE SUMMARY

Operations of Sandia National Laboratories, Nevada (SNL/NV) at the Tonopah Test Range (TTR) resulted in no planned point radiological releases during 1996. Other releases from SNL/NV included diffuse transuranic sources consisting of the three Clean Slate sites. Air emissions from these sources result from wind resuspension of near-surface transuranic contaminated soil particulates. The total area of contamination has been estimated to exceed 20 million square meters. Soil contamination was documented in an aerial survey program in 1977 (EG&G 1979). Surface contamination levels were generally found to be below 400 pCi/g of combined plutonium-238, plutonium-239, plutonium-240, and americium-241 (i.e., transuranic) activity. Hot spot areas contain up to 43,000 pCi/g of transuranic activity. Recent measurements confirm the presence of significant levels of transuranic activity in the surface soil. An annual diffuse source term of 0.39 Ci of transuranic material was calculated for the cumulative release from all three Clean Slate sites.

A maximally exposed individual dose of 1.1 mrem/yr at the TTR airport area was estimated based on the 1996 diffuse source release amounts and site-specific meteorological data. A population dose of 0.86 person-rem/yr was calculated for the local residents. Both dose values were attributable to inhalation of transuranic contaminated dust.

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1.0 INTRODUCTION

This document details the methodology and supplemental data used to calculate radiological dose in support of the Environmental Protection Agency's (EPA) National Emission Standards for Hazardous Air Pollutants (NESHAP), Subpart H, (EPA, 1989). The parent document to this is the *NESHAP Annual Report For CY 1996 SNL, Nevada* (SNL, 1997a). The *NESHAP Annual Report* provides a summary of the dose results and calculational methods that are presented in this supplemental document.

NESHAP compliance at Sandia National Laboratories, Nevada (SNL/NV) utilizes the CAP88-PC (EPA, 1991) computer code, an EPA approved methodology for demonstrating compliance with NESHAP criteria. The CAP88-PC code requires certain types of input data to calculate annual dose. Required site-specific data include the location of potential receptors, demographic data, and meteorological data. Receptor data include the distance and direction of receptors relative to locations of radionuclide releases. Since the NESHAP dose is the cumulative contribution from all emission sources, the maximally exposed receptor location must be determined by calculating dose to receptors at several locations surrounding the source region. As a result, several potentially “maximum” receptor locations were evaluated.

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 the 16 wind direction sectors used by CAP88-PC. In addition, the meteorological data include the frequency-of-occurrence of the six Pasquill atmospheric stability classes (segregated into the 16 wind direction sectors) and the frequency-of-occurrence of each of the 16 wind directions. These supplemental data are presented in this document.

The CAP88-PC code, however, will not calculate the annual source term which must be known in order to calculate annual radiological dose. During 1996, no radionuclides were released from TTR stacks, vents, or other point sources. However, three large areas of surface contamination were calculated to produce diffuse sources 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 the early 1960’s. The methodology for estimating the diffuse source terms is presented in Section 6.

2.0 SANDIA NATIONAL LABORATORIES, NEVADA

2.1 Facility Information

2.1.1 Site Description

SNL/NV is based at the TTR and is operated by Sandia National Laboratories, New Mexico (SNL/NM), for the U.S. Department of Energy (DOE) nuclear ordinance programs. The TTR was used as a bombing range during World War II. SNL/NV activities at TTR date from about 1957 when TTR came into limited use after similar facilities at Salton Sea Test Base, California, and at Yucca Mountain on the Nevada Test Range became inadequate. The TTR was originally designed and equipped to gather raw data on aircraft-delivered inert test vehicles coming under Atomic Energy Commission (AEC) cognizance. Over the years the facilities at TTR and capabilities of SNL/NV have been expanded to accommodate tests related to AEC (later, the DOE) weapons development programs, varying from simple tests of hardware components to rocket launches or air drops of test vehicles.

The TTR is located about 140 miles (225 km) northwest of Las Vegas, Nevada, covering 624 square miles (1,616 km^2) within the boundaries of the Nellis Air Force Range Complex. The nearest population centers are Goldfield, population 659, located about 25 miles (40 km) west of the TTR, and Tonopah, population 4,400, located 30 miles (48 km) northwest of the TTR.

2.1.2 Point Radiological Sources

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

2.1.3 Diffuse Radiological Sources

Experiments conducted at SNL/NV occasionally involve small amounts of radioactive material. During destructive testing experiments, radioactive materials (if present) can be dispersed over a broad area and deposited onto surface soil. This material is a potential source of airborne radionuclide contamination through the wind resuspension of contaminated surface soil. Such experiments are not conducted routinely, and the radionuclide sources are small. Any resulting dose is expected to be well below the allowable NESHAP dose limit.

During the early 1960s, three dispersal tests involving plutonium were conducted at TTR Clean Slates 1, 2, and 3. In 1977, an extensive aerial radiological survey was conducted of the three Clean Slate sites (EG&G 1979). The aerial survey determined the surficial distribution of plutonium-239, -240, and americium-241 related to the three tests. This survey estimated the total area of contamination to be approximately 20 million square meters. The Clean Slate sites pose as diffuse sources of airborne contamination through the process of wind resuspension of contaminated surface soils.

2.2 Air Emission Data

2.2.1 Radiological Releases During 1996

During 1996, the only radiological air emission at the TTR was from the three Clean Slate diffuse sources. The air emission was the result of wind resuspension of contaminated surface soil material. The annual diffuse source terms were calculated using a wind resuspension model to calculate the rate at which soil particulates become airborne. The wind resuspension model utilizes an empirical relation (DOE, 1984) to predict resuspension rates as a function of wind speed. Using local meteorological data (DOC, 1993 and 1997) and soil contamination data (EG&G, 1979), the source term was calculated for each Clean Slate site. A more detailed description of the wind resuspension model is contained in Section 6.

The calculated 1996 cumulative radiological air release for TTR was 0.39 Ci (0.018 Ci Pu-238, 0.27 Ci Pu-239, 0.060 Ci Pu-240, and 0.043 Ci Am-241). This diffuse source term was calculated for resuspended particulates 10 μm or less in diameter and was assumed to be entirely respirable.

2.2.2 Environmental Surveillance Program

In February of 1977, the EG&G Energy Measurement Group performed an aerial radiological survey at TTR. The surveyed areas included Clean Slates 1, 2, and 3. This survey indicated the presence of transuranic contamination outside the Clean Slate access control fences and in the predominant downwind direction. An additional aerial survey was conducted in 1993. The results from the 1993 survey confirm the general shape delineated the 1977 survey.

Routine environmental surveillance activities were begun by SNL/NM at TTR in 1992. Included in these activities are soil and air sampling. The objective of the soil sampling and analysis has been to provide limited data as to the extent of soil contamination in areas that were either known or suspected of being contaminated. Results from soil sampling confirmed the presence of plutonium and americium in the prevailing downwind directions of Clean Slates 1, 2, and 3. The results also confirmed the general shape and activity concentrations indicated by both EG&G surveys.

Limited PM-10 air monitoring has been conducted at TTR. PM-10 air monitors collect air particulates of size 10 um or less. This particulate size range is considered respirable. Air monitoring has been conducted at various locations onsite as part of the TTR routine environmental surveillance program. The objective of this limited air monitoring was to assess the general movement of potentially contaminated material through the air.

All routine environmental surveillance data for TTR have been included in the respective annual *Site Environmental Report, Tonopah Test Range, Tonopah, Nevada*. These reports, and the information contained in the reports, are part of SNL's compliance activities related to DOE Order 5400.1, *General Environmental Protection Program* (DOE 1988).

3.0 RECEPTOR LOCATIONS

3.1 Off-Site Receptors

Figure 1 depicts the locations of off-site receptors around the TTR. Five specific off-site locations were assessed: Tonopah, Tonopah Municipal Airport, Goldfield, Warm Springs Ranch, and East Nellis Air Force Base. Table 1 provides the distance and direction from the location of the Clean Slates to each of the off-site receptors. Distances and directions were measured from the approximate center of Antelope Lake which is located adjacent to the Clean Slates.

3.2 On-Site Receptors

In addition to the off-site NESHAP receptor locations, four receptors are located on-site as shown in Figure 2. The concept of an "on-site receptor" was conservatively assumed to include members of the military, military contractors, and other non-SNL personnel who work at locations on TTR whom SNL has little or no operational control. This definition is believed to be consistent with EPA and current DOE guidance. Based on visual and historical investigations of the TTR, four on-site receptor locations were selected. These locations are: Base Housing, TTR Airport Area, 554th Range Squadron O&M, and the South Perimeter.

Three of the four locations fit the above description of the on-site receptor. The exception is the South Perimeter location which is at the boundary of the TTR and NAFB. The South Perimeter was conservatively chosen as a receptor location because it is the closest point to the Clean Slate sites that a receptor (off-site) could occupy in the southerly direction. Since the location is at the TTR boundary (dividing line between on-site and off-site receptors), the South Perimeter receptor was considered as an on-site receptor. Table 2 summarizes the distance and direction of the on-site receptors to the various diffuse sources at TTR.

Figure 1. Off-Site Receptor Zone Around SNL TTR

Table 1

Distances to Off-Site Receptors Around the TTR

Receptor	Distance and Direction from Clean Slate Sites (Antelope Lake) to Receptor
Tonopah	51 km NW
Tonopah Municipal Airport	42 km NW
Goldfield	39 km W
Warm Springs Ranch	66 km NE
East Nellis Air Force Base	64 km E

Table 2

Distance (km) and Direction to On-Site NESHAP Receptor Locations at the TTR[1]

Receptor	Base Housing	Airport	South Perimeter	554th Range Squadron O&M Complex
Clean Slate 1				
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
Clean Slate 2				
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
Clean Slate 3				
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 sub-divided into two smaller areas for modelling purposes (discussed in Section 5).

4.0 METEOROLOGICAL DATA

Site-specific meteorological data were required for air dispersion and receptor dose modeling. Meteorological data were obtained from two sources: Tonopah Municipal Airport (DOC, 1997) and onsite at TTR (DOC, 1993). Wind direction and wind speed frequency were recorded at TTR between 1989 and 1992 (DOC, 1993). However, the meteorological station at TTR did not collect Pasquill stability class data (derived from wind and solar insolence data) which are required for the modeling. As a result, Pasquill stability class data were obtained from Tonopah Municipal Airport which is approximately 42 km northwest of the Clean Slates. Stability class data was obtained for the time period between 1989 and 1992 (DOC, 1997). Using both datasets, a Stability Array (STAR) meteorological data file was developed for use in the CAP88-PC code to estimate air dispersion of the annual Clean Slate radiological emissions and the consequential dose to public receptors.

Table 3 summarizes the harmonic and arithmetic average wind speeds for the combined TTR and Tonopah Municipal Airport meteorological dataset. Table 3 also contains the frequency-of-occurrence of wind directions. Table 4 summarizes the frequency-of-occurrence of Pasquill stability classes. Other meteorological data used in the CAP88-PC code are summarized in Table 5.

Figure 3 presents the average daily windrose (1989-1992) for the meteorological station at the TTR.

5.0 DEMOGRAPHIC DATA

Demographic data include population, beef cattle, dairy cattle, and the area of food crop harvesting. Although the CAP88-PC code contains default demographic data 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 eighty CAP88-PC code analysis zones (16 wind direction sectors subtended by 5 concentric, equally spaced rings to 50-mi or 80-km). 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. 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 the United States Department of Commerce (DOC, 1991a and 1991b). Agricultural data were taken from the United States Department of Commerce (DOC, 1992). The SNL/NV CAP88-PC grid was centered on Antelope Lake in the center of the TTR and is provided for calculating the regional population dose.

Table 3

Average Wind Speeds*

HARMONIC AVERAGE WIND SPEEDS (WIND TOWARDS)

	Pasquill Stability Class							
Dir	A	B	C	D	E	F	G	Wind Frequency
Harmonic Average								
N	1.187	1.391	2.955	5.470	3.429	1.036	0.000	0.090
NNW	1.427	1.470	2.479	5.031	3.370	1.144	0.000	0.111
NW	1.452	1.320	2.686	3.882	3.340	1.077	0.000	0.092
WNW	1.166	1.320	2.816	3.848	3.448	0.974	0.000	0.063
W	0.948	1.052	1.531	2.919	3.554	0.999	0.000	0.030
WSW	0.880	0.908	1.144	1.765	3.215	0.943	0.000	0.018
SW	0.860	0.902	1.125	2.263	3.161	0.901	0.000	0.025
SSW	0.861	0.845	1.340	4.415	3.520	0.970	0.000	0.041
S	0.798	0.808	1.558	4.077	3.728	0.991	0.000	0.071
SSE	0.813	0.858	1.571	4.154	3.774	1.073	0.000	0.069
SE	0.842	1.100	1.834	5.089	3.778	1.242	0.000	0.114
ESE	1.014	1.177	3.014	5.885	3.681	1.196	0.000	0.108
E	0.893	1.336	2.583	4.076	3.462	1.107	0.000	0.052
ENE	0.904	1.371	2.874	3.878	3.032	0.915	0.000	0.024
NE	1.007	1.238	2.433	4.468	3.211	1.013	0.000	0.031
NNE	1.095	1.496	3.961	5.342	3.604	0.972	0.000	0.063
Arithmetic Average								
N	1.672	2.226	4.696	7.293	3.665	1.429	0.000	
NNW	1.953	2.276	3.621	6.441	3.608	1.608	0.000	
NW	1.977	2.072	3.497	5.294	3.578	1.500	0.000	
WNW	1.642	2.192	3.645	4.947	3.683	1.305	0.000	
W	1.251	1.712	2.653	4.656	3.780	1.357	0.000	
WSW	1.088	1.196	1.799	3.869	3.447	1.239	0.000	
SW	1.036	1.238	1.724	7.986	3.387	1.140	0.000	
SSW	1.038	1.040	2.429	6.737	3.750	1.298	0.000	
S	0.855	0.909	2.566	6.516	3.928	1.341	0.000	
SSE	0.903	1.091	2.730	6.378	3.965	1.495	0.000	
SE	0.986	1.811	3.778	7.451	3.968	1.746	0.000	
ESE	1.386	2.005	4.540	7.260	3.889	1.684	0.000	
E	1.122	2.161	4.078	6.118	3.696	1.550	0.000	
ENE	1.148	2.239	3.858	5.251	3.236	1.174	0.000	
NE	1.372	2.161	4.258	6.195	3.442	1.384	0.000	
NNE	1.531	2.519	5.523	7.263	3.825	1.302	0.000	

*Source: Meteorological data for Tonopah Municipal Airport (DOC 1997) and the TTR (DOC 1993) for the 1989-1992 time period. Wind direction is towards the indicated direction.

Table 4

Frequency of Stability Classes*

	Pasquill Stability Class						
Dir	A	B	C	D	E	F	G
N	0.0123	0.1159	0.1833	0.5145	0.0714	0.1026	0.0000
NNW	0.0112	0.1616	0.2303	0.4285	0.0754	0.0930	0.0000
NW	0.0138	0.2382	0.2479	0.3512	0.0677	0.0811	0.0000
WNW	0.0142	0.2298	0.2124	0.3323	0.0973	0.1140	0.0000
W	0.0360	0.2052	0.1465	0.2666	0.1254	0.2204	0.0000
WSW	0.0321	0.1938	0.2135	0.1713	0.0789	0.3104	0.0000
SW	0.0299	0.1967	0.1724	0.2007	0.0793	0.3210	0.0000
SSW	0.0216	0.1894	0.1455	0.3201	0.0829	0.2406	0.0000
S	0.0153	0.1019	0.0780	0.3298	0.1567	0.3183	0.0000
SSE	0.0119	0.0458	0.0577	0.2853	0.2252	0.3741	0.0000
SE	0.0074	0.0335	0.0726	0.4054	0.2013	0.2797	0.0000
ESE	0.0117	0.0526	0.0862	0.4826	0.1569	0.2100	0.0000
E	0.0279	0.0959	0.1465	0.3665	0.1140	0.2492	0.0000
ENE	0.0460	0.1628	0.1461	0.2369	0.0954	0.3127	0.0000
NE	0.0266	0.2024	0.2168	0.3162	0.0577	0.1804	0.0000
NNE	0.0133	0.1081	0.2142	0.5228	0.0462	0.0954	0.0000
TOT	0.0160	0.1287	0.1548	0.3845	0.1170	0.1989	0.0000

*Source: Meteorological data for Tonopah Municipal Airport (DOC 1997) and the TTR (DOC 1993) for the 1989-1992 time period. Wind direction is towards the indicated direction.

Table 5

Additional Weather Information

Data Type	Value
Average Air Temperature[1]	10 ºC
Annual Precipitation[1]	12.5 cm/yr
Mixing Height[2]	2370 m
Temperature Gradients:	
Stability Class E[3]	0.073 K/m
Stability Class F[3]	0.109 K/m
Stability Class G[3]	0.146 K/m

[1] Source: Schaeffer 1969.
[2] Source: Slade 1968.
[3] CAP88-PC default values.

Figure 3. Tonopah Airport Meteorological Station Windrose

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 net population of Lincoln County, Nevada (3,775), by its area (10,635 sq. mi.) yields a population density of 0.36 people per square mile. This concept was applied to beef and dairy cattle, and food crops. However, for counties with significant population centers, the urban center populations were subtracted from the county population. The resulting population density, therefore, represents a rural population density. The urban and significant population centers were later added to their respective CAP88-PC zones to obtain an overall population grid.

Table 6 lists the significant urban centers for the Tonopah area. Also shown are the CAP88-PC grid locations for the urban centers. Table 7 shows the resulting rural population density by county for the Tonopah area. Tables 8-10 show the beef cattle, dairy cattle, and food crop density information by county for the Tonopah area.

Table 11 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 were added back to Table 11 values before being input to the CAP88-PC code. Tables 12, 13, and 14 summarize the calculation of the beef cattle, dairy cattle, and food crops per zone, respectively, for the Tonopah area.

6.0 SOURCE TERM DEVELOPMENT

The three Clean Slate sites at the TTR are potential diffuse sources of radionuclides. Small amounts of contamination are potentially released from the TTR as fugitive dust originating from near-surface contaminated soil through the action of wind pick-up and suspension. This phenomenon, known as wind resuspension, gives rise to an area source rate release. This section summarizes the methods used in the 1996 dose assessment to estimate the annual release of fugitive dust containing radionuclides at the TTR. These methods were derived from Culp and Kovacic (1995).

6.1 Determination of Surface Soil Activity

The 1977 aerial survey provides the basic information from which the annual radionuclide release was calculated. To use this information, the existing data had to be corrected for elevated surface contamination, additional radionuclides, radioactive decay and ingrowth, and converted from volummetric to area activity concentration. The development of the surface-soil activity concentration for each Clean Slate site are presented below, along with a discussion of the correction factors.

Table 6

Urban Centers by County for the Tonopah Area

County	City	Urban Population*	Sector	Ring
Esmeralda	Goldfield	659	W	3
Lincoln	None			
Nye	Beatty	1652	NA[H]	NA[H]
	Tonopah	3,680	NW	4
Total		5,991		

* Source: DOC 1991a and b.
[H] NA = Not applicable; population of the urban center is outside the 50-mile (80-km) radius-of-concern
.

Table 7

Rural Population Density by County for the Tonopah Area

County	County Area (mi^2)	Total Population[H]	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

[H] Source: DOC 1991a and b.

Table 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	5,559	3,587	0.0	1.55
Lincoln	9,206	10,635	0.0	0.866
Nye	13,403[a]	18,155	4,181	0.959
Nevada Test Site	0	NA	NA	0.00

* Source: DOC 1992.
** Includes the Nevada Test Site, Tonopah Test Range, Air Force test sites, and other restricted federal land.
A 1992 data for Nye County were unavailable. 1987 data were used.
' Excluding NTS area.

Table 9

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	0[a]	3,587	0.0	0.0
Lincoln	12	10,635	0.0	0.00066
Nye	26[b]	18,155	4,181	0.0019
Nevada Test Site	0	NA	NA	0.0

* Source: DOC 1992.
A No dairy cattle were reported for Esmeralda County.
B 1992 data for Nye County were unavailable. 1987 data were used.
** Includes the Nevada Test Site, Tonopah Test Range, Air Force test sites, and other restricted federal land.

Table 10

Food Crop Density by County for the Tonopah Area

County	Harvested Cropland (acres)	Area (mi^2)	NTS Area Exclusion** (mi^2)	Food Crop Density (ac/mi^2)	Food Crop Density (m^2/mi^2)
Esmeralda	9,836	3,587	0	2.74	
Lincoln	14,170	10,635	0	1.33	
Nye	11,076	18,155	4,181	0.793	
Nevada Test Site	0	NA	NA	0.0	0

* Source: DOC 1992.

** Includes the Nevada Test Site, Tonopah Test Range, Air Force test sites, and other restricted federal land.

Table 11

Tonopah Rural Populations by Sector and Ring

Sector	Ring	Division	Partial Area (sq mi)	Population Density (per sq mi)	Rural Population
North	1	Nevada Test Site	19.6	0	0
North	2	Nye County	58.8	0.69	41
North	3	Nye County	117.8	0.69	81
North	4	Nye County	137.5	0.69	95
North	5	Nye County	176.2	0.69	122
North-Northwest	1	Nevada Test Site	19.6	0	0
North-Northwest	2	Nevada Test Site	4.8	0	0
North-Northwest	2	Nye County	54.0	0.69	37
North-Northwest	3	Nye County	117.8	0.69	81
North-Northwest	4	Nye County	137.5	0.69	95
North-Northwest	5	Nye County	176.2	0.69	122
Northwest	1	Nevada Test Site	19.6	0	0
Northwest	2	Nevada Test Site	24.0	0	0
Northwest	2	Nye County	34.8	0.69	24
Northwest	3	Esmeralda County	31.2	0.19	6
Northwest	3	Nye County	86.6	0.69	60
Northwest	4	Nye County	52.8	0.69	36
Northwest	4	Esmeralda County	84.7	0.19	16
Northwest	5	Nye County	72.0	0.69	50
Northwest	5	Esmeralda County	104.2	0.19	20
West-Northwest	1	Nevada Test Site	19.6	0	0
West-Northwest	2	Nevada Test Site	24.0	0	0
West-Northwest	2	Esmeralda County	2.4	0.19	0
West-Northwest	2	Nye County	32.4	0.69	22
West-Northwest	3	Nye County	7.2	0.69	5
West-Northwest	3	Esmeralda County	110.6	0.19	21
West-Northwest	4	Esmeralda County	137.5	0.19	26
West-Northwest	5	Esmeralda County	176.2	0.19	33
West	1	Nevada Test Site	19.6	0	0
West	2	Nevada Test Site	16.8	0	0
West	2	Esmeralda County	7.2	0.19	1
West	2	Nye County	34.8	0.69	24

Table 11

Tonopah Rural Populations by Sector and Ring (Continued)

Sector	Ring	Division	Partial Area (sq mi)	Population Density (per sq mi)	Rural Population
West	3	Esmeralda County	117.8	0.19	22
West	4	Esmeralda County	137.5	0.19	26
West	5	Esmeralda County	176.2	0.19	33
West-Southwest	1	Nevada Test Site	19.6	0	0
West-Southwest	2	Nevada Test Site	19.2	0	0
West-Southwest	2	Esmeralda County	2.4	0.19	0
West-Southwest	2	Nye County	37.2	0.69	26
West-Southwest	3	Esmeralda County	117.8	0.19	22
West-Southwest	4	Esmeralda County	137.5	0.19	26
West-Southwest	5	Esmeralda County	176.2	0.19	33
Southwest	1	Nevada Test Site	19.6	0	0
Southwest	2	Nye County	9.6	0.69	7
Southwest	2	Nevada Test Site	49.2	0	0
Southwest	3	Nevada Test Site	16.8	0	0
Southwest	3	Esmeralda County	101.0	0.19	19
Southwest	4	Esmeralda County	132.7	0.19	25
Southwest	4	Nye County	4.8	0.69	3
Southwest	5	Esmeralda County	176.2	0.19	33
South-Southwest	1	Nevada Test Site	19.6	0	0
South-Southwest	2	Nevada Test Site	58.8	0	0
South-Southwest	3	Nye County	9.6	0.69	7
South-Southwest	3	Nevada Test Site	108.2	0	0
South-Southwest	4	Nevada Test Site	14.4	0	0
South-Southwest	4	Esmeralda County	24.0	0.19	5
South-Southwest	4	Nye County	99.1	0.69	68
South-Southwest	5	Esmeralda County	91.2	0.19	17
South-Southwest	5	Nye County	85.0	0.69	59
South	1	Nevada Test Site	19.6	0	0
South	2	Nevada Test Site	58.8	0	0
South	3	Nevada Test Site	117.8	0	0
South	4	Nye County	16.8	0.69	12
South	4	Nevada Test Site	120.7	0	0

Table 11

Tonopah Rural Populations by Sector and Ring (Continued)

Sector	Ring	Division	Partial Area (sq mi)	Population Density (per sq mi)	Rural Population
South	5	Nevada Test Site	31.2	0	0
South	5	Nye County	145.0	0.69	100
South-Southeast	1	Nevada Test Site	19.6	0	0
South-Southeast	2	Nevada Test Site	58.8	0	0
South-Southeast	3	Nevada Test Site	117.8	0	0
South-Southeast	4	Nevada Test Site	137.5	0	0
South-Southeast	5	Nevada Test Site	171.4	0	0
South-Southeast	5	Nye County	4.8	0.69	3
Southeast	1	Nevada Test Site	19.6	0	0
Southeast	2	Nevada Test Site	58.8	0	0
Southeast	3	Nevada Test Site	117.8	0	0
Southeast	4	Nevada Test Site	137.5	0	0
Southeast	5	Nevada Test Site	176.2	0	0
East-Southeast	1	Nevada Test Site	19.6	0	0
East-Southeast	2	Nevada Test Site	58.8	0	0
East-Southeast	3	Nevada Test Site	117.8	0	0
East-Southeast	4	Nevada Test Site	137.5	0	0
East-Southeast	5	Nevada Test Site	176.2	0	0
East	1	Nevada Test Site	19.6	0	0
East	2	Nevada Test Site	58.8	0	0
East	3	Nevada Test Site	110.6	0	0
East	3	Nye County	7.2	0.69	5
East	4	Nevada Test Site	33.6	0	0
East	4	Nye County	103.9	0.69	72
East	5	Lincoln County	9.6	0.36	3
East	5	Nevada Test Site	48.0	0	0
East	5	Nye County	118.6	0.69	82
East-Northeast	1	Nevada Test Site	19.6	0	0
East-Northeast	2	Nevada Test Site	58.8	0	0
East-Northeast	3	Nye County	38.4	0.69	26
East-Northeast	3	Nevada Test Site	79.4	0	0
East-Northeast	4	Nye County	137.5	0.69	95

Table 11

Tonopah Rural Populations by Sector and Ring (Concluded)

Sector	Ring	Division	Partial Area (sq mi)	Population Density (per sq mi)	Rural Population
East-Northeast	5	Lincoln County	2.4	0.36	1
East-Northeast	5	Nye County	173.8	0.69	120
Northeast	1	Nevada Test Site	19.6	0	0
Northeast	2	Nye County	4.8	0.69	3
Northeast	2	Nevada Test Site	54.0	0	0
Northeast	3	Nye County	26.4	0.69	18
Northeast	3	Nevada Test Site	91.4	0	0
Northeast	4	Nevada Test Site	2.4	0	0
Northeast	4	Nye County	135.1	0.69	93
Northeast	5	Nye County	176.2	0.69	122
North-Northeast	1	Nevada Test Site	19.6	0	0
North-Northeast	2	Nevada Test Site	7.2	0	0
North-Northeast	2	Nye County	51.6	0.69	36
North-Northeast	3	Nevada Test Site	9.6	0	0
North-Northeast	3	Nye County	108.2	0.69	75
North-Northeast	4	Nye County	137.5	0.69	95
North-Northeast	5	Nye County	176.2	0.69	122
				Total Rural Population =	2532
				Total Urban Population =	4339
				Total 80 km Radius Population =	6871

Table 12

Tonopah Beef Cattle by Sector and Ring

Sector	Ring	Division	Partial Area (sq mi)	Beef Cattle Density (per sq mi)	Beef Cattle Population
North	1	Nevada Test Site	19.6	0.0	0.0
North	2	Nye County	58.8	0.959	56.4
North	3	Nye County	117.8	0.959	113.0
North	4	Nye County	137.5	0.959	131.9
North	5	Nye County	176.2	0.959	168.9
North-Northwest	1	Nevada Test Site	19.6	0.0	0.0
North-Northwest	2	Nevada Test Site	4.8	0.0	0.0
North-Northwest	2	Nye County	54.0	0.959	51.8
North-Northwest	3	Nye County	117.8	0.959	113.0
North-Northwest	4	Nye County	137.5	0.959	131.9
North-Northwest	5	Nye County	176.2	0.959	168.9
Northwest	1	Nevada Test Site	19.6	0.0	0.0
Northwest	2	Nevada Test Site	24.0	0.0	0.0
Northwest	2	Nye County	34.8	0.959	33.4
Northwest	3	Esmeralda County	31.2	1.55	48.4
Northwest	3	Nye County	86.6	0.959	83.1
Northwest	4	Nye County	52.8	0.959	50.6
Northwest	4	Esmeralda County	84.7	1.55	131.3
Northwest	5	Nye County	72.0	0.959	69.0
Northwest	5	Esmeralda County	104.2	1.55	161.4
West-Northwest	1	Nevada Test Site	19.6	0.0	0.0
West-Northwest	2	Nevada Test Site	24.0	0.0	0.0
West-Northwest	2	Esmeralda County	2.4	1.55	3.7
West-Northwest	2	Nye County	32.4	0.959	31.1
West-Northwest	3	Nye County	7.2	0.959	6.9
West-Northwest	3	Esmeralda County	110.6	1.55	171.5
West-Northwest	4	Esmeralda County	137.5	1.55	213.2
West-Northwest	5	Esmeralda County	176.2	1.55	273.0
West	1	Nevada Test Site	19.6	0.0	0.0
West	2	Nevada Test Site	16.8	0.0	0.0
West	2	Esmeralda County	7.2	1.55	11.2
West	2	Nye County	34.8	0.959	33.4
West	3	Esmeralda County	117.8	1.55	182.7
West	4	Esmeralda County	137.5	1.55	213.2
West	5	Esmeralda County	176.2	1.55	273.0
West-Southwest	1	Nevada Test Site	19.6	0.0	0.0
West-Southwest	2	Nevada Test Site	19.2	0.0	0.0
West-Southwest	2	Esmeralda County	2.4	1.55	3.7
West-Southwest	2	Nye County	37.2	0.959	35.7
West-Southwest	3	Esmeralda County	117.8	1.55	182.7
West-Southwest	4	Esmeralda County	137.5	1.55	213.2
West-Southwest	5	Esmeralda County	176.2	1.55	273.0
Southwest	1	Nevada Test Site	19.6	0.0	0.0

Table 12

Tonopah Beef Cattle by Sector and Ring (Continued)

Sector	Ring	Division	Partial Area (sq mi)	Beef Cattle Density (per sq mi)	Beef Cattle Population
Southwest	2	Nye County	9.6	0.959	9.2
Southwest	2	Nevada Test Site	49.2	0.0	0.0
Southwest	3	Nevada Test Site	16.8	0.0	0.0
Southwest	3	Esmeralda County	101.0	1.55	156.6
Southwest	4	Esmeralda County	132.7	1.55	205.7
Southwest	4	Nye County	4.8	0.959	4.6
Southwest	5	Esmeralda County	176.2	1.55	273.0
South-Southwest	1	Nevada Test Site	19.6	0.0	0.0
South-Southwest	2	Nevada Test Site	58.8	0.0	0.0
South-Southwest	3	Nye County	9.6	0.959	9.2
South-Southwest	3	Nevada Test Site	108.2	0.0	0.0
South-Southwest	4	Nevada Test Site	14.4	0.0	0.0
South-Southwest	4	Esmeralda County	24.0	1.55	37.2
South-Southwest	4	Nye County	99.1	0.959	95.1
South-Southwest	5	Esmeralda County	91.2	1.55	141.4
South-Southwest	5	Nye County	85.0	0.959	81.5
South	1	Nevada Test Site	19.6	0.0	0.0
South	2	Nevada Test Site	58.8	0.0	0.0
South	3	Nevada Test Site	117.8	0.0	0.0
South	4	Nye County	16.8	0.959	16.1
South	4	Nevada Test Site	120.7	0.0	0.0
South	5	Nevada Test Site	31.2	0.0	0.0
South	5	Nye County	145.0	0.959	139.0
South-Southeast	1	Nevada Test Site	19.6	0.0	0.0
South-Southeast	2	Nevada Test Site	58.8	0.0	0.0
South-Southeast	3	Nevada Test Site	117.8	0.0	0.0
South-Southeast	4	Nevada Test Site	137.5	0.0	0.0
South-Southeast	5	Nevada Test Site	171.4	0.0	0.0
South-Southeast	5	Nye County	4.8	0.959	4.6
Southeast	1	Nevada Test Site	19.6	0.0	0.0
Southeast	2	Nevada Test Site	58.8	0.0	0.0
Southeast	3	Nevada Test Site	117.8	0.0	0.0
Southeast	4	Nevada Test Site	137.5	0.0	0.0
Southeast	5	Nevada Test Site	176.2	0.0	0.0
East-Southeast	1	Nevada Test Site	19.6	0.0	0.0
East-Southeast	2	Nevada Test Site	58.8	0.0	0.0
East-Southeast	3	Nevada Test Site	117.8	0.0	0.0
East-Southeast	4	Nevada Test Site	137.5	0.0	0.0
East-Southeast	5	Nevada Test Site	176.2	0.0	0.0
East	1	Nevada Test Site	19.6	0.0	0.0
East	2	Nevada Test Site	58.8	0.0	0.0
East	3	Nevada Test Site	110.6	0.0	0.0
East	3	Nye County	7.2	0.959	6.9

Table 12

Tonopah Beef Cattle by Sector and Ring (Continued)

Sector	Ring	Division	Partial Area (sq mi)	Beef Cattle Density (per sq mi)	Beef Cattle Population
East	4	Nevada Test Site	33.6	0.0	0.0
East	4	Nye County	103.9	0.959	99.7
East	5	Lincoln County	9.6	0.866	8.3
East	5	Nevada Test Site	48.0	0.0	0.0
East	5	Nye County	118.6	0.959	113.7
East-Northeast	1	Nevada Test Site	19.6	0.0	0.0
East-Northeast	2	Nevada Test Site	58.8	0.0	0.0
East-Northeast	3	Nye County	38.4	0.959	36.8
East-Northeast	3	Nevada Test Site	79.4	0.0	0.0
East-Northeast	4	Nye County	137.5	0.959	131.9
East-Northeast	5	Lincoln County	2.4	0.866	2.1
East-Northeast	5	Nye County	173.8	0.959	166.6
Northeast	1	Nevada Test Site	19.6	0.0	0.0
Northeast	2	Nye County	4.8	0.959	4.6
Northeast	2	Nevada Test Site	54.0	0.0	0.0
Northeast	3	Nye County	26.4	0.959	25.3
Northeast	3	Nevada Test Site	91.4	0.0	0.0
Northeast	4	Nevada Test Site	2.4	0.0	0.0
Northeast	4	Nye County	135.1	0.959	129.6
Northeast	5	Nye County	176.2	0.959	168.9
North-Northeast	1	Nevada Test Site	19.6	0.0	0.0
North-Northeast	2	Nevada Test Site	7.2	0.0	0.0
North-Northeast	2	Nye County	51.6	0.959	49.5
North-Northeast	3	Nevada Test Site	9.6	0.0	0.0
North-Northeast	3	Nye County	108.2	0.959	103.8
North-Northeast	4	Nye County	137.5	0.959	131.9
North-Northeast	5	Nye County	176.2	0.959	168.9

Total 50 mi Radius Rural Beef Cattle Population =	6,156
Beef Cattle Density for 50 Mile Radius (1/sq. mi.) =	0.8
Beef Cattle Density for 50 Mile Radius (1/sq. km.) =	0.31

Table 13

Tonopah Dairy Cattle by Sector and Ring

Sector	Ring	Division	Partial Area (sq mi)	Dairy Cattle Density (per sq mi)	Dairy Cattle Population
North	1	Nevada Test Site	19.6	0.0	0.0
North	2	Nye County	58.8	0.0019	0.1
North	3	Nye County	117.8	0.0019	0.2
North	4	Nye County	137.5	0.0019	0.3
North	5	Nye County	176.2	0.0019	0.3
North-Northwest	1	Nevada Test Site	19.6	0.0	0.0
North-Northwest	2	Nevada Test Site	4.8	0.0	0.0
North-Northwest	2	Nye County	54.0	0.0019	0.1
North-Northwest	3	Nye County	117.8	0.0019	0.2
North-Northwest	4	Nye County	137.5	0.0019	0.3
North-Northwest	5	Nye County	176.2	0.0019	0.3
Northwest	1	Nevada Test Site	19.6	0.0	0.0
Northwest	2	Nevada Test Site	24.0	0.0	0.0
Northwest	2	Nye County	34.8	0.0019	0.1
Northwest	3	Esmeralda County	31.2	0.0	0.0
Northwest	3	Nye County	86.6	0.0019	0.2
Northwest	4	Nye County	52.8	0.0019	0.1
Northwest	4	Esmeralda County	84.7	0.0	0.0
Northwest	5	Nye County	72.0	0.0019	0.1
Northwest	5	Esmeralda County	104.2	0.0	0.0
West-Northwest	1	Nevada Test Site	19.6	0.0	0.0
West-Northwest	2	Nevada Test Site	24.0	0.0	0.0
West-Northwest	2	Esmeralda County	2.4	0.0	0.0
West-Northwest	2	Nye County	32.4	0.0019	0.1
West-Northwest	3	Nye County	7.2	0.0019	0.0
West-Northwest	3	Esmeralda County	110.6	0.0	0.0
West-Northwest	4	Esmeralda County	137.5	0.0	0.0
West-Northwest	5	Esmeralda County	176.2	0.0	0.0
West	1	Nevada Test Site	19.6	0.0	0.0
West	2	Nevada Test Site	16.8	0.0	0.0
West	2	Esmeralda County	7.2	0.0	0.0
West	2	Nye County	34.8	0.0019	0.1
West	3	Esmeralda County	117.8	0.0	0.0
West	4	Esmeralda County	137.5	0.0	0.0
West	5	Esmeralda County	176.2	0.0	0.0
West-Southwest	1	Nevada Test Site	19.6	0.0	0.0
West-Southwest	2	Nevada Test Site	19.2	0.0	0.0
West-Southwest	2	Esmeralda County	2.4	0.0	0.0
West-Southwest	2	Nye County	37.2	0.0019	0.1
West-Southwest	3	Esmeralda County	117.8	0.0	0.0
West-Southwest	4	Esmeralda County	137.5	0.0	0.0
West-Southwest	5	Esmeralda County	176.2	0.0	0.0
Southwest	1	Nevada Test Site	19.6	0.0	0.0

Table 13

Tonopah Dairy Cattle by Sector and Ring (Continued)

Sector	Ring	Division	Partial Area (sq mi)	Dairy Cattle Density (per sq mi)	Dairy Cattle Population
Southwest	2	Nye County	9.6	0.0019	0.0
Southwest	2	Nevada Test Site	49.2	0.0	0.0
Southwest	3	Nevada Test Site	16.8	0.0	0.0
Southwest	3	Esmeralda County	101.0	0.0	0.0
Southwest	4	Esmeralda County	132.7	0.0	0.0
Southwest	4	Nye County	4.8	0.0019	0.0
Southwest	5	Esmeralda County	176.2	0.0	0.0
South-Southwest	1	Nevada Test Site	19.6	0.0	0.0
South-Southwest	2	Nevada Test Site	58.8	0.0	0.0
South-Southwest	3	Nye County	9.6	0.0019	0.0
South-Southwest	3	Nevada Test Site	108.2	0.0	0.0
South-Southwest	4	Nevada Test Site	14.4	0.0	0.0
South-Southwest	4	Esmeralda County	24.0	0.0	0.0
South-Southwest	4	Nye County	99.1	0.0019	0.2
South-Southwest	5	Esmeralda County	91.2	0.0	0.0
South-Southwest	5	Nye County	85.0	0.0019	0.2
South	1	Nevada Test Site	19.6	0.0	0.0
South	2	Nevada Test Site	58.8	0.0	0.0
South	3	Nevada Test Site	117.8	0.0	0.0
South	4	Nye County	16.8	0.0019	0.0
South	4	Nevada Test Site	120.7	0.0	0.0
South	5	Nevada Test Site	31.2	0.0	0.0
South	5	Nye County	145.0	0.0019	0.3
South-Southeast	1	Nevada Test Site	19.6	0.0	0.0
South-Southeast	2	Nevada Test Site	58.8	0.0	0.0
South-Southeast	3	Nevada Test Site	117.8	0.0	0.0
South-Southeast	4	Nevada Test Site	137.5	0.0	0.0
South-Southeast	5	Nevada Test Site	171.4	0.0	0.0
South-Southeast	5	Nye County	4.8	0.0019	0.0
Southeast	1	Nevada Test Site	19.6	0.0	0.0
Southeast	2	Nevada Test Site	58.8	0.0	0.0
Southeast	3	Nevada Test Site	117.8	0.0	0.0
Southeast	4	Nevada Test Site	137.5	0.0	0.0
Southeast	5	Nevada Test Site	176.2	0.0	0.0
East-Southeast	1	Nevada Test Site	19.6	0.0	0.0
East-Southeast	2	Nevada Test Site	58.8	0.0	0.0
East-Southeast	3	Nevada Test Site	117.8	0.0	0.0
East-Southeast	4	Nevada Test Site	137.5	0.0	0.0
East-Southeast	5	Nevada Test Site	176.2	0.0	0.0
East	1	Nevada Test Site	19.6	0.0	0.0
East	2	Nevada Test Site	58.8	0.0	0.0
East	3	Nevada Test Site	110.6	0.0	0.0
East	3	Nye County	7.2	0.0019	0.0

Table 13

Tonopah Dairy Cattle by Sector and Ring (Concluded)

Sector	Ring	Division	Partial Area (sq mi)	Dairy Cattle Density (per sq mi)	Dairy Cattle Population
East	4	Nevada Test Site	33.6	0.0	0.0
East	4	Nye County	103.9	0.0019	0.2
East	5	Lincoln County	9.6	0.00066	0.0
East	5	Nevada Test Site	48.0	0.0	0.0
East	5	Nye County	118.6	0.0019	0.2
East-Northeast	1	Nevada Test Site	19.6	0.0	0.0
East-Northeast	2	Nevada Test Site	58.8	0.0	0.0
East-Northeast	3	Nye County	38.4	0.0019	0.1
East-Northeast	3	Nevada Test Site	79.4	0.0	0.0
East-Northeast	4	Nye County	137.5	0.0019	0.3
East-Northeast	5	Lincoln County	2.4	0.00066	0.0
East-Northeast	5	Nye County	173.8	0.0019	0.3
Northeast	1	Nevada Test Site	19.6	0.0	0.0
Northeast	2	Nye County	4.8	0.0019	0.0
Northeast	2	Nevada Test Site	54.0	0.0	0.0
Northeast	3	Nye County	26.4	0.0019	0.1
Northeast	3	Nevada Test Site	91.4	0.0	0.0
Northeast	4	Nevada Test Site	2.4	0.0	0.0
Northeast	4	Nye County	135.1	0.0019	0.3
Northeast	5	Nye County	176.2	0.0019	0.3
North-Northeast	1	Nevada Test Site	19.6	0.0	0.0
North-Northeast	2	Nevada Test Site	7.2	0.0	0.0
North-Northeast	2	Nye County	51.6	0.0019	0.1
North-Northeast	3	Nevada Test Site	9.6	0.0	0.0
North-Northeast	3	Nye County	108.2	0.0019	0.2
North-Northeast	4	Nye County	137.5	0.0019	0.3
North-Northeast	5	Nye County	176.2	0.0019	0.3

Total 50 mi Radius Rural Dairy Cattle Population =	6
Dairy Cattle Density for 50 Mile Radius (1/sq. mi.) =	7.5E-04
Dairy Cattle Density for 50 Mile Radius (1/sq. km.) =	2.9E-04

Table 14

Tonopah Food Crops by Sector and Ring

Sector	Ring	Division	Partial Area (sq mi)	Food Crop Density (per sq mi)	Food Crop Population
North	1	Nevada Test Site	19.6	0.0	0.0
North	2	Nye County	58.8	0.793	46.6
North	3	Nye County	117.8	0.793	93.4
North	4	Nye County	137.5	0.793	109.1
North	5	Nye County	176.2	0.793	139.7
North-Northwest	1	Nevada Test Site	19.6	0.0	0.0
North-Northwest	2	Nevada Test Site	4.8	0.0	0.0
North-Northwest	2	Nye County	54.0	0.793	42.8
North-Northwest	3	Nye County	117.8	0.793	93.4
North-Northwest	4	Nye County	137.5	0.793	109.1
North-Northwest	5	Nye County	176.2	0.793	139.7
Northwest	1	Nevada Test Site	19.6	0.0	0.0
Northwest	2	Nevada Test Site	24.0	0.0	0.0
Northwest	2	Nye County	34.8	0.793	27.6
Northwest	3	Esmeralda County	31.2	2.74	85.5
Northwest	3	Nye County	86.6	0.793	68.7
Northwest	4	Nye County	52.8	0.793	41.9
Northwest	4	Esmeralda County	84.7	2.74	232.1
Northwest	5	Nye County	72.0	0.793	57.1
Northwest	5	Esmeralda County	104.2	2.74	285.4
West-Northwest	1	Nevada Test Site	19.6	0.0	0.0
West-Northwest	2	Nevada Test Site	24.0	0.0	0.0
West-Northwest	2	Esmeralda County	2.4	2.74	6.6
West-Northwest	2	Nye County	32.4	0.793	25.7
West-Northwest	3	Nye County	7.2	0.793	5.7
West-Northwest	3	Esmeralda County	110.6	2.74	303.2
West-Northwest	4	Esmeralda County	137.5	2.74	376.8
West-Northwest	5	Esmeralda County	176.2	2.74	482.7
West	1	Nevada Test Site	19.6	0.0	0.0
West	2	Nevada Test Site	16.8	0.0	0.0
West	2	Esmeralda County	7.2	2.74	19.7
West	2	Nye County	34.8	0.793	27.6
West	3	Esmeralda County	117.8	2.74	322.9
West	4	Esmeralda County	137.5	2.74	376.8
West	5	Esmeralda County	176.2	2.74	482.7
West-Southwest	1	Nevada Test Site	19.6	0.0	0.0
West-Southwest	2	Nevada Test Site	19.2	0.0	0.0
West-Southwest	2	Esmeralda County	2.4	2.74	6.6
West-Southwest	2	Nye County	37.2	0.793	29.5
West-Southwest	3	Esmeralda County	117.8	2.74	322.9
West-Southwest	4	Esmeralda County	137.5	2.74	376.8
West-Southwest	5	Esmeralda County	176.2	2.74	482.7
Southwest	1	Nevada Test Site	19.6	0.0	0.0

Table 14

Tonopah Food Crops by Sector and Ring
(Continued)

Sector	Ring	Division	Partial Area (sq mi)	Food Crop Density (per sq mi)	Food Crop Population
Southwest	2	Nye County	9.6	0.793	7.6
Southwest	2	Nevada Test Site	49.2	0.0	0.0
Southwest	3	Nevada Test Site	16.8	0.0	0.0
Southwest	3	Esmeralda County	101.0	2.74	276.8
Southwest	4	Esmeralda County	132.7	2.74	363.7
Southwest	4	Nye County	4.8	0.793	3.8
Southwest	5	Esmeralda County	176.2	2.74	482.7
South-Southwest	1	Nevada Test Site	19.6	0.0	0.0
South-Southwest	2	Nevada Test Site	58.8	0.0	0.0
South-Southwest	3	Nye County	9.6	0.793	7.6
South-Southwest	3	Nevada Test Site	108.2	0.0	0.0
South-Southwest	4	Nevada Test Site	14.4	0.0	0.0
South-Southwest	4	Esmeralda County	24.0	2.74	65.8
South-Southwest	4	Nye County	99.1	0.793	78.6
South-Southwest	5	Esmeralda County	91.2	2.74	249.9
South-Southwest	5	Nye County	85.0	0.793	67.4
South	1	Nevada Test Site	19.6	0.0	0.0
South	2	Nevada Test Site	58.8	0.0	0.0
South	3	Nevada Test Site	117.8	0.0	0.0
South	4	Nye County	16.8	0.793	13.3
South	4	Nevada Test Site	120.7	0.0	0.0
South	5	Nevada Test Site	31.2	0.0	0.0
South	5	Nye County	145.0	0.793	115.0
South-Southeast	1	Nevada Test Site	19.6	0.0	0.0
South-Southeast	2	Nevada Test Site	58.8	0.0	0.0
South-Southeast	3	Nevada Test Site	117.8	0.0	0.0
South-Southeast	4	Nevada Test Site	137.5	0.0	0.0
South-Southeast	5	Nevada Test Site	171.4	0.0	0.0
South-Southeast	5	Nye County	4.8	0.793	3.8
Southeast	1	Nevada Test Site	19.6	0.0	0.0
Southeast	2	Nevada Test Site	58.8	0.0	0.0
Southeast	3	Nevada Test Site	117.8	0.0	0.0
Southeast	4	Nevada Test Site	137.5	0.0	0.0
Southeast	5	Nevada Test Site	176.2	0.0	0.0
East-Southeast	1	Nevada Test Site	19.6	0.0	0.0
East-Southeast	2	Nevada Test Site	58.8	0.0	0.0
East-Southeast	3	Nevada Test Site	117.8	0.0	0.0
East-Southeast	4	Nevada Test Site	137.5	0.0	0.0
East-Southeast	5	Nevada Test Site	176.2	0.0	0.0
East	1	Nevada Test Site	19.6	0.0	0.0
East	2	Nevada Test Site	58.8	0.0	0.0
East	3	Nevada Test Site	110.6	0.0	0.0

Table 14

Tonopah Food Crops by Sector and Ring (Concluded)

Sector	Ring	Division	Partial Area (sq mi)	Food Crop Density (per sq mi)	Food Crop Population
East	3	Nye County	7.2	0.793	5.7
East	4	Nevada Test Site	33.6	0.0	0.0
East	4	Nye County	103.9	0.793	82.4
East	5	Lincoln County	9.6	0.10	1.0
East	5	Nevada Test Site	48.0	0.0	0.0
East	5	Nye County	118.6	0.793	94.0
East-Northeast	1	Nevada Test Site	19.6	0.0	0.0
East-Northeast	2	Nevada Test Site	58.8	0.0	0.0
East-Northeast	3	Nye County	38.4	0.793	30.5
East-Northeast	3	Nevada Test Site	79.4	0.0	0.0
East-Northeast	4	Nye County	137.5	0.793	109.1
East-Northeast	5	Lincoln County	2.4	0.10	0.2
East-Northeast	5	Nye County	173.8	0.793	137.8
Northeast	1	Nevada Test Site	19.6	0.0	0.0
Northeast	2	Nye County	4.8	0.793	3.8
Northeast	2	Nevada Test Site	54.0	0.0	0.0
Northeast	3	Nye County	26.4	0.793	20.9
Northeast	3	Nevada Test Site	91.4	0.0	0.0
Northeast	4	Nevada Test Site	2.4	0.0	0.0
Northeast	4	Nye County	135.1	0.793	107.2
Northeast	5	Nye County	176.2	0.793	139.7
North-Northeast	1	Nevada Test Site	19.6	0.0	0.0
North-Northeast	2	Nevada Test Site	7.2	0.0	0.0
North-Northeast	2	Nye County	51.6	0.793	40.9
North-Northeast	3	Nevada Test Site	9.6	0.0	0.0
North-Northeast	3	Nye County	108.2	0.793	85.8
North-Northeast	4	Nye County	137.5	0.793	109.1
North-Northeast	5	Nye County	176.2	0.793	139.7

Total 50 Mile Radius Food Crops Area (acres) =	8,065
Total 50 Mile Radius Food Crops Area (sq. miles) =	12.6
Land Fraction Cultivated for Food Crops =	1.5E-03

6.1.1 Area Weighted Soil Activity Concentrations

The purpose of the 1977 aerial survey was to determine the surficial distribution of the material dispersed during the three tests (EG&G 1979). The results of the aerial survey were presented as isopleth maps of soil activity due to Am-241, Pu-239, and Pu-240. Up to thirteen isopleths were reported for each Clean Slate site. Each isopleth represents a discrete range of radionuclide concentrations. The equipment used to determine the surficial distribution of contaminants was calibrated specifically for each surveyed dispersal test site.

Based on the isopleth maps, the area weighted activity concentrations were determined for each Clean Slate site. This was done by multiplying the fraction of the total contaminated area, represented by each isopleth, by its representative activity concentration. These values were then summed for each dispersal test site. The area weighted soil activity concentration for each Clean Slate site was calculated using the following equation:

$$C_v = \sum_{0}^{n} \frac{A_i \ C_i}{A_{TOT}}$$

(1)

Where:
C_V = weighted mean soil activity (pCi/g),
n = total number of isopleths in the test area,
A_i = area of isopleth i (m^2),
C_i = activity of soil in isopleth i (pCi/g), and
A_{TOT} = total area of the test area (m^2).

The Clean Slate sites have the appearance of elongated rectangles. The CAP88-PC code, however, only allows for circular area source terms. For large receptor location distances (assumed to be greater than 15 km which is approximately 5 times the maximum Clean Slate dimension), the Clean Slate sites can be combined and assumed to be a single circular area. However, at shorter distances, this assumption cannot be applied because a significant amount of error could result in the computed receptor doses. As a result, for the computation of "near" (on-site) receptor doses, each Clean Slate site was sub-divided into two component areas. Each of these sub-divisions approximates a circular configuration allowing it to be appropriately utilized by the CAP88-PC code for the purpose of calculating nearby receptor doses. Each sub-division was modeled as an independent source possessing its own unique distances and directions from its geographic center to receptor locations. Since two of the four on-site receptors are within 15-km of the Clean Slate sites, this method was utilized for computing on-site receptor dose. All of the off-site receptor distances exceed 15-km. As a result, a single circular area source term was used for computing all off-site receptor doses.

The sub-divided Clean Slate sites are delineated as 1a, 1b, 2a, 2b, 3a, and 3b. The average surface contamination of the sub-divided sites, calculated using Equation (1), are presented in Tables 15-20.

Table 15

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	$7.7x10^5$	0.90	328	295
B	$1.9x10^4$	0.022	820	18
C	$1.4x10^4$	0.017	1220	21
D	$1.4x10^4$	0.017	1820	31
E	$1.8x10^4$	0.021	2640	55
F	$9.6x10^3$	0.011	3790	42
G	$6.2x10^3$	0.0073	5530	40
H	$3.7x10^3$	0.0043	8220	35
I	$1.9x10^3$	0.0023	12200	28
Total	$8.5x10^5$	1.00		$5.65x10^2$

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

Table 16

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	$9.6x10^5$	0.91	328	298
B	$5.1x10^4$	0.049	820	40
C	$4.1x10^4$	0.039	1220	48
D	$6.6x10^3$	0.0062	1820	11
E	$1.1x10^3$	0.0011	2640	3
Total	$1.1x10^6$	1.01		$4.0x10^2$

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

Table 17

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	$1.2x10^6$	0.80	256	205
B	$5.2x10^4$	0.035	641	22
C	$3.6x10^4$	0.024	950	23
D	$2.6x10^4$	0.017	1420	24
E	$2.6x10^4$	0.017	2050	35
F	$3.4x10^4$	0.023	3130	72
G	$3.9x10^4$	0.026	4300	112
H	$4.3x10^4$	0.029	6400	186
I	$2.0x10^4$	0.013	9440	123
J	$1.6x10^4$	0.011	14100	155
K	$1.9x10^4$	0.013	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 - Contamination from Pu-239, Pu-240, and Am-241.
2 - Calculated from data presented in EG&G, 1979.

Table 18

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	$6.4x10^5$	0.653	256	167
B	$9.8x10^4$	0.10	641	64
C	$1.4x10^5$	0.143	950	136
D	$5.9x10^4$	0.06	1420	85
E	$2.7x10^4$	0.028	2050	57
F	$9.7x10^3$	0.0099	3130	31
G	$1.0x10^4$	0.010	4300	43
Total	$9.8x10^5$	1.00		583

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

Table 19

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	$2.3x10^6$	0.41	220	90
B	$9.6x10^5$	0.17	552	94
C	$7.1x10^5$	0.13	818	106
D	$8.4x10^5$	0.15	1220	183
E	$4.6x10^5$	0.082	1780	146
F	$3.3x10^5$	0.059	2550	150
G	$9.3x10^2$	0.00017	3720	0.6
H	$9.6x10^3$	0.0017	5530	9
Total	$5.6x10^6$	1.00		779

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

Table 20

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	$4.4x10^6$	0.89	220	196
B	$2.9x10^5$	0.058	552	32
C	$1.6x10^5$	0.032	818	26
D	$9.5x10^4$	0.019	1220	23
Total	$5.0x10^6$	0.999		277

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

6.1.2 Correction for Elevated Surface Contamination

The 1977 aerial survey presented soil contamination results as the average concentration in the top 5-cm of soil and assumed that the activity decreased exponentially with depth (EG&G 1979). Since only the uppermost layer of the soil is potentially wind resuspendable, a correction factor was needed to estimate the surface contamination of the soil based on the existing information.

The generic exponential equation giving the soil contamination concentration as a function of depth below the surface is:

$$C = C_o \, e^{-(kz)}$$

(2)

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

The contamination concentration can be calculated from the integral of the above expression evaluated over the averaging distance as:

$$C_{AVE} = \frac{1}{D} \int_{o}^{D} C_o \, e^{-(kz)} \, dz$$

(3)

Where:
C_{AVE} = the average contamination concentration as a function of depth (pCi/g), and
D = the averaging depth (m).

When integrated and evaluated between the surface (z=0) and the averaging depth (z=D=5-cm), the above expression becomes:

$$C_{AVE} = C_o \frac{1 - e^{-(kD)}}{kD}$$

(4)

The exponential rate constant, k, can be found from Equation (2) by imposing the condition that 99% of the contamination exists above the 5-cm depth (i.e., D=0.05 m), as implied by the EG&G study. Substituting $C=0.01C_o$ and D=0.05 m (5-cm) into Equation (2) yields $k=92.1 \text{ m}^{-1}$. Substituting the value of k into Equation (4) together with the other known parameters, it was found that the surface contamination, C_o, is equal to 4.65 times the average through the 5-cm depth.

6.1.3 Correction for Unreported Radionuclides

The plutonium used in the original three dispersal tests was a weapons-grade mixture assumed to have originated from the Rocky Flats Plant in Golden, Colorado. Table 21 summarizes the radionuclide constituents found in fresh Rocky Flats weapons-grade plutonium (Rockwell International 1985). The aerial survey conducted in 1977 accounted for the Am-241, Pu-239, and Pu-240 present at that time. Pu-238, Pu-241, and Pu-242 were also present in the initial test material mixture but were not reported. As a result, a correction was required to account for the unreported radionuclides.

From Table 21, the Pu-238 contribution to the total initial mixture is 0.0050 Ci/g which is approximately 7% of the reported total activity (the combined contributions from Pu-239, Pu-240, and Am-241). The relative contribution from Pu-242 is very small compared to that of the other radionuclides present in the mixture and was, therefore, neglected. The dose contribution from Pu-241, a beta/gamma emitter, is relatively small compared to that of Pu-239, Pu-240, and Am-241 and was, thus, disregarded in the dose assessment. However, the ingrowth of Am-241 from Pu-241 decay is significant. Am-241 ingrowth is discussed in the next section.

6.1.4 Correction for Radioactive Decay and Ingrowth

Radionuclide concentrations were corrected for radionuclide decay and ingrowth. The age of the test material at the time of the plutonium dispersal tests are unknown. It was assumed that the test material was fresh at the time of the testing (i.e., decay time equals 0 years). Table 22 summarizes the 1963, 1977, and 1996 activity concentrations of the test material radionuclides. The concentrations presented for 1977 and 1996 were decay corrected with respect to 1963 using standard decay calculations. After decay correction, the Pu-238 activity concentration is approximately equal to 4.8% of the combined Pu-239, Pu-240, and Am-241 activity for 1996 (t=33 years). 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 4.9% was, therefore, added to the 1977 aerial survey aerial survey results to account for the Pu-238 contamination.

The 1977 study accounted for Am-241 that was present at that time. While no appreciable decay of Am-241 has occurred since the initial dispersal tests, Am-241 has been formed from the decay of Pu-241. The total Am-241 concentration is the summation of the Am-241 present in the initial test material (decay corrected) and the Am-241 ingrowth due to the radioactive decay of Pu-241. To correct for the additional activity associated with the ingrowth of Am-241, the combined activity of Pu-239, Pu-240, and Am-241 in 1996 was compared with that in 1977. The combined 1996 activity was determined to be 4.1% greater than that in 1977. Thus, a correction factor of 4.1% was applied to the 1977 aerial survey results to correct for the additional ingrowth of Am-241.

Table 21

Composition of Rocky Flats Plutonium[1]

Isopope	Half-Life (yr)	Mode of Decay	Activity[2] (Ci/g mixture)
Pu-238	87.8	alpha	0.00500
Pu-239	24,131	alpha	0.0576
Pu-240	6,569	alpha	0.0129
Pu-241[2]	14.4	beta/gamma	0.336
Pu-242	1.8×10^5	alpha	1.20×10^{-6}
Am-241	432	alpha	0.000600

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

Table 22

Radioactive Decay and Ingrowth

Isotope		Half-Life (yr)	Decay Constant (1/yr)	Activity (Ci/g)		
				1963[1]	1977[2]	1996[3]
Pu-238		87.8	7.9×10^{-3}	0.00500	0.00448	0.00385
Pu-239		24131	2.9×10^{-5}	0.0576	0.0576	0.0575
Pu-240		6569	1.0×10^{-4}	0.0129	0.0129	0.0129
Pu-241		14.4	4.8×10^{-2}	0.336	0.171	0.0686
Pu-242		3.8×10^5	1.8×10^{-6}	1.20×10^{-6}	1.20×10^{-6}	1.20×10^{-6}
Am-241	Original:	432	1.6×10^{-3}	0.000600	0.000587	0.000569
	Ingrowth:			0.0	0.00542	0.00862
Am-241 Total				0.000600	0.00601	0.00919
Total Pu-239, Pu-240, and Am-241				0.0711	0.0765	0.0796

1 - The assumed mixture at the time of the studies is new Rocky Flats grade plutonium.
2 - Represents the assumed mixture at the time of the EG&G study corrected for decay.
3 - Represents the assumed mixture during the 1996 calendar year.

6.1.5 Total Correction Factor

The previously discussed correction factors were needed in order to accurately use the 1977 aerial survey data for determining an annual diffuse release. The first correction factor converts the average contamination concentration through a depth of 5-cm to a surface contamination value that is potentially resuspendible. The surface conversion factor results in an increase of 465% which implies that the surface contamination is 4.65 times greater than the average through the 5-cm depth. The second correction factor results in a 4.8% increase which accounts for the lack of a Pu-238 component in the original contamination considered in the 1977 study. The third correction factor results in a 4.1% increase in the total activity due to the ingrowth of Am-241 during the 18 years since the 1977 aerial survey.

The cumulative correction factor is 5.07 (4.65 x 1.048 x 1.041). When the results of the aerial survey are multiplied by the cumulative correction factor, the product represents the Pu-238, Pu-239, Pu-240, and Am-241 activity concentration in the surface material in 1996.

6.1.6 Conversion from Volummetric to Area Contamination

The total corrected surface soil activity was expressed in units of picocuries per gram (pCi/g). For the resuspension model, the contamination must be converted to units of picocuries per square meter (pCi/m^2). This was accomplished using the following conversion equation:

$$C_A = C_{V,C} \, \rho L \, 10^6$$

(5)

Where:
C_A = surface soil activity per unit area (pCi/m^2),
$C_{V,C}$ = corrected mean soil activity concentration (pCi/g),
D = soil bulk density (g/cm^3),
L = skin depth (m), and
10^6 = conversion from cm^3 to m^3.

A measured soil bulk density of 0.9 g/cm^3 was assumed in the 1977 aerial survey (EG&G, 1979). This soil bulk density was specifically determined for the sandy, high-desert conditions at the study area (White et al., 1977). A skin depth of 2.0x10^{-4} m was used (NRC, 1983).

Table 23 summarizes the corrected/converted area surface contamination level for each of the Clean Slate sub-divisions.

Table 23

Corrected Surface Contamination Levels at the Clean Slate Sites

Site	Area (m^2)	EG&G study Contamination[1] (pCi/g)	Corrected Contamination (pCi/g)	Conversion to Area Contamin. (pCi/m^2)
Clean Slate 1a	$8.5x10^5$	570	2892	$5.2x10^5$
Clean Slate 1b	$1.1x10^6$	400	2030	$3.7x10^5$
Clean Slate 2a	$1.5x10^6$	1420	7206	$1.3x10^6$
Clean Stale 2b	$9.8x10^5$	583	2958	$5.3x10^5$
Clean Slate 3a	$5.6x10^6$	779	3953	$7.1x10^5$
Clean Slate 3b	$5.0x10^6$	277	1406	$2.5x10^5$

1 - Average contamination across site subdivision. Source: Tables 15-20

6.2 Wind Resuspension Model

The three large diffuse sources were considered as potential sources of inhalation exposure to radionuclide contaminated fugitive dust. Particulates that are 10 microns (μm) or less in diameter were considered potentially respirable and potentially dispersable. Small amounts of contaminated material can be released to the atmosphere as fugitive dust originating from near-surface transuranic contaminated soil through the action of wind pick-up and suspension. This phenomenon is known as wind resuspension.

The annual resuspended radionuclide release from each diffuse source was calculated using a wind-speed-dependent resuspension rate, the surface radionuclide contamination concentrations, as corrected, and the area of contamination. The annual release term for each Clean Slate sub-division was calculated as follows:

$$Q = S\, C_A\, A\, t$$

(6)

Where:
Q = annual release term (pCi/yr),
S = wind speed weighted resuspension rate (s^{-1}),
C_A = corrected surface-soil activity per unit area (pCi/m^2),
A = area of contamination (m^2), and
t = conversion from seconds to years = $3.1536x^{107}$ s/yr.
The area of contamination, A, is the area of surface contamination represented by the corrected surface soil activity, C_A. The annual release term, Q, is the total radionuclide activity (Pu-238,

Pu-239, Pu-240, and Am-241) that is resuspended into the atmosphere.

The resuspension rate (S) is weighted with respect to wind speed frequency. The weighted mean resuspension rate was determined by summing the products of the annual wind speed class frequency-of-occurrence (expressed as a percent) and the representative resuspension rate. The results of this calculation are presented in Table 24. The annual weighted mean resuspension rate was determined to be 1.5×10^{-9} s^{-1}. The wind speed class resuspension rates in Table 24 were derived from Figure 4 (DOE, 1984). The data used to generate Figure 4 were collected from studies conducted at a site similar to the TTR. The resuspension rates are for soil particles that range in size from 1 to 10 µm in diameter.

The Clean Slate source terms generated using Equation (6) are provided in Table 25.

6.3 Clean Slate Site Diffuse Source Terms

The potential releases from the Clean Slate sites occur as a result of the wind resuspension of soil particulates (fugitive dust) contaminated with plutonium and americium. A total annual release of 0.39 Ci/yr of contaminated material was calculated to occur from all three Clean Slate sites combined. The diffuse sources are assumed to be composed of particulates less than 10 µm diameter with the potential to disperse downwind. It is also assumed that all resuspended particulates are respirable resulting in a conservative estimate of the dose.

Table 25 summarizes the annual source term calculated for each Clean Slate site. This table also shows the radionuclide-specific source terms for each Clean Slate site. Radionuclide-specific source terms were derived by multiplying the radionuclide activity fractions (also shown in Table 25) with the overall source terms . From Table 25, Clean Slate 3a is shown to have the largest overall source term of 0.18 Ci/yr.

The development of the diffuse source terms using the wind resuspension model was found to be in agreement with the criteria specified in the EPA guidance document *Considerations in Developing and using Methods for Estimating Diffuse or Fugitive Air Emissions of Radionuclides at DOE Facilities* (EPA, 1994). The EPA guidance specifies a preference for direct measurement of the emissions directly at the source. Unfortunately, this method could not be utilized due to the vastness of the contaminated area and the variation in contaminant levels across the TTR. The EPA guidance, however, does allow for the computation of the diffuse source terms via historical and site characterization information if direct emissions measurements cannot be accomplished. As previously shown, these types of information were available and were utilized in the wind resuspension model to obtain the diffuse source terms shown in Table 25.

Table 24

Annual Weighted Mean Resuspension Rate Calculation

Wind Direction	Wind Speed Class (knots)	Resuspension Rate (1/s)	Wind Speed/Direction Frequency	Weighted Resuspension Rate
North	1-3	0.0E+00	1.3E-02	0.0E+00
North	4-6	1.5E-11	1.7E-02	2.6E-13
North	7-10	1.8E-10	2.0E-02	3.5E-12
North	11-16	1.6E-09	2.2E-02	3.6E-11
North	17-21	8.3E-09	1.2E-02	9.9E-11
North	>21	2.0E-08	5.4E-03	1.1E-10
North-Northwest	1-3	0.0E+00	1.6E-02	0.0E+00
North-Northwest	4-6	1.5E-11	3.2E-02	4.9E-13
North-Northwest	7-10	1.8E-10	3.1E-02	5.6E-12
North-Northwest	11-16	1.6E-09	2.1E-02	3.3E-11
North-Northwest	17-21	8.3E-09	8.3E-03	6.9E-11
North-Northwest	>21	2.0E-08	3.0E-03	5.9E-11
Northwest	1-3	0.0E+00	1.7E-02	0.0E+00
Northwest	4-6	1.5E-11	3.2E-02	4.7E-13
Northwest	7-10	1.8E-10	2.7E-02	4.9E-12
Northwest	11-16	1.6E-09	1.4E-02	2.2E-11
Northwest	17-21	8.3E-09	2.3E-03	1.9E-11
Northwest	>21	2.0E-08	2.2E-04	4.4E-12
West-Northwest	1-3	0.0E+00	1.4E-02	0.0E+00
West-Northwest	4-6	1.5E-11	1.7E-02	2.5E-13
West-Northwest	7-10	1.8E-10	2.5E-02	4.4E-12
West-Northwest	11-16	1.6E-09	7.0E-03	1.1E-11
West-Northwest	17-21	8.3E-09	5.6E-04	4.6E-12
West-Northwest	>21	2.0E-08	7.1E-05	1.4E-12
West	1-3	0.0E+00	1.2E-02	0.0E+00
West	4-6	1.5E-11	7.4E-03	1.1E-13
West	7-10	1.8E-10	8.6E-03	1.5E-12
West	11-16	1.6E-09	2.1E-03	3.3E-12
West	17-21	8.3E-09	3.7E-04	3.1E-12
West	>21	2.0E-08	1.1E-04	2.2E-12
West-Southwest	1-3	0.0E+00	1.0E-02	0.0E+00
West-Southwest	4-6	1.5E-11	4.9E-03	7.3E-14
West-Southwest	7-10	1.8E-10	1.7E-03	3.0E-13
West-Southwest	11-16	1.6E-09	6.1E-04	9.8E-13
West-Southwest	17-21	8.3E-09	2.0E-04	1.7E-12
West-Southwest	>21	2.0E-08	7.8E-05	1.6E-12
Southwest	1-3	0.0E+00	1.5E-02	0.0E+00
Southwest	4-6	1.5E-11	5.6E-03	8.3E-14
Southwest	7-10	1.8E-10	2.6E-03	4.6E-13
Southwest	11-16	1.6E-09	1.7E-03	2.8E-12
Southwest	17-21	8.3E-09	4.6E-04	3.8E-12

Table 24

Annual Weighted Mean Resuspension Rate Calculation (Continued)

Wind Direction	Wind Speed Class (knots)	Resuspension Rate (1/s)	Wind Speed/Direction Frequency	Weighted Resuspension Rate
Southwest	>21	2.0E-08	1.8E-04	3.6E-12
South-Southwest	1-3	0.0E+00	1.8E-02	0.0E+00
South-Southwest	4-6	1.5E-11	7.7E-03	1.2E-13
South-Southwest	7-10	1.8E-10	5.3E-03	9.5E-13
South-Southwest	11-16	1.6E-09	6.8E-03	1.1E-11
South-Southwest	17-21	8.3E-09	2.1E-03	1.8E-11
South-Southwest	>21	2.0E-08	1.0E-03	2.0E-11
South	1-3	0.0E+00	2.7E-02	0.0E+00
South	4-6	1.5E-11	1.4E-02	2.1E-13
South	7-10	1.8E-10	1.3E-02	2.4E-12
South	11-16	1.6E-09	1.2E-02	1.9E-11
South	17-21	8.3E-09	3.4E-03	2.8E-11
South	>21	2.0E-08	1.3E-03	2.7E-11
South-Southeast	1-3	0.0E+00	2.1E-02	0.0E+00
South-Southeast	4-6	1.5E-11	1.7E-02	2.5E-13
South-Southeast	7-10	1.8E-10	1.7E-02	3.1E-12
South-Southeast	11-16	1.6E-09	9.5E-03	1.5E-11
South-Southeast	17-21	8.3E-09	2.6E-03	2.1E-11
South-Southeast	>21	2.0E-08	1.1E-03	2.3E-11
Southeast	1-3	0.0E+00	2.2E-02	0.0E+00
Southeast	4-6	1.5E-11	2.6E-02	3.9E-13
Southeast	7-10	1.8E-10	2.9E-02	5.3E-12
Southeast	11-16	1.6E-09	2.0E-02	3.2E-11
Southeast	17-21	8.3E-09	8.8E-03	7.3E-11
Southeast	>21	2.0E-08	8.0E-03	1.6E-10
East-Southeast	1-3	0.0E+00	1.7E-02	0.0E+00
East-Southeast	4-6	1.5E-11	2.1E-02	3.1E-13
East-Southeast	7-10	1.8E-10	2.8E-02	5.0E-12
East-Southeast	11-16	1.6E-09	2.8E-02	4.5E-11
East-Southeast	17-21	8.3E-09	9.4E-03	7.8E-11
East-Southeast	>21	2.0E-08	5.4E-03	1.1E-10
East	1-3	0.0E+00	1.3E-02	0.0E+00
East	4-6	1.5E-11	1.2E-02	1.8E-13
East	7-10	1.8E-10	1.3E-02	2.4E-12
East	11-16	1.6E-09	1.1E-02	1.7E-11
East	17-21	8.3E-09	2.3E-03	1.9E-11
East	>21	2.0E-08	4.7E-04	9.4E-12
East-Northeast	1-3	0.0E+00	8.8E-03	0.0E+00
East-Northeast	4-6	1.5E-11	6.6E-03	9.9E-14
East-Northeast	7-10	1.8E-10	5.8E-03	1.1E-12
East-Northeast	11-16	1.6E-09	2.2E-03	3.5E-12

Table 24

Annual Weighted Mean Resuspension Rate Calculation (Concluded)

Wind Direction	Wind Speed Class (knots)	Resuspension Rate (1/s)	Wind Speed/Direction Frequency	Weighted Resuspension Rate
East-Northeast	17-21	8.3E-09	3.9E-04	3.3E-12
East-Northeast	>21	2.0E-08	9.4E-05	1.9E-12
Northeast	1-3	0.0E+00	8.9E-03	0.0E+00
Northeast	4-6	1.5E-11	5.8E-03	8.8E-14
Northeast	7-10	1.8E-10	7.8E-03	1.4E-12
Northeast	11-16	1.6E-09	6.5E-03	1.0E-11
Northeast	17-21	8.3E-09	1.2E-03	1.0E-11
Northeast	>21	2.0E-08	2.5E-04	5.0E-12
North-Northeast	1-3	0.0E+00	8.9E-03	0.0E+00
North-Northeast	4-6	1.5E-11	7.5E-03	1.1E-13
North-Northeast	7-10	1.8E-10	1.4E-02	2.5E-12
North-Northeast	11-16	1.6E-09	2.1E-02	3.4E-11
North-Northeast	17-21	8.3E-09	8.3E-03	6.9E-11
North-Northeast	>21	2.0E-08	2.8E-03	5.7E-11
Annual Weighted Mean Resuspension Rate (1/s) =				1.5E-09

1 - Source: Figure 4.
2 - Source: Meteorological data for the TTR, Nevada (DOC, 1993).

Figure 4 Resuspension Rate vs Wind Speed

7.0 DOSE ASSESSMENT RESULTS

7.1 Individual Dose Assessment

Individual dose values were calculated for the four on-site receptors in Figure 2. The distance and wind sector values presented in Table 2 along with the radionuclide-specific source terms in Table 25 were input into the CAP88-PC code which computed the individual doses due to each Clean Slate site. The cumulative dose for each on-site receptor was obtained by summing the Clean Slate site-specific individual doses. Table 26 summarizes the Clean Slate site-specific and cumulative dose for each TTR on-site receptor. The cumulative dose values ranged from 0.72 mrem/yr at the Base Housing to 1.1 mrem/yr at the TTR Airport Area. The dose to each receptor results primarily from inhalation of Pu-239. The maximum dose is about a factor of nine below the NESHAP standard of 10.0 mrem/yr. The on-site receptor dose results calculated using the CAP88-PC code are presented in Appendix A.

Individual dose values were also calculated for the off-site receptors discussed in Section 2.1 using the CAP88-PC code. As was stated in Section 6, the dose was calculated using a single cumulative area source term (0.39 Ci) rather than separate source terms for each Clean Slate site. The "total" radionuclide-specific source terms presented in Table 25 were used in the CAP88-PC computations (the summation of these equalling 0.39 Ci). The off-site receptor dose results are presented in Table 27. The Tonopah Airport receptor was estimated to receive the highest annual off-site dose of 0.18 mrem. The CAP88-PC off-site receptor dose output are presented in Appendix B.

7.2 Population Dose Assessment

A regional population dose was calculated using the CAP88-PC code (CAP88-PC output is presented in Appendix C). The estimated residential population of 6,871 persons within a 50-mile (80-km) radius of the TTR (see Section 4) were placed into the CAP88-PC 16 sector, 5 ring grid for analysis. The population data were obtained from 1990 census results which are presented in Section 4. The source term used was 0.39 Ci/yr of transuranic contamination, and the dose calculations were performed using the methodology for computing off-site receptor doses. The population was conservatively assumed to obtain all of their food supply locally in the CAP88-PC computations. Using the 0.39 Ci/yr source term, the resulting population dose was calculated to be 0.86 person-rem/yr due primarily to the inhalation of Pu-239.

Table 25

Clean Slate Site-Specific Source Terms

Clean Slate Site	Radionuclide-Specific Source Terms (Ci/yr)				Overall Source Term (Ci/yr)
	Pu-238	Pu-239	Pu-240	Am-241	
Cs-1a	9.4×10^{-4}	1.4×10^{-2}	3.1×10^{-3}	2.2×10^{-3}	2.0×10^{-2}
Cs-1b	8.5×10^{-4}	1.3×10^{-2}	2.8×10^{-3}	2.0×10^{-3}	1.8×10^{-2}
Cs-2a	4.1×10^{-3}	6.1×10^{-2}	1.4×10^{-2}	9.8×10^{-3}	8.9×10^{-2}
Cs-2b	1.1×10^{-3}	1.6×10^{-2}	3.7×10^{-3}	2.6×10^{-3}	2.4×10^{-2}
Cs-3a	8.4×10^{-3}	1.3×10^{-1}	2.8×10^{-2}	2.0×10^{-2}	1.8×10^{-1}
Cs-3b	2.7×10^{-3}	4.0×10^{-2}	8.9×10^{-3}	6.4×10^{-3}	5.8×10^{-2}
Total	1.8×10^{-2}	2.7×10^{-1}	6.0×10^{-2}	4.3×10^{-2}	3.9×10^{-1}
Activity Fraction	4.6×10^{-2}	6.9×10^{-1}	1.5×10^{-1}	1.1×10^{-1}	

Table 26

Individual Dose (mrem/yr) to TTR On-site Receptors

Receptor	CS-1a	CS-1b	CS-2a	CS-2b	CS-3a	CS-3b	Total
Base Housing	0.029	0.023	0.12	0.029	0.42	0.097	0.72
TTR Airport Area	0.046	0.036	0.16	0.038	0.67	0.15	1.1
South Perimeter	0.059	0.063	0.15	0.041	0.32	0.13	0.76
554th Range Squadron O&M Complex	0.026	0.025	0.32	0.094	0.37	0.15	0.99

Table 27

Dose to Off-Site Receptors

Receptor Location	Receptor Dose (mrem/yr)
Tonopah	0.14
Tonopah Municipal Airport	0.18
Goldfield	0.12
Warm Springs Ranch	0.039
East Nellis Air Force Base	0.074

8.0 NESHAP COMPLIANCE MONITORING

The information presented in this section was taken from the *National Emission Standard for Hazardous Air Pollutants (NESHAP) Monitoring Plan for the Tonopah Test Range* (SNL, 1995).

8.1 Air Monitoring Activities

Based on the dose assessment results, the EDE to the MEI (TTR Airport Area) was determined to be in excess of 0.1 mrem/yr but less than 10 mrem/yr. As a result, the fugitive source at the TTR requires continuous air monitoring according to the criteria specified in 40 CFR 61, Subpart H.

Due to the large size of the fugitive source (approximately 20 million square meters), monitoring of the source is not considered practical. An alternate method which involves the monitoring of air at the TTR Airport Area for a period of one year was used to demonstrate compliance with NESHAP. Using the collected air data, the EDE to the MEI can be calculated. The NESHAP Monitoring Plan for the TTR (SNL, 1995) was approved by EPA Region IX in 1995 and implementation was begun in 1996.

All samples collected at the TTR Airport Area will be analyzed for isotopic Pu and Am-241 by alpha spectroscopy. The Pu isotopic analysis includes: Pu-238, Pu-239, and Pu-240. For NESHAP compliance, the analysis of Pu-238 is not required due to its low contribution (< 10%) to the total EDE. However, since the isotopic Pu analysis includes Pu-238, the Pu-238 results has been included in all calculations and summaries.
The NESHAP air monitoring data will be compared to the values presented in Table 2 of 40 CFR 61 Appendix E. Compliance with the NESHAP standard is satisfied if the measured air concentration values are less than those presented in this table.

The EDE to the MEI will also be estimated from the air monitoring results using DOE and EPA exposure criteria (factors and equations) and dose conversion factors (DCFs) listed in Federal Guidance Report No. 11. The annual EDE for each radionuclide of concern will be summed to provide the total EDE to the MEI for the one year of continuous air monitoring for the radionuclides of concern. Future air monitoring requirements at TTR will be based on the results of the one year continuous air monitoring and use of Report No. 11.

The results of the one-year continuous air monitoring were not available when the NESHAP Annual Report for CY 1996 was being prepared. The results from the continuous monitoring will be summarized and provided to EPA as a separate document. The results will also be presented in the NESHAP Annual Report for 1997.

8.2 Other NESHAP Compliance Criteria

8.2.1 New or Modified Radiological Sources

During 1996, there were no new or modified radiological sources at SNL/NV.

8.2.2 NESHAP Subparts Q and T

During 1996, no radon emissions occurred from SNL/NV.

8.2.3 Unplanned Radiological Releases

During 1996, there were no unplanned or accidental radiological releases from SNL/NV.

9.0 CONCLUSION

No point-source radiological releases occurred from SNL/NV during 1996. Diffuse-source releases were calculated for the Clean Slate sites using a wind resuspension model and carefully selected supporting data. A cumulative annual release of 0.39 Ci/yr of transuranic contamination was calculated for all three Clean Slate sites. The diffuse sources were used to calculate a regional population dose of 0.86 person-rem/yr and a maximally exposed individual on-site dose of 1.1 mrem/yr at the TTR Airport Area. The MEI dose is about a factor of 9 below the applicable NESHAP standard of 10 mrem/yr. The primary pathway of exposure was through inhalation of contaminated dust. Pu-239 was responsible for the majority of the dose.

The differences in dose values between CY 1995 and CY 1996 are related to source radioactive decay, radionuclide ingrowth, and new Pasquill stability class data. Tonopah Airport 1989-1992 Pasquill stability class data was used because it matches the time period that the TTR meteorological data were collected. The new Pasquill stability class dataset was the major contributor to the dose differences between CY 1995 and CY 1996.

The CAP88-PC code was used for all dose calculations. The parameters and factors used in the CAP88-PC code are summarized in Table 28.

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 29 summarizes the key-components and references that were used in the diffuse source term derivation.

Table 28

CAP88-PC Modeling Parameters

Parameter	Exposure Scenario		
	Onsite	Offsite	Population
Run Information			
Run Type	Individual	Individual	Population
Distances	See Table 2	See Table 1 & Section 2.1	Not Applicable
Population File	Not Applicable	Not Applicable	See Appendix D and Tables 6 & 11
Meteorological Data			
Wind File[a]	TTR89-92.WND	TTR89-92.WND	TTR89-92.WND
Annual Precipitation[b]	12.5 cm/yr	12.5 cm/yr	12.5 cm/yr
Annual Ambient Temperature[b]	10°C	10°C	10°C
Height of Mixing Lid[c]	2,370 m	2,370 m	2,370 m
Source Data			
Source Type	Area	Area	Area
Number of Sources	1[d]	1	1
Source Height	0 m	0 m	0 m
Area	See Table 25[d]	1.5×10^{7} m^2	1.5×10^{7} m^2
Plume Rise	Zero	Zero	Zero
Agricultural Data			
Source	Imported	Regional	Regional
Beef Cattle Density	6.0×10^{-1} / km^2	6.0×10^{-1} / km^2	6.0×10^{-1} / km^2
Milk Cattle Density	2.0×10^{-3} / km^2	2.0×10^{-3} / km^2	2.0×10^{-3} / km^2
Land Fraction Cultivated for Vegetable Crops	1.1×10^{-4}	1.1×10^{-4}	1.1×10^{-4}
Radionuclide Data			
Radionuclide List	See Table 25[e]	See Table 25[f]	See Table 25[f]
Release Data	See Table 25[e]	See Table 25[f]	See Table 25[f]
Size Data	Pu-238 1 µm	Pu-238 1 µm	Pu-238 1 µm
	Pu-239 1 µm	Pu-239 1 µm	Pu-239 1 µm
	Pu-240 1 µm	Pu-240 1 µm	Pu-240 1 µm
	Am-241 1 µm	Am-241 1 µm	Am-241 1 µm
Class Data	Pu-238 Year	Pu-238 Year	Pu-238 Year
	Pu-239 Year	Pu-239 Year	Pu-239 Year
	Pu-240 Year	Pu-240 Year	Pu-240 Year
	Am-241 Week	Am-241 Week	Am-241 Week

[a] STAR file for TTR89-92.WND is presented in Appendix D.
[b] Reference: Schaeffer, 1969.
[c] Reference: Slade, 1968.
[d] Each Clean Slate subdivision was modeled as an independent source for the onsite exposure scenario.
[e] Clean Slate subdivision-specific radionuclide source terms were used for the onsite exposure scenario.
[f] Total radionuclide-specific source terms were used for the population and offsite exposure scenarios.

Table 29

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)	Culp and Kovacic, 1995 DOE, 1984
Wind Data	STAR Data for Tonopah Airport and theTTR DOC, 1993 and DOC, 1997
Soil Contamination	
Initial Data	EG&G, 1979
Correction for Pu-238	Rockwell, 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, 1979
Size of Contaminated Areas	EG&G, 1979, calculated from contour figures
Isotopic Composition of plutonium	Rockwell, 1985
Conversion from Volumetric to Areal Contamination	Skin depth given by NRC, 1983
NESHAP Receptor Locations	SNL/NV and SNL/NM
Dose Calculation	EPA, 1992 EPA, 1991

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