7.0 DOSE ASSESSMENT

The oversite for the Nevada Test Site (NTS) operations, conducted by the U.S. Environmental Protection Agency's (EPA's) Radiation and Indoor Environments National Laboratory in Las Vegas (R&IE-LV), measured no radiation exposures attributable to NTS operations during 1999. However, using onsite emission measurements and calculated resuspension data as input to the EPA's Clean Air Package 1988 (CAP88-PC) model, a potential effective dose equivalent (EDE) to the maximally exposed individual (MEI) was calculated to be 0.12 mrem (1.2×10^{-3} mSv) to a hypothetical resident at Springdale, Nevada, located 58 km (36 mi) west-northwest of Control Point 1 (CP-1) on the NTS. This is only 1.2 percent of the National Emission Standards for Hazardous Air Pollutants (NESHAP) regulatory limit of 10 mrem/yr for airborne radioactive emissions from the NTS. The calculated population dose (collective EDE) to the approximately 36,000 residents living within 80 km (50 mi) from each of the NTS airborne emission sources was 0.38 person-rem (3.8×10^{-3} person-Sv). Oversite data indicated an external exposure to the MEI of 143 mrem/yr (1.43 mSv/yr) from normal background radiation. A conservative EDE of 0.63 mrem/yr (6.3×10^{-4} mSv/yr to this individual by NTS pathways was also estimated from the summation of the above inhalation dose to the MEI, the estimated dose from the ingestion of milk (0.010 mrem/yr) and the EDE estimated from the ingestion of meat from the hunting of wild life (doves, rabbits, and deer) migrating offsite from a contaminated site on the NTS. This maximized dose estimate, excluding background, is less than 1 percent of the 100 mrem/yr dose limit for the general public.

The application of Biota Concentration Guides to the radionuclide inventories in NTS surface soils determined from past radiological surveys indicated that the radiation doses to terrestrial biota on the NTS are within limits recommended by the Biota Dose Assessment Committee sponsored by the U.S. Department of Energy (DOE). The concentrations of ^{90}Sr and ^{137}Cs were found to be the major contributors to the doses to terrestrial biota. The area suspected of contributing the highest biota dose is Area 10. Since the radionuclide content of the E Tunnel ponds sediment have not been characterized, a similar evaluation for the aquatic biota at this location could not be completed.

7.1 ESTIMATED DOSE FROM NTS ACTIVITIES

The potential radiation doses to offsite residents resulting from work activities on the NTS may be caused through the following pathways:

- Inhalation of airborne radioactivity from operational releases and resuspension of surface contamination.
- Ingestion of meat from migratory wild game animals which drank water and ate vegetation containing test-related radioactivity while residing on the NTS.
- Ingestion of milk from cows feeding from pasture on which radioactive fallout was deposited from past airborne releases of radioactivity at the NTS or from foreign nuclear tests.

- Ingestion of water contaminated by underground deposits of radioactivity created by past nuclear tests.

- Ingestion of locally grown food crops and meats in areas which received radioactive fallout from past nuclear test releases at the NTS and from world-wide fallout.

The dose assessment for 1999 excludes the last three pathways for the following reasons:

- In past reports and also indicated by the results for water samples reported in Chapter 5, no test-related radioactivity has migrated offsite in groundwater to cause a radiation dose to offsite residents.

- Due to recent budget cuts and reorganization, no sampling of milk, meat, and food crops was performed in 1999. No significant concentrations of test-related radioactivity are anticipated in these media; however, periodic sampling of milk and food crops is required by the Routine Radiological Environmental Monitoring Plan (RREMP) and will be done during the next calendar year. Based upon conclusions of the RREMP, sampling of wild game was chosen instead of locally produced meat.

In the past, two methods for estimating the EDE to offsite residents were used. The first method used effluent release estimates based upon onsite monitoring data or calculated resuspension of deposited radioactivity which were used as inputs to EPA's CAP88-PC computer model. The model then estimated the EDEs for all locations within a 80 km radius for each individual release point. The total EDE for each location was then determined by summing the contributions from all onsite sources during the year to determine compliance with the NESHAP limit of 10 mrem/yr EDE to the MEI in the offsite area. The second method used offsite monitoring data with documented assumptions and dose conversion factors to calculate the EDE from NTS emissions, naturally occurring ^{7}Be, and ^{85}Kr from worldwide sources. As past reports have shown the EDEs from ^{7}Be and ^{85}Kr to be insignificant (<0.001 mrem/yr) and ^{85}Kr is no longer monitored onsite due to no detectable emissions, the second method will only compare the EDEs calculated from measured concentrations of radioactivity by offsite monitoring with the EDEs determined from estimated NTS emissions. As in the past, the EDEs determined by both methods will be compared to offsite gamma exposures resulting from background radiation (from cosmic, terrestrial, and worldwide fallout radiations).

ESTIMATED DOSE USING OPERATIONAL RELEASES AND CALCULATED NTS EMISSIONS

Onsite source emission measurements, as provided by the DOE Nevada Operations Office, are listed in Chapter 4, Table 4.5, and include tritium and plutonium. These are estimates of releases made at the point of origin. Meteorological data collected by the Air Resources Laboratory, Special Operations and Research Division (ARL/SORD) were used to construct wind roses and stability arrays for the following areas: Mercury, Area 12, Area 20, Yucca Flat, and the Radioactive Waste Management Site in Area 5. A calculation of estimated dose from NTS emissions was performed using EPA's CAP88-PC model (DOE 1997c). The results of the model indicated that the hypothetical individual with the maximum calculated dose from airborne NTS radioactivity would reside at Springdale, Nevada, 58 km (36 mi) west-northwest of CP-1. The maximum dose to that individual could have been 0.12 mrem (1.2×10^{-3} mSv) (Grossman 2000). For comparison, data from the PIC monitoring network indicated an exposure of 143 mrem (1.43 mSv) from background gamma radiation occurring in that area. The population living within a radius of 80 km (50 mi) from the airborne

sources on the NTS was estimated to be 36,517 individuals, based on estimated population data. The collective population dose within 80 km (50 mi) from each of these sources was calculated to be 0.38 person-rem (3.8×10^{-3} person-Sv). Activity concentrations in air that would cause these calculated doses are much higher than actually detected by the offsite monitoring network. For example, most of the 0.12 mrem of the calculated EDE to the MEI is due to plutonium. The annual average plutonium concentration in air that would cause this EDE is 3.5×10^{-17} µCi/mL (1.3 µBq/m^3); this is about 13 times the annual average plutonium concentration in air (0.27×10^{-17} µCi/mL [0.1 µBq/m^3] [Chapter 4, Table 4.15]) measured at Beatty, Nevada, (nearest community). Table 7.1 summarizes the annual contributions to the EDEs due to 1999 NTS operations as calculated by use of CAP88-PC and the radionuclides listed in Chapter 4, Table 4.5.

Input data for the CAP88-PC model included meteorological data from ARL/SORD and effluent release data calculated from monitoring results and from resuspension estimates. These release data are known to be estimates, and the meteorological data are mesoscale, e.g., representative of an area approximately 40 km (25 mi) or less around the point of collection. However, these data are considered sufficient for model input, primarily because the model itself is not designed for complex terrain such as that on and around the NTS. Errors introduced by the use of the effluent and meteorological data are small compared to the errors inherent in the model. The model results are considered over-estimates of the dose to offsite residents. This has been confirmed by comparison with the offsite monitoring results.

COMMITTED EFFECTIVE DOSE EQUIVALENT (CEDE) FROM CONSUMPTION OF WILD GAME

Although hunting is prohibited on the NTS, there is the remote possibility that animals drinking water and feeding on the NTS could migrate offsite where hunters could harvest them. For this reason, the analytical results for the water and vegetation samples discussed in Chapter 10 were used to estimate the CEDE to what is considered to be the most critical offsite individual, a hunter consuming meat from three game species: mourning dove (Zenaida macroura), black-tailed jack rabbit (Lepus californicus), and mule deer (Odocoileus hemionus). The samples were collected at two locations where the radioculide concentrations in the environment were the highest: the vegetation and surface water at the E Tunnel Ponds in Area 12 and the vegetation in the Area 5 Cambric Ditch (normally dry). The CEDE was calculated from a pathway model by Kennedy and Strenge (1992) into which the radionuclide concentrations measured in the vegetation and pond water were inputted.

Assuming that the game animals fed on vegetation in the Cambric Ditch, the total potential CEDE to a hypothetical hunter resulting from the consumption of the edible parts of all three species (based upon state bag limits) was calculated to be 0.05 mrem (5×10^{-4} mSv) per year. Assuming that the game animals fed and drank at the E Tunnel Pond, the CEDE was calculated to be 0.5 mrem/y (5×10^{-3} mSv) (Table 7.2). The latter dose estimate is higher than the dose estimates based upon actual radionuclide measurements of deer samples reported in the annual reports for 1990 to 1995 (see Table 7.3). This was expected because the pathway model is conservative, the animals were assumed to feed and drink only in a highly contaminated area, and the estimate is based upon the bag limits for all three animal species.

ESTIMATED DOSE USING MONITORING NETWORK DATA

As shown in Table 4.14, the highest offsite annual average concentration of $^{239+240}$Pu was measured at Rachel by R&IE-LV and

BN. The higher concentration reported by BN was used to calculate the potential CEDE to a hypothetical individual at this location. Although Springdale was the location of the MEI, as determined from the CAP88-PC estimate from NTS airborne emissions, no air sampler was operated at Springdale, so an EDE could not be calculated from measured concentrations. The nearest air sampler to Springdale is at Beatty, 14 km (9 mi) south of Springdale, which is too far away to be used.

Since airborne tritium was not sampled at Rachel, an annual average of the results of samples collected at Indian Springs and Amargosa Valley was used. Also, as no milk samples were collected offsite during 1999, an average of the ^{90}Sr concentrations reported for the EPA Milk Surveillance Network for the years 1995 to 1998 was used.

The concentrations of radioactivity detected by the offsite monitoring networks and used in the dose calculations are shown in Table 7.2. These concentrations are converted to a dose by using the assumptions and dose conversion factors described below. The dose conversion factors assume continuous presence at a fixed location and no loss of radioactivity in storage or handling prior to ingestion of materials. The assumptions used in the calculation of the CEDEs were as follows:

- Adult respiration rate = 8,400 m^3/yr from International Commission on Radiological Protection Publication (ICRP) 21 (ICRP 1975).

- Milk intake (average for 20 and 40 yr old) = 110 L/yr (ICRP 1975).

The CEDE conversion factors were obtained from “Internal Dose Conversion Factors for Calculation of Dose to the Public” (DOE 1988). Those used here are:

- ^{3}H: 6.4×10^{-8} mrem/pCi (ingestion or inhalation).

- ^{90}Sr: 1.4×10^{-4} mrem/pCi (ingestion).

- $^{238,239+240}Pu$: 3.7×10^{-4} mrem/pCi (ingestion, $f_1=10^{-4}$); 3.1×10^{-1} mrem/pCi (inhalation, Class Y).

The algorithm for the internal dose calculation is:

- (concentration) x (intake in volume [mass]/unit time) x (CEDE conversion factors) = CEDE.

As an example calculation, the following is the result of breathing a concentration of tritium in air of 3.8 pCi/m^3:

- (3.8 pCi/m^3) x (8,400 m^3/yr) x (6.4×10^{-8} mrem/pCi) = 2.0×10^{-3} mrem/yr.

However, in calculating the inhalation CEDE from ^{3}H, the value must be increased by 50 percent to account for skin absorption (ICRP 1979). The total dose in one year, therefore is $2.0 \times 10^{-3} \times 1.5 = 3.0 \times 10^{-3}$ mrem/yr.

Dose calculations from the offsite data and CAP88-PC estimate for the MEI are summarized in Table 7.2. As shown at the bottom of this table, the individual CEDEs, from the various pathways, added together give a total of 0.11 mrem/yr (1.1×10^{-3} mSv/yr) at Rachel and 0.13 mrem/yr (1.3×10^{-3} mSv/yr) at Springdale. These doses are small compared to the gamma radiation background measured by pressurized ion chambers (PICs) at Rachel and at Beatty (nearest PIC to Springdale), which indicated doses of 146 mrem/yr (1.46 mSv/yr) and 143 mrem/yr (1.43 mSv/yr), respectively.

The annual average concentration of $^{239+240}Pu$ used in the CEDE calculation for Rachel (2.8×10^{-5} pCi/m^3, 1.0×10^{-6} Bq/m^3) was determined from samples collected by BN. The annual average from samples collected from the EPA sampler at Rachel was 1.4×10^{-6} pCi/m^3 (5.2×10^{-8} Bq/m^3).

The higher concentration by the BN sampler is possibly due to the fact that it was operated only for six months from July through December 1999, when the climate was drier and more favorable for the resuspension of surface soil. Both averages are higher than all other sampling locations because Rachel was in the path of most radioactive emissions from nuclear tests during the 1950's and 1960's.

7.2 ONSITE BIOTA DOSES

There are deposits of radioactivity in the soil of the NTS that may cause radiation doses to any biota that exist within it boundaries. There are no natural rivers or streams on the NTS, but there is a set of tunnel drainage ponds that have existed for many years and may support some aquatic organisms. Although the soil contamination on the NTS is well characterized, the contamination in the sediment of the tunnel drainage ponds is not. Therefore, only those contaminated NTS locations with non-aquatic biota were evaluated by a "screening" technique to determine whether radiation doses to biota are in compliance with guidelines specified in a recent DOE regulatory standard created by the Biota Dose Assessment Committee (DOE 2000). According to this standard, an area is in compliance if the sum of the ratios of maximum radionuclide concentrations in a medium such as soil to a biota concentration guide (BCG) is less than one. The results of the evaluation are as follows.

The principal contributors to the biota doses were determined to be ^{90}Sr and ^{137}Cs, because their BCGs were smaller by a factor 1/35 to 1/20,000 times the guides of other radionuclides found on the NTS. The concentrations of radioactivity in Ci/mi^2 determined from previous surveys (DOE 1991d) were converted to pCi/g by assuming a soil density of 1.5 g/cm^3 and a depth of penetration of 3 cm for the transuranics and 30 cm for the mobile radionuclides.

The NTS areas with the highest concentrations of ^{90}Sr and ^{137}Cs were then chosen, and the ratio of the soil concentration to the BCG was calculated for all radionuclides found by surveys and the ratios summed. Since the sum for the areas with the highest concentrations were less than one, all other areas would also be less than one. The location with the highest radionuclide concentrations, Area 10, had a ratio sum of only 0.325.

7.3 SUMMARY

Based upon the estimated airborne emissions of radioactivity from the NTS for all possible sources, the MEI was determined with CAP88-PC software to be at Springdale, Nevada, 58 km (36 mi) west-northwest of CP-1. The CEDE to a hypothetical receptor at Springdale was calculated to be 0.12 mrem/yr (1.2×10^{-3} mSv/yr). The total calculated CEDE, including contributions to the dose from ^{90}Sr in milk (doses from onsite emissions of tritium were already included in the CAP88-PC estimate) was 0.13 mrem/yr (0.0013 mSv/yr).

The offsite environmental surveillance systems operated around the NTS detected no radioactivity attributed to the NTS except for the high volume air samplers, which consistently detected concentrations of airborne $^{239+240}$Pu above the minimum detectable concentration. The highest annual average concentration was from high-volume air filter samples collected at Rachel, which had a calculated CEDE of 0.096 mrem/yr (9.6×10^{-4} mSv/yr). When summed with the CEDEs from airborne tritium and ^{90}Sr in milk estimated from other network data, the total CEDE at Rachel would be 0.11 mrem/yr (1.1×10^{-3} mSv/yr).

Assuming that a resident at Springdale also harvested wild game (doves, rabbits, and deer) which migrated offsite after drinking and feeding at radioactively contaminated locations on the NTS and received the

estimated CEDE of 0.5 mrem/yr (0.005 mSv/yr), the total CEDE at Springdale becomes 0.63 mrem/yr (0.0063 mSv/yr), which is 0.6 percent of the 100 mrem/yr limit for the general public as specified by DOE regulations. For comparison, the natural radiation background measured by PICs located at Beatty (nearest PIC to Springdale) indicated a dose of 143 mrem/yr (1.43 mSv/yr).

An evaluation of radiation doses to terrestrial biota was conducted based upon the radionuclide concentrations in soil determined from past surveys at the NTS. From a comparison of the magnitudes of the BCGs for radionuclides in the soil, ^{90}Sr and ^{137}Cs were found to be the principal contributors to doses to biota. The results of the evaluation found all NTS terrestrial areas to be in compliance with a recent draft of a DOE standard for evaluating radiation doses to aquatic and terrestrial biota (DOE 2000). The location which would contribute the highest dose to terrestrial biota was Area 10. Since the radionuclide content of the E Tunnel ponds sediments have not been completely characterized, an evaluation of dose to aquatic biota could not be completed in time for this report. The E Tunnel ponds, the location of the only aquatic biota that exists in a contaminated environment on the NTS, will be evaluated next year.

Table 7.1 NTS Radiological Dose Reporting Table for Calendar Year 1999

Pathway	Dose to Maximally Exposed Individual (mrem)	(mSv)	Percent of DOE 100-mrem Limit	Estimated Population Dose (person-rem)	(person-Sv)	Population within 80 km	Estimated Natural Population Dose (person-rem)
Air+Milk +Wild Life[a]	0.63	0.0063	0.63	0.38	0.0038	36,517	5,220
Air only	0.12	0.0012	1.2[b]	0.38	0.0038	36,517	5,220

(a) According to Chapter 10, the conservative CEDE of 0.5 mrem/yr from wild life is unlikely because the migration of wild life is usually within the NTS boundaries.
(b) The 10 mrem limit of the NESHAPs was used for the air pathway.

Table 7.2 Summary of Data Used in Dose Calculations - 1999

Medium	Radionuclide	Concentration	Mrem/Year	Comment
Air	^{3}H	3.8 [b] (0.14)	0.0030	Concentration is average of BN offsite results
	$^{239+240}Pu$	2.8×10^{-5} [b] (1.0×10^{-6})	0.096[C]	Highest offsite average conc. (Rachel, Nevada)
	$^{239+240}Pu$	-	0.12 [c]	CEDE at Springdale calculated by CAP88-PC
Milk	^{90}Sr	0.67 [a] (0.025)	0.010	Concentration average for network results 1995 to1998
	^{3}H	0	0	Not Analyzed
Wild Life	^{3}H, ^{137}Cs, ^{90}Sr ^{238}Pu,$^{239+240}Pu$,	-	0.5[d]	See Table 10.1 for concentrations

TOTAL CEDE for Rachel (air CEDEs from tritium and plutonium + milk CEDE) = 0.11 mrem/yr
TOTAL CEDE for Springdale (CEDE by CAP88-PC + milk CEDE) = 0.13 mrem/yr

(a) Units are pCi/L and (Bq/L).
(b) Units are pCi/m^3 and (Bq/m^3).
(c) Corrected to include contribution to the EDE by ^{241}Am.
(d) EDE of 0.5 mrem from wildlife was based upon pathway dose model and radionuclide concentrations measured in water and vegetation collected at E Tunnel pond. The MEI was assumed to harvest State bag limits for doves, rabbits, and deer. Study referred to in Chapter 10 indicated that the migration of these animals is unlikely.

Table 7.3 Comparison of 1999 EDEs from Wild Game with Past Estimates

Year	Sample Type	EDE (mrem/year)
1990	Deer	0.004
1991	Deer	0.027
1992	Deer	0.014
1993	Deer + Chukar	0.053
1994	Deer	0.00047
1995	Deer	0.0087
1996	(Not Sampled)	-
1997	(Not Sampled)	-
1998	(Not Sampled)	-
1999	Rabbit, dove, deer[a]	0.5

(a) Not sampled; EDE calculated from pathway dose model.