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Nevada
Environmental
Restoration
Project

Clean Slate Transportation and Human Health Risk Assessment

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Environmental Restoration
Division

U.S. Department of Energy
Nevada Operations Office

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CLEAN SLATE TRANSPORTATION AND HUMAN HEALTH RISK ASSESSMENT

DOE Nevada Operations Office
Las Vegas, Nevada

February 1997

CLEAN SLATE TRANSPORTATION AND HUMAN HEALTH RISK ASSESSMENT

DISCLAIMER

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List of Acronyms and Abbreviations

AEC	U.S. Atomic Energy Commission
AWRE	United Kingdom Atomic Energy Authority
DOE/NV	U.S. Department of Energy, Nevada Operations Office
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
EA	Environmental Assessment
ERDA	U.S. Energy Research and Development Administration
ft	Foot (feet)
ft^3	Cubic foot (feet)
ha	Hectare(s)
ICRP	International Commission on Radiological Protection
km	Kilometer(s)
LCF	Latent cancer fatality(ies)
m	Meter(s)
m^3	Cubic meter(s)
mi	Mile(s)
NAFR	Nellis Air Force Range
NAS	National Academy of Sciences
NDOT	Nevada Department of Transportation
NRC	U.S. Nuclear Regulatory Commission
NTS	Nevada Test Site
pCi/g	PicoCurie(s) per gram
PPE	Personal protective equipment
RWMS	Radioactive Waste Management Site
TRU	Transuranic
TTR	Tonopah Test Range
UDOT	Utah Department of Transportation

1.0 Introduction

1.1 Purpose and Scope

Public concern regarding activities involving radioactive material generally focuses on the human health risk associated with exposure to ionizing radiation. This report describes the results of a risk analysis conducted to evaluate risk for excavation, handling, and transport of soil contaminated with transuranics at the Clean Slate sites. Transportation risks were estimated for public transport routes from the Tonopah Test Range (TTR) to the Envirocare disposal facility or to the Area 3 Radioactive Waste Management Site (RWMS) at the Nevada Test Site (NTS) for both radiological risk and risk due to traffic accidents. Human health risks were evaluated for occupational and radiation-related health effects to workers. This report was generated to respond to this public concern, to provide an evaluation of the risk, and to assess feasibility of transport of the contaminated soil for disposal.

1.2 Background

In order to test the safety of nuclear weapons under accident conditions, the U.S. Atomic Energy Commission (AEC) (now the U.S. Department of Energy [DOE]) detonated single plutonium-bearing devices to simulate an accidental detonation of the high-explosive portion of nuclear weapons. This resulted in the uncontained spread of plutonium and radionuclides such as americium and depleted uranium in the vicinity of these experiments. Preliminary characterization data do not indicate the presence of regulated hazardous waste constituents. A soil surface area of approximately 1,310 hectares (ha) (3,240 acres) in the NTS, TTR, and the Nellis Air Force Range (NAFR) was contaminated in excess of 200 picoCuries per gram (pCi/g) (DOE/NV, 1995).

Operation Roller Coaster was a joint field operation which consisted of four tests conducted by the AEC, the U.S. Department of Defense, and the United Kingdom Atomic Energy Authority (AWRE) to study plutonium dispersal from the accidental explosion of plutonium-bearing weapons.

The first test, Double Tracks, was performed west of the Cactus Mountain Range in the Nellis Air Force Range on May 15, 1963 (Figure 1-1). This test created the smallest contamination area of the Operation Roller Coaster sites. With the exception of on-going revegetation activities, an interim corrective action for this site was completed in August of 1996. Remedial alternatives

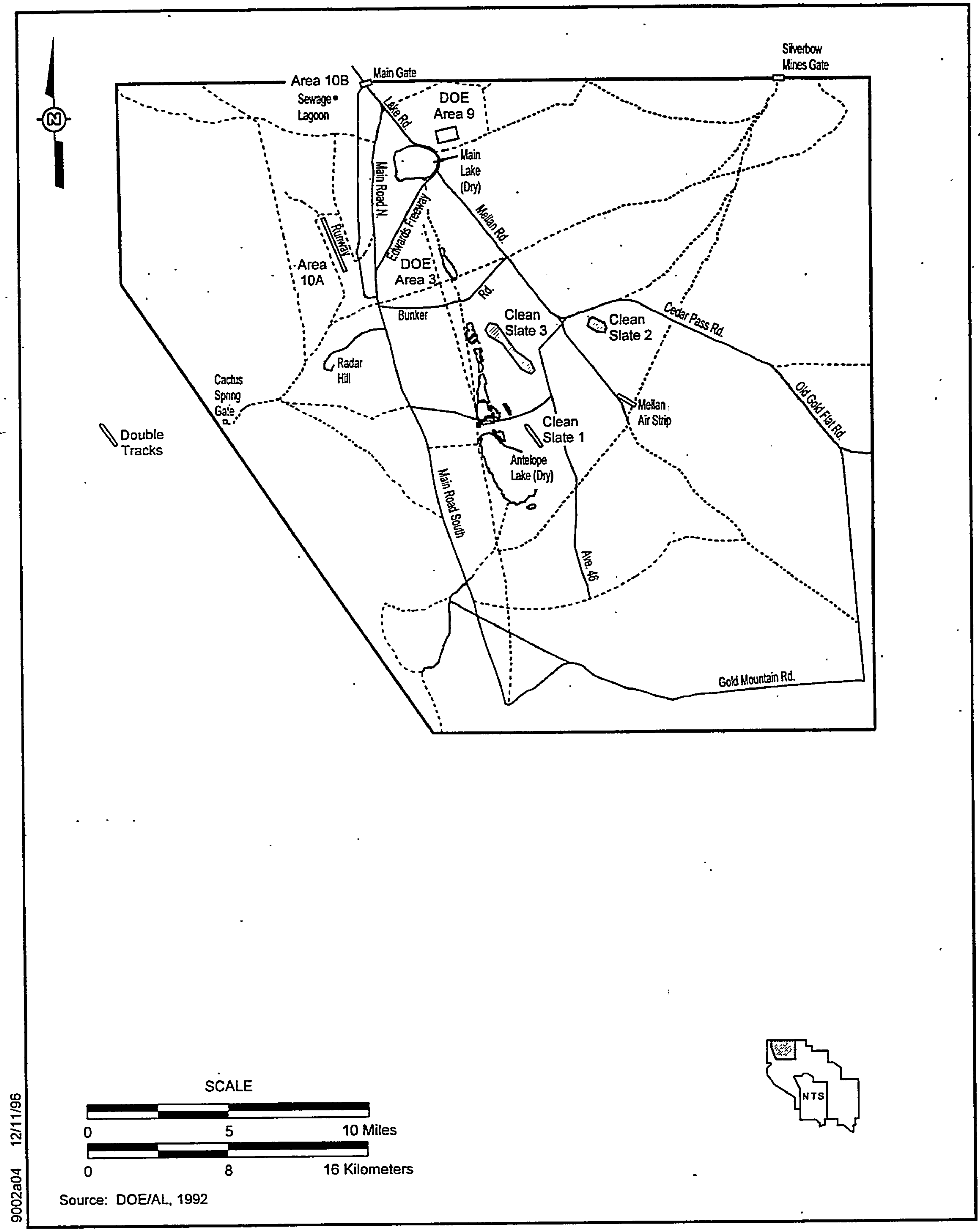

Figure 1-1
Tonopah Test Range Detail

were explored during the corrective action to better determine the remediation method for the larger Clean Slate sites.

The remaining three tests, known as Clean Slate 1, 2, and 3, were performed at Cactus Flat in the central portion of the Tonopah Test Range (Figure 1-1). While the Double Tracks test involved the detonation of only one device on a hard surface with minimal entrainment of soil, the three Clean Slate tests were multiple bursts of 9, 19, and 19 units. In all three of the Cleans Slate tests, only one unit contained plutonium; the other remaining units contained depleted uranium (U.S. Energy Research and Development Administration [ERDA], 1975). Clean Slate 1 was fired on a concrete pad with no cover. Clean Slate 2 and 3 were detonated in structures covered with 0.6 meter (m) (2 feet [ft]) and 2.4 m (8 ft) of earth, respectively (Shreve, 1965).

Subsequent to the testing, the inner areas of highest residual contamination were fenced. Metal and concrete debris in the vicinity of each ground zero and fragments out to a range of 762 m (2.500 ft) were collected and buried in a pit inside the fenced ground zero area (Talmage and Chilton, 1987). The contaminated surface around each ground zero and areas contaminated by jetting were scraped to a depth of several inches. The soil was placed in the pit or mounded, covered with dirt, compacted, and watered (Talmage and Chilton, 1987).

During preliminary characterization work at each of the sites in the spring of 1996, very highly radioactively contaminated metal fragments were found; they were placed in a drum and left at the site. More of these fragments may be found during further characterization. Field readings indicate that these discrete elements exhibit concentrated radioactivity and may qualify as transuranic (TRU) waste when further analyzed. TRU waste is defined as waste that has transuranic elements (i.e., has an atomic number greater than 92, is an alph-emitter, has a half-life greater than 20 years) <u>and</u> has an activity higher than 100 nanocuries per gram. These "hot spots" would be gathered for separate storage and disposal. The total volume of hot spot material is not expected to exceed 0.05 cubic meter (m^3) (1.8 cubic feet [ft^3]). The bulk soil that is contaminated with transuranics would not quality TRU waste because activity levels, based on characterization information, would be less than 100 nanocuries per gram.

The remainder of this report focuses on the risk associated with the remediation of the Clean Slate sites and the risk associated with transport of the waste resulting from the remediation.

1.3 *Summary of Results*

The results of this study are presented in the following two parts: (1) the risks associated with transportation of soil contaminated with transuranics from the Clean Slate sites to the Envirocare and NTS disposal facilities and (2) the health and safety impacts related to the remediation activities. Detailed results of the transportation and human health risk analyses for all three Clean Slate sites are provided in Sections 2.0 and 3.0, respectively. Results for the individual Clean Slate sites are presented in Appendices A, B, and C. Small numbers are given in scientific notation, a mathematical representation of any decimal number as a number between one and ten raised to a specific power of ten. A detailed explanation of scientific notation is presented in Section 2.1.

Traffic accidents dominate the transportation risks associated with this activity. The greatest number of vehicle-related deaths and injuries is estimated at 0.21 and 2.3, respectively. These death and injury numbers result from the transportation alternative which encompasses waste transport using the longer of two potential routes to the Envirocare disposal facility and transportainer containerization. The risk of radiation-related health effects associated with the transportation is small in all cases and is approximately 10 million times smaller than the risk associated with traffic accidents. For instance, the greatest number of public radiation-related health effects would be attributed to latent cancer fatalities (LCF) and would account for 1.9×10^{-7} LCFs during the approximate 42 months it would take to complete transport of the soil. Simplified, this means that the project would have to last 18.4 million years for 1 latent cancer fatality to occur due to Clean Slate waste transport. The highest incidence of public radiation detriment predicted for Clean Slate waste transport is even lower than the risk of LCFs.

Human health risk to workers engaged in activities such as excavation and bagging is dominated by occupational injuries. Approximately 0.34 injuries are predicted for the duration of this project. Occupational fatalities, LCFs, and radiation detriments are estimated at 6.1×10^{-4}, 2.2×10^{-4}, and 1.1×10^{-4}, respectively, for remediation workers. Because the results of the risk analysis indicate that the number of health effects in all instances would be less than one, workers engaged in the Clean Slate remediation would not be expected to incur any harmful health effects during the operation.

In summary, human health risk for the Clean Slate remediation operation would be dominated by injuries and fatalities due to traffic and occupational accidents. Although these risks dominate the total human health risk, they are still very low. No injuries or fatalities would be expected from the cleanup of Clean Slate soil. Transport activities could result in injuries due to traffic accidents; however, no deaths would be anticipated. Radiation-related risk is much lower than the risk due to traffic and occupational accidents. No radiation-related health effects would be expected for the Clean Slate remediation.

2.0 Transportation Risk

2.1 Methodology and Scenarios

To evaluate risk, three components must be defined: scenarios, likelihood, and consequence. Scenarios consist of one basic failure event followed by subsequent failures that lead to some undesirable outcome. Likelihood describes how often the scenario is expected to occur and may be expressed as a probability, which is an expression of the belief that something will or will not occur. Probability is a unitless number between zero and one. Likelihood may also be expressed as a frequency (e.g., 5×10^{-5} accidents per mile [mi]). The final component of risk is consequence, the undesired results of the scenario. To evaluate consequences, the source term (what is released, how much, and what form it takes) must be defined, and, for release scenarios, dispersion of the source term must be predicted. From the exposure, a dose is calculated and that dose is related to a health effect. The health effects (consequences) are determined through examination of the different scenarios defined for the risk assessment.

Evaluation of risk routinely results in the use of very small or very large numbers. Very small and very large numbers are sometimes written using scientific notation rather than using decimals or fractions. Scientific notation uses exponents to indicate the power of 10 as a multiplier (i.e.. 10^n, or the number multiplied by itself "n" times; 10^n or the reciprocal of the number 10 multiplied by itself "n" times).

For example:

$$10^3 = 10 \times 10 \times 10 = 1{,}000$$

$$10^{-2} = \frac{1}{10 \times 10} = 0.01$$

In scientific notation, large and small numbers are written as a decimal between 1 and 10 multiplied by the appropriate power of 10. Examples that are used in this document include:

0.00005 accidents per mile = 5×10^{-5} accidents per mile
2,100,000 ft^3 of soil = 2.1×10^6 ft^3 of soil

This risk assessment includes both incident-free and accident-initiated scenarios. Because exposure to ionizing radiation from the cargo can occur without a release (external dose), incident-free exposure must be considered. In accident-initiated releases, a vehicle accident is the initiating event and must be followed by failure of the packaging in order to result in the actual release of the radioactive contents. The consequences of interest in this study are vehicle-related and cargo-related. Vehicle-related consequences include traffic injuries and fatalities. Cargo-related consequences are divided into the following four types:

- Radiation-induced LCF (i.e., a cancer occurring approximately 20 years or more after exposure that results in a fatality)

- Radiation-induced detriment (i.e., other chronic health effects including nonfatal cancer [such as genetic damage or birth defects] occurring approximately 20 years or more after exposure)

- Early radiation-induced fatality due to acute exposure occurring almost immediately under accident conditions (i.e., life-shortening effects)

- Early radiation-induced injury due to acute exposure occurring almost immediately under accident conditions (i.e., central nervous system damage, nausea, and vomiting)

The model used to perform the Clean Slate transportation risk analysis is identical to the model described in the *Summary of the Transportation Risk Assessment Results for the Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DOE/NV, 1996). This model is a RADTRAN-like model that uses spreadsheets and FORTRAN codes to assist in the determination of risk for the transportation of soil contaminated with transuranics.

The input parameters used in the risk assessment can be broadly divided into three categories:

- Cargo-specific parameters - These parameters include the characteristics of the cargo (e.g., the number of shipments), the total activity of the soil, and the radionuclides in the soil.

- Route-specific parameters - These parameters include traffic and population characteristics for the transport route (e.g., accident rate, injury and fatality rates, vehicle count rate, length of the route, and population density).

- Scenario-specific parameters - These parameters include a variety of parameters that are generally independent of the cargo transported and the route taken (e.g., the number of people in vehicles, the average speed of vehicles, dosimetry functions, and dose conversion coefficients).

Cargo-specific input data were generated from recent field investigations of the Clean Slate sites. Route-specific input data were obtained from the HIGHWAY routing model (Johnson et al., 1993), the Nevada Department of Transportation (NDOT, 1995a), and the Utah Department of Transportation (UDOT, 1996). Scenario-specific input data were generally similar to those data used in the *Double Tracks Test Site Environmental Assessment* (EA) (DOE, 1996) and the transportation study completed for the *Summary of the Transportation Risk Assessment Results for the Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DOE/NV, 1996).

2.2 Transportation Alternatives

Several alternatives exist for the transport of contaminated soils from the Clean Slate sites to disposal. Alternatives evaluated as part of this risk assessment are presented in Table 2-1. The following variables account for these alternatives: routine transport/transport involving an accident, transport vehicle containerization, and routing. As previously noted, scenarios are evaluated for routine transport and transport involving an accident. All alternatives assumed a clean-up level of 200 pCi/g, which results in an average shipment activity concentration of 1,223 pCi/g. The 200 pCi/g clean-up level was assumed based on results of RESRAD modeling used to evaluate different clean-up levels. The results of this modeling are presently being evaluated by the DOE and State of Nevada; however, it appears at this time that a 200 pCi/g clean-up level is most likely.

Two containment options consisting of three containment methods were also examined for Clean Slate soil. The containment options entail single and double containment. One method involves containerization similar to that used during the Double Tracks soil transport and was modeled as double containment. At Double Tracks, the supersacks were placed inside transportainers that were subsequently loaded onto flatbed trucks for transport. The second method involves the use of supersacks strapped directly to a flatbed truck with removable sides (referred to as a stakebed), and the third entails bulk transport in bottom- or end-dump trucks. Although the dump trucks may use an interior liner that fully envelops the load to inhibit truckbed contamination and to provide some further containment, and though the flatbed trucks will have removable sides that are in place during transport, these methods both are modeled as single containment because they do not qualify as strong tight containers. In all cases dump trucks will be tightly covered.

The different containerization methods account for variations in the amount of material that could be released in the case of an accident during transport. The release fractions for the transport method using transportainers were based on information presented in the *Final*

Table 2-1
Transportation Risk Analysis Alternatives

Alternative	Clean-Up Level (pCi/g)	Average Shipment (pCi/g)	Routine/ Accident	Disposal Site/Route #	Container
1	200	1,223	Routine	Area 3 - NTS/ Route 1	Stakebed/Bulk
2	200	1,223	Routine	Area 3 - NTS/ Route 1	Transportainer
3	200	1,223	Accident	Area 3 - NTS/ Route 1	Stakebed/Bulk
4	200	1,223	Accident	Area 3 - NTS/ Route 1	Transportainer
5	200	1,223	Routine	Envirocare/ Route 2	Stakebed/Bulk
6	200	1,223	Routine	Envirocare/ Route 2	Transportainer
7	200	1,223	Accident	Envirocare/ Route 2	Stakebed/Bulk
8	200	1,223	Accident	Envirocare/ Route 2	Transportainer
9	200	1,223	Routine	Envirocare/ Route 3	Stakebed/Bulk
10	200	1,223	Routine	Envirocare/ Route 3	Transportainer
11	200	1,223	Accident	Envirocare/ Route 3	Stakebed/Bulk
12	200	1,223	Accident	Envirocare/ Route 3	Transportainer

Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes (NRC, 1977). These values were modified for the stakebed and bulk transport containers to account for an increased probability of soil release in the case of an accident. It was assumed that the release fractions would be the same for both bulk transport and for stakebed transport. It was also assumed that the release fractions would be 10 times greater for these containment methods when compared to a transportainer for the same accident severity.

Routing characteristics were also evaluated for three routes to the two disposal facilities. The route to the NTS disposal facility and the two routes to the Envirocare disposal facility are diagramed in Figures 2-1 and 2-2, respectively. All three of the routes predominantly travel through rural areas, but vary in length considerably. Trucks would travel approximately 300 kilometers (km) (186 miles [mi]), 696 km (433 mi), and 573 km (356 mi) on public roads over Routes 1, 2, and 3, respectively. The separate routes for transport to the Envirocare disposal facility were examined because of the uncertain road conditions for U.S. Highway 93A during winter months. Interstate 80 and U.S. 93 are more traveled and more likely to receive maintenance during the winter.

2.3 Transportation Risk Assumptions

System definition includes the determination of factors that characterize the waste shipments. Shipments were evaluated based on many factors including, but not limited to, the following: total amount of radioactivity of average shipments, number of shipments, population density along the transport corridor, distance of the transport route, average time spent at rest stops, average distance between stops, probability of an accident occurring, and fraction of waste aerosolized in the case of a dispersal accident. The following assumptions were also used to calculate the transportation risk:

- Population density along the transport routes was estimated by the HIGHWAY code.
- The total number of shipments is based on vehicle weight restrictions and use of 1.4 m^3 (50 ft^3) bags, where applicable, which limits stakebed and bulk shipments to 14.16 m^3 (500 ft^3) and transportainer shipments to 12.74 m^3 (450 ft^3).
- The total number of stakebed and bulk shipments is the upper limit of the estimate (i.e., given 5,125 ± 10 percent round-trips, 5,645 trips would be used as an upper bound). The total number of transportainer shipments is the upper limit of the estimate (i.e., given 5,695 ± 10 percent round-trips, 6,270 trips would be used as an upper bound).
- The total distance used to calculate injuries and fatalities due to traffic accidents is based on a round-trip. The total distance used to calculate risks due to exposure to radiation is based on one-way trips.
- Risk coefficients for human health effects are taken from Nuclear Regulatory Commission and International Commission on Radiological Protection guidance.

Additionally, several determinations were made during the generation of input factors for the model with respect to the alternatives for transport. It is anticipated that approximately

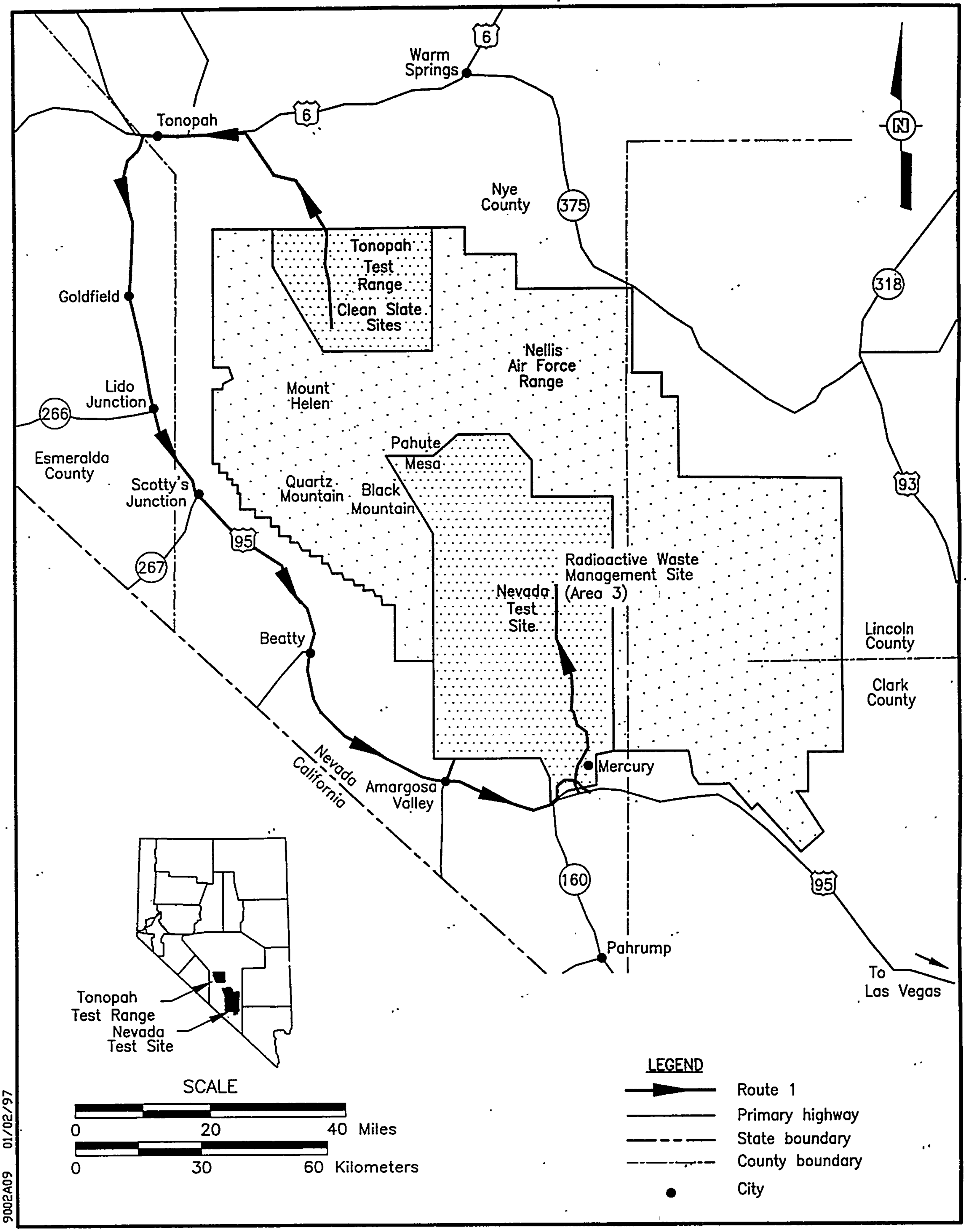

Figure 2-1
Transportation Route 1: Clean Slate Sites to Nevada Test Site

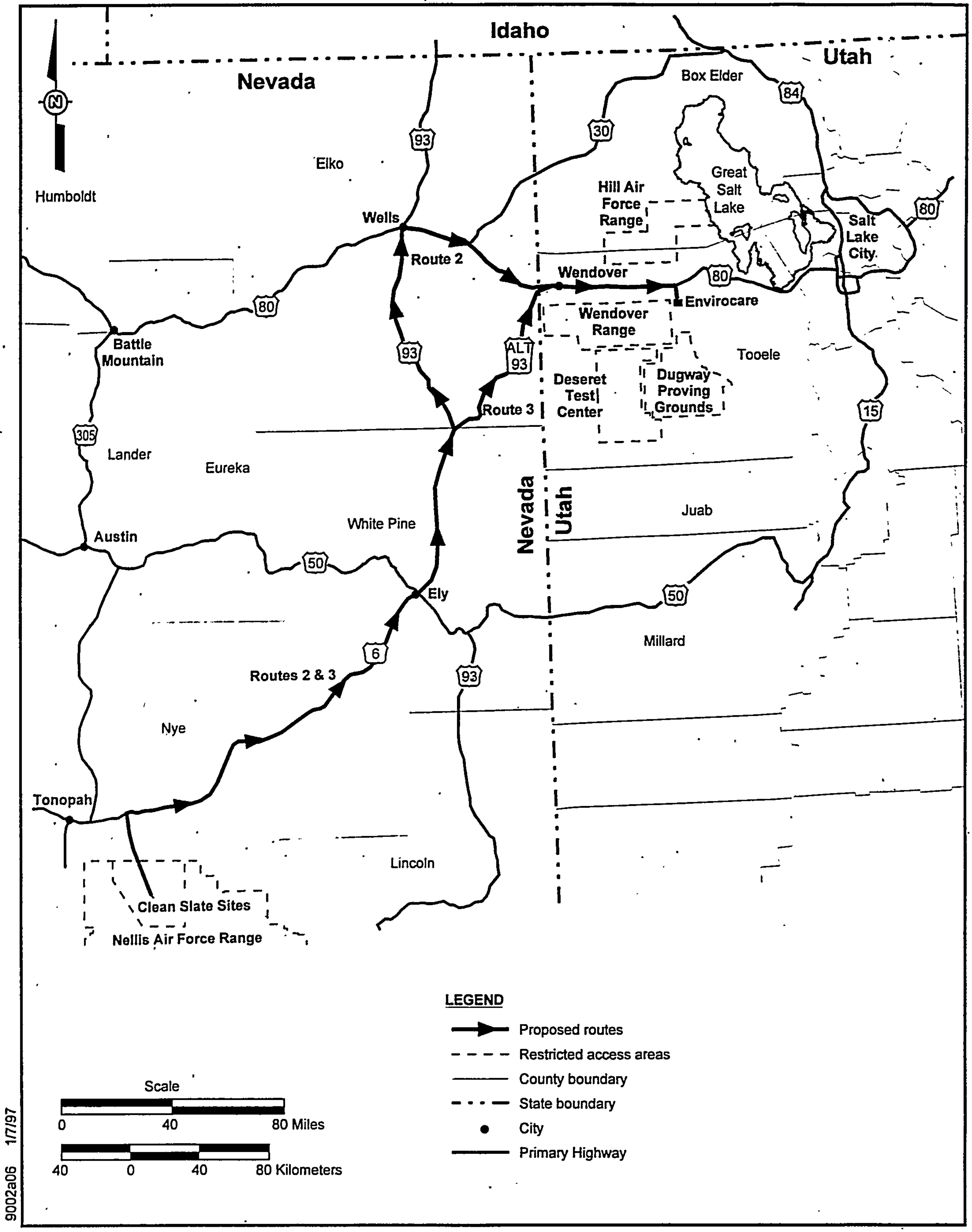

Figure 2-2
Transportation Routes 2 and 3:
Clean Slate Sites to Envirocare

59,469 m^3 (2.1×10^6 ft^3) of earth would be actually excavated; however, this soil expands when stockpiled and handled during the bagging operation. Because Double Tracks soil expanded approximately 22 percent from these activities, it was assumed that the Clean Slate soil would expand similarly for a total transport volume of 72,553 m^3 (2.6×10^6 ft^3).

2.4 Transportation Risk Results

The risk modeling for the Clean Slate waste transportation was performed to provide the number of human health effects expected for this action. The results of the transportation risk analysis for all three sites are presented in Tables 2-2 through 2-7. These tables detail the number and type of health effects from transportation activities for each of the listed human health effects for both incident-free transport and transport involving accidents. Transportation risk related to the individual Clean Slate sites can be found in Appendices A, B, and C. Estimated dose is provided in the tables for the radiation-related health effects. Although the number of radiation-related human health effects is extremely small, approximately 80 percent of the LCF incidents under routine conditions would be due to exposure to members of the public along roadside stops. This risk could be mitigated by limiting the number of truck stops and/or restricting those stops to areas of low population density.

As indicated in Tables 2-2 through 2-7, injuries and fatalities due to traffic accidents are the dominant risk in transporting shipments of soil contaminated with transuranics from the TTR to either Envirocare or the Area 3 RWMS on the NTS. Additionally, results indicate that the different transport routes do not vary significantly with regard to risk. Radiation risk is, on average, approximately 10 million times lower than the risk related to traffic injuries. Because the results of the risk analysis indicate that the number of fatalities would be less than one in all cases, no public or transport crew fatalities would be anticipated. Injuries could result from transport along any of the identified routes with any of the transport containerization methods; these predicted injuries would result from traffic accidents. Approximately 22,000 injuries are caused by traffic accidents each year in the state of Nevada (NDOT, 1995b). The predicted injuries resulting from Clean Slate transportation activities would represent only an approximate 0.01 percent increase over the annual traffic injury rate in Nevada. Because the remediation of the Clean Slate sites is likely to continue for greater than one year, the potential increase would actually be less than 0.01 percent. Additionally, the injury rates used in this risk analysis are based on general traffic accident data, not accident data for radioactive waste shipments. It is anticipated that the accident rates for the shipments of Clean Slate soil would be much lower compared with general populace traffic accident rates.

Table 2-2
Transportation Risk for Waste Transport Using Route 1 to the Nevada Test Site and Stakebed or Bulk Transport Vehicles

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.10
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.85
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	2.7×10^{-4}	5.4×10^{-8}
	Transport Crew	1.8×10^{-4}	3.6×10^{-8}
Radiation Detriment	Public	2.7×10^{-4}	1.6×10^{-8}
	Transport Crew	1.8×10^{-4}	1.0×10^{-8}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	7.4×10^{-6}	3.7×10^{-9}
Radiation Detriment	Public and Transport Crew	7.4×10^{-6}	1.7×10^{-9}
Early Radiation Fatalities	Public and Transport Crew	7.4×10^{-6}	2.4×10^{-8}
Early Radiation Injuries	Public and Transport Crew	7.4×10^{-6}	5.0×10^{-8}

Table 2-3
Transportation Risk for Waste Transport Using Route 2 to Envirocare and Stakebed or Bulk Transport Vehicles

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.19
Injuries due to Traffic Accidents	Public and Transport Crew	NA	2.1
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	9.5×10^{-4}	1.9×10^{-7}
	Transport Crew	4.2×10^{-4}	8.4×10^{-8}
Radiation Detriment	Public	9.5×10^{-4}	5.5×10^{-8}
	Transport Crew	4.2×10^{-4}	2.4×10^{-8}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	2.3×10^{-5}	1.2×10^{-8}
Radiation Detriment	Public and Transport Crew	2.3×10^{-5}	5.3×10^{-9}
Early Radiation Fatalities	Public and Transport Crew	2.3×10^{-5}	7.6×10^{-8}
Early Radiation Injuries	Public and Transport Crew	2.3×10^{-5}	1.5×10^{-7}

Table 2-4
Transportation Risk for Waste Transport Using Route 3 to Envirocare and Stakebed or Bulk Transport Vehicles

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.15
Injuries due to Traffic Accidents	Public and Transport Crew	NA	1.7
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	8.5×10^{-4}	1.7×10^{-7}
	Transport Crew	3.5×10^{-4}	6.9×10^{-8}
Radiation Detriment	Public	8.5×10^{-4}	4.9×10^{-8}
	Transport Crew	3.5×10^{-4}	2.0×10^{-8}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	2.0×10^{-5}	1.0×10^{-8}
Radiation Detriment	Public and Transport Crew	2.0×10^{-5}	4.7×10^{-9}
Early Radiation Fatalities	Public and Transport Crew	2.0×10^{-5}	6.7×10^{-8}
Early Radiation Injuries	Public and Transport Crew	2.0×10^{-5}	1.4×10^{-7}

Table 2-5
Transportation Risk for Waste Transport Using Route 1 to the Nevada Test Site and Transportainer Containerization

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.11
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.94
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	2.7×10^{-4}	5.4×10^{-8}
	Transport Crew	1.8×10^{-4}	3.6×10^{-8}
Radiation Detriment	Public	2.7×10^{-4}	1.6×10^{-8}
	Transport Crew	1.8×10^{-4}	1.0×10^{-8}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	2.9×10^{-6}	1.4×10^{-9}
Radiation Detriment	Public and Transport Crew	2.9×10^{-6}	6.6×10^{-10}
Early Radiation Fatalities	Public and Transport Crew	2.9×10^{-6}	9.5×10^{-9}
Early Radiation Injuries	Public and Transport Crew	2.9×10^{-6}	1.9×10^{-8}

Table 2-6
Transportation Risk for Waste Transport Using Route 2 to Envirocare and Transportainer Containerization

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.21
Injuries due to Traffic Accidents	Public and Transport Crew	NA	2.3
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	9.5×10^{-4}	1.9×10^{-7}
	Transport Crew	4.2×10^{-4}	8.4×10^{-8}
Radiation Detriment	Public	9.5×10^{-4}	5.5×10^{-8}
	Transport Crew	4.2×10^{-4}	2.4×10^{-8}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	1.1×10^{-5}	5.4×10^{-9}
Radiation Detriment	Public and Transport Crew	1.1×10^{-5}	2.5×10^{-9}
Early Radiation Fatalities	Public and Transport Crew	1.1×10^{-5}	3.6×10^{-8}
Early Radiation Injuries	Public and Transport Crew	1.1×10^{-5}	7.2×10^{-8}

Table 2-7
Transportation Risk for Waste Transport Using Route 3 to Envirocare and Transportainer Containerization

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.17
Injuries due to Traffic Accidents	Public and Transport Crew	NA	1.9
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	8.5×10^{-4}	1.7×10^{-7}
	Transport Crew	3.5×10^{-4}	6.9×10^{-8}
Radiation Detriment	Public	8.5×10^{-4}	4.9×10^{-8}
	Transport Crew	3.5×10^{-4}	2.0×10^{-8}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	1.0×10^{-5}	5.0×10^{-9}
Radiation Detriment	Public and Transport Crew	1.0×10^{-5}	2.3×10^{-9}
Early Radiation Fatalities	Public and Transport Crew	1.0×10^{-5}	3.3×10^{-8}
Early Radiation Injuries	Public and Transport Crew	1.0×10^{-5}	6.7×10^{-8}

3.0 Remediation Risk

3.1 Methodology

Evaluation of human health risk as a result of remediation activities is very similar in concept to the determination of risk for transportation activities. The three components described in the transportation methodology (i.e., scenarios, likelihood, and consequence) must be defined with respect to the activities performed, and the risk is a product of probability and consequence. Risk for individual members of the public as a result of dust-generating operations has been previously considered in the Double Tracks EA (DOE, 1996). The results of that analysis indicated extremely small risk to the general public. Those results, coupled with the fact that the Clean Slate sites are more distant from public receptors and that preliminary results from site particulate monitors showed very little dust generation during the Double Tracks remediation activities, indicate that public risk from remediation activities would be negligible for this action; therefore, they will not be evaluated in this section.

Non-radiation-related worker risk can be determined from accident statistics related to specific industries from the U.S. Department of Labor (DOL) and other sources. For the activities that would be performed at the Clean Slate sites, the DOE industrial labor classification of construction was used to estimate the injury and fatality rates per man-hour. From the classification and unit risk information gained from DOL statistics, risk models were constructed using the assumption that there is a linear relationship between total effort in man-hours and risk.

Radiation risk occurs because workers are exposed to ionizing radiation in the form of penetrating X-rays, gamma radiations of the radioisotopes associated with weapons-grade plutonium, or alpha radiation from the inhalation of airborne plutonium. Estimates of dose to on-site workers were obtained by interpreting exposure data gained from the Double Tracks remediation and by making assumptions about the anticipated conditions at the Clean Slate sites.

3.2 Remediation Risk Assumptions

System definition includes the determination of factors that characterize the working environment. The following assumptions were used to calculate the remediation risk for both radiation- and non-radiation-related human health effects to workers:

- Worker exposures to radiation under normal operating conditions would be controlled under established procedures that require doses to be kept as low as reasonably achievable.

- Risk of occupational injury per man-hour of excavation (construction labor classification) is 3.1×10^{-5} or 3 chances in 100,000 (DOL, 1990).

- Risk of occupational fatality per man-hour of excavation (construction labor classification) is 5.5×10^{-8} or approximately 6 chances in 100 million (DOL, 1990).

- Excavation of 1 m^3 (35.3 ft^3) of soil is estimated to require 0.15 man-hours (assuming Level C personal protective equipment [PPE]) (DOE/NV, 1995).

- All excavation and soil handling workers are assumed to don PPE (i.e., air-purifying respirators) per the approved *Site-Specific Health and Safety Plan*; therefore, the risk due to plutonium inhalation is not considered.

- The volume of soil that would be excavated at the Clean Slate sites to achieve a remediation action level of 200 pCi/g is 72,553 m^3 (2.6×10^6 ft^3). Although only 59,469 m^3 (2.1×10^6 ft^3) of soil will actually be excavated, the soil will expand after excavation, and the larger volume will be handled. The larger value is used to estimate worker risk for all activities.

- Uranium concentrations are not considered to contribute to risk because characterization information indicates that uranium does not contribute significantly to the soil activity.

- Data are reported as plutonium-239/240 in pCi/g. The ratio of plutonium-239 to plutonium-240 is 10:1 by activity.

- The plutonium-239/240 ratio to americium-241 is 16:1 by activity.

- The maximum annual dose received by the workers is assumed to be similar to annualized doses received during the Double Tracks remediation. This maximum annual dose is 100 millirem.

- Latent cancer fatality estimates are based on the BEIR V cancer risk coefficient of 4×10^{-4} per person-rem for workers. Radiation detriment estimates are based on the BEIR V coefficient of 2×10^{-4} per person-rem (National Academy of Sciences [NAS], 1990).

3.3 Remediation Risk Results

This section details the results of the human health risk impact analysis. Table 3-1 summarizes the results of the risk analysis. The results of this analysis indicate that human health risks are expected to be dominated by occupational injuries and fatalities to workers. The dominant risk, injuries from occupational injuries, is still not anticipated to result in any adverse health effects because the risk result is less than one.

Table 3-1
Health Risks to Workers

Operation	Worker Health Risks			
	Occupational Safety Risks		Occupational Radiation Risks	
	Injuries	Fatalities	Radiation LCFs[a]	Radiation Detriment[b]
Clean Slate Remediation	0.34	6.1×10^{-4}	2.2×10^{-4}	1.1×10^{-4}

[a]Number of radiation-induced LCFs in the exposed worker population associated with Clean Slate remediation activities
[b]Number of radiation-induced detrimental health effects (e.g., nonfatal cancers, genetic effects) in the exposed worker population associated with Clean Slate remediation activities

4.0 Conclusions

Results of the risk analysis indicate that, regardless of transport method or disposal location, transportation risk to the public and transport crew is dominated by vehicle-related deaths and injuries. Radiation-related detriments and cancers are extremely unlikely in all cases. Based on these factors, cost and regulatory drivers, not risk, should be the deciding factors for the selection of transportation alternatives. The reasoning behind this conclusion is largely dependant on two factors. First, the calculated risk is largely dependant on the distance of the shipment, but the differential in risk is not substantial enough to warrant selection of a route solely based on distance from loading to unloading. Second, the difference in risk for the distinct containment methods is also not substantial, largely due to the fact that all three transport routes run through rural populations on roads that receive low annual traffic volumes.

Remediation risk is directly related to the amount of soil to be excavated and containerized. Although the risk increases from Clean Slate 1 to Clean Slate 3, as a result of the larger excavation volumes, the cumulative risk is still not anticipated to result in any adverse health effects.

5.0 References

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Appendix A

Clean Slate 1 Risk Assessment Results

A.1.0 Clean Slate 1 Risk Assessment Results

This appendix presents the results of the Clean Slate 1 risk assessment. A discussion of the combined results of the transportation and human health risk for Clean Slate 1, 2, and 3 is presented in Chapters 2 and 3.

A.1.1 Results of the Clean Slate 1 Transportation Risk Assessment

Tables A-1 through A-6 present the results of the transportation risk assessment for Clean Slate 1. The tables are separated by transport containerization method and route.

Table A-1
Transportation Risk for Waste Transport Using Route 1 to the Nevada Test Site and Stakebed or Bulk Transport Vehicles

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.008
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.062
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	9.7×10^{-6}	2.0×10^{-9}
	Transport Crew	6.4×10^{-6}	1.3×10^{-9}
Radiation Detriment	Public	9.7×10^{-6}	5.6×10^{-10}
	Transport Crew	6.4×10^{-6}	3.7×10^{-10}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	2.7×10^{-7}	1.3×10^{-10}
Radiation Detriment	Public and Transport Crew	2.7×10^{-7}	6.1×10^{-11}
Early Radiation Fatalities	Public and Transport Crew	2.7×10^{-7}	8.8×10^{-10}
Early Radiation Injuries	Public and Transport Crew	2.7×10^{-7}	1.8×10^{-9}

Table A-2
Transportation Risk for Waste Transport Using Route 2 to Envirocare and Stakebed and Bulk Transport Vehicles

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.014
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.152
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	3.4×10^{-5}	6.8×10^{-9}
	Transport Crew	1.5×10^{-5}	3.0×10^{-9}
Radiation Detriment	Public	3.4×10^{-5}	2.0×10^{-9}
	Transport Crew	1.5×10^{-5}	8.7×10^{-10}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	8.3×10^{-7}	4.1×10^{-10}
Radiation Detriment	Public and Transport Crew	8.3×10^{-7}	1.9×10^{-10}
Early Radiation Fatalities	Public and Transport Crew	8.3×10^{-7}	2.7×10^{-9}
Early Radiation Injuries	Public and Transport Crew	8.3×10^{-7}	5.5×10^{-9}

Table A-3
Transportation Risk for Waste Transport Using Route 3 to Envirocare and Stakebed and Bulk Transport Vehicles

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.011
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.125
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	3.1×10^{-5}	6.1×10^{-9}
	Transport Crew	1.2×10^{-5}	2.5×10^{-9}
Radiation Detriment	Public	3.1×10^{-5}	1.8×10^{-9}
	Transport Crew	1.2×10^{-5}	7.1×10^{-10}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	7.3×10^{-7}	3.6×10^{-10}
Radiation Detriment	Public and Transport Crew	7.3×10^{-7}	1.7×10^{-10}
Early Radiation Fatalities	Public and Transport Crew	7.3×10^{-7}	2.4×10^{-9}
Early Radiation Injuries	Public and Transport Crew	7.3×10^{-7}	4.9×10^{-9}

Table A-4
Transportation Risk for Waste Transport Using Route 1 to the NTS and Transportainer Containerization

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.008
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.069
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	9.7×10^{-6}	2.0×10^{-9}
	Transport Crew	6.4×10^{-6}	1.3×10^{-9}
Radiation Detriment	Public	9.7×10^{-6}	5.6×10^{-10}
	Transport Crew	6.4×10^{-6}	3.7×10^{-10}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	1.0×10^{-7}	5.2×10^{-11}
Radiation Detriment	Public and Transport Crew	1.0×10^{-7}	2.4×10^{-11}
Early Radiation Fatalities	Public and Transport Crew	1.0×10^{-7}	3.4×10^{-10}
Early Radiation Injuries	Public and Transport Crew	1.0×10^{-7}	6.9×10^{-10}

Table A-5
Transportation Risk for Waste Transport Using Route 2 to Envirocare and Transportainer Containerization

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.016
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.169
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	3.4×10^{-5}	6.8×10^{-9}
	Transport Crew	1.5×10^{-5}	3.0×10^{-9}
Radiation Detriment	Public	3.4×10^{-5}	2.0×10^{-9}
	Transport Crew	1.5×10^{-5}	8.7×10^{-10}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	3.9×10^{-7}	1.9×10^{-10}
Radiation Detriment	Public and Transport Crew	3.9×10^{-7}	8.9×10^{-11}
Early Radiation Fatalities	Public and Transport Crew	3.9×10^{-7}	1.3×10^{-9}
Early Radiation Injuries	Public and Transport Crew	3.9×10^{-7}	2.6×10^{-9}

Table A-6
Transportation Risk for Waste Transport Using Route 3 to Envirocare and Transportainer Containerization

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.013
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.139
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	3.0×10^{-5}	6.1×10^{-9}
	Transport Crew	1.2×10^{-5}	2.5×10^{-9}
Radiation Detriment	Public	3.0×10^{-5}	1.8×10^{-9}
	Transport Crew	1.2×10^{-5}	7.1×10^{-10}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	3.6×10^{-7}	1.8×10^{-10}
Radiation Detriment	Public and Transport Crew	3.6×10^{-7}	8.2×10^{-11}
Early Radiation Fatalities	Public and Transport Crew	3.6×10^{-7}	1.2×10^{-9}
Early Radiation Injuries	Public and Transport Crew	3.6×10^{-7}	2.4×10^{-9}

A.1.2 Results of the Clean Slate 1 Human Health Risk Assessment

Table A-7 presents the results of the Clean Slate 1 human health risk assessment. All results are for workers and indicate predicted number of consequences.

Table A-7
Clean Slate 1 Human Health Risk

Health Effect	Total Number of Health Effects
Fatalities due to Excavation Activities	4.4×10^{-5}
Injuries due to Excavation Activities	2.5×10^{-2}
Latent Cancer Fatalities	1.6×10^{-5}
Radiation Detriment	8.0×10^{-6}

Appendix B

Clean Slate 2 Risk Assessment Results

B.1.0 Clean Slate 2 Risk Assessment Results

This appendix presents the results of the Clean Slate 2 risk assessment. A discussion of the combined results of the transportation and human health risk for Clean Slate 1, 2, and 3 is presented in Chapters 2 and 3.

B.1.1 Results of the Clean Slate 2 Transportation Risk Assessment

Tables B-1 through B-6 present the results of the transportation risk assessment for Clean Slate 1. The tables are separated by transport containerization method and route.

Table B-1
Transportation Risk for Waste Transport Using Route 1 to the Nevada Test Site and Stakebed or Bulk Transport Vehicles

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.042
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.349
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	9.5×10^{-5}	1.9×10^{-8}
	Transport Crew	6.3×10^{-5}	1.3×10^{-8}
Radiation Detriment	Public	9.5×10^{-5}	5.5×10^{-9}
	Transport Crew	6.3×10^{-5}	3.6×10^{-9}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	2.6×10^{-6}	1.3×10^{-9}
Radiation Detriment	Public and Transport Crew	2.6×10^{-6}	6.0×10^{-10}
Early Radiation Fatalities	Public and Transport Crew	2.6×10^{-6}	8.5×10^{-9}
Early Radiation Injuries	Public and Transport Crew	2.6×10^{-6}	1.7×10^{-8}

Table B-2
Transportation Risk for Waste Transport Using Route 2 to Envirocare and Stakebed and Bulk Transport Vehicles

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.080
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.854
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	3.3×10^{-4}	6.6×10^{-8}
	Transport Crew	1.5×10^{-4}	2.9×10^{-8}
Radiation Detriment	Public	3.3×10^{-4}	1.9×10^{-8}
	Transport Crew	1.5×10^{-4}	8.5×10^{-9}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	8.1×10^{-6}	4.0×10^{-9}
Radiation Detriment	Public and Transport Crew	8.1×10^{-6}	1.9×10^{-9}
Early Radiation Fatalities	Public and Transport Crew	8.1×10^{-6}	2.7×10^{-8}
Early Radiation Injuries	Public and Transport Crew	8.1×10^{-6}	5.4×10^{-8}

Table B-3
Transportation Risk for Waste Transport Using Route 3 to Envirocare and Stakebed and Bulk Transport Vehicles

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.064
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.702
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	3.0×10^{-4}	6.0×10^{-8}
	Transport Crew	1.2×10^{-4}	2.4×10^{-8}
Radiation Detriment	Public	3.0×10^{-4}	1.7×10^{-8}
	Transport Crew	1.2×10^{-4}	7.0×10^{-9}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	7.1×10^{-6}	3.6×10^{-9}
Radiation Detriment	Public and Transport Crew	7.1×10^{-6}	1.6×10^{-9}
Early Radiation Fatalities	Public and Transport Crew	7.1×10^{-6}	2.3×10^{-8}
Early Radiation Injuries	Public and Transport Crew	7.1×10^{-6}	4.8×10^{-8}

Table B-4
Transportation Risk for Waste Transport Using Route 1 to the NT and Transportainer Containerization

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.047
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.388
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	9.5×10^{-5}	1.9×10^{-8}
	Transport Crew	6.3×10^{-5}	1.3×10^{-8}
Radiation Detriment	Public	9.5×10^{-5}	5.5×10^{-9}
	Transport Crew	6.3×10^{-5}	3.6×10^{-9}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	1.0×10^{-6}	5.0×10^{-10}
Radiation Detriment	Public and Transport Crew	1.0×10^{-6}	2.3×10^{-10}
Early Radiation Fatalities	Public and Transport Crew	1.0×10^{-6}	3.3×10^{-9}
Early Radiation Injuries	Public and Transport Crew	1.0×10^{-6}	6.7×10^{-9}

Table B-5
Transportation Risk for Waste Transport Using Route 2 to Envirocare and Transportainer Containerization

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.088
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.949
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	3.3×10^{-4}	6.6×10^{-8}
	Transport Crew	1.5×10^{-4}	2.9×10^{-8}
Radiation Detriment	Public	3.3×10^{-4}	1.9×10^{-8}
	Transport Crew	1.5×10^{-4}	8.5×10^{-8}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	3.8×10^{-6}	1.9×10^{-9}
Radiation Detriment	Public and Transport Crew	3.8×10^{-6}	8.7×10^{-10}
Early Radiation Fatalities	Public and Transport Crew	3.8×10^{-6}	1.3×10^{-8}
Early Radiation Injuries	Public and Transport Crew	3.8×10^{-6}	2.5×10^{-8}

Table B-6
Transportation Risk for Waste Transport Using Route 3 to Envirocare and Transportainer Containerization

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.071
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.780
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	3.0×10^{-4}	6.0×10^{-8}
	Transport Crew	1.2×10^{-4}	2.4×10^{-8}
Radiation Detriment	Public	3.0×10^{-4}	1.7×10^{-8}
	Transport Crew	1.2×10^{-4}	7.0×10^{-9}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	3.5×10^{-6}	1.8×10^{-9}
Radiation Detriment	Public and Transport Crew	3.5×10^{-6}	8.0×10^{-10}
Early Radiation Fatalities	Public and Transport Crew	3.5×10^{-6}	1.2×10^{-8}
Early Radiation Injuries	Public and Transport Crew	3.5×10^{-6}	2.3×10^{-8}

B.1.2 Results of the Clean Slate 2 Human Health Risk Assessment

Table B-7 presents the results of the Clean Slate 2 human health risk assessment. All results are for workers and indicate predicted number of consequences.

Table B-7
Clean Slate 2 Human Health Risk

Health Effect	Total Number of Health Effects
Fatalities due to Excavation Activities	2.5×10^{-4}
Injuries due to Excavation Activities	1.4×10^{-1}
Latent Cancer Fatalities	9.0×10^{-5}
Radiation Detriment	4.5×10^{-5}

C.1.0 Clean Slate 3 Risk Assessment Results

This appendix presents the results of the Clean Slate 3 risk assessment. A discussion of the combined results of the transportation and human health risk for Clean Slate 1, 2, and 3 is presented in Chapters 2 and 3.

C.1.1 Results of the Clean Slate 1 Transportation Risk Assessment

Tables C-1 through C-6 present the results of the transportation risk assessment for Clean Slate 3. The tables are separated by transport containerization method and route.

Table C-1
Transportation Risk for Waste Transport Using Route 1 to the Nevada Test Site and Stakebed or Bulk Transport Vehicles

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.052
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.434
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	1.7×10^{-4}	3.3×10^{-8}
	Transport Crew	1.1×10^{-4}	2.2×10^{-8}
Radiation Detriment	Public	1.7×10^{-4}	9.6×10^{-9}
	Transport Crew	1.1×10^{-4}	6.3×10^{-9}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	4.6×10^{-6}	2.3×10^{-9}
Radiation Detriment	Public and Transport Crew	4.6×10^{-6}	1.1×10^{-9}
Early Radiation Fatalities	Public and Transport Crew	4.6×10^{-6}	1.5×10^{-8}
Early Radiation Injuries	Public and Transport Crew	4.6×10^{-6}	3.0×10^{-8}

Table C-2
Transportation Risk for Waste Transport Using Route 2 to Envirocare and Stakebed and Bulk Transport Vehicles

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.099
Injuries due to Traffic Accidents	Public and Transport Crew	NA	1.06
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	5.8×10^{-4}	1.2×10^{-7}
	Transport Crew	2.6×10^{-4}	5.2×10^{-8}
Radiation Detriment	Public	5.8×10^{-4}	3.4×10^{-8}
	Transport Crew	2.6×10^{-4}	1.5×10^{-8}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	1.4×10^{-5}	7.1×10^{-9}
Radiation Detriment	Public and Transport Crew	1.4×10^{-5}	3.3×10^{-9}
Early Radiation Fatalities	Public and Transport Crew	1.4×10^{-5}	4.7×10^{-8}
Early Radiation Injuries	Public and Transport Crew	1.4×10^{-5}	9.5×10^{-8}

Table C-3
Transportation Risk for Waste Transport Using Route 3 to Envirocare and Stakebed and Bulk Transport Vehicles

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.079
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.874
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	5.2×10^{-4}	1.1×10^{-7}
	Transport Crew	2.1×10^{-4}	4.3×10^{-8}
Radiation Detriment	Public	5.2×10^{-4}	3.0×10^{-8}
	Transport Crew	2.1×10^{-4}	1.2×10^{-8}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	1.3×10^{-5}	6.2×10^{-9}
Radiation Detriment	Public and Transport Crew	1.3×10^{-5}	2.9×10^{-9}
Early Radiation Fatalities	Public and Transport Crew	1.3×10^{-5}	4.1×10^{-8}
Early Radiation Injuries	Public and Transport Crew	1.3×10^{-5}	8.4×10^{-8}

Table C-4
Transportation Risk for Waste Transport Using Route 1 to the NTS and Transportainer Containerization

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.058
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.482
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	1.7×10^{-4}	3.3×10^{-8}
	Transport Crew	1.1×10^{-4}	2.2×10^{-8}
Radiation Detriment	Public	1.7×10^{-4}	9.6×10^{-9}
	Transport Crew	1.1×10^{-4}	6.3×10^{-9}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	1.8×10^{-6}	8.8×10^{-10}
Radiation Detriment	Public and Transport Crew	1.8×10^{-6}	4.1×10^{-10}
Early Radiation Fatalities	Public and Transport Crew	1.8×10^{-6}	5.8×10^{-9}
Early Radiation Injuries	Public and Transport Crew	1.8×10^{-6}	1.2×10^{-8}

Table C-5
Transportation Risk for Waste Transport Using Route 2 to Envirocare and Transportainer Containerization

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.110
Injuries due to Traffic Accidents	Public and Transport Crew	NA	1.18
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	5.8×10^{-4}	1.2×10^{-7}
	Transport Crew	2.6×10^{-4}	5.2×10^{-8}
Radiation Detriment	Public	5.8×10^{-4}	3.4×10^{-8}
	Transport Crew	2.6×10^{-4}	1.5×10^{-8}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	6.6×10^{-6}	3.3×10^{-9}
Radiation Detriment	Public and Transport Crew	6.6×10^{-6}	1.5×10^{-9}
Early Radiation Fatalities	Public and Transport Crew	6.6×10^{-6}	2.2×10^{-8}
Early Radiation Injuries	Public and Transport Crew	6.6×10^{-6}	4.4×10^{-8}

Table C-6
Transportation Risk for Waste Transport Using Route 3 to Envirocare and Transportainer Containerization

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.088
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.970
Radiation-Related Health Effects Under Routine Conditions			
Latent Cancer Fatalities	Public	5.2×10^{-4}	1.1×10^{-7}
	Transport Crew	2.1×10^{-4}	4.3×10^{-8}
Radiation Detriment	Public	5.2×10^{-4}	3.0×10^{-8}
	Transport Crew	2.1×10^{-4}	1.2×10^{-8}
Radiation-Related Health Effects Under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	6.1×10^{-6}	3.1×10^{-9}
Radiation Detriment	Public and Transport Crew	6.1×10^{-6}	1.4×10^{-9}
Early Radiation Fatalities	Public and Transport Crew	6.1×10^{-6}	2.0×10^{-8}
Early Radiation Injuries	Public and Transport Crew	6.1×10^{-6}	4.1×10^{-8}

C.1.2 Results of the Clean Slate 1 Human Health Risk Assessment

Table C-7 presents the results of the Clean Slate 3 human health risk assessment. All results are for workers and indicate predicted number of consequences.

Table C-7
Clean Slate 3 Human Health Risk

Health Effect	Total Number of Health Effects
Fatalities due to Excavation Activities	3.2×10^{-4}
Injuries due to Excavation Activities	1.7×10^{-1}
Latent Cancer Fatalities	1.1×10^{-4}
Radiation Detriment	5.6×10^{-5}

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