

Nevada
Environmental
Restoration
Project

DOE/NV--567



Corrective Action Decision Document
for Corrective Action Unit 407:
Roller Coaster RADS AFE Area,
Tonopah Test Range, Nevada

Controlled Copy No.: ____

Revision No.: 0

September 1999

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**CORRECTIVE ACTION DECISION DOCUMENT
FOR CORRECTIVE ACTION UNIT 407:
ROLLER COASTER RADSAFE AREA,
TONOPAH TEST RANGE, NEVADA**

DOE Nevada Operations Office
Las Vegas, Nevada

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**CORRECTIVE ACTION DECISION DOCUMENT
FOR CORRECTIVE ACTION UNIT 407:
ROLLER COASTER RADSAFE AREA,
TONOPAH TEST RANGE, NEVADA**

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List of Acronyms and Abbreviations

Am	Americium
AMAD	Activity median aerodynamic diameters
bgs	Below ground surface
CADD	Corrective Action Decision Document
CAIP	Corrective Action Investigation Plan
CAS	Corrective Action Site
CAU	Corrective Action Unit
CEDE	Committed Effective Dose Equivalent
CFR	<i>Code of Federal Regulations</i>
CLP	Contract Laboratory Program
cm/sec	Centimeter(s) per second
COC	Contaminant(s) of concern
COPC	Contaminant(s) of potential concern
cpm	Count(s) per minute
DOE	U.S. Department of Energy
DOE/NV	U.S. Department of Energy, Nevada Operations Office
dpm	Disintegration(s) per minute
dpm/100 cm ²	Disintegration(s) per minute/100 square centimeters
DQO	Data quality objectives
EPA	U.S. Environmental Protection Agency
FFACO	<i>Federal Facility Agreement and Consent Order</i>
FIDLER	Field instrument for the detection of low energy radiation
FSL	Field-screening level
ft	Feet (foot)
ft ²	Square feet (foot)
g/d	Gram(s) per day

List of Acronyms and Abbreviations (Continued)

g/m ³	Gram(s) per cubic meter
GPR	Ground-penetrating radar
ICP	Inductively coupled plasma
IDW	Investigation-derived waste
in.	Inch(es)
LCS	Laboratory control samples
m	Meter(s)
m ²	Square meter(s)
m ³ /hr	Cubic meter(s) per hour
mg/kg	Milligram(s) per kilogram
mi	Mile(s)
mrem/yr	Millirem(s) per year
MS/MSD	Matrix spike/matrix spike duplicate
NAC	<i>Nevada Administrative Code</i>
NDEP	Nevada Division of Environmental Protection
NIST	National Institute for Standards and Technology
NRS	<i>Nevada Revised Statutes</i>
PAL	Preliminary action level(s)
PCB	Polychlorinated biphenyl(s)
pCi/g	Picocurie(s) per gram
ppm	Part(s) per million
PRG	Preliminary remediation goal(s)
PU	Polyurethane
Pu	Plutonium
QA	Quality assurance
QAPP	<i>Industrial Sites Quality Assurance Project Plan</i>

List of Acronyms and Abbreviations (Continued)

QC	Quality control
RCRA	<i>Resource Conservation and Recovery Act</i>
RCRSA	Roller Coaster RADSAFE Area
RESRAD	Residual Radiation
RPD	Relative percent difference
SDG	Sample delivery group
SVOC	Semivolatile organic compound(s)
TPH	Total petroleum hydrocarbon(s)
TD	Total depth
TRU	Transuranic
TTR	Tonopah Test Range
U	Uranium
USAF	U.S. Air Force
UST	Underground storage tank
VOC	Volatile organic compound(s)
yd ³	Cubic yard(s)
µg/kg	Microgram(s) per kilogram
µm	Micrometer(s)
%R	Percent recovery

Executive Summary

This Corrective Action Decision Document has been prepared for Corrective Action Unit 407, the Roller Coaster RADS SAFE Area, in accordance with the *Federal Facility Agreement and Consent Order* (1996) that was agreed to by the Nevada Division of Environmental Protection; the U.S. Department of Energy, Nevada Operations Office; and the U.S. Department of Defense. The Corrective Action Decision Document provides or references the specific information necessary to recommend a preferred corrective action for Corrective Action Site, TA-23-001-TARC, within Corrective Action Unit 407. The purpose of this Corrective Action Decision Document is to identify and provide a rationale for the selection of a recommended corrective action alternative for Corrective Action Unit 407.

The scope of this Corrective Action Decision Document consists of the following:

- Develop corrective action objectives.
- Identify corrective action alternative screening criteria.
- Develop corrective action alternatives.
- Perform detailed and comparative evaluations of corrective action alternatives in relation to corrective action objectives and screening criteria.
- Recommend and justify a preferred corrective action alternative for the Corrective Action Unit.

In June through November 1998, a corrective action investigation was conducted in accordance with the requirements set forth in the *Corrective Action Investigation Plan for the Roller Coaster RADS SAFE Area, Corrective Action Unit 407, Tonopah Test Range, Nevada* (DOE/NV, 1998).

Gamma spectrometry, isotopic plutonium, and isotopic uranium analytical results above preliminary action levels were reported for surface and subsurface soils at the site. The contaminants identified above preliminary action levels were plutonium, uranium, and americium. No other contaminants were detected above preliminary action levels.

Based on the potential exposure pathways identified during the Data Quality Objectives process, the following corrective action objectives have been identified for Corrective Action Unit 407:

- Prevent or mitigate human exposure to subsurface soil containing contaminants of concern.
- Prevent adverse impacts to groundwater quality.

Based on the review of existing data, future use, and current operations at the Tonopah Test Range, the following alternatives were developed for consideration at the Roller Coaster RADS SAFE Area:

- Alternative 1 - No Further Action
- Alternative 2 - Partial Excavation, Disposal, and Closure in Place with Administrative Controls
- Alternative 3 - Partial Excavation, Disposal, Closure in Place with a Surface Cap, and Administrative Controls
- Alternative 4 - Clean Closure by Excavation and Disposal
- Alternative 5 - Clean Closure by Excavation, Screening, and Disposal

The corrective action alternatives were evaluated based on four general corrective action standards and five remedy selection decision factors. Based on the results of this evaluation, the preferred alternative for Corrective Action Unit 407 is Alternative 3, Partial Excavation, Disposal, Closure in Place with a Surface Cap, and Administrative Controls.

The preferred corrective action alternative was evaluated on technical merit, focusing on performance, reliability, feasibility, and safety. The alternative was judged to meet all requirements for the technical components evaluated. The alternative meets all applicable state and federal regulations for closure of the site and will reduce potential future exposure pathways to subsurface contaminated soil.

1.0 Introduction

This Corrective Action Decision Document (CADD) has been prepared for Corrective Action Unit (CAU) 407, Roller Coaster RADS SAFE Area (RCRSA) in accordance with the *Federal Facility Agreement and Consent Order* (FFACO) of 1996 that was agreed to by the Nevada Division of Environmental Protection (NDEP); the U.S. Department of Energy, Nevada Operations Office (DOE/NV); and the U.S. Department of Defense (FFACO, 1996). The CADD provides or references the specific information necessary to recommend a preferred corrective action for Corrective Action Site (CAS), TA-23-001-TARC, within CAU 407.

Corrective Action Unit 407 is located at the Tonopah Test Range (TTR), Nevada. The TTR is approximately 140 miles (mi) northwest of Las Vegas, Nevada ([Figure 1-1](#)). The RCRSA is located on the northeast corner of the intersection of Main Road and Browne's Lake Road, which is approximately 5 mi south of Area 3 ([Figure 1-2](#)). The RCRSA was used during May and June 1963 to decontaminate vehicles, equipment, and personnel from the Clean Slate tests. The surface and subsurface soils have been impacted by plutonium and other contaminants of potential concern (COPCs) associated with decontamination activities at this site.

1.1 Purpose

This CADD identifies potential corrective action alternatives, as well as evaluates and provides a rationale for the selection of a recommended alternative for the CAU. The need for these alternatives is based on process knowledge and the results of investigative activities conducted in accordance with the *Corrective Action Investigation Plan for the Roller Coaster RADS SAFE Area, Corrective Action Unit No. 407, Tonopah Test Range, Nevada* (DOE/NV, 1998).

1.2 Scope

The scope of this CADD consists of the following:

- Develop corrective action objectives.
- Identify corrective action alternative screening criteria.

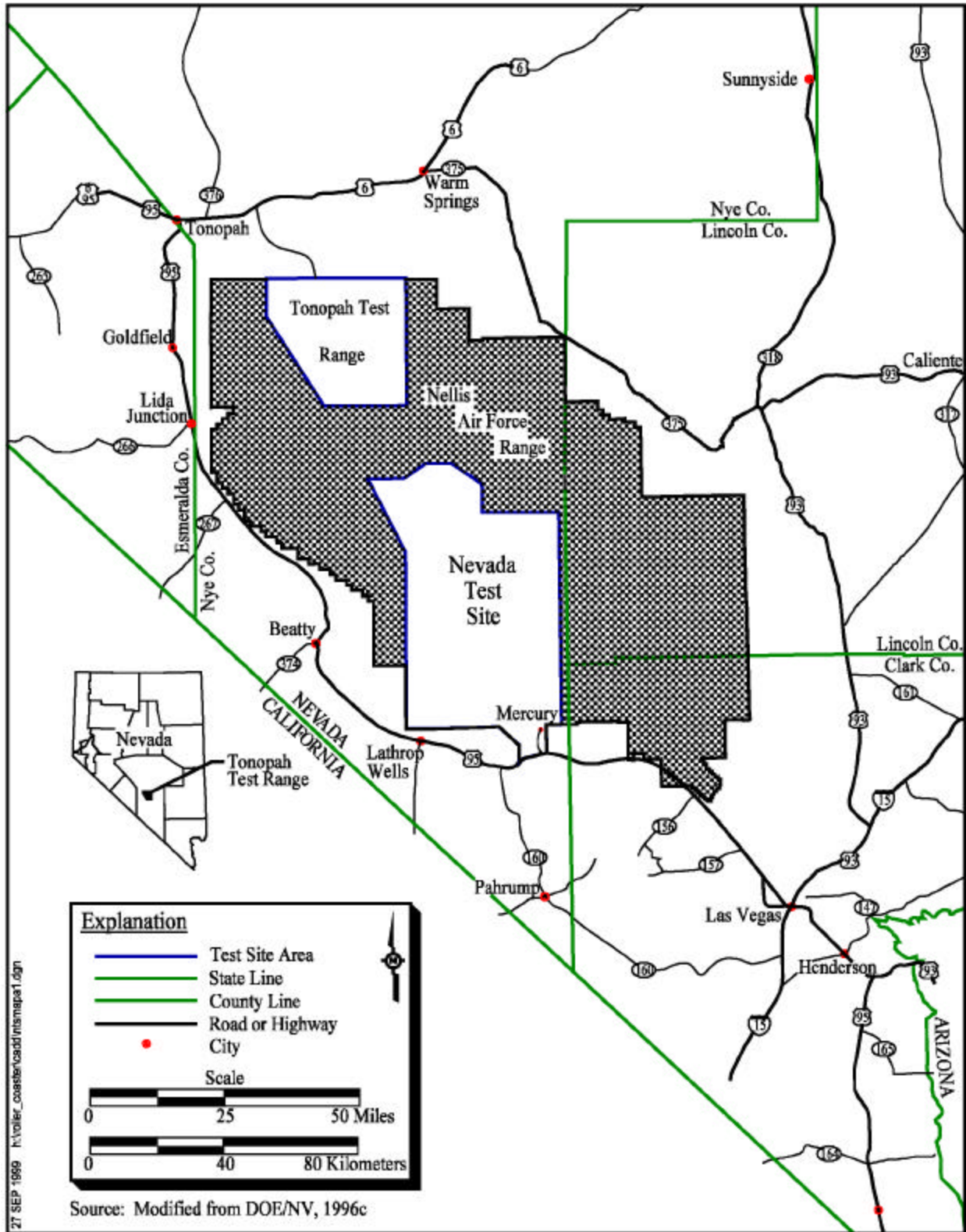


Figure 1-1
 Tonopah Test Range Location Map

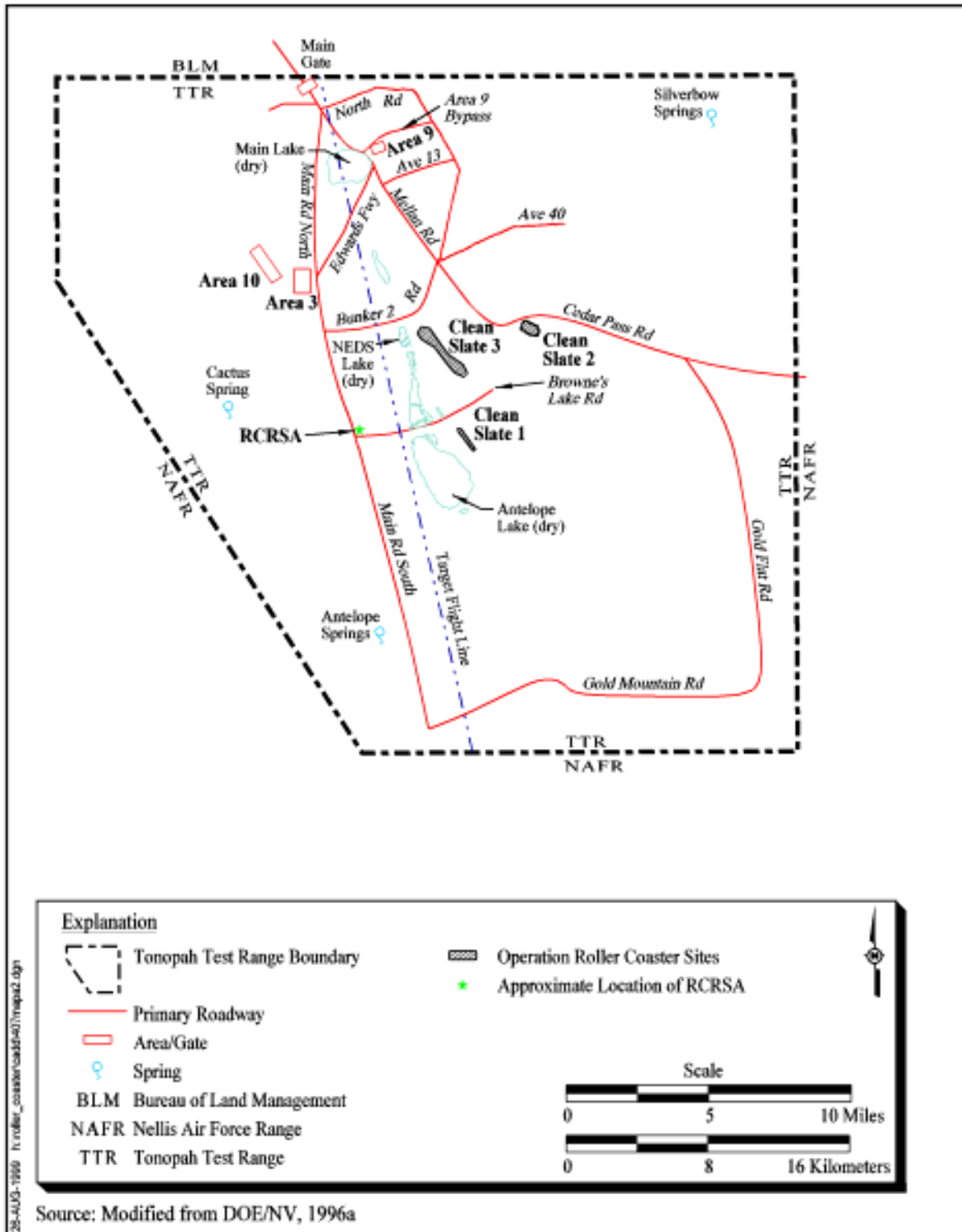


Figure 1-2
 Location of CAU 407, Roller Coaster RADS SAFE Area, Tonopah Test Range

- Develop corrective action alternatives.
- Perform detailed and comparative evaluations of corrective action alternatives in relation to corrective action objectives and screening criteria.
- Recommend and justify a preferred corrective action alternative for the CAU.

1.3 CADD Contents

This CADD is divided into the following sections:

- [Section 1.0](#) - Introduction: summarizes the purpose, scope, and contents of this CADD.
- [Section 2.0](#) - Corrective Action Investigation Summary: summarizes the investigation field activities, the results of the investigation, and the need for corrective action.
- [Section 3.0](#) - Evaluation of Alternatives: documents steps taken to determine a preferred corrective action alternative.
- [Section 4.0](#) - Recommended Alternative: presents the preferred corrective action alternative and the rationale for its selection based on the corrective action objectives and alternative screening criteria.
- [Section 5.0](#) - References: provides a list of all referenced documents.
- [Appendix A](#) - *Corrective Action Investigation Report for Corrective Action Unit 407: Roller Coaster RADSAFE Area, Tonopah Test Range, Nevada*
- [Appendix B](#) - Soil Boring Logs
- [Appendix C](#) - Cost Estimates
- [Appendix D](#) - Radiological Survey of CAU 407, CAS TA-23-001-TARC, Roller Coaster RADSAFE Area
- [Appendix E](#) - Roller Coaster RADSAFE Area Dose Assessment
- [Appendix F](#) - Roller Coaster RADSAFE Area ALARA Analysis
- [Appendix G](#) - Nevada Environmental Restoration Project Document Review Sheets

All work was performed in accordance with the following documents:

- *Corrective Action Investigation Plan for the Roller Coaster RADSAFE Area, Corrective Action Unit 407, Tonopah Test Range, Nevada* (DOE/NV, 1998)
- *Industrial Sites Quality Assurance Project Plan* (DOE/NV, 1996d)
- *Corrective Action Unit Work Plan for the Tonopah Test Range* (DOE/NV, 1996a)
- *Federal Facility Agreement and Consent Order* (1996)
- *Project Management Plan* (DOE/NV, 1994)

2.0 Corrective Action Investigation Summary

The following sections describe and summarize the results of the investigation activities conducted at CAU 407. For detailed investigation results, please refer to [Appendix A](#).

2.1 Investigation Activities

A radiological survey was conducted in January 1998 to determine the type and location of surface and subsurface contamination. A total of 50 alpha, 50 beta, and 149 gamma measurements were recorded. Radiological measurements of the surface soils at CAU 407 indicate alpha, beta, and gamma activity greater than background. The results of the survey are in [Appendix D](#) (memo from Carl Speer to Steven Adams, January 1999).

In June and July 1998, corrective action investigation activities were performed as defined in the Corrective Action Investigation Plan (CAIP) (DOE/NV, 1998). The following describes the purpose of the investigation:

- Determine the RCRSA decontamination facility locations (vehicle and personnel decontamination areas, decontamination sumps, and waste disposal pit).
- Identify the presence and nature of COPCs within the RCRSA.
- Determine the vertical and lateral extent of COPCs.
- Provide sufficient information and data from which corrective action alternatives may be developed in this CADD for this CAU.

The following items summarize the investigation activities (details of the investigation are presented in [Appendix A](#)):

- Drilled 10 investigation borings and one background boring in the RCRSA to a maximum depth of 30 feet (ft) using the sonic drilling method.
- Collected samples from each of the borings for field screening and laboratory analyses ([Figure A.2-2](#) in [Appendix A](#) shows boring locations).

- Analyzed environmental samples from the investigation borings for total volatile organic compounds (VOCs), total semivolatile organic compounds (SVOCs), total *Resource Conservation and Recovery Act* (RCRA) metals, total petroleum hydrocarbons (TPH) gasoline and diesel/oil, total pesticides and polychlorinated biphenyls (PCBs), radionuclides using gamma spectrometry, isotopic plutonium, and isotopic uranium.
- Analyzed geotechnical samples from investigation borings for initial moisture content, dry bulk density, calculated porosity, saturated/unsaturated hydraulic conductivity, particle size distribution, and water-release curve.

Sixteen additional surface soil samples were collected on November 23, 1998, from areas that were suspected to have surface radiological contamination. These samples were analyzed for gamma spectrometry, isotopic plutonium, and isotopic uranium.

2.2 Results

The corrective action investigation results indicated the following:

- Subsurface plutonium-239/240 contamination greater than background concentrations is present in the waste disposal pit. The maximum lateral dimensions of the waste pit are 20 ft by 35 ft and depth ranges from a minimum of 10 ft to 20 ft.
- Americium-241, uranium-235, uranium-238, and plutonium-239/240 contamination greater than background is associated with surface soils.
- With the exception of arsenic, the preliminary action levels (PALs) were not exceeded for total VOCs, total SVOCs, total PCBs, and total RCRA metals for any of the subsurface samples collected at the RCRSA site.
- Arsenic concentrations were detected above the industrial soil preliminary remediation goal (PRG) (EPA, 1998) in several samples collected; however, these concentrations were below the maximum background concentration detected for arsenic in the background boring BGB-1. Based on the background concentrations, arsenic is considered naturally occurring at these levels.
- The geologic and geotechnical results revealed that the soil beneath the RCRSA is comprised of sand with discontinuous gravel lenses.

- The contaminants identified above preliminary action levels are americium, isotopic plutonium, and isotopic uranium; corrective actions for addressing these elevated levels are evaluated in this CADD.

Details of the methods used and results found during the investigation are presented in [Appendix A](#).

2.3 Need for Corrective Action

Analytes detected during the corrective action investigation were evaluated against PALs to determine contaminants of concern (COCs) for CAU 407. Plutonium was detected above the PAL (DOE/NV, 1998) in samples taken from surface and subsurface soil within the exclusion zone. Uranium and americium were detected above the PAL in samples taken from surface soil within the exclusion zone. No other COCs were identified above PALs as specified in the CAIP; therefore, potential corrective actions will be identified and evaluated in this CADD to ensure worker, public, and environmental protection against potential exposure to the radiological contamination in accordance with U.S. Department of Energy (DOE) Order 5400.5 and 10 *Code of Federal Regulations* (CFR) 20 (DOE, 1993; CFR, 1998a).

3.0 Evaluation of Alternatives

The purpose of this section is to present the corrective action objectives for CAU 407, describe the general standards and decision factors used to screen the corrective action alternatives, and develop and evaluate a set of corrective action alternatives that could be used to meet the corrective action objectives.

3.1 Corrective Action Objectives

The corrective action objectives are media-specific goals for protecting human health and the environment. Based on the potential exposure pathways (see [Section 3.1.2](#)), the following corrective action objectives have been identified for CAU 407:

- Prevent or mitigate human exposure to surface and subsurface soil containing COCs.
- Prevent adverse impacts to groundwater quality.

Each corrective action alternative must meet the generic and specific guidelines established in the DOE Order 5400.5 and the 25-millirem per year (mrem/yr) limit established in title 10 CFR Part 20 Subsection E (DOE, 1993; CFR, 1998a). DOE Order 5400.5 established both generic and site-specific guidelines for residual radioactive material in soil (DOE, 1993). A guideline is the concentration of a radionuclide in soil that is acceptable for use of property without restrictions due to residual radioactive material. The basis for the guidelines is a presumed worst-case plausible use scenario for the property.

The generic guidelines established in DOE Order 5400.5 are independent of the property, are taken from existing federal radiation protection standards, and address the concentration of radium-226, radium-228, thorium-230, and thorium-232. These four radionuclides are not COCs at the RCRSA; therefore, the generic guidelines do not apply.

The site-specific property guidelines are derived from a basic dose limit of 100 mrem/yr to the future land user and site-specific property models and data. The radiological dose assessment process estimates the dose to hypothetical future individuals by applying the mathematical models in the Residual Radiation (RESRAD) code that quantify the transport of radionuclides through the

environment, subsequent intake, and resultant dose. The RESRAD code, procedures, and the property data required for deriving site-specific guidelines are contained in Gilbert et al. (1989) and the RESRAD code manuals (Yu et al., 1993a and b).

The RCRSA is located on the TTR that is operated by the U.S. Air Force (USAF). For protection of their workers, the public, and the environment from radiological activities and operations, the USAF adheres to the requirements of the U.S. Nuclear Regulatory Commission stipulated in Title 10 CFR Part 20 (CFR, 1998a). Title 10 CFR Part 20 Subsection E states that the dose to members of the public should not exceed 25 mrem/yr subsequent to facility decommissioning, but could be raised up to 500 mrem/yr if it can be demonstrated that further reductions are not technically achievable, are prohibitively expensive, or would result in net public environmental harm (CFR, 1998a).

For each corrective action alternative, the radiological data collected at the RCRSA are statically analyzed and compared to RESRAD calculated soil concentrations of plutonium, americium, and uranium that correspond to 25 mrem/yr.

3.1.1 Contaminants of Concern

Contaminants of potential concern were determined in the Data Quality Objectives (DQO) process as outlined in the CAIP (DOE/NV, 1998). Analytical results obtained from the corrective action investigation were evaluated to determine if COPCs were detected above PALs. Compounds exceeding these levels would be COCs for CAU 407 that must be addressed by corrective action. Based on the results of this evaluation, elevated levels of plutonium, uranium, and americium were identified above PALs (see [Section A.3.0](#) of [Appendix A](#)). No other COCs were identified.

3.1.2 Potential Exposure Pathways

As identified in the DQO process, the future use for the RCRSA area is assumed to be similar to its current use. This portion of the TTR has been identified as open and used for testing and military training programs (DOE/NV, 1996c). Neither the U.S. Department of Energy nor the USAF have any specific future plans for use of the RCRSA site. However, because there are roads and a groundwater well in the vicinity of the site, it is assumed that the area could possibly be used for

industrial purposes. As part of the CAIP (DOE/NV, 1998), a conceptual model for CAU 407 was developed which identified the potential exposure pathway as ingestion of soils under occupational scenarios. The scenario in [Appendix E](#) is an industrial worker exposed to radionuclides via inhalation, ingestion, and external pathways.

3.2 Screening Criteria

The screening criteria used to evaluate and select the preferred corrective action alternatives are identified in the U.S. Environmental Protection Agency's (EPA's) *Guidance on Resource Conservation and Recovery Act Corrective Action Decision Documents* (EPA, 1991) and the *Final RCRA Corrective Action Plan* (EPA, 1994).

Corrective action alternatives will be evaluated based on four general corrective action standards and five remedy selection decision factors. All corrective action alternatives must meet the general standards to be selected for evaluation using the remedy selection decision factors.

The general corrective action standards are as follows:

- Protection of human health and the environment
- Compliance with media cleanup standards
- Control of the source(s) of the release
- Compliance with applicable federal, state, and local standards for waste management

The remedy selection decision factors are as follows:

- Short-term reliability and effectiveness
- Reduction of toxicity, mobility, and/or volume
- Long-term reliability and effectiveness
- Feasibility
- Cost

3.2.1 Corrective Action Standards

The following text describes the corrective action standards used to evaluate the corrective action alternatives.

Protection of Human Health and the Environment

Protection of human health and the environment is a general mandate of the RCRA statute (CFR, 1998b). This mandate requires that the corrective action include any protective measures that are needed. These measures may or may not be directly related to media cleanup, source control, or management of wastes. The corrective action alternatives are evaluated for the ability to meet corrective action objectives as defined in [Section 3.1](#).

Compliance with Media Cleanup Standards

Each corrective action alternative must have the ability to meet the proposed media cleanup standards as set forth in applicable regulations. Each corrective action alternative must meet the generic and specific guidelines established in the DOE Order 5400.5 and the 25-mrem/yr limit established in title 10 CFR Part 20 Subsection E (DOE, 1993; CFR, 1998a).

Control of the Source(s) of the Release

An objective of corrective action remedy is to stop further environmental degradation by controlling or eliminating additional releases that may pose a threat to human health and the environment. Unless source control measures are taken, efforts to clean up releases may be ineffective or, at best, will essentially involve a perpetual cleanup. Therefore, each corrective action alternative must use an effective source control program to ensure the long-term effectiveness and protectiveness of the corrective action.

Compliance with Applicable Federal, State, and Local Standards for Waste Management

During implementation of any corrective action alternative, all waste management activities must be conducted in accordance with applicable state and federal regulations (e.g., *Nevada Revised Statutes* [NRS] 459.400 - 459.600 [NRS, 1995]; 40 CFR 261 - 281, "RCRA Regulations" [CFR, 1998b]; 40 CFR 268, "Land Disposal Restrictions" (CFR, 1998b); and *Nevada Administrative Code* [NAC] 459.9974, "Disposal and Evaluation of Contaminated Soil" [NAC, 1998b]). The requirements for management of the waste, if any, derived from the corrective action will be determined based on applicable state and federal regulations, field observations,

process knowledge, characterization data, and data collected and analyzed during corrective action implementation. Administrative controls (e.g., decontamination procedures and corrective action strategies) will minimize waste generated during site corrective action activities. Decontamination activities will be performed in accordance with approved procedures as specified in the NDEP-approved TTR work plan (DOE/NV, 1996a) and will be designated according to the contaminants present at the site.

3.2.2 Remedy Selection Decision Factors

The following sections describe the remedy selection decision factors used to evaluate the corrective action alternatives.

Short-Term Reliability and Effectiveness

Each corrective action alternative must be evaluated with respect to its effects on human health and the environment during the construction and implementation phase of the corrective action. The following factors will be addressed for each alternative:

- Protection of the community from potential risks associated with implementation, such as fugitive dusts, transportation of hazardous materials, and explosion
- Protection of workers during construction and implementation
- Environmental impacts that may result from construction and implementation
- The amount of time until the corrective action objectives are achieved

Reduction of Toxicity, Mobility, and/or Volume

Each corrective action alternative must be evaluated for its ability to reduce the toxicity, mobility, and/or volume of the contaminated media. Reduction in toxicity, mobility, and/or volume refers to changes in one or more characteristics of the contaminated media by the use of corrective measures that decrease the inherent threats associated with that media.

Long-Term Reliability and Effectiveness

Each corrective action alternative must be evaluated in terms of risk remaining at the CAU after the corrective action alternative has been implemented. The primary focus of this evaluation is on the extent and effectiveness of the controls that may be required to manage risk posed by treatment residuals and/or untreated wastes.

Feasibility

The feasibility criterion addresses the technical and administrative feasibility of implementing a corrective action alternative and the availability of services and materials needed during implementation. Each corrective action alternative must be evaluated for the following criteria:

- **Construction and Operation:** This refers to the feasibility of implementing a corrective action alternative given the existing waste and site-specific conditions.
- **Administrative Feasibility:** This refers to the administrative activities needed to implement the corrective action alternative (e.g., permits, public acceptance, rights of way, off-site approval).
- **Availability of Services and Materials:** This refers to the availability of adequate off-site and on-site treatment, storage capacity, disposal services, needed technical services and materials, and availability of prospective technologies for each corrective action alternative.

Cost

Costs for each alternative are estimated for comparison purposes only. The cost estimate for each corrective action alternative includes both capital and operation and maintenance costs, as applicable. The following is a brief description of each component:

- **Capital Costs:** These costs include both direct and indirect costs. Direct costs may consist of materials, labor, mobilization, demobilization, site preparation, construction materials, equipment purchase and rental, sampling and analysis, waste disposal, and health and safety measures. Indirect costs include such items as engineering design, permits and/or fees, start-up costs, and any contingency allowances.
- **Operation and Maintenance Costs:** These costs include labor, training, sampling and analysis, maintenance materials, utilities, and health and safety measures.

Cost summaries for this CADD are provided in [Appendix C](#).

3.3 Development of Corrective Action Alternatives

This section identifies and briefly describes the viable corrective action technologies and the corrective action alternatives considered for the affected media. Based on the review of existing data, future use, and current operations at the TTR, the following alternatives have been developed for consideration at the RCRSA:

- Alternative 1 - No Further Action
- Alternative 2 - Partial Excavation, Disposal, and Closure in Place with Administrative Controls
- Alternative 3 - Partial Excavation, Disposal, Closure in Place with a Surface Cap, and Administrative Controls
- Alternative 4 - Clean Closure by Excavation and Disposal
- Alternative 5 - Clean Closure by Excavation, Screening and Disposal

The following analysis of NAC 445A.227 (2) (a-k) criteria (NAC, 1998a) supports the protection of groundwater from the CAU 407 COCs; therefore, groundwater monitoring is not considered in the remainder of the document:

- a. The depth to groundwater is approximately 400 ft (DOE/NV, 1996a). The precipitation for the area (5 to 6 inches [in.] annually) (DOE/NV, 1996a) does not significantly influence the movement of the contaminants. The geologic, hydraulic, and geotechnical results revealed that the soil beneath the RCRSA is comprised of a sand with discontinuous gravel lenses ([Appendix A](#)).
- b. The distance to the nearest drinking water well (Sandia 6) is 4.4 mi north-northwest of the CAS. Groundwater in this area moves generally to the northwest (DOE/NV, 1996a). The total lateral extent of the contaminated soil as determined in the site investigation is limited to approximately 700 square feet (ft²) (see [Figure A.2-3](#) in [Appendix A](#)); therefore, in order for the contaminants to affect the drinking water well, they will need to travel the vertical distance to the groundwater and then travel through the groundwater to the radius of influence of the well. Lateral and vertical migration of the contamination is minimal

(Figure A.2-1 in Appendix A). Based on the small area of contamination, the likelihood of any impacts to the well is negligible.

The Roller Coaster Well (TTR Sandia 8) is approximately 1,000 ft north of the site. This well is not currently used as a drinking water well.

- c. Geotechnical analysis of four samples taken at the site from different horizons showed evidence of a decrease in porosity with a increase in depth. The porosity measured in the analysis ranged from 31.1 percent to 44.8 percent. Permeabilities ranged from 9.6×10^{-4} to 1.1×10^{-3} centimeters per second (cm/sec) (Appendix A).
- d. Annual precipitation is typically 5 to 6 in. Annual evaporation is between 58 and 66 in. (DOE/NV, 1996a). The high evaporation and low precipitation create a negative water balance for the area; therefore, no driving force associated with precipitation is available to mobilize contaminants to groundwater. Ponding is not likely at the CAU because the ground surface slopes enabling surface water to run off site.
- e. The type of wastes disposed at the site are believed to be from the decontamination of personnel, vehicles, and equipment associated with the Clean Slate tests. The COCs are americium, plutonium, and uranium from the decontamination activities associated with the Clean Slate tests and fluids from decontaminated vehicles. Redwood chips, coarse gravel, and debris associated with the waste disposal pit (plastic, wood, rubber, metal tape, and other construction debris) were also identified in the subsurface soil. The subsurface contamination is limited to within the boundaries of the waste disposal pit. Surface contamination is limited to the boundaries of the exclusion zone.
- f. The total lateral extent of contamination is estimated to be 700 ft². The maximum vertical extent of contamination is approximately 20 ft. The movement of the contaminants laterally and vertically is significantly limited by the low movement potential of the COCs in soil (Essington et al., 1975; DOE/NV, 1996b; DOE/NV, 1997).
- g. Presently, the CAU is located in a government-controlled facility with the potential future use similar to current use. Neither the DOE nor the USAF has any specific future plans for use of the RCRSA site. However, because there are roads and a groundwater well in the vicinity of the site, it is assumed that the site could possibly be used for industrial purposes. The TTR is a restricted area that is guarded on a 24-hour, 365-day per year basis; unauthorized personnel are not admitted to the facility. The highest subsurface levels of contamination identified is currently covered by a minimum of 10 ft of soil, preventing inadvertent access. Alternatives will be evaluated for control of inadvertent intrusion to the contaminated zone.
- h. Preferred routes of migration are redistribution of the particulate material. Surface contamination is limited to several small areas. Inadvertent intrusion is the only pathway from the subsurface contaminants to potential receptors.

- i. The highest levels of subsurface contamination are located a minimum of 10 ft below ground surface (bgs). The RCRSA is located just northeast of the intersection of Main and Browne's Lake Road. Access to the RCRSA is limited by an exclusion zone fence surrounding the area. Several aboveground features include a vehicle ramp, concrete pad, and several pipes. Underground utilities include water lines, a telephone cable, and other buried utilities (Figure A.2-1).
- j. The potential for a hazard related to fire, vapor, or explosion is nonexistent due to the COCs at the CAU. There is a potential for explosions from bombing activities.
- k. No other site-specific factors are known at this time.

3.3.1 Alternative 1 - No Further Action

Under the No Further Action Alternative, no corrective action activities will be implemented. This alternative is a baseline case used to compare the other corrective action alternatives and their ability to meet the corrective action standards. This alternative does not meet the corrective action objectives because no actions are taken to prevent human contact with the COCs. This alternative will not be compared to the other alternatives using the selection decision factors.

3.3.2 Alternative 2 - Partial Excavation, Disposal, and Closure in Place with Administrative Controls

Alternative 2 consists of removing the contaminated surface soil. Surface soil with contamination greater than 2 to 3 times background or as determined by field screening, whichever is greater, will be excavated to a depth of 6 in. Contaminated soil will be disposed of at an approved disposal facility. Excavated areas will be backfilled with clean borrow soil from a proximal location and recontoured to eliminate topographic depressions and allow runoff. Following excavation, administrative controls would be instituted to preclude inadvertent intrusion into the remaining subsurface contamination at the CAU. The surface of the waste disposal pit will be contoured to minimize erosion. Diversion ditches will be constructed around the waste disposal pit to minimize impacts from surface water.

Administrative controls are used to prevent inadvertent contact with contaminated media. Administrative controls would consist of use restrictions to prevent intrusive activities. The future use of the contaminated land associated with this CAU would be restricted from any activity that would alter or modify the containment control unless appropriate concurrence was obtained.

Administrative controls are commonly used and can effectively eliminate potential exposure pathways. Administrative controls are effective because the TTR, including CAU 407, is a restricted-access facility. The implementation of administrative controls requires the coordination of all entities at a facility to ensure that the restrictions are enforced.

3.3.3 Alternative 3 - Partial Excavation, Disposal, and Administrative Controls With a Surface Cap

Alternative 3 consists of removal and disposal of the contaminated surface soil as described in Alternative 2. In addition, an engineered surface cap will be constructed over the waste disposal pit area where subsurface COCs will remain. This cap will prevent inadvertent intrusive activities by humans and native wildlife and mobilization of the COCs.

Administrative controls will also be implemented under this alternative to restrict intrusive activities as described in Alternative 2 and impose long-term maintenance requirements of the surface cap.

3.3.4 Alternative 4 - Clean Closure by Excavation and Disposal

Alternative 4 consists of removing surface and subsurface soil and material with COC concentrations greater than 2 to 3 times background or as determined by field screening, whichever is greater. The excavated soil and material will be disposed of in an appropriate disposal facility. Clean borrow soil will be used to backfill remaining voids as necessary.

Under this alternative, soil will be excavated to a depth of 20 ft at the waste disposal pit. Contaminated surface soil will be excavated as described in Alternative 2. Activities will include excavation and disposal of approximately 1,856 cubic yards (yd³) of contaminated soil. Verification sampling will be performed in approximately the same locations as those identified in the investigation as having COC concentrations exceeding 2 to 3 times background to ensure complete removal of contaminated soil.

The RCRSA site will be closed in accordance with NAC 445A (NAC, 1998a) as described in this section.

3.3.5 Alternative 5 - Clean Closure by Excavation, Screening, and Disposal

Alternative 5 consists of removing surface and subsurface soil and material with COC concentrations greater than 2 to 3 times background or as determined by field screening, whichever is greater. The excavated soil and material will be disposed of in an appropriate disposal facility. Clean borrow soil will be used to backfill in remaining voids as necessary.

Under this alternative, soil will be excavated to a depth of 20 ft at the waste disposal pit. Surface soil with COCs exceeding 2 to 3 times background will be excavated as described in Alternative 2. Activities will include excavation and screening of the top 8 ft of soil in the waste disposal pit. The remaining soil in the waste disposal pit will be excavated for disposal as radiologically impacted soil. The volume to be screened is approximately 1,024 yd³ and approximately 832 yd³ of contaminated soil will be excavated for disposal. Verification sampling will be performed in approximately the same locations as those identified in the investigation as having COC concentrations exceeding 2 to 3 times background to ensure complete removal of contaminated soil.

The RCRSA site will be closed in accordance with NAC 445A (NAC, 1998a) as described in this section.

3.4 Evaluation and Comparison of Alternatives

The general corrective action standards and remedy selection decision factors described in [Section 3.2](#) were used to conduct a detailed evaluation of each corrective action alternative. A comparative evaluation of each corrective action alternative was performed using the evaluation criteria. In this way, the advantages and disadvantages of each alternative are assessed to select a preferred alternative for CAU 407. [Table 3-1](#) presents a summary of the detailed analysis of the alternatives. [Table 3-2](#) presents the comparative analysis of alternatives. A summary of costs for the five alternatives is provided in [Appendix C](#).

Table 3-1
Detailed Evaluation of Alternatives
 (Page 1 of 4)

Evaluation Criteria	Alternative 1 No Further Action	Alternative 2 Partial Excavation, Disposal, and Closure in Place with Administrative Controls	Alternative 3 Partial Excavation, Disposal, and Administrative Controls with a Surface Cap	Alternative 4 Clean Closure by Excavation and Disposal	Alternative 5 Clean Closure by Excavation, Screening, and Disposal
Closure Standards					
Protection of Human Health and the Environment	<ul style="list-style-type: none"> • Does not meet corrective action objective of preventing redistribution of surface contamination and inadvertent intrusion into contaminated soil zone • No worker exposure associated with implementation • NAC 445A.227 (2) (a-k) analysis (Section 3.3) shows groundwater is protected. 	<ul style="list-style-type: none"> • Meets corrective action guidelines in DOE Order 5400.5 and 10 CFR 20. • Prevents inadvertent intrusion and redistribution of surface contamination. • Moderate risk to workers during implementation because of surface excavation requirement and exposure to COC • Low risk to public because of remote location and controlled access to the TTR • NAC 445A.227 (2) (a-k) analysis (Section 3.3) shows groundwater is protected. 	<ul style="list-style-type: none"> • Meets corrective action guidelines in DOE Order 5400.5 and 10 CFR 20. • Prevents inadvertent intrusion and redistribution of surface contamination. • Moderate risk to workers during implementation because of surface excavation requirement and exposure to COC • Low risk to public because of remote location and controlled access to the TTR • NAC 445A.227 (2) (a-k) analysis (Section 3.3) shows groundwater is protected. 	<ul style="list-style-type: none"> • Meets corrective action guidelines in DOE Order 5400.5 and 10 CFR 20. • Prevents inadvertent intrusion and redistribution of surface contamination. • Highest risk to workers during implementation because of excavation requirement and exposure to COCs • Low risk to public because of remote location and controlled access to the TTR • NAC 445A.227 (2) (a-k) analysis (Section 3.3) shows groundwater is protected. 	<ul style="list-style-type: none"> • Meets corrective action guidelines in DOE Order 5400.5 and 10 CFR 20. • Prevents inadvertent intrusion and redistribution of surface contamination. • Highest risk to workers during implementation because of excavation requirement and exposure to COCs • Low risk to public because of remote location and controlled access to the TTR • NAC 445A.227 (2) (a-k) analysis (Section 3.3) shows groundwater is protected.

Table 3-1
Detailed Evaluation of Alternatives
 (Page 2 of 4)

Evaluation Criteria	Alternative 1 No Further Action	Alternative 2 Partial Excavation, Disposal, and Closure in Place with Administrative Controls	Alternative 3 Partial Excavation, Disposal, and Administrative Controls with a Surface Cap	Alternative 4 Clean Closure by Excavation and Disposal	Alternative 5 Clean Closure by Excavation, Screening, and Disposal
Compliance with Media Cleanup Standards	<ul style="list-style-type: none"> Does not currently comply with media cleanup standards because action is not taken to address COCs identified significantly above preliminary action levels. 	<ul style="list-style-type: none"> Meets corrective action guidelines in DOE Order 5400.5 and 10 CFR 20. Surface contamination removed. 	<ul style="list-style-type: none"> Meets corrective action guidelines in DOE Order 5400.5 and 10 CFR 20. Surface contamination removed. 	<ul style="list-style-type: none"> Meets corrective action guidelines in DOE Order 5400.5 and 10 CFR 20. All contamination exceeding preliminary action levels removed. 	<ul style="list-style-type: none"> Meets corrective action guidelines in DOE Order 5400.5 and 10 CFR 20. All contamination exceeding preliminary action levels removed.
Control of the Source(s) of Release	<ul style="list-style-type: none"> The source(s) for release of COCs to the environment are no longer viable. 	<ul style="list-style-type: none"> The source(s) for release of COCs to the environment are no longer viable. Some potential for release of COCs during excavation and disposal activities. 	<ul style="list-style-type: none"> The source(s) for release of COCs to the environment are no longer viable. Some potential for release of COCs during excavation and disposal activities. 	<ul style="list-style-type: none"> The source(s) for release of COCs to the environment are no longer viable. Some potential for release of COCs during excavation and disposal activities. 	<ul style="list-style-type: none"> The source(s) for release of COCs to the environment are no longer viable. Some potential for release of COCs during excavation and disposal activities.
Compliance with Applicable Federal, State, and Local Standards for Waste Management	No waste generated	<ul style="list-style-type: none"> Waste will be generated from removal of COC contaminated soil. Will be handled and disposed of per applicable standards. 	<ul style="list-style-type: none"> Waste will be generated from removal of COC contaminated soil. Will be handled and disposed of per applicable standards. 	<ul style="list-style-type: none"> Waste will be generated from removal of COC contaminated soil. Will be handled and disposed of per applicable standards. 	<ul style="list-style-type: none"> Waste will be generated from removal of COC contaminated soil. Will be handled and disposed of per applicable standards.

Table 3-1
Detailed Evaluation of Alternatives
 (Page 3 of 4)

Evaluation Criteria	Alternative 1 No Further Action	Alternative 2 Partial Excavation, Disposal, and Closure in Place with Administrative Controls	Alternative 3 Partial Excavation, Disposal, and Administrative Controls with a Surface Cap	Alternative 4 Clean Closure by Excavation and Disposal	Alternative 5 Clean Closure by Excavation, Screening, and Disposal
Remedy Selection Decision Factors					
Short-Term Reliability and Effectiveness	Not evaluated	<ul style="list-style-type: none"> • Moderate risk to workers associated with excavation and disposal activities and exposure to COCs. • Public protected by remote location and TTR site access controls. 	<ul style="list-style-type: none"> • Moderate risk to workers associated with excavation and disposal activities and exposure to COCs. • Public protected by remote location and TTR site access controls. 	<ul style="list-style-type: none"> • High risk to workers associated with excavation and disposal activities and exposure to COCs. • Public protected by remote location and TTR site access controls. 	<ul style="list-style-type: none"> • High risk to workers associated with excavation and disposal activities and exposure to COCs. • Public protected by remote location and TTR site access controls.
Reduction of Toxicity, Mobility, and/or Volume	Not evaluated	<ul style="list-style-type: none"> • Highest levels of contamination removed. • Spread of remaining contamination controlled by administrative controls. 	<ul style="list-style-type: none"> • Highest levels of contamination removed. • Spread of remaining contamination controlled by surface cap and administrative controls. 	<ul style="list-style-type: none"> • All parameters reduced by removal of COCs exceeding preliminary action levels. 	<ul style="list-style-type: none"> • All parameters reduced by removal of COCs exceeding preliminary action levels.
Long-Term Reliability and Effectiveness	Not evaluated	<ul style="list-style-type: none"> • Controls inadvertent intrusion. • Administrative controls must be maintained. • Highest levels of contamination removed. 	<ul style="list-style-type: none"> • Controls inadvertent intrusion. • Administrative controls must be maintained. • Highest levels of contamination removed. 	<ul style="list-style-type: none"> • Clean Closure will ensure that no risk remains. 	<ul style="list-style-type: none"> • Clean Closure will ensure that no risk remains.

Table 3-1
Detailed Evaluation of Alternatives
 (Page 4 of 4)

Evaluation Criteria	Alternative 1 No Further Action	Alternative 2 Partial Excavation, Disposal, and Closure in Place with Administrative Controls	Alternative 3 Partial Excavation, Disposal, and Administrative Controls with a Surface Cap	Alternative 4 Clean Closure by Excavation and Disposal	Alternative 5 Clean Closure by Excavation, Screening, and Disposal
Feasibility	Not evaluated	<ul style="list-style-type: none"> • Easily implemented. • Coordination of all entities is necessary to ensure compliance with administrative controls to prevent intrusion. 	<ul style="list-style-type: none"> • Easily implemented. • Coordination of all entities is necessary to ensure compliance with administrative controls to prevent intrusion. 	<ul style="list-style-type: none"> • Depth of removal area would require significant excavation or shoring to protect workers on the project. • If removal by coring instead of excavation, equipment availability may be a concern. 	<ul style="list-style-type: none"> • Depth of removal area would require significant excavation or shoring to protect workers on the project. • If removal by coring instead of excavation, equipment availability may be a concern.
Cost	\$0	\$152,091	\$309,172	\$1,438,331	\$895,451

**Table 3-2
 Comparative Evaluation of Alternatives
 (Page 1 of 2)**

Evaluation Criteria	Comparative Evaluation
Closure Standards	
Protection of Human Health Environment	Alternatives 2, 3, 4, and 5 meet corrective action objectives; Alternative 1 does not. Worker exposure to risks increases from no risk associated with Alternative 1, to greatest risk associated with Alternatives 4 and 5. An evaluation of NAC 445A.227 (2) (a-k) (Section 3.3 ; NAC, 1998a) demonstrates that waters of the state of Nevada are not endangered by site conditions.
Compliance with Media Cleanup Standards	Alternatives 2, 3, 4, and 5 comply with corrective action guidelines. Alternative 1 does not.
Control of the Source(s) of the Release	Disposal activities are no longer conducted at the site. Alternatives 2, 3, 4, and 5 have some potential for release of the COCs associated with removal of contaminated soils and subsequent disposal. Alternatives 2 and 3 limit release by inadvertent intrusion.
Compliance with Applicable Federal, State, and Local Standards for Waste Management	Alternative 1 does not generate any waste. Alternatives 2, 3, 4, and 5 generate waste associated with removal of contaminated soil. All waste will be managed and disposed per applicable standards.
Remedy Selection Decision Factors	
Short-Term Reliability and Effectiveness	Worker exposure to risks increases from moderate risk associated with Alternatives 2 and 3, to highest risk associated with Alternatives 4 and 5.
Reduction of Toxicity, Mobility, and/or Volume	Alternatives 2, 3, 4 and 5 result in reduced toxicity, mobility, and volume due to removal of contamination or limiting contact. Alternative 4 and 5 result in a reduction of all three parameters in less time. Alternatives 2 and 3 result in some immediate reduction associated with removal of surface COCs.
Long-Term Reliability and Effectiveness	Residual risk for all alternatives is low. Alternatives 2 and 3 require some maintenance of administrative controls. Alternative 4 and 5 result in clean closure with no long-term monitoring requirements.

Table 3-2
Comparative Evaluation of Alternatives
(Page 2 of 2)

Evaluation Criteria	Comparative Evaluation
Feasibility	Alternatives 2, 3, 4, and 5 are feasible; Alternatives 4 and 5 are less feasible because of the depth of the required excavation and the availability of coring equipment (if this method is used for removal of contaminated soil).
Cost	The cost for Alternative 1 is \$0. The cost for Alternative 2 is \$152,091 for partial removal and disposal of contaminated surface soil and implementation of administrative controls. Alternative 3 is estimated to cost \$309,172 for partial removal and disposal of contaminated surface soil, construction of a surface cap, and implementation of administrative controls. The cost for Alternative 4 is \$1,438,331 for removal and disposal of contaminated soil and debris. The cost for Alternative 5 is \$895,451 for removal, screening and disposal of contaminated soil and debris.

4.0 Recommended Alternative

Based on the results of the detailed and comparative analysis of the potential corrective action alternatives presented in this document, the preferred corrective action alternative selected for implementation at CAU 407 is Alternative 3, Partial Excavation, Disposal, Closure With a Surface Cap, and Administrative Controls. Alternative 3 was chosen for the following reasons:

- Plutonium, uranium, and americium were identified as surface COCs. Plutonium and americium were identified as subsurface COCs.
- This alternative meets corrective action objectives under DOE Order 5400.5 and 10 CFR 20.
- Long-term risks are minimized by removing surface contamination and precluding inadvertent intrusion.
- Only minimal wastes are generated.
- It is easily implemented using existing resources and technologies with minimal disturbances to surrounding areas.
- It provides a cost-effective method for achieving protection and meeting closure requirements.

The proposed cleanup criteria established to remove surface soil with contamination levels greater than 2 to 3 times background or as determined by field screening, whichever is greater, is based on the specific site conditions at the RCRSA. This criteria was determined to be feasible based on the limited surface area impacted by COCs and the dose assessment calculations.

The preferred corrective action alternative was evaluated on its technical merits, focusing on performance, reliability, feasibility, and safety. During corrective action implementation, this alternative will present moderate potential threat to site workers. However, appropriate health and safety procedures will be developed and implemented. The alternative was judged to meet all requirements for the technical components evaluated. The alternative meets all applicable state and federal regulations for closure of the site and will reduce potential future exposure pathways to subsurface contaminated soil.

The future use of this CAU, as described by this CADD, is restricted from any activity that may alter or modify the containment control as approved by the State of Nevada and identified in the CAU closure report or other CAU documentation unless appropriate concurrence is obtained in advance.

5.0 References

CFR, see *Code of Federal Regulations*.

Code of Federal Regulations. 1998a. Title 10 CFR Part 20, "Standards for Protection Against Radiation." Washington, DC: U.S. Government Printing Office.

Code of Federal Regulations. 1998b. Title 40 CFR Parts 260 - 281, "RCRA Regulations." Washington, DC: U.S. Government Printing Office.

DOE/NV, see U.S. Department of Energy, Nevada Operations Office.

EPA, see U.S. Environmental Protection Agency.

Essington, E.H., R.O. Gilbert, L.L. Eberhardt, and E.B. Fowler. 1975. *Plutonium, Americium and Uranium Concentrations in Nevada Test Site Soil Profiles*, LA-UR-75-1770, IAEA-SM-199/76. Las Vegas, NV: U.S. Energy Research and Development Administration, Nevada Operations Office.

FFACO, see *Federal Facility Agreement and Consent Order*.

Federal Facility Agreement and Consent Order. 1996 (as amended). Agreed to by the State of Nevada, the U.S. Department of Energy, and the U.S. Department of Defense.

Gilbert, T.L. C. Yu, Y.C. Yuan, A.J. Zieler, M.J. Jusko, and A. Wallo III. 1989. *A Manual for Implementing Residual Radioactive Material Guidelines: A Supplement to the U.S. Department of Energy Guidelines for Residual Radioactive Material at FUSRAP [Formerly Utilized Sites Remedial Action Program] Sites*, ANL/ES-160. Argonne, IL: Argonne National Laboratory.

NAC, see *Nevada Administrative Code*.

Nevada Administrative Code. 1998a. NAC 445A, "Water Controls." Carson City, NV.

Nevada Administrative Code. 1998b. NAC 459, "Hazardous Materials." Carson City, NV.

Nevada Revised Statutes. 1995. NRS 459.400-459-600, "Disposal of Hazardous Waste." Carson City, NV.

NRC, see U.S. Nuclear Regulatory Commission.

NRS, see *Nevada Revised Statutes*.

- U.S. Department of Energy. 1993. *Radiation Protection of the Public and the Environment*, DOE Order 5400.5. Washington, DC.
- U.S. Department of Energy, Nevada Operations Office. 1994. *Project Management Plan*, Rev. 0. Las Vegas, NV.
- U.S. Department of Energy, Nevada Operations Office. 1996a. *Corrective Action Unit Work Plan for the Tonopah Test Range*, DOE/NV--443. Las Vegas, NV.
- U.S. Department of Energy, Nevada Operations Office. 1996b. *Double Tracks Test Site Characterization Report*, DOE/NV--484. Las Vegas, NV.
- U.S. Department of Energy, Nevada Operations Office. 1996c. *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada*, DOE/EIS-243. Las Vegas, NV.
- U.S. Department of Energy, Nevada Operations Office. 1996d. *Industrial Sites Quality Assurance Project Plan*, DOE/NV--372. Las Vegas, NV.
- U.S. Department of Energy, Nevada Operations Office. 1997. *Clean Slate I Corrective Action Decision Document Corrective Action Unit No. 412*, DOE/NV-UC-700. Las Vegas, NV.
- U.S. Department of Energy, Nevada Operations Office. 1998. *Corrective Action Investigation Plan for the Roller Coaster RADS SAFE Area, Corrective Action Unit No. 407, Tonopah Test Range, Nevada*, DOE/NV--503. Las Vegas, NV.
- U.S. Environmental Protection Agency. 1991. *Guidance on Resource Conservation and Recovery Act (RCRA) Corrective Action Decision Documents*, EPA/540/G-91/011. Washington, DC: Office of Research and Development.
- U.S. Environmental Protection Agency. 1994. *Final RCRA Corrective Action Plan*, EPA/520-R-94-004. Washington, DC: Office of Solid Waste and Emergency Response.
- U.S. Environmental Protection Agency. 1998. Memo from S. J. Smucker regarding Region 9 Preliminary Remediation Goals (PRGs), 1 August. San Francisco, CA.
- Yu, C., A.J. Zielen, J.-J. Cheng, Y.C. Yuan, L.G. Jones, D.J. LePoire, Y.Y. Wang, C.O. Loureiro, E. Enanapragasm, E. Faillace, A. Wallo III, W.A. Williams, and H. Peterson. 1993a. *Manual for Implementation Residual Radioactive Material Guidelines Using RESRAD*, Version 5.0, Publication ANL/EAD/LD-2. Argonne, IL: Argonne National Laboratory.
- Yu, C., C. Loureiro, J.-J. Cheng, L.G. Jones, Y.Y. Wang, Y.P. Chia, and E. Faillace. 1993b. *Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil*, Publication ANL/EAIS-8. Argonne, IL: Argonne National Laboratory.

Appendix A

Corrective Action Investigation Report for CAU 407: Roller Coaster RADSAFE Area, Tonopah Test Range

A.1.0 Introduction

This report presents the investigation activities and analytical results from the corrective action investigation conducted at the RCRSA, CAU 407. This CAU consists of CAS Number TA-23-001-TARC and is found in Table 3-1 of the *Corrective Action Unit Work Plan, Tonopah Test Range, Nevada* (DOE/NV, 1996a) (hereafter referred to as the TTR Work Plan). The corrective action investigation was conducted in accordance with the requirements set forth in the *Corrective Action Investigation Plan for the Roller Coaster RADS SAFE Area, Corrective Action Unit 407, Tonopah Test Range, Nevada* (DOE/NV, 1998), as developed under the FFACO (FFACO, 1996).

The RCRSA is located on the northeast corner of the intersection of Main Road and Browne's Lake Road which is approximately 5 mi south of Area 3 (see [Figure 1-1](#) and [Figure 1-2](#) of the CADD). The RCRSA was used during May and June 1963 to decontaminate vehicles, equipment, and personnel from the Clean Slate tests. The surface and subsurface soils were investigated because they were potentially impacted by plutonium and other COPCs associated with decontamination activities at this site. Additional information relating to the site history, planning, and scope of the investigation is presented in the CAIP (DOE/NV, 1998) and the TTR Work Plan (DOE/NV, 1996a) and is not repeated in this report.

A.1.1 Project Objectives

The primary objectives for this project were to identify the vertical and lateral extent of possible contamination at the RCRSA and to provide sufficient information and data to develop appropriate corrective action alternatives for the RCRSA.

As part of the DQO process outlined in the CAIP (DOE/NV, 1998), potential routes of migration for possible contaminants associated with the RCRSA were proposed. The soil within the RCRSA was investigated by conducting a subsurface drilling program and by collecting soil for field-screening and environmental samples for laboratory analysis. The drilling locations were

selected based on the strategy devised in the DQO process and site conditions. The following tasks were performed to meet project objectives:

- Conducted a surface walkover radiological survey
- Drilled boreholes through the RCRSA to investigate impact on underlying soils
- Drilled step-out boreholes to constrain impact boundaries
- Field screened soil from boreholes to guide depth and lateral extent of investigation
- Collected surface samples to determine impact on surface soils
- Collected samples for laboratory and geotechnical analysis

A.1.2 Report Content

This corrective action investigation report is intended to provide information and data in sufficient detail to support the selection of a preferred corrective action alternative in the CADD. The contents of this report are as follows:

- [Section A.1.0](#) describes the investigation background, objectives, and the report content.
- [Section A.2.0](#) provides information regarding the field activities and sampling methods.
- [Section A.3.0](#) summarizes the results of the laboratory analysis from the investigation sampling.
- [Section A.4.0](#) discusses the quality assurance (QA) and quality control (QC) procedures that were followed and the results of the QA and QC activities.
- [Section A.5.0](#) summarizes the significant results pertaining to the RCRSA corrective action investigation program.
- [Section A.6.0](#) cites the references.

To make this report a concise summary, the complete field documentation and laboratory data, including Field Activity Daily Logs, Sample Collection Logs, Analysis Request/Chain-of-Custody Forms, soil sample descriptions, laboratory certificates of analyses, analytical results, and surveillance results are not contained in this report. These documents are retained in project files.

A.2.0 Field Investigation and Sampling Activities

Field investigation activities are divided into two separate phases. The initial phase consisted of geophysical and radiation surveys; and the final phase was the surface and subsurface investigation. Details of the geophysical survey are discussed in the CAIP and are not documented in this report. The radiation survey is included as [Appendix D](#) and is briefly discussed in [Section A.2.2](#). The following is a brief summary of all CAI activities provided as background information:

- Conducted ground-penetrating radar (GPR), magnetic, and electromagnetic surveys in 1993 to determine the location of the hotline.
- Conducted GPR, magnetic, and electromagnetic surveys in 1998 to determine the location of the hotline, vehicle decontamination area, sumps, and waste disposal pit.
- Conducted surface radiation surveys in 1998 to determine presence of gross radiological activity.
- Drilled 11 vertical boreholes:
 - Conducted field screening for radiological contaminants and VOCs
 - Conducted visual field screening
 - Collected environmental samples for laboratory analysis
 - Collected soil samples for geotechnical analysis
 - Logged soil cuttings to assess site geology
- Collected additional surface soil samples for laboratory analysis.

The field investigation and sampling program were managed in accordance with the requirements set forth in the CAIP (DOE/NV, 1998). The field activities were performed in accordance with an approved Site-specific Health and Safety Plan (IT, 1998). The samples were collected and documented by following approved sampling, field activity and sample collection documentation, decontamination, chain of custody, shipping, and radiation screening protocols and procedures as indicated in the CAIP (DOE/NV, 1998). Quality control samples (e.g., field blanks, equipment rinsate blanks, trip blanks, and sample duplicates) were collected as required by the *Industrial Sites Quality Assurance Project Plan* (QAPP) (DOE/NV, 1996b) and approved procedures. During field

activities, waste minimization practices were followed according to approved procedures, including segregation of the waste by waste stream.

A.2.1 Site Description and Conditions

The RCRSA is located just northeast of the intersection of Main and Browne's Lake Road. Access to most of the RCRSA is limited by an exclusion zone fence surrounding the area. Aboveground features include a vehicle ramp, concrete pad, and several pipes. Underground utilities include water lines, a telephone cable, and other buried utilities.

A.2.2 Surface Radiation Survey

A surface radiation survey was conducted in January 1998 to identify any surface contamination that may be present. Results of this survey were not available for inclusion into the CAIP, but are provided in [Appendix D](#) (Speer, 1999).

The radiation survey identified several areas of radioactive surface contamination. The exclusion zone fence had to be extended on the east end of the investigation area to contain one area of surface contamination. The field work conducted in June and July 1998 had provisions to clear these areas of contamination; however, attempts were unsuccessful and contamination remains at the surface. Additional surface sampling activities were conducted in November 1998 and are discussed in [Section A.2.4](#).

A.2.3 Subsurface Investigation

Ten boreholes were drilled inside the exclusion zone fence ([Figure A.2-1](#)) and one background boring was drilled west of Main Road to investigate the subsurface soils at the RCRSA. The rotary sonic ("sonic") drilling method was used to produce continuous soil cores from vertical borings through and around the RCRSA. Recovery of continuous core allowed detailed field observations and sampling of the subsurface soil. Samples were collected from the cores at specified depth intervals for field screening and laboratory analyses. All borings were drilled to a depth of 30 ft bgs. Field screening for radiation and VOCs (headspace screening) was used to guide the lateral and vertical extent of the investigation in the field. Sampling intervals and sample

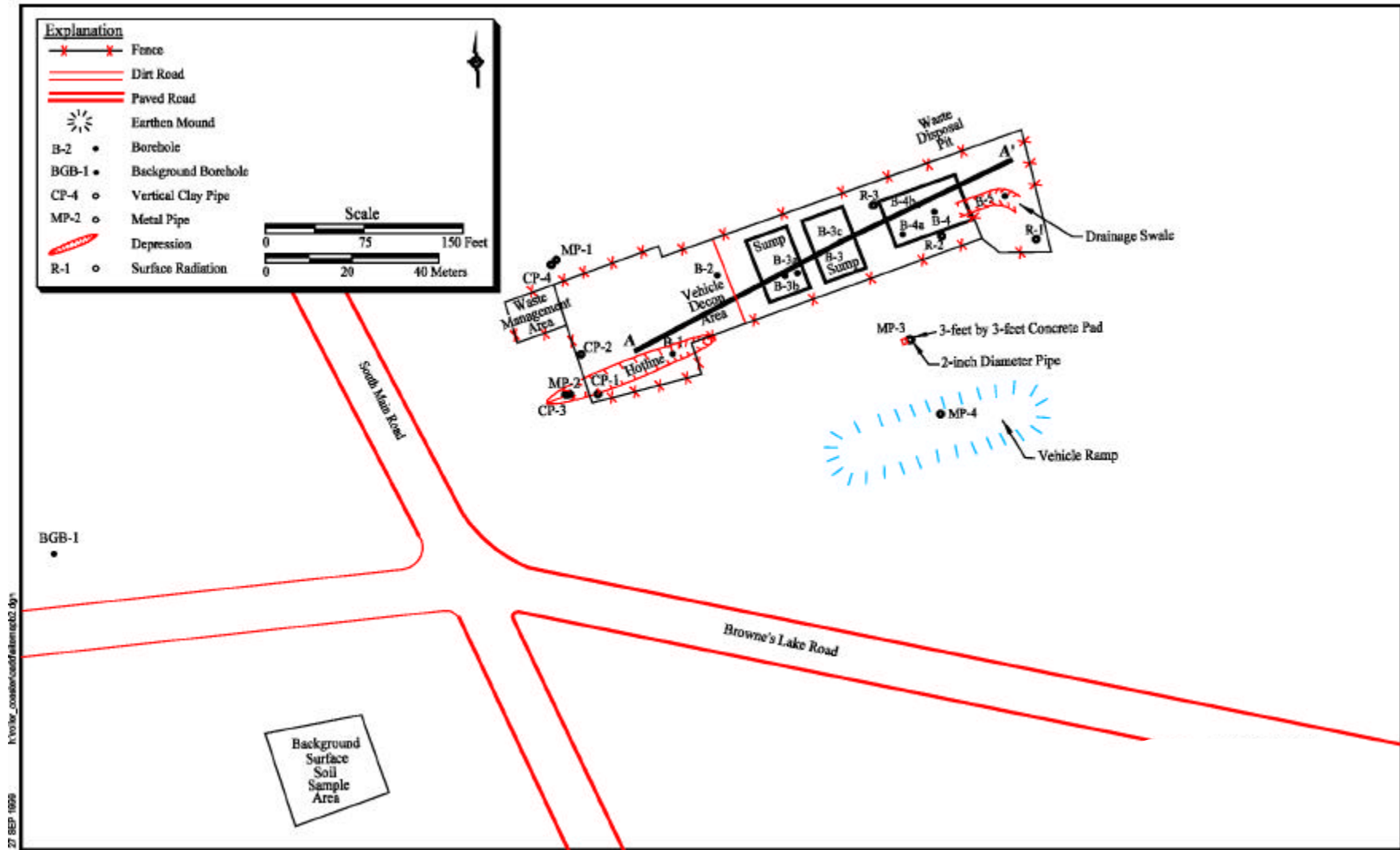


Figure A.2-1
 Site Map of CAU 407, Roller Coaster RADSAFE Area

submission frequency were based on minimum requirements established during the DQO process, field-screening results, and the discretion of the site supervisor.

A.2.3.1 Drilling

The sonic drilling method uses vibration and rotation of the drill string to advance a core barrel and an outer casing. The casing is used to stabilize the hole and also minimizes potential cross contamination produced by soil from shallower levels falling down the hole (sloughing) as the core barrel is removed for cuttings extrusion. After the bit at the end of the core barrel reaches the specified depth, the core barrel is withdrawn from the borehole and the contents are extruded into polyurethane (PU) bags. While the sonic drilling method produced some heat from friction, the samples were hand carried to the sampling table and were not observed to be hot on any occasion. For this project, 6-in. diameter core barrels and 8-in. diameter casing were advanced. The casing was removed, and the boreholes were filled with grout at the completion of the project.

Soil cuttings were delivered to the field geologist and sampling team in labeled PU bags in approximately 2.5-ft long sections. The soil cuttings were suitable for field screening, sampling, and visual classification of the soil described in subsequent subsections.

Six borings (including one background boring) were planned for the subsurface investigation. The background borehole (BGB-1), located outside the exclusion zone fence and west of Main Road, was drilled first and native soil was encountered, as expected, throughout the borehole. Field screening was performed and samples were sent to the laboratory for analysis from 10, 20, and 30 ft depths.

The remaining five borings and five stepouts were drilled within the exclusion zone fence ([Figure A.2-2](#)) to help delineate the original site features and potential waste from the operations in 1963. [Figure A.2-3](#) shows a southwest-northeast schematic cross section through the exclusion zone, some of the site features intercepted by the borings, and subsurface sample locations and sample intervals. Borehole B-1 (B-1) was drilled on the personnel decontamination line and encountered gravel (french-drain gravel) to a depth of 1.5 ft bgs. Native soil was penetrated below this point to total depth (TD). Borehole B-2 was drilled to intercept the vehicle decontamination

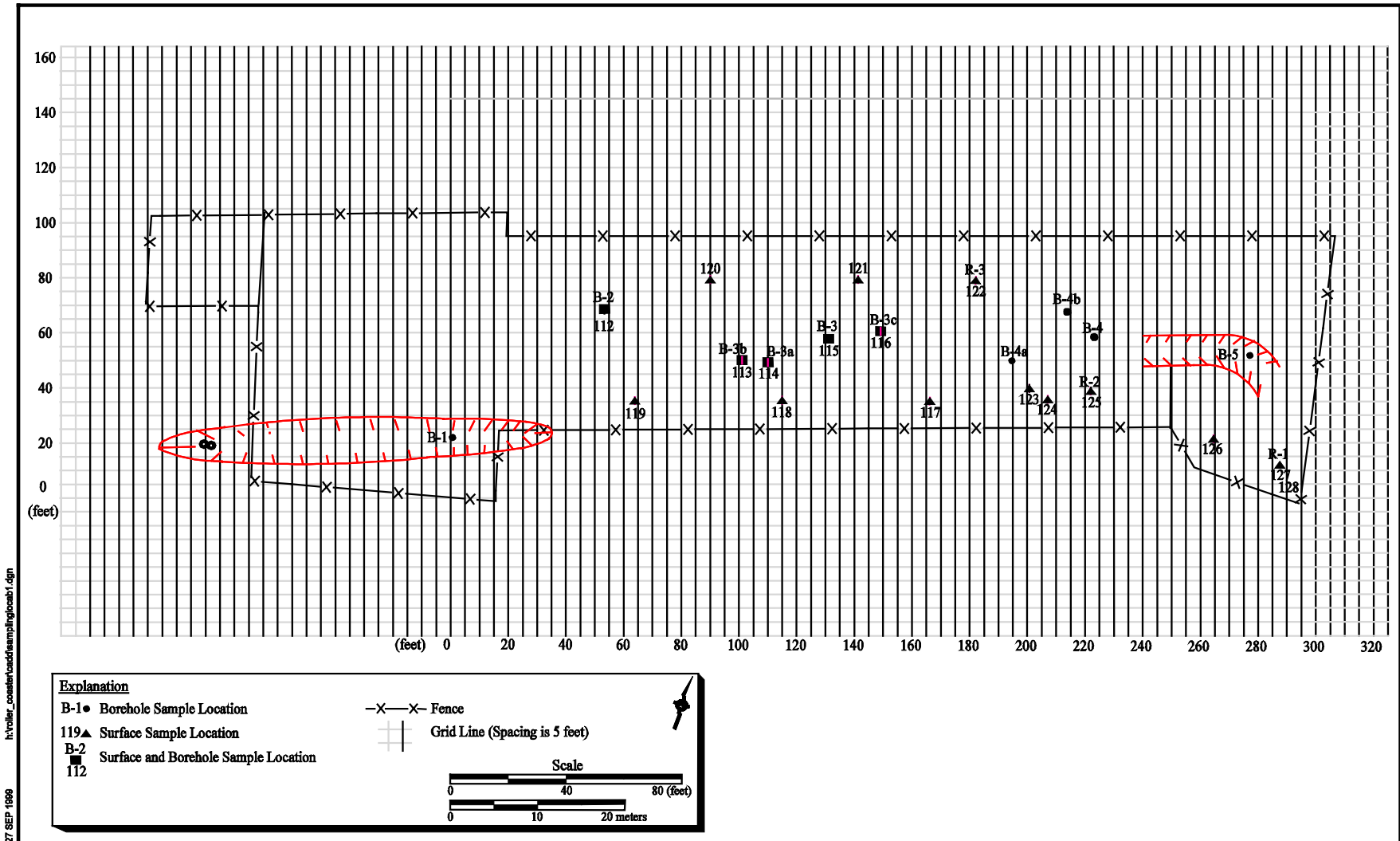


Figure A.2-2
Sampling Locations Inside the Exclusion Zone at the Roller Coaster RADSAFE Area

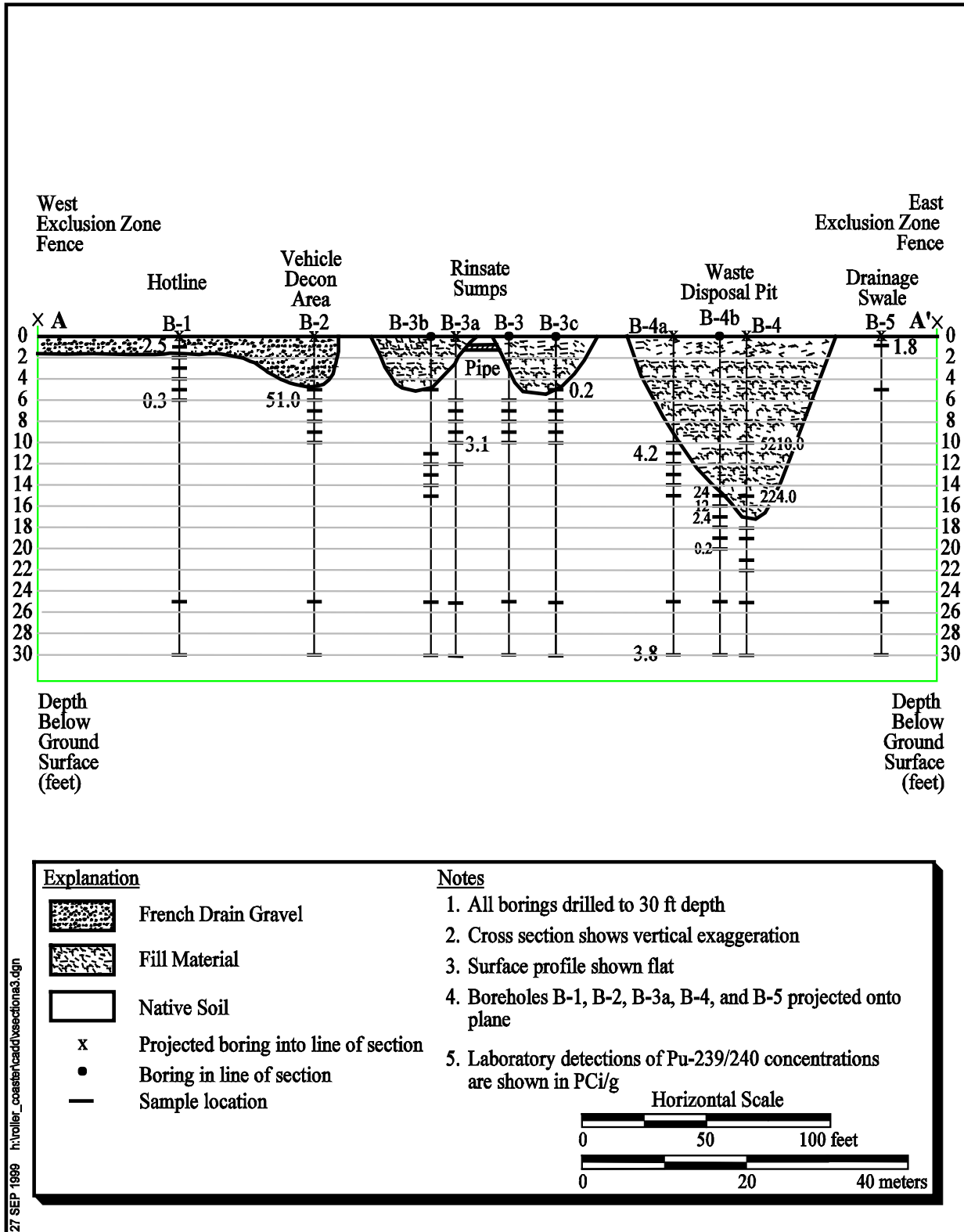


Figure A.2-3
Cross Section Through the Exclusion Zone at the Roller Coaster RADSAFE Area

pad. This boring encountered gravel (french-drain gravel) to a depth of 4.5 ft bgs and native soil was penetrated below this point to TD. No stepout borings were drilled for B-1 and B-2.

Borehole B-3 was drilled in an attempt to intercept one of the decontamination sumps used to contain rinsate water during the site operations in 1963. Redwood chips and coarse gravel (French-drain gravel) were encountered to a depth of 5 ft bgs, representing the bottom of the sump. French-drain gravel may have been dumped into one of the sumps during closure activities in 1963. Native soil was encountered below this depth to TD. Three stepout borings were drilled, B-3a and B-3b did not intercept any discernible features. Stepout boring B-3c was drilled due to a depression that resembled a sump. Wood chips and plastic debris were seen to a depth of 5 ft. French-drain gravel was not encountered indicating that this boring may have intercepted the waste disposal pit and not one of the sumps as planned.

Boring B-4 was drilled to help define the boundaries of the waste disposal pit. Plastic, wood, rubber, metal rebar, and other construction debris were encountered in this boring. The base of the waste disposal pit appears to be at a depth of 17.5 ft and native soil was penetrated below this point to TD. Stepout B-4a encountered plastic, wire, cable and wood to a depth of 10 ft and native soil was penetrated below this point to TD. Stepout boring B-4b penetrated wood, particle board, wires, aluminum, battery clips, springs, radiation tape, and other construction debris to a depth of 16 ft, the bottom of the waste disposal pit.

Boring B-5 was drilled in a drainage swale on the east end of the location. As expected, native soil was encountered throughout this boring to TD.

A.2.3.2 Surface Soil Sampling

Sixteen additional surface soil samples were collected on November 23, 1998. [Figure A.2-2](#) shows the surface areas sampled. These surface soil sample locations were numbered from 112 through 128 and analyzed for gamma-emitting radionuclides, isotopic plutonium and isotopic uranium. Sample locations 122-128 were collected from suspected areas of surface radiological contamination.

Field screening was performed using an Electra and a field instrument for the detection of low energy radiation (FIDLER) at each sampling location. No elevated readings were observed from locations 112-121; however, elevated readings were seen at locations 122-128. The FIDLER readings measuring gamma radiation in counts per minute ranged from 6,700 to 246,000 at location 127. Alpha and beta measured with the Electra in disintegrations per minute (dpm) were also elevated at 207 and 3,159, respectively.

A.2.3.3 Field Screening

Field screening was performed on all borings at 2.5-ft intervals to a TD of 30 ft at all borings. Supplementary field screening was conducted at the discretion of the Site Supervisor at additional depths. The screening methods included the following:

- Radiological screening for alpha and beta radiation using an Electra instrument
- Radiological screening for gamma radiation using a FIDLER instrument
- Headspace screening for VOCs using a headspace method

The preliminary action level for VOC field-screening results was 20 parts per million (ppm) or 2.5 times background, whichever was higher. The field-screening level (FSL) for radiation monitoring results at the RCRSA was established as the average activity of 20 background samples plus two times the standard deviation of the average activity of the 20 background samples. An Electra instrument was used for establishing the FSL for alpha at 97 dpm and beta at 1,852 dpm. A FIDLER was used to establish the FSL for gamma radiation at 456 counts per minute (cpm). Field-screening levels were established to guide the advancement of the borehole and to provide a basis for collecting unplanned environmental samples or drilling additional boreholes.

The headspace measurement results from field screening were below the FSL of 20 ppm for all samples. Headspace measurements were 3 ppm or less, except in borehole B-4 where a sample from a depth of 15 ft yielded a 14.6 ppm detection and had a hydrocarbon odor associated with it. This sample was submitted for laboratory analysis as sample RCR00026.

Results of the radiological field screening detected elevated readings above the established FSLs on some of the soil samples. Alpha, beta, or gamma radiation was detected above FSLs in nearly all

the borings; however, most of these readings were due to daily fluctuations of the background measurements. Daily background checks were above the FSLs on two days during field activities. The only significant detections were in borehole B-4. The highest alpha and gamma readings were 500 dpm and 2,000 cpm, respectively, and were obtained from a metal object found at a depth of 10 ft. A swipe survey was taken of the metal object and no removable contamination was detected. A soil sample was submitted for laboratory analysis as sample RCR00025.

Surface radiological contamination was identified during a January 1998 survey. The contamination was believed to be limited to solid debris and concrete. Efforts made to remove the contamination during the July field effort were unsuccessful. Surveys of the surface soil after removal of debris detected elevated readings above the established FSLs. Detections of gamma radiation were made using a FIDLER instrument. Three areas were measured and are shown on [Figure A.2-1](#) with the designation R-1, R-2, and R-3. The readings were 35,000 cpm, 10,000 cpm, and 6,500 cpm, respectively. Further discussion of the surface contamination can be found in [Section A.2.4](#).

A.2.3.4 Sampling

Sample collection followed the procedures specified in the CAIP (DOE/NV, 1998). Soil cores were moved from the boreholes to the sampling area in two, approximately 2.5-ft lengths contained in PU bags. The bags were split open and screened for alpha, beta, and gamma radiological contamination. The breathing zone was monitored for VOCs using a photoionization detector before and during sample collection. Samples were collected in appropriate containers with temporary sample labels and sealed with custody tape. Volatile samples (VOCs, TPH gasoline, headspace field screening) were collected directly from the soil cores immediately after required radiation field screening and breathing zone monitoring for VOCs was conducted. The remainder of the samples were collected from soil representative of the sampling interval after homogenization in a stainless steel bowl.

After samples were identified as laboratory samples, labels preprinted with the sample number, sample collection date/time, sampling team members, container preservative, medium type, and requested analysis were attached to each of the containers. Each sample container was then sealed

with custody tape, wrapped in protective bubble wrap (if applicable), placed into a sealable bag, and placed in an iced cooler with a trip blank (if applicable). Samples not submitted to the laboratory were containerized with other soil cuttings from the same boring after removing or defacing temporary sample labels and lids.

A.2.3.5 Waste Management

Investigation-derived waste (IDW) was segregated into the following four waste streams:

- Personal protective equipment and sampling equipment that contacted potentially contaminated media
- Decontamination rinsate that contacted potentially contaminated media
- Soil and debris incidental to sample collection (e.g., soil cuttings, discarded samples)
- Plastic or other material (e.g., soil, absorbent materials) contaminated by equipment hydrocarbon leaks (i.e., minor amounts of hydraulic oil from the drilling rig)

Potentially hazardous waste generated during site operations was labeled as such and transferred to a Hazardous Waste Accumulation Area daily. The IDW was documented using a hazardous waste log. All IDW was confirmed as nonhazardous waste and removed from the TTR under Radioactive Material Shipping Record numbers ITG-001 and ITG-002 and transferred to the Area 6 Radiological Material Storage Area on the NTS. The low-level waste has been transferred to the Area 5 low-level waste landfill for permanent disposal.

A.2.4 Geology

The RCRSA site consists of reworked and compacted sands and gravels (fill material) overlying native soils. Regional native surface soil consists of poorly graded, moderately consolidated alluvial silty sands with gravel and cobble-sized volcanic detritus (DOE/NV, 1996a). Field descriptions were performed for each boring by the field geologist and recorded on Visual Classification of Soil Logs ([Appendix B](#)) and augmented by laboratory analysis of four

geotechnical samples ([Section A.3.6](#)). The strata encountered at the RCRSA are summarized below:

- Well-graded sands and gravels are the predominant fill material at the site.
- Well-graded gravels were used for the french drain at the vehicle and personnel decontamination pad.
- Native soil consisted of predominately well-graded sands and gravels.
- Silt is present but typically composes less than five percent of the soil.

A.2.5 Hydrology

The RCRSA topography slopes gently to the east with surface drainage flowing in the same direction. Depth to groundwater beneath the RCRSA is estimated at 400 ft bgs (DOE/NV, 1996a). No saturated zones (e.g., perched water) were found in the subsurface at the RCRSA.

A.3.0 Investigation Results

The analytical results of samples collected from the Roller Coaster RADS SAFE Area have been compiled and evaluated to determine the presence and/or extent of contamination. The analytical results are summarized in the following subsections. The complete laboratory result data packages are available in the project files.

During the investigation activities, a total of 111 samples (87 soil and 24 liquid samples) were collected and submitted for laboratory analysis. Four of the soil samples were submitted for geotechnical analysis. A list of the sample numbers (including field duplicate and other quality control samples) and their relationship to the boreholes is presented in [Table A.3-1](#). The analytical parameters and laboratory analytical methods requested for this investigation are presented in [Table A.3-2](#). The analytical parameters were selected through the application of site process knowledge using the EPA's *Guidance for the Data Quality Objectives Process* (EPA, 1994c). Preliminary action levels for off-site laboratory analytical methods were determined during the DQO process and are based on NAC 445A.2272 (NAC, 1998) and the EPA Region 9 PRGs (EPA, 1998) for chemical parameters under the industrial scenario. The results of the DQO process are documented in the CAIP (DOE/NV, 1998) with the remainder of the documentation retained in the project files. Sampling activities were designed to detect contaminants of potential concern and conducted to either confirm or disprove the assumptions made in the DQO process.

Samples were analyzed by DATACHEM Laboratories, Inc. in Salt Lake City, Utah, with the exception of the isotopic plutonium and uranium analysis. These analyses were performed by Quanterra Environmental Services Laboratory, in Richland, Washington. The additional surface soil samples collected from the RCRSA in November 1998 were analyzed by Bechtel Nevada Analytical Services Laboratory in Mercury, Nevada. The geotechnical samples were analyzed by Daniel B. Stephens & Associates in Albuquerque, New Mexico. Third-party data validation was completed by Quanterra Services in Knoxville, Tennessee.

Table A.3-1
Samples Collected During the Roller Coaster RADSAFE Area Investigation
(Page 1 of 5)

Borehole Number	Sample Number	Depth^{a,b} (in feet bgs)	Sample Type	Sample Analysis
	RCR00001	NA	Trip Blank	VOC
	RCR00002	NA	Source Blank	Reg/Rad
	RCR00003	NA	Trip Blank	VOC
	RCR00004	NA	Equipment Rinsate Blank	Reg/Rad
BGB1	RCR00005	10	Soil	Reg/Rad
	RCR00006	20	Soil	Reg/Rad
	RCR00007	30	Soil	Reg/Rad
	RCR00008	NA	Trip Blank	VOC
B1	RCR00040	5	Soil	Reg/Rad
	RCR00041	25	Soil	Reg/Rad
	RCR00042	30	Soil	Reg/Rad
	RCR00043	6.5	Soil	Geotechnical
	RCR00044	1	Soil	Pu/U
	RCR00045	2	Soil	Pu/U
	RCR00046	3	Soil	Pu/U
	RCR00047	4	Soil	Pu/U
	RCR00048	5	Soil	Pu/U
RCR00049	6	Soil	Pu/U	
B2	RCR00031	5	Soil	Reg/Rad
	RCR00032	25	Soil	Reg/Rad
	RCR00033	30	Soil	Reg/Rad
	RCR00034	6	Soil	Pu/U
	RCR00035	7	Soil	Pu/U
	RCR00036	8	Soil	Pu/U
	RCR00037	9	Soil	Pu/U
	RCR00038	10	Soil	Pu/U
	RCR00039	NA	Trip Blank	VOC

Table A.3-1
Samples Collected During the Roller Coaster RADSAFE Area Investigation
(Page 2 of 5)

Borehole Number	Sample Number	Depth^{a,b} (in feet bgs)	Sample Type	Sample Analysis
B3	RCR00009	NA	Trip Blank	VOC
	RCR00010	10	Soil	Reg/Rad
	RCR00011	25	Soil	Reg/Rad
	RCR00012	30	Soil	Reg/Rad
	RCR00013	6	Soil	Pu/U
	RCR00014	7	Soil	Pu/U
	RCR00015	8	Soil	Pu/U
	RCR00016	9	Soil	Pu/U
	RCR00018	18	Soil	Geotechnical
	RCR00020	NA	Field Blank	Reg/Rad
B3A	RCR00055	NA	Equipment Rinsate Blank	Reg/Rad
	RCR00057	NA	Field Blank	Reg/Rad
	RCR00058	NA	Trip Blank	VOC
	RCR00059	NA	Trip Blank	VOC
	RCR00061	NA	Trip Blank	VOC
	RCR00062	6	Soil	Pu/U
	RCR00063	7	Soil	Pu/U
	RCR00064	8	Soil	Pu/U
	RCR00065	9	Soil	Pu/U
	RCR00066	10	Soil	Pu/U
	RCR00067	12	MS/MSD	Pu/U
	RCR00068	10	Soil	Reg/Rad
	RCR00069	10	MS/MSD	Reg/Rad
	RCR00070	25	Soil	Reg/Rad
	RCR00071	30	Soil	Reg/Rad
RCR00072	30	Duplicate of RCR000071	Reg/Rad	

Table A.3-1
Samples Collected During the Roller Coaster RADSAFE Area Investigation
(Page 3 of 5)

Borehole Number	Sample Number	Depth^{a,b} (in feet bgs)	Sample Type	Sample Analysis
B3B	RCR00073	5	Soil	Reg/Rad
	RCR00074	25	Soil	Reg/Rad
	RCR00075	30	Soil	Reg/Rad
	RCR00076	NA	Trip Blank	VOC
	RCR00077	11	Soil	Pu/U
	RCR00078	12	Soil	Pu/U
	RCR00079	13	Soil	Pu/U
	RCR00080	14	Soil	Pu/U
	RCR00081	15	Soil	Pu/U
B3C	RCR00101	NA	Field Blank	Rad
	RCR00102	NA	Equipment Rinsate Blank	Pu/U
	RCR00103	NA	Source Blank	Pu/U
	RCR00104	5	Soil	Reg/Rad
	RCR00105	25	Soil	Reg/Rad
	RCR00106	30	Soil	Reg/Rad
	RCR00107	6	Soil	Pu/U
	RCR00108	7	Soil	Pu/U
	RCR00109	8	Soil	Pu/U
	RCR00110	9	Soil	Pu/U
	RCR00111	10	Soil	Pu/U
B4	RCR00017	26.5	Soil	Geotechnical
	RCR00019	NA	Trip Blank	VOC
	RCR00021	18	Soil	Pu/U
	RCR00022	19	Soil	Pu/U
	RCR00023	21	Soil	Pu/U
	RCR00024	22	Soil	Pu/U
	RCR00025	10	Soil	Reg/Rad
	RCR00026	15	MS/MSD	Reg/Rad
	RCR00027	25	Soil	Reg/Rad
	RCR00028	25	Duplicate of RCR000027	Reg/Rad
	RCR00029	30	Soil	Reg/Rad
	RCR00030	NA	Trip Blank	VOC

Table A.3-1
Samples Collected During the Roller Coaster RADSAFE Area Investigation
(Page 4 of 5)

Borehole Number	Sample Number	Depth^{a,b} (in feet bgs)	Sample Type	Sample Analysis
B4A	RCR00092	NA	Trip Blank	VOC
	RCR00093	10	Soil	Reg/Rad
	RCR00094	25	Soil	Reg/Rad
	RCR00095	30	Soil	Reg/Rad
	RCR00096	11	Soil	Pu/U
	RCR00097	12	Soil	Pu/U
	RCR00098	13	Soil	Pu/U
	RCR00099	14	Soil	Pu/U
	RCR00100	15	Soil	Pu/U
B4B	RCR00082	NA	Trip Blank	VOC
	RCR00083	15	Soil	Reg/Rad
	RCR00084	25	Soil	Reg/Rad
	RCR00085	30	Soil	Reg/Rad
	RCR00086	16	Soil	Pu/U
	RCR00087	17	Soil	Pu/U
	RCR00088	18	Soil	Pu/U
	RCR00089	19	Soil	Pu/U
	RCR00090	20	Soil	Pu/U
RCR00091	11.5	Soil	Geotechnical	
B5	RCR00050	1	Soil	Reg/Rad
	RCR00051	5	Soil	Reg/Rad
	RCR00052	25	Soil	Reg/Rad
	RCR00053	30	Soil	Reg/Rad
	RCR00054	NA	Trip Blank	VOC

Table A.3-1
Samples Collected During the Roller Coaster RADSAFE Area Investigation
(Page 5 of 5)

Borehole Number	Sample Number	Depth^{a,b} (in feet bgs)	Sample Type	Sample Analysis
Surface Samples	RCR00112	NA	Soil	Rad
	RCR00113	NA	Soil	Rad
	RCR00114	NA	Soil	Rad
	RCR00115	NA	Soil	Rad
	RCR00116	NA	Soil	Rad
	RCR00117	NA	Soil	Rad
	RCR00118	NA	Soil	Rad
	RCR00119	NA	Soil	Rad
	RCR00120	NA	Soil	Rad
	RCR00121	NA	Soil	Rad
	RCR00122	NA	Soil	Rad
	RCR00123	NA	MS/MSD	Rad
	RCR00124	NA	Soil	Rad
	RCR00125	NA	Soil	Rad
	RCR00126	NA	Soil	Rad
	RCR00127	NA	Soil	Rad
RCR00128	NA	Soil	Rad	
RCR00129	NA	Equipment Rinsate Blank	Rad	

^aSoil samples collected from 1-ft intervals ending at depth shown.

^bGeotechnical samples collected from 1.5-ft intervals ending at depth shown.

VOC = Sample analysis for volatile organic compounds only

"Reg" sample analysis refers to all analytical parameters on [Table A.3-2](#), except gamma spectrometry, isotopic plutonium, and isotopic uranium

"Rad" sample analysis refers to gamma spectrometry, isotopic plutonium, and isotopic uranium

Pu/U = Sample analysis for isotopic plutonium and isotopic uranium only

MS/MSD = Matrix Spike/Matrix Spike Duplicate

NA = Not Applicable

**Table A.3-2
Laboratory Analytical Methods Used for
the Roller Coaster RADSAFE Area Investigation Samples**

Analytical Parameter	Analytical Method	
Total volatile organic compounds	EPA 8260B ^a	
Total semivolatile organic compounds	EPA 8270C ^a	
Total petroleum hydrocarbons - gasoline and diesel/oil	EPA 8015B (modified) ^a	
Total RCRA metals (arsenic, barium, cadmium, chromium, lead, selenium, silver, and mercury)	EPA 6010B/7470A ^a EPA 6010B/7471A ^a	
Total polychlorinated biphenyls	EPA 8082 ^a	
Total Pesticides	EPA 8081A ^a	
Isotopic plutonium	NAS-NS 3058 ^b	
Isotopic uranium	NAS-NS 3050 ^b	
Gamma spectrometry	HASL 300, 4.5.23 ^c	
	EPA 901 WR-EP-3025 (water) ^d	
Geotechnical Parameter	Proposed Method	Actual Method(s)
Initial moisture content	ASTM ^e D 2216	ASTM ^e D 2216-92
Dry bulk density	EM ^f -1110-2-1906	ASTM ^e D 2937-94
Calculated porosity	EM ^f -1110-2-1906	MOSA ^g Chp. 18
Saturated hydraulic conductivity	ASTM ^e D 5084	ASTM ^e D 2434-68(74) MOSA ^g Chp. 28
Unsaturated hydraulic conductivity		Van Genuchten ^h
Particle-size distribution	ASTM ^e D 422	ASTM ^e D 422-63(90)
Water-release (moisture retention) curve	ASTM ^e D 3152	MOSA ^g Chp. 26 ASTM ^e D 2325-68(94) MOSA ^g Chp. 24 Karanthanas and Hajek ⁱ

^a EPA *Test Methods for Evaluating Solid Waste*, 3rd Edition, Parts 1-4, SW-846 (EPA, 1996)

^b National Academy of Sciences, *Nuclear Science Series*, September 1963 or equivalent method

^c *Environmental Methods Laboratory Procedures Manual*, HASL 300 (DOE, 1992) or equivalent method

^d *Prescribed Procedures for Measurements of Radioactivity in Drinking Water* (EPA, 1980) or equivalent method

^e *Annual Book of American Society for Testing and Materials Standards*, Section 4, "Construction," Volume 04.08, "Soil and Rock (1)," and Volume 04.09, "Soil and Rock (11)," (ASTM, 1996)

^f United States Army Corps of Engineers (USACE), *Engineer Manual* (EM) 1110-2-1906, "Laboratory Soils Testing," Appendix II, (USACE, 1970)

^g *Methods of Soil Analysis*, 2nd Edition, Part 1, (Soil Science Society of America, 1986)

^h van Genuchten, M. "A Closed Form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils," *Soil Science Society of America Journal*, 44:892-898 (van Genuchten, 1980)

ⁱ Karanthanas, A.D. and B.F. Hajek, 1982. "Quantitative Evaluation of Water Adsorption on Soil Clays," *Soil Science Society of America Journal*, 46:1321-1325 (Karanthanas and Hajek, 1982)

A.3.1 Total Petroleum Hydrocarbon Results

The TPH compounds detected above minimum reporting limits as specified in the CAIP (DOE/NV, 1998) were from borings B-2 and B-4; however, the associated PALs were not exceeded in any boring. In boring B-4, the TPH detect was 1.8 milligrams per kilogram (mg/kg) at a depth of 15 ft bgs for sample RCR00026. Headspace field screening revealed a 14.6 ppm detection at this same depth.

A.3.2 Total Volatile Organic Compound Analytical Results

The total VOC analytical results above minimum reporting limits as specified in the CAIP (DOE/NV, 1998), along with the associated PALs, are presented in [Table A.3-3](#).

The laboratory data indicate that contaminants were either not present above the minimum reporting limits or, if present, were below the PALs. Acetone, the only VOC detected during the investigation, is at a level indicative of laboratory contamination. This constituent is a common laboratory contaminant (see [Section A.4.7.1](#)) and does not correspond to any other elevated contaminants detected during this investigation.

A.3.3 Total Semivolatile Organic Compound Analytical Results

The laboratory SVOCs results indicate that contaminants were not present above the minimum reporting limits except for a 340 micrograms per kilogram ($\mu\text{g}/\text{kg}$) concentration of di-n-butyl phthalate found in boring B-4b at a depth of 15 ft. This constituent is a common laboratory contaminant (see [Section A.4.7.1](#)) and does not correspond to any other elevated contaminants detected during this investigation.

A.3.4 Total RCRA Metals Results

The total RCRA metals detected above the minimum reporting limits are presented in [Table A.3-4](#). The total RCRA metals results were all below the preliminary action levels except for arsenic (EPA, 1998). Arsenic was detected above the Industrial PRG (2.4 mg/kg) in several samples; however, arsenic was not detected above the maximum background concentration of 11 mg/kg

**Table A.3-3
Soil Sample Results for Total Volatile Organic Compounds Detected Above
Minimum Reporting Limits, Roller Coaster RADSAFE Area, TTR**

Borehole Number	Sample Number	Start Depth (feet) bgs	End Depth (feet) bgs	Contaminants of Concern (µg/kg)
				Acetone
				Preliminary Action Levels (µg/kg) (Industrial Soil PRG) ^a
				8,800,000
B4	RCR00025	9	10	27 (J)
	RCR00026	14	15	20 (J)
B2	RCR00031	4	5	12 (J)
B1	RCR00041	24	25	13 (J)
B5	RCR00050	0	1	15 (J)
	RCR00051	4	5	14 (J)
B4B	RCR00083	14	15	20 (J)
B4A	RCR00093	9	10	18 (J)

^aU.S. Environmental Protection Agency, Region 9 Preliminary Remediation Goals (PRGs) (EPA, 1998)

(J) = Estimated value

µg/kg = Micrograms per kilogram

bgs = Below ground surface

established in background borehole BGB-1 drilled nearby. Based on this information, the concentrations of arsenic are considered to be representative of ambient conditions at the site.

Other RCRA metals detected during the investigation are limited to barium, cadmium, chromium, lead, and mercury. These RCRA metal concentrations did not exceed the PALs.

A.3.5 Total Pesticide/PCB Analytical Results

Table A.3-5 presents the total pesticide and PCB analytical results above minimum reporting limits as specified in the CAIP (DOE/NV, 1998), along with the associated PALs. The pesticide 4,4'-DDT was detected in boring B-4b (sample RCR00083) at a depth of 15 ft at 11 µg/kg, a substantially lower concentration than the PRG of 13,000 µg/kg. Other detections for this sample include a pesticide-related PCB (Aroclor-1260), detected at 170 µg/kg. Aroclor-1260 was detected in several samples, also below the PRG of 340 µg/kg. Additionally, endrine ketone has no PRG, and was found in one sample.

Table A.3-4
Soil Sample Results for Total RCRA Metals Detected Above Minimum Reporting Limits
Roller Coaster RADSAFE Area, TTR
(Page 1 of 2)

Borehole Number	Sample Number	Start Depth (ft bgs)	End Depth (ft bgs)	Contaminants of Potential Concern (mg/kg)					
				Arsenic	Barium	Cadmium	Chromium	Lead	Mercury
				Preliminary Action Levels (Industrial Soil PRG) ^a				2.4	100,000
BGB1	RCR00005	9	10	9.9	68	--	--	11	--
	RCR00006	19	20	11	110	--	--	10	--
	RCR00007	29	30	11	75	--	--	14	--
B3	RCR00010	9	10	8.0	120 (J)	--	3.2 (J)	8.1	--
	RCR00011	24	25	7.4	110 (J)	--	4.5 (J)	8.6	--
	RCR00012	29	30	6.6	88 (J)	--	2.4 (J)	9.3	0.17
B4	RCR00025	9	10	9.0	160 (J)	--	18 (J)	10	--
	RCR00026	14	15	9.8	220 (J)	--	7.7 (J)	9.7	--
	RCR00027	24	25	8.5	120 (J)	--	4.0 (J)	7.1	--
	RCR00028	24	25	8.1	130 (J)	--	3.7 (J)	8.3	--
	RCR00029	29	30	8.5	120 (J)	--	3.1 (J)	9.2	--
B2	RCR00031	4	5	8.3	170 (J)	--	3.5 (J)	11	--
	RCR00032	24	25	7.4	100 (J)	--	7.3 (J)	9.0	--
	RCR00033	29	30	8.6	120 (J)	--	3.9 (J)	9.2	--
B1	RCR00040	4	5	5.5	110 (J)	--	2.9 (J)	7.1	--
	RCR00041	24	25	6.5	110 (J)	--	2.9 (J)	8.7	--
	RCR00042	29	30	6.6	120 (J)	--	4.1 (J)	8.1	--
B5	RCR00050	0	1	7.0	130 (J)	--	6.9 (J)	11	--
	RCR00051	4	5	11	130 (J)	--	3.5 (J)	8.2	--
	RCR00052	24	25	10	190 (J)	--	5.1 (J)	11	--
	RCR00053	29	30	7.6	250 (J)	--	5.2 (J)	9.6	--
B3A	RCR00068	9	10	8.9	170 (J)	--	3.2 (J)	9.5	--
	RCR00070	24	25	7.1	150 (J)	--	3.5 (J)	7.1	--
	RCR00071	29	30	5.3	55 (J)	--	2.3 (J)	6.4	--
	RCR00072	29	30	9.6	85 (J)	--	3.9 (J)	9.0	--
B3B	RCR00073	4	5	7.8	110 (J)	--	3.4 (J)	8.3	--
	RCR00074	24	25	7.9	350 (J)	--	5.9 (J)	9.8	--
	RCR00075	29	30	7.3	210 (J)	--	3.3 (J)	9.1	--

Table A.3-4
Soil Sample Results for Total RCRA Metals Detected Above Minimum Reporting Limits
Roller Coaster RADSAFE Area, TTR
(Page 2 of 2)

Borehole Number	Sample Number	Start Depth (ft bgs)	End Depth (ft bgs)	Contaminants of Potential Concern (mg/kg)					
				Arsenic	Barium	Cadmium	Chromium	Lead	Mercury
				Preliminary Action Levels (Industrial Soil PRG) ^a					
				2.4	100,000	850	450	1,000	68
B4B	RCR00083	14	15	7.2	120 (J)	8.3	5.1 (J)	10	--
	RCR00084	24	25	7.8	180 (J)	--	3.5 (J)	8.5	--
	RCR00085	29	30	5.9	98 (J)	--	4.2 (J)	9.4	--
B4A	RCR00093	9	10	7.0	120 (J)	--	3.2 (J)	7.0	--
	RCR00094	24	25	7.5	92 (J)	--	1.9 (J)	5.6	--
	RCR00095	29	30	8.6	120 (J)	--	4.0 (J)	8.7	--
B3C	RCR00104	4	5	5.7	150 (J)	--	5.1 (J)	13	--
	RCR00105	24	25	9.2	140 (J)	--	3.6 (J)	9.0	--
	RCR00106	29	30	7.7	73 (J)	--	3.8 (J)	9.7	--

^aU.S. Environmental Protection Agency, Region 9 Preliminary Remediation Goals (PRGs) (EPA, 1998)
(J) = Estimated value
-- Not detected above minimum reporting limit as stated in CAIP (DOE/NV, 1998)
mg/kg = Milligrams per kilogram

Table A.3-5
Soil Sample Results for Total Pesticide/PCB Contaminants Detected
Above Minimum Reporting Limits, Roller Coaster RADSAFE Area, TTR

Borehole Number	Sample Number	Start Depth (ft bgs)	End Depth (ft bgs)	Contaminant of Potential Concern (µg/kg)		
				4,4'-DDT	Aroclor-1260	Endrin Ketone
				Preliminary Action Levels (Industrial Soil PRG) ^a		
				5,600	340	NI
B2	RCR00031	4	5	--	85	--
B4B	RCR00083	14	15	11	170	--
B3C	RCR00104	4	5	--	51	3.8

^aU.S. Environmental Protection Agency, Region 9 Preliminary Remediation Goals (PRGs) (EPA, 1998)
(J) = Estimated value
-- Not detected above minimum reporting limit as stated in CAIP (DOE/NV, 1998)
µg/kg = Micrograms per kilogram
NI = Not identified

A.3.6 *Gamma Spectroscopy Results*

The gamma spectrometry analytical results for drilling samples and the additional surface samples above minimum reporting limits as specified in the CAIP (DOE/NV, 1998), along with the associated background concentrations, are presented in [Table A.3-6](#) and [Table A.3-7](#) for subsurface and surface samples, respectively.

A.3.7 *Isotopic Plutonium and Uranium Results*

The isotopic plutonium and uranium analytical results for drilling samples and the additional surface samples above minimum reporting limits as specified in the CAIP (DOE/NV, 1998), along with the associated background concentrations, are presented in [Table A.3-8](#) and [Table A.3-9](#) for subsurface and surface samples, respectively.

A.3.8 *Geotechnical Analysis Results*

Geotechnical samples (RCR00017, RCR00018, RCR00043, RCR00091 [see boring logs provided in [Appendix B](#) for specific boreholes, locations and depths]) were collected. Each sample was collected in two 6-in. brass sleeves using a California Modified split-spoon sampler. The findings are summarized in this document, and the report is maintained in the project files.

The methods used for the geotechnical analysis are equivalent to those specified in the CAIP (DOE/NV, 1998) (see [Table A.3-2](#)). The results of the geotechnical observations suggest that the subsurface soil is primarily comprised of poorly graded sands and sands with gravel. Silty sand with gravel and well-graded sand with gravel are also present. The results of the laboratory analysis of the geotechnical samples are presented in [Tables A.3-10](#) to [A.3-12](#).

Table A.3-6
Subsurface-Soil Sample Results for Gamma Spectrometry Contaminants, Roller Coaster RADSAFE Area, TTR
(Page 1 of 2)

Borehole Number	Sample Number	Start Depth (ft)	End Depth (ft)	Contaminant of Potential Concern (pCi/g)										
				Lead-212	Lead-214	Potassium-40	Radium-224	Radium-226	Thallium-208	Thorium-234	Uranium-235	Actinium-228	Americium-241	Bismuth-214
Background Concentrations				0.86 - 2.9 ^a	0.5 - 2.9 ^b	11 - 96 ^a	0.5 - 2.4 ^b	0.21 - 3.21 ^b	0.5 - 3.4 ^a	0.21 - 3.2 ^b	<0.05 - 0.1 ^a	0.4 - 3.64 ^a	0.00006 - 0.048 ^b	0.1 - 3.47 ^a
BGB1	RCR00005	9	10	2.33 ± 0.804	1.69 ± 0.444	38.8 ± 11	--	2.37 ± 0.729	1.27 ± 0.425	4.61 ± 1.55	--	--	--	--
	RCR00006	19	20	1.9 ± 0.637	1.43 ± 0.338	34.3 ± 8.14	21.5 ± 7.26	1.39 ± 0.44	0.876 ± 0.23	5.78 ± 1.4	--	2.46 ± 0.917	--	1.39 ± 0.445
	RCR00007	29	30	1.87 ± 0.584	1.38 ± 0.295	30 ± 6.88	21.1 ± 6.67	1.5 ± 0.388	0.814 ± 0.199	5.51 ± 1.41	--	1.94 ± 0.804	--	--
B3	RCR00010	9	10	1.47 ± 0.484 (J)	1.24 ± 0.302 (J)	28.2 ± 6.45 (J)	--	1.32 ± 0.396 (J)	0.943 ± 0.197 (J)	--	--	1.82 ± 0.745 (J)	--	1.32 ± 0.402 (J)
	RCR00011	24	25	1.96 ± 0.688 (J)	1.67 ± 0.384 (J)	39.1 ± 10.90 (J)	--	2.3 ± 0.777 (J)	1.37 ± 0.379 (J)	--	--	--	--	--
	RCR00012	29	30	2.11 ± 0.705 (J)	1.99 ± 0.414 (J)	30.8 ± 7.33 (J)	--	2.6 ± 0.603 (J)	0.787 ± 0.229 (J)	--	--	2.71 ± 0.896 (J)	--	--
B4	RCR00025	9	10	1.75 ± 0.55 (J)	1.47 ± 0.337 (J)	29.5 ± 6.75 (J)	--	1.95 ± 0.411 (J)	0.744 ± 0.191 (J)	--	0.497 ± 0.213 (J)	2.41 ± 0.887 (J)	54.1 ± 5.18 (J)	1.95 ± 0.423 (J)
	RCR00026	14	15	2.22 ± 3.00	2.02 ± 0.415 (J)	35.8 ± 10.10 (J)	--	1.87 ± 0.694 (J)	1.17 ± 0.369 (J)	--	--	--	1.17 ± 0.476	--
	RCR00027	24	25	1.61 ± 0.554 (J)	1.76 ± 0.353 (J)	32.2 ± 7.65 (J)	--	2.03 ± 0.497 (J)	0.661 ± 0.241 (J)	--	--	2.22 ± 0.719 (J)	--	--
	RCR00028	24	25	1.71 ± 0.538 (J)	1.49 ± 0.302 (J)	31 ± 7.02 (J)	--	1.91 ± 0.429 (J)	0.765 ± 0.205 (J)	--	--	2.04 ± 0.751 (J)	--	--
	RCR00029	29	30	1.76 ± 0.593 (J)	1.29 ± 0.292 (J)	32.8 ± 7.76 (J)	--	1.76 ± 0.486 (J)	0.830 ± 0.214 (J)	--	--	2.5 ± 0.845 (J)	--	--
B2	RCR00031	4	5	1.65 ± 0.538 (J)	1.34 ± 0.295 (J)	30 ± 6.79 (J)	--	1.88 ± 0.403 (J)	0.672 ± 0.223 (J)	--	--	1.99 ± 0.742 (J)	2.9 ± 0.416 (J)	--
	RCR00032	24	25	2.29 ± 0.793 (J)	1.82 ± 0.469 (J)	39.1 ± 11.00 (J)	--	1.51 ± 0.626 (J)	1.03 ± 0.327 (J)	--	--	--	--	--
	RCR00033	29	30	1.86 ± 0.583 (J)	1.88 ± 0.365 (J)	30.3 ± 6.88 (J)	--	1.73 ± 0.413 (J)	0.886 ± 0.204 (J)	--	--	2.7 ± 0.881 (J)	--	1.73 ± 0.422 (J)
B1	RCR00040	4	5	2.29 ± 0.791 (J)	1.59 ± 0.409 (J)	40.5 ± 11.40 (J)	--	1.89 ± 0.681 (J)	1.32 ± 0.394 (J)	--	--	2.35 ± 0.949 (J)	--	--
	RCR00041	24	25	1.70 ± 0.534 (J)	1.25 ± 0.312 (J)	27.2 ± 6.26 (J)	--	1.35 ± 0.349 (J)	0.853 ± 0.214 (J)	--	--	2.11 ± 0.742 (J)	--	--
	RCR00042	29	30	--	1.44 ± 0.301 (J)	31.7 ± 7.62 (J)	--	1.63 ± 0.471 (J)	0.956 ± 0.255 (J)	--	--	2.46 ± 0.9 (J)	--	--
B5	RCR00050	0	1	--	1.28 ± 0.283 (J)	32.9 ± 7.41 (J)	--	1.57 ± 0.403 (J)	0.756 ± 0.18 (J)	--	--	1.82 ± 0.738 (J)	2.34 ± 0.877 (J)	--
	RCR00051	4	5	1.59 ± 0.567 (J)	2.55 ± 0.527 (J)	29.8 ± 8.47 (J)	--	2.48 ± 0.906 (J)	0.867 ± 0.321 (J)	--	--	--	--	--
	RCR00052	24	25	1.58 ± 0.536 (J)	1.26 ± 0.304 (J)	32.7 ± 7.73 (J)	--	1.75 ± 0.485 (J)	0.823 ± 0.214 (J)	--	--	2.58 ± 1 (J)	--	--
	RCR00053	24	25	1.95 ± 0.609 (J)	1.63 ± 0.372 (J)	33 ± 7.45 (J)	--	1.54 ± 0.386 (J)	0.806 ± 0.188 (J)	--	--	2.59 ± 0.819 (J)	--	--
B3A	RCR00068	9	10	1.77 ± 0.643 (J)	1.76 ± 0.436 (J)	37.3 ± 10.5 (J)	--	2.37 ± 0.774 (J)	0.988 ± 0.351 (J)	--	--	3.33 ± 1.16 (J)	--	--
	RCR00070	24	25	1.74 ± 0.549 (J)	1.7 ± 0.366 (J)	27.6 ± 6.34 (J)	--	1.95 ± 0.452 (J)	0.728 ± 0.201 (J)	--	--	2.59 ± 0.814 (J)	--	1.95 ± 0.463 (J)
	RCR00071	29	30	2.06 ± 0.716 (J)	1.83 ± 0.424 (J)	40.2 ± 11.2 (J)	--	2.58 ± 0.793 (J)	1.24 ± 0.411 (J)	--	--	3.45 ± 1.21 (J)	--	--
	RCR00072	29	30	1.78 ± 0.597 (J)	1.64 ± 0.35 (J)	32.8 ± 7.77 (J)	--	1.75 ± 0.5 (J)	0.648 ± 0.215 (J)	--	--	2.25 ± 0.821 (J)	--	--

Table A.3-6
Subsurface-Soil Sample Results for Gamma Spectrometry Contaminants, Roller Coaster RADSAFE Area, TTR
(Page 2 of 2)

Borehole Number	Sample Number	Start Depth (ft)	End Depth (ft)	Contaminant of Potential Concern (pCi/g)										
				Lead-212	Lead-214	Potassium-40	Radium-224	Radium-226	Thallium-208	Thorium-234	Uranium-235	Actinium-228	Americium-241	Bismuth-214
Background Concentrations				0.86 - 2.9^a	0.5 - 2.9^b	11 - 96^a	0.5 - 2.4^b	0.21 - 3.21^b	0.5 - 3.4^a	0.21 - 3.2^b	<0.05 - 0.1^a	0.4 - 3.64^a	0.00006 - 0.048^b	0.1 - 3.47^a
B3B	RCR00073	4	5	1.46 ± 0.476 (J)	1.5 ± 0.303 (J)	28.2 ± 6.5 (J)	--	1.81 ± 0.404 (J)	0.814 ± 0.206 (J)	--	--	--	--	--
	RCR00074	24	25	2.33 ± 0.807 (J)	1.73 ± 0.442 (J)	36.9 ± 10.5 (J)	--	2.38 ± 0.839 (J)	1 ± 0.332 (J)	--	--	3.31 ± 1.2 (J)	--	--
	RCR00075	29	30	1.84 ± 0.616 (J)	1.41 ± 0.308 (J)	30.9 ± 7.34 (J)	--	1.63 ± 0.47 (J)	0.958 ± 0.235 (J)	--	--	2.43 ± 0.851 (J)	--	--
B4B	RCR00083	14	15	1.72 ± 0.543 (J)	1.43 ± 0.35 (J)	28.6 ± 6.52 (J)	--	1.67 ± 0.423 (J)	0.703 ± 0.193 (J)	--	--	--	--	--
	RCR00084	24	25	1.9 ± 0.638 (J)	1.52 ± 0.332 (J)	33.6 ± 7.95 (J)	--	1.52 ± 0.422 (J)	0.794 ± 0.235 (J)	--	--	2.77 ± 0.853 (J)	--	--
	RCR00085	29	30	1.74 ± 0.545 (J)	1.34 ± 0.312 (J)	30.6 ± 6.97 (J)	--	1.41 ± 0.389 (J)	0.739 ± 0.202 (J)	--	--	--	--	1.41 ± 0.396 (J)
B4A	RCR00093	9	10	2.32 ± 0.802 (J)	1.86 ± 0.432 (J)	36.7 ± 10.4 (J)	--	2.62 ± 0.805 (J)	1.16 ± 0.35 (J)	--	--	--	--	--
	RCR00094	24	25	1.74 ± 0.585 (J)	2.1 ± 0.405 (J)	31.5 ± 7.53 (J)	--	2.14 ± 0.504 (J)	0.779 ± 0.26 (J)	--	--	2.56 ± 0.816 (J)	--	--
	RCR00095	29	30	--	1.26 ± 0.291 (J)	28.1 ± 6.44 (J)	--	1.36 ± 0.399 (J)	0.819 ± 0.192 (J)	--	--	2.23 ± 0.734 (J)	--	1.36 ± 0.405 (J)
B3C	RCR00104	4	5	2.15 ± 0.747 (J)	1.92 ± 0.454 (J)	33.1 ± 9.42 (J)	--	2.11 ± 0.712 (J)	0.903 ± 0.297 (J)	--	--	3.61 ± 1.37 (J)	--	2.11 ± 0.721 (J)
	RCR00105	24	25	1.85 ± 0.631 (J)	1.52 ± 0.347 (J)	31.5 ± 7.47 (J)	--	1.83 ± 0.491 (J)	0.936 ± 0.238 (J)	--	--	--	--	1.83 ± 0.5 (J)
	RCR00106	29	30	1.68 ± 0.527 (J)	1.32 ± 0.297 (J)	30.1 ± 6.9 (J)	--	1.33 ± 0.39 (J)	0.676 ± 0.169 (J)	--	--	2.04 ± 0.702 (J)	--	1.33 ± 0.396 (J)

^a McArthur, B.D. and F.L. Miller. 1989. *Off-Site Radiation Exposure Review Project Phase II Soil Program*, Water Resources Center Publication No. 45064. Las Vegas, NV: Desert Research Institute.

^b U.S. Ecology and Atlan-Tech. 1992. *Environmental Monitoring for the Proposed Ward Valley California Low Level Radioactive Waste Facility*. Auburn, CA.

Shaded sample result indicates concentration exceeds preliminary action level (DOE/NV, 1998)

pCi/g = Picocuries per gram

Table A.3-7
Surface Soil Sample Results for Gamma Spectrometry, Roller Coaster RADSAFE Area, TTR

Sample No.	Contaminant of Potential Concern (pCi/g)							
	Cesium-137	Potassium-40	Radium-226	Thorium-228	Thorium-232	Uranium-235	Uranium-238	Americium-241
Background Concentrations	0.04 - 7 ^a	11 - 96 ^b	0.21 - 3.21 ^a	0.49 - 2.4 ^a	0.49 - 2.4 ^a	0.05 - 0.1 ^b	0.21 - 3.2 ^a	0.00006 - 0.048 ^a
RCR00112	0.12 ± 0.03 (J)	26.74 ± 2.66 (J)	1.09 ± 0.14 (J)	2.29 ± 0.24 (J)	1.93 ± 0.27 (J)	--	--	--
RCR00113	0.12 ± 0.03 (J)	25.41 ± 2.55 (J)	1.22 ± 0.15 (J)	2.17 ± 0.23 (J)	1.8 ± 0.26 (J)	--	--	--
RCR00114	0.11 ± 0.03 (J)	24.35 ± 2.47 (J)	1.07 ± 0.14 (J)	2.24 ± 0.23 (J)	1.85 ± 0.26 (J)	--	--	--
RCR00115	0.18 ± 0.04 (J)	23.99 ± 2.44 (J)	1.02 ± 0.14 (J)	2.03 ± 0.21 (J)	1.71 ± 0.25 (J)	--	--	--
RCR00116	0.31 ± 0.05 (J)	24.05 ± 2.44 (J)	1.01 ± 0.13 (J)	1.98 ± 0.21 (J)	1.67 ± 0.25 (J)	--	--	0.26 ± 0.11 (J)
RCR00117	0.09 ± 0.03 (J)	24.88 ± 2.50 (J)	1.01 ± 0.13 (J)	2.19 ± 0.23 (J)	1.87 ± 0.26 (J)	--	--	--
RCR00118	--	24.13 ± 2.45 (J)	1.16 ± 0.15 (J)	2.55 ± 0.26 (J)	2.07 ± 0.28 (J)	--	--	--
RCR00119	0.21 ± 0.04 (J)	25.38 ± 2.55 (J)	1.25 ± 0.16 (J)	2.2 ± 0.23 (J)	1.77 ± 0.26 (J)	--	--	--
RCR00120	0.16 ± 0.04 (J)	25.37 ± 2.54 (J)	1.07 ± 0.14 (J)	2.09 ± 0.22 (J)	1.78 ± 0.25 (J)	--	--	--
RCR00121	0.08 ± 0.03 (J)	25.50 ± 2.56 (J)	1.13 ± 0.14 (J)	2.18 ± 0.23 (J)	1.70 ± 0.25 (J)	--	--	--
RCR00122	0.05 ± 0.03 (J)	21.94 ± 2.28 (J)	0.98 ± 0.13 (J)	1.99 ± 0.21 (J)	1.59 ± 0.24 (J)	--	--	129.14 ± 9.66 (J)
RCR00123	0.12 ± 0.03 (J)	23.78 ± 2.41 (J)	1.21 ± 0.15 (J)	2.18 ± 0.23 (J)	1.72 ± 0.25 (J)	--	4.47 ± 3.52 (J)	2.35 ± 0.30 (J)
RCR00124	0.11 ± 0.03 (J)	25.06 ± 2.52 (J)	--	2.36 ± 0.24 (J)	2.03 ± 0.28 (J)	--	--	14.97 ± 1.28 (J)
RCR00125	0.14 ± 0.03 (J)	24.86 ± 2.51 (J)	1.15 ± 0.15 (J)	2.35 ± 0.24 (J)	1.78 ± 0.25 (J)	--	--	85.99 ± 6.53 (J)
RCR00126	0.33 ± 0.05 (J)	25.10 ± 2.53 (J)	1.22 ± 0.15 (J)	2.15 ± 0.23 (J)	1.88 ± 0.27 (J)	--	--	1,189.44 ± 85.11 (J)
RCR00127	0.26 ± 0.05 (J)	25.25 ± 2.54 (J)	1.30 ± 0.16 (J)	2.36 ± 0.25 (J)	1.76 ± 0.26 (J)	20.01 ± 5.71 (J)	54.66 ± 9.14 (J)	4,158.24 ± 294.55 (J)
RCR00128	0.29 ± 0.14 (J)	25.91 ± 4.88 (J)	1.70 ± 0.40 (J)	--	1.70 ± 0.63 (J)	--	115.03 ± 32.96 (J)	7,916.40 ± 572.82 (J)

^a McArthur, R.D. and F.L. Miller. 1989. *Off-Site Radiation Exposure Review Project Phase II Soil Program*, Water Resources Center Publication No. 45064. Las Vegas, NV: Desert Research Institute.

^b U.S. Ecology and Atlan-Tech. 1992. *Environmental Monitoring for the Proposed Ward Valley California Low Level Radioactive Waste Facility*. Auburn, CA.

Shaded sample result indicates concentration exceeds preliminary action level (DOE/NV, 1998)

pCi/g = Picocuries per gram

Table A.3-8
Subsurface-Soil Sample Results for Isotopic Plutonium and Uranium,
Roller Coaster RADSAFE Area, TTR
(Page 1 of 3)

Borehole Number	Sample Number	Start Depth (ft)	End Depth (ft)	Contaminant of Potential Concern in (pCi/g)			
				Plutonium-238	Plutonium-239/240	Uranium-234	Uranium-238
Background Concentrations				<0.002^a	0.0003 - 0.24^a	0.10 - 2.6^b	0.21 - 3.2^a
BGB1	RCR00005	9	10	--	--	0.35 ± 0.23 (J)	--
	RCR00006	19	20	--	--	0.467 ± 0.24 (J)	0.223 ± 0.15 (J)
	RCR00007	29	30	--	--	0.532 ± 0.23 (J)	0.411 ± 0.2 (J)
B3	RCR00010	9	10	--	--	0.339 ± 0.19 (J)	--
	RCR00010DUP	9	10	--	--	0.359 ± 0.21 (J)	--
	RCR00011	24	25	--	--	0.429 ± 0.21 (J)	0.288 ± 0.16 (J)
	RCR00012	29	30	--	--	0.552 ± 0.25 (J)	0.335 ± 0.19 (J)
	RCR00013	5	6	--	--	0.577 ± 0.25 (J)	0.421 ± 0.21 (J)
	RCR00014	6	7	--	--	0.567 ± 0.31 (J)	0.536 ± 0.3 (J)
	RCR00015	7	8	--	--	0.631 ± 0.31 (J)	0.46 ± 0.25 (J)
	RCR00016	8	9	--	--	0.212 ± 0.14 (J)	--
B4	RCR00021	17	18	--	--	0.342 ± 0.17 (J)	0.344 ± 0.17 (J)
	RCR00022	18	19	--	--	--	0.493 ± 0.23 (J)
	RCR00023	20	21	--	--	0.457 ± 0.22 (J)	0.411 ± 0.21 (J)
	RCR00024	21	22	--	--	0.493 ± 0.25 (J)	0.518 ± 0.25 (J)
	RCR00025	9	10	34.2 ± 17 (J)	5210 ± 680 (J)	--	--
	RCR00026	14	15	1.52 ± 0.36 (J)	224 ± 27 (J)	0.498 ± 0.22 (J)	0.435 ± 0.21 (J)
	RCR00027	24	25	--	--	0.339 ± 0.19 (J)	--
	RCR00028	24	25	--	--	0.38 ± 0.19 (J)	0.38 ± 0.19 (J)
	RCR00029	29	30	--	--	0.301 ± 0.17 (J)	0.386 ± 0.19 (J)
B2	RCR00031	4	5	0.34 ± 0.18 (J)	51 ± 6.8 (J)	0.357 ± 0.19 (J)	0.313 ± 0.18 (J)
	RCR00033	29	30	--	--	0.633 ± 0.28 (J)	0.422 ± 0.22 (J)
	RCR00034	5	6	--	--	--	0.331 ± 0.2 (J)
	RCR00035	6	7	--	--	--	0.26 ± 0.19 (J)
	RCR00036	7	8	--	--	0.274 ± 0.15 (J)	--
	RCR00036DUP	7	8	--	--	0.311 ± 0.17 (J)	--
	RCR00037	8	9	--	--	0.53 ± 0.26 (J)	0.404 ± 0.22 (J)
	RCR00038	9	10	--	--	0.419 ± 0.21 (J)	--

Table A.3-8
Subsurface-Soil Sample Results for Isotopic Plutonium and Uranium,
Roller Coaster RADSAFE Area, TTR
(Page 2 of 3)

Borehole Number	Sample Number	Start Depth (ft)	End Depth (ft)	Contaminant of Potential Concern in (pCi/g)			
				Plutonium-238	Plutonium-239/240	Uranium-234	Uranium-238
Background Concentrations				<0.002^a	0.0003 - 0.24^a	0.10 - 2.6^b	0.21- 3.2^a
B1	RCR00040	4	5	--	--	0.518 ± 0.24 (J)	0.239 ± 0.15 (J)
	RCR00041	24	25	--	--	0.49 ± 0.24 (J)	--
	RCR00042	29	30	--	--	0.346 ± 0.19 (J)	0.306 ± 0.17 (J)
	RCR00044	0	1	--	2.53 ± 0.51 (J)	0.367 ± 0.21 (J)	0.315 ± 0.19 (J)
	RCR00045	1	2	--	--	0.325 ± 0.17 (J)	0.349 ± 0.18 (J)
	RCR00046	2	3	--	--	0.539 ± 0.25 (J)	0.425 ± 0.21 (J)
	RCR00047	3	4	--	--	0.341 ± 0.2 (J)	0.365 ± 0.21 (J)
	RCR00048	4	5	--	0.287 ± 0.17 (J)	0.56 ± 0.24 (J)	0.373 ± 0.19 (J)
	RCR00049	5	6	--	--	0.371 ± 0.22 (J)	--
B5	RCR00050	0	1	--	1.81 ± 0.46 (J)	0.405 ± 0.21 (J)	--
	RCR00051	4	5	--	--	0.628 ± 0.3 (J)	0.765 ± 0.34 (J)
	RCR00052	24	25	--	--	--	0.305 ± 0.19 (J)
	RCR00053	29	30	--	--	0.315 ± 0.19 (J)	0.29 ± 0.18 (J)
B3A	RCR00062	5	6	--	--	0.561 ± 0.27 (J)	0.4 ± 0.22 (J)
	RCR00063	6	7	--	--	0.357 ± 0.2 (J)	0.264 ± 0.17 (J)
	RCR00064	7	8	--	--	0.381 ± 0.18 (J)	0.275 ± 0.15 (J)
	RCR00065	8	9	--	--	0.347 ± 0.19 (J)	--
	RCR00067	11	12	--	--	0.57 ± 0.33 (J)	--
	RCR00068	9	10	--	3.1 ± 0.54	0.38 ± 0.13 (J)	0.344 ± 0.13 (J)
	RCR00069	9	10	--	--	0.262 ± 0.11 (J)	--
	RCR00070	24	25	--	--	0.395 ± 0.22 (J)	--
	RCR00071	29	30	--	--	0.509 ± 0.24 (J)	0.37 ± 0.2 (J)
RCR00072	29	30	--	--	0.414 ± 0.22 (J)	--	
B3B	RCR00073	4	5	--	--	0.391 ± 0.22 (J)	0.421 ± 0.23 (J)
	RCR00074	24	25	--	--	0.443 ± 0.21 (J)	0.232 ± 0.15 (J)
	RCR00079	12	13	--	--	0.245 ± 0.17 (J)	0.326 ± 0.2 (J)
	RCR00080	13	14	--	--	0.302 ± 0.18 (J)	--
	RCR00081	14	15	--	--	0.458 ± 0.25 (J)	--

Table A.3-8
Subsurface-Soil Sample Results for Isotopic Plutonium and Uranium,
Roller Coaster RADSAFE Area, TTR
(Page 3 of 3)

Borehole Number	Sample Number	Start Depth (ft)	End Depth (ft)	Contaminant of Potential Concern in (pCi/g)			
				Plutonium-238	Plutonium-239/240	Uranium-234	Uranium-238
Background Concentrations				<0.002^a	0.0003 - 0.24^a	0.10 - 2.6^b	0.21- 3.2^a
B4B	RCR00083	14	15	--	24.1 ± 3.4	0.501 ± 0.23 (J)	0.377 ± 0.19 (J)
	RCR00084	24	25	--	--	--	0.228 ± 0.13 (J)
	RCR00085	29	30	--	--	0.288 ± 0.15 (J)	0.199 ± 0.12 (J)
	RCR00086	15	16	--	12.5 ± 1.8	0.282 ± 0.17 (J)	0.264 ± 0.16 (J)
	RCR00087	16	17	--	2.44 ± 0.48	0.519 ± 0.29 (J)	0.485 ± 0.28 (J)
	RCR00088	17	18	--	--	0.414 ± 0.19 (J)	0.215 ± 0.13 (J)
	RCR00089	18	19	--	--	0.473 ± 0.23 (J)	--
	RCR00090	19	20	--	0.245 ± 0.14 (J)	0.405 ± 0.2 (J)	0.538 ± 0.24 (J)
B4A	RCR00093	9	10	--	--	0.426 ± 0.15 (J)	0.33 ± 0.12 (J)
	RCR00093DUP			--	--	0.277 ± 0.1 (J)	0.303 ± 0.11 (J)
	RCR00094	24	25	--	--	0.32 ± 0.12 (J)	0.285 ± 0.11 (J)
	RCR00095	29	30	--	3.88 ± 0.85	0.241 ± 0.099 (J)	0.204 ± 0.09 (J)
	RCR00096	10	11	--	4.2 ± 0.72	0.347 ± 0.13 (J)	0.143 ± 0.079 (J)
	RCR00097	11	12	--	--	0.191 ± 0.086 (J)	0.31 ± 0.11 (J)
	RCR00098	12	13	--	--	0.297 ± 0.12 (J)	0.224 ± 0.1 (J)
	RCR00099	13	14	--	--	0.338 ± 0.14 (J)	0.252 ± 0.12 (J)
B3C	RCR00104	4	5	--	0.182 ± 0.1	0.447 ± 0.16 (J)	0.286 ± 0.12 (J)
	RCR00105	24	25	--	--	0.397 ± 0.14 (J)	0.267 ± 0.11 (J)
	RCR00106	29	30	--	--	0.506 ± 0.17 (J)	0.383 ± 0.14 (J)
	RCR00107	5	6	--	--	0.378 ± 0.14 (J)	0.304 ± 0.12 (J)
	RCR00108	6	7	--	--	0.421 ± 0.15 (J)	0.323 ± 0.13 (J)
	RCR00109	7	8	--	--	0.384 ± 0.13 (J)	0.565 ± 0.17 (J)
	RCR00110	8	9	--	--	0.345 ± 0.12 (J)	0.367 ± 0.13 (J)
	RCR00111	9	10	--	--	0.398 ± 0.13 (J)	0.332 ± 0.11 (J)

^a McArthur, R.D. and F.L. Miller. 1989. *Off-Site Radiation Exposure Review Project Phase II Soil Program*, Water Resources Center Publication No. 45064. Las Vegas, NV: Desert Research Institute.

^b U.S. Ecology and Atlan-Tech. 1992. *Environmental Monitoring for the Proposed Ward Valley California Low Level Radioactive Waste Facility*. Auburn, CA.

Shaded sample result indicates concentration exceeds preliminary action level (DOE/NV, 1998)

-- Not detected above minimum reporting limit as stated in CAIP (DOE/NV, 1998)

J = Estimated value

pCi/g = Picocuries per gram

**Table A.3-9
Surface Soil Sample Results for Isotopic Plutonium and Uranium,
Roller Coaster RADSAFE Area, TTR**

Sample No.	Contaminant of Potential Concern (pCi/g)		
	Plutonium-239,240	Uranium-234	Uranium-238
Background Concentrations	0.0003 - 0.24 ^a	0.1 - 2.6 ^b	0.21 - 3.2 ^a
RCR00112	2.03 ± 0.30 (J)	1.09 ± 0.20 (J)	0.98 ± 0.19 (J)
RCR00113	0.45 ± 0.13 (J)	1.22 ± 0.23 (J)	1.22 ± 0.23 (J)
RCR00114	0.49 ± 0.11 (J)	1.03 ± 0.19 (J)	1.05 ± 0.19 (J)
RCR00115	0.23 ± 0.09 (J)	0.84 ± 0.18 (J)	0.89 ± 0.19 (J)
RCR00116	2.93 ± 0.40 (J)	0.87 ± 0.18 (J)	0.87 ± 0.18 (J)
RCR00117	0.10 ± 0.05 (J)	0.65 ± 0.16 (J)	0.87 ± 0.18 (J)
RCR00118	--	1.05 ± 0.20 (J)	0.95 ± 0.19 (J)
RCR00119	0.50 ± 0.14 (J)	1.11 ± 0.22 (J)	0.92 ± 0.20 (J)
RCR00120	0.14 ± 0.05 (J)	1.17 ± 0.23 (J)	1.30 ± 0.24 (J)
RCR00121	0.91 ± 0.16 (J)	0.98 ± 0.20 (J)	0.89 ± 0.19 (J)
RCR00122	3,970.26 ± 1,439.28 (J)	--	--
RCR00123	16.86 ± 3.17 (J)	1.03 ± 0.20 (J)	--
RCR00123	11.49 ± 2.43 (J)	--	--
RCR00124	334.37 ± 34.63 (J)	0.96 ± 0.19 (J)	1.00 ± 0.19 (J)
RCR00124	131.17 ± 18.85 (J)	--	--
RCR00126	19,507.41 ± 2,959.10 (J)	--	--
RCR00127	79,353.88 ± 8,124.28 (J)	--	--
RCR00128	159,167.44 ± 24,409.72 (J)	--	--

^a McArthur, R.D. and F.L. Miller. 1989. *Off-Site Radiation Exposure Review Project Phase II Soil Program*, Water Resources Center Publication No. 45064. Las Vegas, NV: Desert Research Institute.

^b U.S. Ecology and Atlan-Tech. 1992. *Environmental Monitoring for the Proposed Ward Valley California Low Level Radioactive Waste Facility*. Auburn, CA.

Shaded sample result indicates concentration exceeds preliminary action level (DOE/NV, 1998)

pCi/g = Picocuries per gram

**Table A.3-10
Summary of Particle Size Characterization**

Borehole Number	Sample Number	Sample Depth ^a (feet)	d ₁₀ (mm)	d ₃₀ (mm)	d ₅₀ (mm)	d ₆₀ (mm)	Cu	Cc	Method
B-4	RCR00017	26.5	0.077	0.63	1.6	2.5	32	2.1	WS/H
B-3	RCR00018	18.0	0.010	0.45	1.7	2.9	290	7.0	WS/H
B-1	RCR00043	6.5	0.020	0.22	0.94	2.0	100	1.2	WS/H
B-4b	RCR00091	11.5	0.019	0.37	1.3	2.2	120	3.3	WS/H

^aGeotechnical samples collected from 1.5-ft intervals ending at depth shown

mm = Millimeter(s)

d₅₀ = Median particle diameter

Cu = Uniformity coefficient = d_{60}/d_{10}

Cc = Coefficient of curvature = $(d_{30})^2/(d_{10} * d_{60})$

WS = Wet sieve

H = Hydrometer

**Table A.3-11
Summary of Initial Moisture Content, Dry Bulk Density, Wet Bulk Density, and Calculated Porosity Results**

Borehole Number	Sample Number	Sample Depth ^a (ft)	Initial Moisture Content		Dry Bulk Density (g/cm ³)	Wet Bulk Density (g/cm ³)	Calculated Porosity (%)
			Gravimetric (% g/g)	Volumetric (% cm ³ /cm ³)			
B-4	RCR00017	26.5	5.3	9.6	1.83	1.92	31.1
B-3	RCR00018	18.0	7.7	12.4	1.61	1.73	39.4
B-1	RCR00043	6.5	14.9	21.9	1.46	1.68	44.8
B-4b	RCR00091	11.5	6.2	9.7	1.56	1.66	41.0

^aGeotechnical samples collected from 1.5-ft intervals ending at depth shown

% = Percent

g/g = Gram per gram

cm³ = Cubic centimeter

g/cm³ = Gram per cubic centimeter

**Table A.3-12
Summary of Hydrologic Parameters Test Results**

Borehole Number	Sample Number	Sample Depth ^a (feet)	Saturated Hydraulic Conductivity	Unsaturated Hydraulic Conductivity			
			Ksat (cm/s)	α (cm ⁻¹)	N (dimensionless)	Θ_r %	Θ_s %
B-4	RCR00017	26.5	1.1E-03	0.3351	1.2538	0.0624	0.3110
B-3	RCR00018	18.0	4.4E-04	0.2253	1.1524	0.0000	0.3426
B-1	RCR00043	6.5	1.5E-04	0.1070	1.1557	0.0000	0.4435
B-4b	RCR00091	11.5	9.6E-04	0.1977	1.1491	0.0000	0.3504

^aGeotechnical samples collected from 1.5-ft intervals ending at depth shown

Ksat = Saturated permeability
cm/s = Centimeter(s) per second
 α = Calculated parameter
N = Calculated parameter
cm⁻¹ = Units per centimeter
 Θ_r = Residual soil-water content
% = Percent
 Θ_s = Saturated soil-water content

A.4.0 Quality Assurance

The results of QA/QC activities for the RCRSA corrective action investigation sampling event are summarized in the following text. A discussion about measurement of the QA/QC objectives is also included. The QA/QC procedures related to geotechnical samples and analyses are contained in the *Standard Specifications for Transportation Materials and Methods of Sampling and Testing* (AASHTO, 1995) and are not discussed further in this text. Detailed information on the QA program for this sampling event is contained in the Industrial Sites QAPP (DOE/NV, 1996b).

Quality control results are typically discussed in terms of precision, accuracy, representativeness, completeness, and comparability, the five PARCC parameters as described in the following sections.

A.4.1 Precision

Precision is a quantitative measure of the variability of a group of measurements from their average value. Precision is assessed by collecting and analyzing duplicate field samples and comparing the results with the original sample. Precision is also assessed by creating, preparing, analyzing, and comparing laboratory duplicates from one or more field samples in inorganic analyses and matrix spike and matrix spike duplicate (MS/MSD) samples for organic analyses. Precision is reported as relative percent difference (RPD) which is calculated as the difference between the measured concentrations of duplicate samples, divided by the average of the two concentrations, and multiplied by 100. Any deviations from these requirements have been documented and explained and the related data qualified accordingly. The qualification process is described in [Section A.4.7.1](#).

A.4.2 Accuracy

Analytical accuracy is defined as the nearness of a measurement to the true or accepted reference value. It is the composite of the random and systematic components of the measurement system and measures bias in a measurement system. The random component of accuracy is measured and documented through the analyses of spiked samples. Sampling accuracy is assessed by evaluating

the results of spiked samples and laboratory control samples. Accuracy measurements are calculated as percent recovery by dividing the measured sample concentration by the true concentration and multiplying the quotient by 100.

Field accuracy is assessed by confirming that the documents of record track the sample from origin, through transfer of custody, to disposal. The goal of field accuracy is for all samples to be collected from the correct locations at the correct time, placed in a correctly labeled container with the correct preservative, and sealed with custody tape to prevent tampering. All samples in this sampling event were properly collected and forwarded to the laboratory as described above.

A.4.3 Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, or an environmental condition (EPA, 1987). Sample representativeness was achieved through the implementation of a sampling program designed to ensure proper sampling locations, number of samples, and the use of validated analytical methods. Representativeness was assessed through analysis of duplicate samples. Representativeness of the samples taken in this sampling event was assured by collecting the required samples shown in [Section A.2.0](#) and by analyzing them using the approved analytical methods shown in [Table A.3-2](#).

A.4.4 Completeness

Completeness is defined as the percentage of measurements made that are judged to be valid. A sampling and analytical requirement of 80 percent completeness was established for this project (DOE/NV, 1996b). The RCRSA sampling data exhibit a high degree of completeness. The sampling and analytical program were executed in accordances with approved field sampling instructions in the CAIP (DOE/NV, 1998). The specified sampling locations were used as planned. All specified samples were collected, and all sample containers reached the laboratory intact and properly preserved (when applicable). Except for two samples, sample temperature was maintained during shipment to the laboratory, and sample chain of custody was maintained during sample storage and/or shipment (DOE/NV, 1996b). Sample numbers RCR00056 (source blank) and RCR00060 (trip blank) arrived at DATACHEM at an unacceptable temperature. All analysis

associated with these two samples were cancelled; however, this did not affect the validity of the other samples.

A.4.5 Comparability

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared to another (EPA, 1987). To ensure comparability, the RCRSA field-sampling activities were performed and documented in accordance with approved procedures; a standardized sampling approach and analytical methodology were used; and all samples were collected per the CAIP (DOE/NV, 1998). Approved standardized methods and procedures were also used to analyze and report the data (e.g., EPA SW-846 Methods and Contract Laboratory Program [CLP] [EPA, 1994b] and/or CLP-like data packages). This approach ensures that the data from this project can be compared to other data sets. Based on the minimum comparability requirements specified in the Industrial Sites QAPP (DOE/NV, 1996b), all requirements were met.

Sample-handling documentation, laboratory nonconformance reports, and the precision and accuracy of quality-control sample results were evaluated for their effect on the results of the associated environmental soil samples. The environmental sample results were then qualified according to processes outlined in the following section. Documentation of the data qualifications resulting from these reviews is retained in project files as both hard copy and electronic media and will be supplied upon request.

A.4.6 Data Evaluations

All laboratory data from samples collected at the RCRSA have been evaluated for data quality according to EPA Functional Guidelines (EPA, 1994a and 1994b). These guidelines were implemented in a tiered process and are presented in the following text. Modifications to the laboratory-generated qualifiers were required to account for estimated values and associated blank contamination. No data rejected during the data evaluation process were used to reach the conclusions presented in [Section A.3.0](#). Only detections, whether estimated (i.e., J-qualified) or not, were used in reaching conclusions.

Changes resulting from the data evaluation process are documented in project files and summarized in memoranda for each sample delivery group (SDG). These memoranda are maintained with the SDGs in the project files and are available for inspection upon request.

A.4.6.1 Tier I

Tier I evaluation for chemical analysis examines (but is not limited to):

- Sample count/type consistent with chain of custody
- Analysis count/type consistent with chain of custody
- Correct sample matrix
- Significant problems stated in cover letter or case narrative
- Completeness of certificates of analysis
- Completeness of CLP or CLP-like packages
- Completeness of signatures, dates, and times on chain of custody
- Condition-upon-receipt variance form included
- Requested analyses performed on all samples
- Date received/analyzed given for each sample
- Correct concentration units indicated
- Correct detection limits achieved
- Electronic data transfer supplied
- Results reported for field and laboratory QC samples
- Whether or not the deliverable met the overall objectives of the project

A.4.6.2 Tier II

Tier II evaluation for chemical analysis examines (but is not limited to):

Chemical:

- Correct detection limits achieved
- Sample date, preparation date, and analysis date for each sample
- Holding time criteria met
- QC batch association for each sample
- Cooler temperature upon receipt
- Sample pH for aqueous samples, as required

- Detection limits properly adjusted for dilution, as required
- Blank contamination evaluated and applied to sample results/qualifiers
- MS/MSD percent recoveries (%R) and RPDs evaluated and applied to laboratory results/qualifiers
- Field duplicate RPDs evaluated using professional judgement and applied to laboratory results/qualifiers
- Laboratory duplicate RPDs evaluated and applied to laboratory results/qualifiers
- Surrogate %Rs evaluated and applied to laboratory results/qualifiers
- Laboratory control sample %Rs evaluated and applied to laboratory results/qualifiers
- Initial and continuing calibration evaluated and applied to laboratory results/qualifiers
- Internal standard evaluated and applied to laboratory results/qualifiers
- Recalculation of 10 percent of laboratory results from raw data

Radioanalytical:

- Correct detection limits achieved
- Blank contamination evaluated and applied to sample results/qualifiers
- Certificate of Analysis consistent with data package documentation
- Quality control sample results (duplicates, laboratory control samples, laboratory blanks) evaluated and applied to laboratory result qualifiers
- Sample results, error, and minimum detectable activity evaluated and applied to laboratory result qualifiers
- Detector system calibrated to National Institute for Standards and Technology (NIST) traceable sources
- Calibration sources preparation was documented, demonstrating proper preparation and appropriateness for sample matrix, emission energies, and concentrations

- Detector system response to daily, weekly, and monthly background and calibration checks for peak energy, peak centroid, peak full-width half-maximum, and peak efficiency
- Tracers NIST-traceable, appropriate for the analysis performed, and recoveries that met QC requirements
- Documentation of all QC sample preparation complete and properly performed
- Spectra lines, emissions, particle energies, peak areas, and background peak areas support the identified radionuclide and its concentration

A.4.6.3 Tier III

Additional data quality considerations included in EPA data review functional guidelines are evaluated as a third party Tier III review. Tier III review of chemical results include the following additional evaluations:

- Mass spectrometer tuning criteria
- Initial and continuing calibration verification
- Internal standard evaluation
- Organic compound quantitation
- Inductively coupled plasma (ICP) interference check sample evaluation
- Graphite furnace atomic absorption quality control
- ICP serial dilution effects
- Recalculation of all laboratory results from raw data

Tier I and II data evaluations are summarized in a memorandum for each SDG showing results and qualifiers that were changed and the reason for these changes.

A Tier III review of five percent of the analytical data was performed by Quanterra Environmental Services, Knoxville, Tennessee. Changes to the data resulting from this review have been documented in project files and are reflected in the analytical summary tables in [Section A.3.0](#).

A.4.7 Quality Control Samples

Twenty-nine quality control samples (i.e., trip blanks, equipment rinsate blanks, field blanks, source blanks, field duplicates, and MS/MSD) were collected and submitted for laboratory analysis, as shown in [Table A.3-1](#). The blanks and duplicates were assigned individual sample numbers and

sent to the laboratory “blind.” Additional samples were selected by the laboratory to be analyzed as laboratory replicates, duplicates, matrix duplicates, and matrix spike duplicates. Documentation related to the collection and analysis of these samples is retained in project files and will be supplied upon request.

A.4.7.1 Field Quality Control Samples

All blanks except trip blanks (i.e., equipment rinsate blanks, field blanks, and source blanks) were analyzed for the parameters listed in [Table A.3-2](#) (trip blanks were analyzed for VOCs only) and showed contamination associated with common laboratory contaminants (acetone, methylene chloride, 2-butanone, and phthalate esters as defined in the EPA Functional Guidelines) and with arsenic. These blank detections were used to qualify the results of the associated environmental samples according to EPA Functional Guidelines (EPA, 1994a and 1994b).

According to the EPA Functional Guidelines, no qualification action is taken if a compound is found in an associated blank, but not in the sample, or if a compound is found in the sample, but not in an associated blank. The action taken when a compound is detected in both the sample and the associated blank varies depending upon the analyte involved and is known as “The 5X/10X Rule.”

For most VOCs, SVOCs, pesticides, and PCBs, an analyte detected in the sample that was also detected in an associated blank is qualified as undetected (U) if the sample concentration is less than five times (5X) the blank concentration. For the common laboratory contaminants (methylene chloride, acetone, 2-butanone [methyl ethyl ketone], and phthalate esters [especially bis(2-ethylhexyl)phthalate]), the factor is raised to ten times (10X) the blank concentration. For both the 5X/10X rule, the sample result is elevated to the quantitation limit if it is less than the quantitation limit or remains unaltered if the sample result is greater than or equal to the quantitation limit and qualified as undetected (U).

For inorganics (metals), sample results greater than the instrument detection limit but less than five times (5X) the amount found in an associated blank are qualified as undetected (U). There are no common metallic laboratory contaminants, so there is no “10X Rule” for metals, and the sample result is never altered. When applying the 5X criteria to soil sample data or calibration blank data,

the raw data results are used to evaluate and qualify the reported results on the Certificate of Analysis.

Documentation of the data qualifications resulting from the application of these guidelines is retained in project files as both hard copy and electronic media and will be supplied upon request.

Two field duplicate soil samples were sent as blind samples to the laboratory to be analyzed for the analytical parameters listed in [Table A.3-2](#). For these samples, the duplicate results precision (i.e., relative percent differences between the environmental sample results and their corresponding field duplicate sample results) were compared to criteria set forth in EPA Functional Guidelines (EPA, 1994a and 1994b), and the associated environmental sample results were qualified accordingly.

The EPA Functional Guidelines give no required review criteria for field duplicate analyses comparability, but allow the data reviewer to exercise professional judgement. Detected target analytes have been qualified as estimated (J) if the relative percent difference between an environmental sample and its field duplicate fell outside established criteria.

The laboratory duplicate samples were compared to the criteria set forth in the EPA Functional Guidelines (EPA, 1994a and b) and the associated sample results were qualified accordingly. Both detections and nondetections have been qualified as estimated (J and UJ, respectively) if the relative percent difference between the environmental sample and its laboratory duplicate fell outside the established criteria.

Three field samples were selected for use as MS/MSD samples. The %R of these samples (a measure of accuracy) and the RPDs in these sample results (a measure of precision) were compared to EPA Functional Guideline (EPA, 1994a and 1994b) criteria, and the results were used to qualify associated environmental sample results accordingly.

The EPA Functional Guidelines for review of organic data state that no data qualification action is taken on the basis of MS/MSD results alone. The data reviewer exercises professional judgment in considering these results in conjunction with the results of laboratory control samples (less) and other QC criteria in applying qualifiers to the data.

The EPA Functional Guidelines for inorganic data review allow professional judgment to be applied in evaluating the results of matrix spikes. Generally, if spike recoveries are greater than the upper acceptance limits, nondetections are not qualified. If spike recovery is greater than the upper acceptance limits or less than the lower acceptance limit, positive results are qualified as estimated (J), and nondetections are either unqualified or qualified as estimated (UJ), respectively. If spike recoveries are grossly low (less than 30 percent), positive results are unqualified, and nondetections are unusable (R).

A.4.7.2 Laboratory Quality Control Samples

Analysis of method QC blanks and surrogate spikes for organic analyses, method blanks, preparation blanks, initial and continuing calibration blanks for total metals, and laboratory control samples (LCS) were performed for each SDG by DATACHEM Laboratories. The results of these analyses were used to qualify associated environmental sample results according to EPA Functional Guidelines (EPA, 1994a and 1994b).

A.4.8 Field Deficiencies

No field deficiencies were identified for this project.

A.5.0 Summary

Analysis of the data generated from sampling activities conducted during corrective action investigation activities at the Roller Coaster RADSAFE Area indicates the following:

- Subsurface plutonium-239/240 contamination greater than background concentrations is present in the waste disposal pit. The maximum lateral dimensions of the waste disposal pit are 20 ft by 35 ft and depth ranges from a minimum of 10 ft to 20 ft.
- Americium-241, uranium-235, uranium-238, and plutonium-239/240 contamination greater than background is associated with surface soils.
- With the exception of arsenic, the PALs were not exceeded for total VOCs, total SVOCs, total PCBs, and total RCRA metals for any of the subsurface samples collected at the RCRSA site.
- Arsenic concentrations were detected above the industrial soil PRG in several samples collected; however, these concentrations were below the maximum background concentration detected for arsenic in the background boring BGB-1. Based on the background concentrations, arsenic is considered naturally occurring at these levels.
- The geologic and geotechnical results revealed that the soil beneath the RCRSA is comprised of a sand with discontinuous gravel lenses with a low migration potential.
- The contaminants identified above PALs are americium, isotopic plutonium, and isotopic uranium; corrective actions for addressing these elevated levels are evaluated in the CADD.

A.6.0 References

AASHTO, see American Association of State Highway and Transportation Officials.

American Association of State Highway and Transportation Officials. 1995. *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*. Washington, DC.

American Society for Testing Materials. 1996. *Annual Book of American Society for Testing and Materials (ASTM) Standards*, Section 4, "Construction," Vol. 04.08, "Soil and Rock (1)," and Vol. 04.09, "Soil and Rock (11)." Philadelphia, PA.

ASTM, see American Society for Testing Materials.

DOE/NV, see U.S. Department of Energy, Nevada Operations Office.

EPA, see U.S. Environmental Protection Agency.

FFACO, see *Federal Facility Agreement and Consent Order*.

Federal Facility Agreement and Consent Order. 1996 (as amended). Agreed to by the State of Nevada, the U.S. Department of Energy, and the U.S. Department of Defense.

IT, see IT Corporation.

IT Corporation. 1998. *Site-Specific Health and Safety Plan for CAU 407, Roller Coaster RADS SAFE Area, Subsurface Investigation, Tonopah Test Range*. Las Vegas, NV.

Karathanasis, A.D. and B.F. Hajek. 1982. "Quantitative Evaluation of Water Adsorption on Soil Clays." In *Soil Science Society of America Journal*, 46: 1321-1325.

McArthur, R.D. and F.L. Miller. 1989. *Off-Site Radiation Exposure Review Project Phase II Soil Program*, Water Resources Center Publication No. 45064. Las Vegas, NV: Desert Research Institute.

NAC, see *Nevada Administrative Code*.

National Academy of Sciences. 1963. *Nuclear Science Series*.

Nevada Administrative Code. 1998. NAC 445A.227, "Contamination of soil: Order by director of corrective action; factors to be considered in determining whether corrective action is required." Carson City, NV.

- Soil Science Society of America. 1986. *Methods of Soil Analysis*, 2nd Edition, Part 1.
- Speer, C.L. (IT Corporation). 1999. Letter to Steve Adams regarding “Transmittal of a Radiological Survey of CAU 407, CAS TA-23-001-TARC, Roller Coaster RADSAFE Area.” Las Vegas, NV.
- USACE, see U.S. Army Corps of Engineers.
- U.S. Army Corps of Engineers. 1970. “Laboratory Soils Testing.” In *Engineer Manual (EM)*, 1110-2-1906, Appendix II. Washington, DC.
- U.S. Department of Energy. 1992. *Environmental Measurements Laboratory Procedures Manual*, HASL-300, 27th Edition, Vol. 1. New York, NY.
- U.S. Department of Energy, Nevada Operations Office. 1996a. *Corrective Action Unit Work Plan, Tonopah Test Range*, DOE/NV-443. Las Vegas, NV.
- U.S. Department of Energy, Nevada Operations Office. 1996b. *Industrial Sites Quality Assurance Project Plan, Nevada Test Site, Nevada*, Rev. 1, DOE/NV-372. Las Vegas, NV.
- U.S. Department of Energy, Nevada Operations Office. 1998. *Corrective Action Investigation Plan for the Roller Coaster RADSAFE Area, Corrective Action Unit 407, Tonopah Test Range, NV*, Rev. 0, DOE/NV-503. Las Vegas, NV.
- U.S. Ecology and Atlan-Tech. 1992. *Environmental Monitoring for the Proposed Ward Valley California Low Level Radioactive Waste Facility*. Auburn, CA.
- U.S. Environmental Protection Agency. 1980. *Prescribed Procedures for Measurements of Radioactivity in Drinking Water*, EPA-600/4-80-032. Washington, DC.
- U.S. Environmental Protection Agency. 1987. *Data Quality Objectives for Remedial Response Activities*, EPA/540/G-87-003. Washington, DC.
- U.S. Environmental Protection Agency. 1994a. *Contract Laboratory Program National Functional Guidelines for Organic Data Review*, EPA 540/R-94/012. Washington, DC.
- U.S. Environmental Protection Agency. 1994b. *Contract Laboratory Program National Functional Guidelines for Inorganic Data Review*, EPA 540/R-94/013. Washington, DC.
- U.S. Environmental Protection Agency. 1994c. *Guidance for the Data Quality Objectives Process*, EPA QA/G-4. Washington, DC.

U.S. Environmental Protection Agency. 1996. *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, SW-846, CD ROM PB97-501928GEI (CD ROM contains updates 1986, 1992, 1994, and 1996). Washington, DC.

U.S. Environmental Protection Agency. 1998. Memo from S. J. Smucker to PRG Table Mailing List regarding Region 9 Preliminary Remediation Goals (PRGs), 1 August. San Francisco, CA.

van Genuchten, M. 1980. "A Closed Form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils." In *Soil Science Society of America Journal*, 44: 892-898.

Appendix B
Soil Boring Logs

SOIL BORING LOG

PROJECT NAME: RCRSA		BORING NUMBER: B-1		CAU 407 CADD Appendix B Revision: 0 Date: 09/27/99 Page B-1 of B-11
PROJECT NUMBER: 772847.01.02.02.00		DATE HOLE STARTED: 07/02/98		
HOLE SURFACE ELEVATION (feet): 5573.60		DATE HOLE COMPLETED: 07/02/98		
TOTAL DEPTH DRILLED (feet): 30.00		EASTING: 523645.70		
ENVIRONMENTAL CONTRACTOR: IT Corporation		NORTHING: 4174394.50		
DRILLING METHOD: RotoSonic		GEOLOGIST: D. Arnold		
DRILLING CONTRACTOR: Boart Longyear		QA CHECK:		
ELEVATION DATUM: Mean Sea Level		COMMENTS:		

Depth Feet	Depth Meters	Legend	USCS	Classification (Description)	Remarks	Sample Number
0.0	0.0		GW	Well-graded gravel with cobbles; no fines; less than 5% sand; clasts range from .5 to 4 inches, subangular to subrounded with layer of pea-gravel at base of 1.5 interval. (grain size .5 inch).	Represents french drain gravel from RCRSA "hotline". Rad samples for U and Pu taken at 1 foot intervals.	RCR00044
						RCR00045
	1.0		SM	Well-graded sand with silt; 10YR 6/4; silt at 15%; sand fraction at 40% med, 30% fine, 20% coarse. Iron oxides leaching near 5 ft.		RCR00046
						RCR00047
5.0				Geotechnical sample taken; 10YR 7/4; silty sand with gravel; gravel at 15%, silt 35%.	1.5 ft interval proposed interface between french drain and native soil.	RCR00040, RCR00048
	2.0					RCR00049
			SW	Well-graded sand with gravel; 10YR 6/4; gravel at 15%, <5% silt; sand fraction is 50% fine, 30% med, 20% coarse	Geotechnical sample interval	RCR00043
	3.0		GP	Sand gravel; medium clasts for gravels; no fines		
			SW	Well-graded sand with gravel; 10YR 6/4; gravel at 15%, <5% silt; sand fraction is 50% fine, 30% medium, and 20% coarse.		
	4.0					
15.0						
	5.0					
	6.0			Same as above with increase of gravel to 20% and silt to 5%	A few cobbles up to 4 inches present	
	7.0		SP	Gravelly sand; 10YR 7/4; 60% sand, 35% gravel, 5% silt. Gravels range fine to medium	Cobbles up to 4 inches. Drilling stopped at 0933.	RCR00041
25.0						
	8.0					
	9.0					RCR00042

SOIL BORING LOG

PROJECT NAME: RCRSA		BORING NUMBER: B-2		CAU 407 CADD Appendix B Revision: 0 Date: 09/27/99 Page B-2 of B-11
PROJECT NUMBER: 772847.01.02.02.00		DATE HOLE STARTED: 07/01/98		
HOLE SURFACE ELEVATION (feet): 5572.40		DATE HOLE COMPLETED: 07/02/98		
TOTAL DEPTH DRILLED (feet): 30.00		EASTING: 523656.10		
ENVIRONMENTAL CONTRACTOR: IT Corporation		NORTHING: 4174413.30		
DRILLING METHOD: RotoSonic		GEOLOGIST: D. Arnold		
DRILLING CONTRACTOR: Boart Longyear		QA CHECK:		
ELEVATION DATUM: Mean Sea Level		COMMENTS:		

Depth Feet	Depth Meters	Legend	USCS	Classification (Description)	Remarks	Sample Number
0.0	0.0		SW	Well-graded sand; 10YR 6/4; 80% sand, 10% gravel; <10% fines	Soil damp	
	1.0		GP	Gravel layer with no fines, little sand. Clasts are 2-4 inches	This layer proposed as french drain/sump gravel. Proposed interface with native soil. Sampling for rad every 1 ft interval	
	5.0		SW	Same as first 2 feet	Soil is unconsolidated throughout whole boring.	RCR00031
	2.0			Same as above with <5% fines		RCR00034
	3.0			Well-graded sand with gravel; <5% silt		RCR00035
	4.0			Same as above with slight increase in fines		RCR00036
	5.0			Silt remains same but gravel amount and coarseness increases to 25% and medium grained, respectively		RCR00037
	6.0					RCR00038
	7.0		GP	Sandy gravel; 10 YR 6/4; with cobbles. Sand fraction is predominantly medium to coarse.	Drilling stopped for the day at 20 feet. At 1600.	
	8.0				Cobbles up to 4 inches	
	9.0		SW	Gravelly sand; 10YR 7/4; sand is coarse to fine; <5% silt, gravel at 35%	Gravel mostly fine to medium	RCR00032
	8.0			Well-graded sand with gravel, gravel less abundant at 15-20%. Gravel remains fine to medium grained		
	9.0				No significant changes in lithology beneath the "sump" gravel layer. No geotechnical samples taken on this borehole. Drilling stopped at 0733.	RCR00033

SOIL BORING LOG

PROJECT NAME: RCRSA		BORING NUMBER: B-3		CAU 407 CADD Appendix B Revision: 0 Date: 09/27/99 Page B-3 of B-11
PROJECT NUMBER: 772847.01.02.02.00		DATE HOLE STARTED: 06/30/98		
HOLE SURFACE ELEVATION (feet): 5570.60		DATE HOLE COMPLETED: 07/01/98		
TOTAL DEPTH DRILLED (feet): 30.00		EASTING: 523679.70		
ENVIRONMENTAL CONTRACTOR: IT Corporation		NORTHING: 4174418.70		
DRILLING METHOD: RotoSonic		GEOLOGIST: D. Arnold		
DRILLING CONTRACTOR: Boart Longyear		QA CHECK:		
ELEVATION DATUM: Mean Sea Level		COMMENTS:		

Depth Feet	Depth Meters	Legend	USCS	Classification (Description)	Remarks	Sample Number
0.0	0.0		AV	Slough, Moist and dark	Top 2-3 feet appear to be slough; plants and roots visible; no odor	
	1.0		GP	Fill material with little sand; gravel and cobbles ranging in size from 2.5 to 5 inches dominant matrix; 10 YR 4/3.	Wood pieces at 5.0 ft (redwood). The gravel and cobbles almost uniform in size	
5.0	2.0		SM	Silty sand with gravel; 10 YR 6/6; 40% sand, 30% silt, and 30% gravel with clasts up to 2 inches.	The five foot interval represents the interface between fill material and native soil. The wood and uniform gravel/cobble disappear.	RCR00013
				Same as above but less silt about 20%; mixture becomes 50% sand, 20% silt, 30% gravel	Some carbonate coating visible on clasts	RCR00014
						RCR00015
						RCR00016
10.0	3.0		SW	Gravelly sand; 10 YR 6/4; 60% coarse to medium sand, 30% gravel, 10% silt; gravel ranges fine to medium	Attempt to collect geotechnical sample but encounter slough in hole; had to resample next day from 15 to 16.5 feet. Drilling stopped for the day at 15 feet on 06-30-98 and resumed on 07-01-98.	RCR00010
	4.0			Same except increased silt to about 15% and gravel fraction mostly fine		
15.0	5.0			Geotechnical sample collected with full recovery; gravelly sand with about 60% sand	Coarse gravel in bottom sleeve had to be removed from sleeve.	
				Boundary noticed at 17 feet with cobbles up to 6 inches with more gravel	Calcareous coating common.	RCR00018
				Gravelly sand; 10 YR 5/4; 65% sand, 25% gravel, 10% silt; less gravel at 19 feet with more sand		
20.0	6.0		GW	Sandy gravel; 10 YR 6/4; sand fraction fine to coarse; gravel mostly medium grained		
	7.0					RCR00011
25.0	8.0		SW	Gravelly sand; 10 YR 6/4; 65% sand, 30% gravel, 5% silt; layer of cobbles about 4 inches max; sand fraction 50% coarse; gravel fine to medium; moist.	Core became more gravelly at depth. Stopped at 1000.	
	9.0					RCR00012


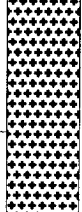
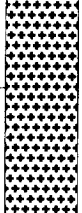
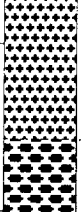
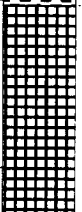
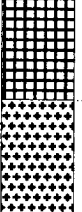


SOIL BORING LOG

PROJECT NAME: RCRSA		BORING NUMBER: B-3A		CAU 407 CADD Appendix B Revision: 0 Date: 09/27/99 Page B-4 of B-11
PROJECT NUMBER: 772847.01.02.02.00		DATE HOLE STARTED: 07/06/98		
HOLE SURFACE ELEVATION (feet): 5571.40		DATE HOLE COMPLETED: 07/06/98		
TOTAL DEPTH DRILLED (feet): 30.00		EASTING: 523674.60		
ENVIRONMENTAL CONTRACTOR: IT Corporation		NORTHING: 4174413.90		
DRILLING METHOD: RotoSonic		GEOLOGIST: D. Arnold		
DRILLING CONTRACTOR: Boart Longyear		QA CHECK:		
ELEVATION DATUM: Mean Sea Level		COMMENTS:		

Depth Feet	Depth Meters	Legend	USCS	Classification (Description)	Remarks	Sample Number
0.0	0.0		GP	GP/SP; Sandy gravel; 10YR 6/4; 50% gravel, 50% sand, gravels mostly fine with <5% coarse. Sand med to coarse grained; Moist	First 5 feet no defining sections; no debris. A few cobbles up to 4 inches	
	1.0		SP	Same except less gravel down to 30%		
5.0	2.0		GP	GP/SP; gravel increases back up to about 50%	Site supervisor ordered sampling for Pu and U every 1 foot between 6-10 feet interval. Assumption that sump was not intercepted or unable to discern.	RCR00062 RCR00063 RCR00064 RCR00065 RCR00066, RCR00068, RCR00067
10.0	3.0					
	4.0		SW	At 13 feet hit about .75 feet of well-graded sand. At 13.75 goes back to GP/SP with 1-5% silt present.	Cobbles increase slightly, size about 4 inches. Hit large rock (6 inches) at 15 feet.	
15.0	5.0		SP	Gravelly sand; 10YR 6/4; 70% sand, 30% gravel, silt 5-10%.	No debris or evidence of sump.	
	6.0			Same as above with decrease in gravel to about 15-20%, silt 15%		
	7.0		GM	At 23 feet get sandy gravel with silt; gravel fine to coarse; gravel 40%, sand 40%, silt 20%.		
25.0	8.0		GP	Sandy gravel with <5% silt; gravel fine to medium grained with sand fraction 40-45%.	Cobbles up to 4 inches. Few coarse gravels.	RCR00070
	9.0			Same as above except decrease in sand to about 30-35%.	Stop drilling at 1140 at 30 feet.	RCR00071, RCR00072

SOIL BORING LOG

PROJECT NAME: RCRSA		BORING NUMBER: B-3B		CAU 407 CADD Appendix B Revision: 0 Date: 09/27/99 Page B-5 of B-11
PROJECT NUMBER: 772847.01.02.02.00		DATE HOLE STARTED: 07/06/98		
HOLE SURFACE ELEVATION (feet): 5571.70		DATE HOLE COMPLETED: 07/06/98		
TOTAL DEPTH DRILLED (feet): 30.00		EASTING: 523671.80		
ENVIRONMENTAL CONTRACTOR: IT Corporation		NORTHING: 4174413.30		
DRILLING METHOD: RotoSonic		GEOLOGIST: D. Arnold		
DRILLING CONTRACTOR: Boart Longyear		QA CHECK:		
ELEVATION DATUM: Mean Sea Level		COMMENTS:		

Depth Feet	Depth Meters	Legend	USCS	Classification (Description)	Remarks	Sample Number
0.0	0.0		SW	Well-graded sand; 10YR 6/4; gravel <10%, silt <5%	Start 1415. Soil may be fill material due to grade of sand. Difficult to differentiate. No debris or evidence of sump.	
	1.0					RCR00073
5.0	2.0					
	3.0			Gravelly well-graded sand; 10YR 6/4; gravel 20%; slightly consolidated between 8-10 feet.		
10.0	4.0			Same as above	Site supervisor decided to sample for Pu and U every 1 foot between 10-15 feet.	RCR00077 RCR00078 RCR00079
	5.0			Well-graded sand with gravel; 20-25% gravel, <5% silt	Gravel becoming coarser up to 2 inches.	RCR00080 RCR00081
15.0	6.0		GW	Sandy gravel; well-graded gravel; 40-45% sand, 50-55% gravel, <5% silt	A few cobbles within interval up to 4 inches	
	7.0		SP	Gravelly sand with 20% gravel, 10% silt		
20.0	8.0			Same as above	No debris. No elevated rad readings to this point.	
	9.0		SW	Well-graded sand with gravel; gravel 15-20% and fine to medium grained.		RCR00074
25.0					Soil becomes consolidated/cemented with higher % of silt in matrix.	
				Same as above with slight increase in gravel to 30%. Calcareous coating common throughout last 2 feet of borehole		
30.0					Stopped drilling at 1550 at 30 feet depth. No elevated rad readings through whole boring.	RCR00075

SOIL BORING LOG

PROJECT NAME: RCRSA		BORING NUMBER: B-3C	CAU 407 CADD Appendix B Revision: 0 Date: 09/27/99 Page B-6 of B-11
PROJECT NUMBER: 772847.01.02.02.00		DATE HOLE STARTED: 07/07/98	
HOLE SURFACE ELEVATION (feet): 5569.60		DATE HOLE COMPLETED: 07/07/98	
TOTAL DEPTH DRILLED (feet): 30.00		EASTING: 523684.60	
ENVIRONMENTAL CONTRACTOR: IT Corporation		NORTHING: 4174421.40	
DRILLING METHOD: RotoSonic		GEOLOGIST: D. Arnold	
DRILLING CONTRACTOR: Boart Longyear		QA CHECK:	
ELEVATION DATUM: Mean Sea Level		COMMENTS:	

Depth Feet	Depth Meters	Legend	USCS	Classification (Description)	Remarks	Sample Number
0.0	0.0		SP	SP/SM; silty sand; 10YR 6/4; silt about 15%, sand is fine to medium grained. Soil slightly moist	Start 1445	
	1.0				No elevated rad readings.	
5.0	2.0			Soil same as above, no debris	No elevated rad readings: samples for PU & U every foot at 6 to 10 foot interval. Assumed interface with native soil.	RCR00104
	3.0					RCR00107
	4.0					RCR00108
	5.0					RCR00109
	6.0		SW	Gravelly sand, well-graded sand; 10YR 6/4; little fines; color banding in soil from 6.5 to 10 feet, alternate between 10YR 6/4 and 7/4		RCR00110
10.0	7.0			Gravel increases to 25%, grain size increases to max of 1-1.5 inches		RCR00111
	8.0					
	9.0			Well-graded sand with little gravel or fines		
15.0	10.0					
	11.0					
	12.0					
	13.0					
	14.0					
	15.0					
	16.0					
	17.0					
	18.0					
	19.0					
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	25.0					
	26.0					
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	28.0					
	29.0					
	30.0					

SOIL BORING LOG

PROJECT NAME: RCRSA		BORING NUMBER: B-4	CAU 407 CADD Appendix B Revision: 0 Date: 09/27/99 Page B-7 of B-11
PROJECT NUMBER: 772847.01.02.02.00		DATE HOLE STARTED: 07/01/98	
HOLE SURFACE ELEVATION (feet): 5568.12		DATE HOLE COMPLETED: 07/01/98	
TOTAL DEPTH DRILLED (feet): 30.00		EASTING: 523706.30	
ENVIRONMENTAL CONTRACTOR: IT Corporation		NORTHING: 4174428.70	
DRILLING METHOD: RotoSonic		GEOLOGIST: D. Arnold	
DRILLING CONTRACTOR: Boart Longyear		QA CHECK:	
ELEVATION DATUM: Mean Sea Level		COMMENTS:	

Depth Feet	Depth Meters	Legend	USCS	Classification (Description)	Remarks	Sample Number
0.0	0.0		SM	Silty sand with gravel; 10YR 4/4; 70% Sand, silt 20%, gravel 10%; sand well graded with gravel fraction fine to medium grained.	Nothing unusual in top 6 feet that indicates waste. Soil moister than previous boring B-3.	
1.0						
2.0			GP	Well graded soil with 40% gravel, 30% sand, 30% silt. Gravel fine to coarse. 10YR 8/2; laminated but not firm. Soil much drier than above.	Layer of rust beginning at base of 8 feet. Cores came at 2 foot intervals from 5 feet to 15 feet. Rust continues through to 9 feet.	
3.0			SM	Silty sand with gravel. Color change to 7.5 YR 6/4. Silt increased to 35 to 40% with less gravel than above.	Elevated Rad readings due to metallic objects found in 9-11 foot interval. Source of rust leachate. Represents section of waste disposal pit. Rebar and misc. metal pieces.	RCR00025
4.0			SP	Gravelly sand with silt; 10YR 8/2; 60% sand, 30% gravel, 10% silt. Gravel fine to medium and sand fine to coarse	No objects of interest after the 9-11 foot interval. Rad reading background	
5.0				Soil same as above except color change to 10YR 6/4 and slight silt increase. Debris encountered.	At 14 to 15 feet, encountered wood, plastic and rubber with slight hydrocarbon odor. Represents another section of waste disposal pit. Sampling increased to every 1 foot for PU & U. Rad at background. No objects encountered after the 14-15 foot interval.	RCR00026
6.0				Soil same as above		RCR00021
7.0				Dark grey tuffaceous layer of gravels and cobbles up to 5 inches.	Broken up pieces; distinct layer proposed as bottom of sump/waste pit at 17.5	RCR00022
8.0				Gravelly sand with silt; 10YR 6/4; gravel coarser than above 17 foot interval; silt about 15-20%; gravel ranges fine to coarse		RCR00023
9.0						RCR00024
10.0						RCR00027, RCR00028
11.0					A few cobbles present up to 4 inches. Geotechnical sample collected at 25 to 26.5 ft interval.	RCR00017
12.0				Gravelly sand; color same; 60% sand, 40% gravel; less than 5% silt. Sand is medium to coarse; gravel predominantly fine to medium		
13.0					Stopped boring at 30 feet at 1430.	RCR00029

SOIL BORING LOG		BORING NUMBER: B-4A		CAU 407 CADD Appendix B Revision: 0 Date: 09/27/99 Page B-8 of B-11
PROJECT NAME: RCRSA		DATE HOLE STARTED: 07/07/98		
PROJECT NUMBER: 772847.01.02.02.00		DATE HOLE COMPLETED: 07/07/98		
HOLE SURFACE ELEVATION (feet): 5568.90		EASTING: 523698.90		
TOTAL DEPTH DRILLED (feet): 30.00		NORTHING: 4174423.20		
ENVIRONMENTAL CONTRACTOR: IT Corporation		GEOLOGIST: D. Arnold		
DRILLING METHOD: RotoSonic		QA CHECK:		
DRILLING CONTRACTOR: Boart Longyear		COMMENTS:		
ELEVATION DATUM: Mean Sea Level				

Depth Feet	Depth Meters	Legend	USCS	Classification (Description)	Remarks	Sample Number
0.0	0.0		sw	Well-graded sand; 10YR 6/4; silt 10%, gravel <10%	Start drilling at 1241, soil moist.	
	1.0		SP	Silt increases to 20%; sand remains well-graded.	Soil moisture at 5 feet depth	
	2.0		sw	Well-graded gravelly sand with equal grain size of sand; gravels are fine. Debris at 9 feet.	Debris encountered at 9 feet to 10 feet. Debris includes plastic, wire, cable, and wood. No elevated rad readings.	RCR00093
10.0	3.0			Gravel increases to about 30-35% and coarseness increases with average grain size at .5 to 1 inch	No obvious debris after 10 feet. Started collecting 1 ft interval samples for Pu and U at 10 foot depth.	RCR00096 RCR00097 RCR00098
	4.0		SP	At 13 feet—less gravel and more fine grained sand		RCR00099 RCR00100
15.0	5.0			Less fines in sand and increased gravel up to 25% with <5% silt/fines	No debris; stopped sampling for PU and U at the 15 foot depth	
	6.0		sw	Sand well-graded, gravel decrease to 10-15%; no fines		
20.0	7.0		SP	SP/SM; poorly graded sand with about 50-60% fines; gravel 10-15%; silt at 10%.	Hitting some large cobble size rocks up to 5 inches.	
	8.0		sw	Back to well-graded gravelly sand with less fines; gravels about 20% with mostly fine grain size.		RCR00094
25.0	8.0			Same as above except color change to 10YR 5/6	Color change due to protolith change for alluvium	
	9.0			Same as above	Stop at 1400. No elevated rad readings through out entire boring.	RCR00095

SOIL BORING LOG

PROJECT NAME: RCRSA		BORING NUMBER: B-4B		CAU 407 CADD Appendix B Revision: 0 Date: 09/27/99 Page B-9 of B-11
PROJECT NUMBER: 772847.01.02.02.00		DATE HOLE STARTED: 07/07/98		
HOLE SURFACE ELEVATION (feet): 5569.10		DATE HOLE COMPLETED: 07/07/98		
TOTAL DEPTH DRILLED (feet): 30.00		EASTING: 523702.60		
ENVIRONMENTAL CONTRACTOR: IT Corporation		NORTHING: 4174430.40		
DRILLING METHOD: RotoSonic		GEOLOGIST: D. Arnold		
DRILLING CONTRACTOR: Boart Longyear		QA CHECK:		
ELEVATION DATUM: Mean Sea Level		COMMENTS:		

Depth Feet	Depth Meters	Legend	USCS	Classification (Description)	Remarks	Sample Number
0.0	0.0		SM	Silty sand; 10YR 6/4; sand 80% fine to med; silt 20%. At 1 foot depth changes to 10YR 5/6 well-graded sand with only <10% silt and <10% gravel.	Start drilling at 0740. Soil becomes moist at 1 foot depth.	
			SW	Well-graded sand with <10% silt and <10% gravel; 10YR 5/6		
	1.0					
5.0			SP	Sand with gravel; 10YR 7/4; Fines >50% with gravel <10%. Gravel ranges med to coarse med with max clasts at 2 inches	Soil moist than other boreholes at this interval. No elevated rad readings. Hit large tuffaceous rocks at 5 feet depth.	
	2.0					
				Same as above. Geotechnical sample collected at 10 to 11.5 depth in fill material.	No elevated rad readings from 5-10 feet. Soil much drier.	
10.0	3.0			Soil same. Debris encountered. Soil discolored near debris, possible staining.	Wood was found in shoe of split spoon near 11.5 depth.	RCR00091
	4.0			Soil same. Debris through whole section. Soil minimal but coarser sand; 10YR 6/4.	Debris consisted of plastic, rubber, aluminum, particleboard, wood, wires, misc metal, battery clips, springs. Wires mostly small diameter of 1/8. Also found radiation tape.	RCR00083
15.0			SW	Fill material until 16 feet depth. Then soil becomes well-graded sand with gravel; gravel fine to medium and about 15%.	Slight hydrocarbon odor.	RCR00086
	5.0					RCR00087
						RCR00088
				Gravel coarseness increase towards 20 feet	No debris encountered after 16 feet.	RCR00089
	6.0					RCR00090
20.0						
	7.0					
25.0				Same above	1 foot sample interval for Pu and U collected between 16 and 20 feet.	RCR00084
	8.0					
				Same as above	At 26 feet had slough. Pieces of debris were found. Drillers informed us that casing fell in.	RCR00085
	9.0					



SOIL BORING LOG

PROJECT NAME: RCRSA		BORING NUMBER: B-5	CAU 407 CADD Appendix B Revision: 0 Date: 09/27/99 Page B-10 of B-11
PROJECT NUMBER: 772847.01.02.02.00		DATE HOLE STARTED: 07/02/98	
HOLE SURFACE ELEVATION (feet): 5566.80		DATE HOLE COMPLETED: 07/02/98	
TOTAL DEPTH DRILLED (feet): 30.00		EASTING: 523722.60	
ENVIRONMENTAL CONTRACTOR: IT Corporation		NORTHING: 4174432.50	
DRILLING METHOD: RotoSonic		GEOLOGIST: D. Arnold	
DRILLING CONTRACTOR: Boart Longyear		QA CHECK:	
ELEVATION DATUM: Mean Sea Level		COMMENTS:	

Depth Feet	Depth Meters	Legend	USCS	Classification (Description)	Remarks	Sample Number
0.0	0.0		SM	Silty sand; 10YR 4/4; 60% sand, 30% silt, little gravel; Moist	Started drilling at 1050. Soil very moist in spots	RCR00050
1.0	1.0					
5.0	2.0		SW	Well-graded sand; 10YR 5/6; <10% silt, 10-15% gravel		RCR00051
10.0	3.0			Same as above, except for color change at 11 feet 10 YR 7/4; more silt at 15%	Soil is drier.	
15.0	4.0			Gravel increases to 15%; silt decreases to 10%	No environmental samples taken at the 15-20 interval per the site supervisor.	
20.0	5.0			Same as above; gravel size increases slightly to medium grained	Environmental samples resumed at 24-25 interval per site supervisor.	
25.0	6.0					
8.0	7.0				Nothing of interest throughout entire boring. Appears to be native soil through entire boring. No elevated rad readings.	
9.0	8.0			Same as above; gravel size increases to include coarse, medium and fine gravel	Drilling stopped at 1115. Environmental samples taken at 29-30 interval. Nothing of interest throughout entire boring. Appears to be native soil. No elevated rad readings.	

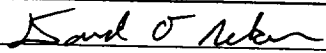
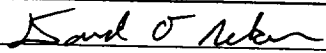
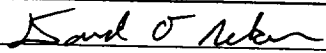
SOIL BORING LOG

PROJECT NAME: RCRSA		BORING NUMBER: BGB-1	CAU 407 CADD Appendix B Revision: 0 Date: 09/27/99 Page B-11 of B-11
PROJECT NUMBER: 772847.01.02.02.00		DATE HOLE STARTED: 06/30/98	
HOLE SURFACE ELEVATION (feet): 5586.70		DATE HOLE COMPLETED: 06/30/98	
TOTAL DEPTH DRILLED (feet): 30.00		EASTING: 523502.60	
ENVIRONMENTAL CONTRACTOR: IT Corporation		NORTHING: 4174346.40	
DRILLING METHOD: RotoSonic		GEOLOGIST: D. Arnold	
DRILLING CONTRACTOR: Boart Longyear		QA CHECK:	
ELEVATION DATUM: Mean Sea Level		COMMENTS:	

Depth Feet	Depth Meters	Legend	USCS	Classification (Description)	Remarks	Sample Number
0.0	0.0		SM	Silty sand with gravel; 10 YR 6/6; 60% sand, 30% silt, 10% gravel; Moist soil; Max clast size about 1.5 inches	Drilling started at 0955.	
	1.0		SW	Gravelly sand with silt; 10 YR 8/2; 60% sand, 25% gravel, 15% silt; max clast size 2.5 inches; sand is 50-60% coarse with 40% medium.	Soil much drier than top 3 feet.	
5.0	2.0			Description same as above except less gravel and higher percentage of coarse sand	Color change to 10 YR 6/4.	
	2.0			See more gravel otherwise same	Color change to 10 YR 6/6.	
10.0	3.0			Same as above	Color change to 10 YR 6/8	RCR00005
	4.0					
15.0	5.0			Same as above; becomes slightly more gravelly		
	6.0					
20.0	6.0			Same except color change to 10 YR 6/6; Gravel more coarse, with gravel reaching between 30 and 40% with less than 10% fines	Soil slightly more cemented.	RCR00006
	7.0					
25.0	8.0			Same with less gravel, down to 20%	Clumping common. Drilling stopped at 1130.	
	8.0					
	9.0					RCR00007

Appendix C
Cost Estimates

(As received from Bechtel Nevada [BN])

EST: CAU 407 CADD	BN ENVIRONMENTAL RESTORATION COST ESTIMATE SUMMARY	Prep Date: 7/28/99 Print Date: 7/28/99															
TO: JEFF SMITH - Environmental Restoration Task Manager		FROM: ABDEL AGALLOUCH - ER Project Controls															
SUBJECT: REMEDIAL ALTERNATIVES		TEC: (see totals below)															
WORK PKGE: CAU 407 Roller Coaster Rad Safe Area		WBS: 1040102130301															
TAP: CONTAMINATED WASTE SITES SOURCE GROUP		LOCATION: NTS															
<table style="width:100%; border: none;"> <tr> <td style="text-align: center; border-bottom: 1px solid black;">TYPE OF ESTIMATE</td> <td style="border: none;"></td> <td style="text-align: center; border-bottom: 1px solid black;">TYPE OF WORK</td> </tr> <tr> <td style="border: none;"><input checked="" type="checkbox"/> ORDER OF MAGNITUDE</td> <td style="border: none;"><input type="checkbox"/> PRELIMINARY TITLE II</td> <td style="border: none;"><input type="checkbox"/> RI / FS</td> </tr> <tr> <td style="border: none;"><input type="checkbox"/> PLANNING/STUDY</td> <td style="border: none;"><input type="checkbox"/> WORK ORDER</td> <td style="border: none;"><input checked="" type="checkbox"/> REMEDIATION</td> </tr> <tr> <td style="border: none;"><input type="checkbox"/> CONCEPTUAL/BUDGET</td> <td style="border: none;"><input type="checkbox"/> COMPARATIVE</td> <td style="border: none;"><input checked="" type="checkbox"/> CONSTRUCTION</td> </tr> <tr> <td style="border: none;"><input type="checkbox"/> TITLE I / PRELIMINARY</td> <td style="border: none;"><input type="checkbox"/> OTHER</td> <td style="border: none;"><input type="checkbox"/> OTHER</td> </tr> </table>		TYPE OF ESTIMATE		TYPE OF WORK	<input checked="" type="checkbox"/> ORDER OF MAGNITUDE	<input type="checkbox"/> PRELIMINARY TITLE II	<input type="checkbox"/> RI / FS	<input type="checkbox"/> PLANNING/STUDY	<input type="checkbox"/> WORK ORDER	<input checked="" type="checkbox"/> REMEDIATION	<input type="checkbox"/> CONCEPTUAL/BUDGET	<input type="checkbox"/> COMPARATIVE	<input checked="" type="checkbox"/> CONSTRUCTION	<input type="checkbox"/> TITLE I / PRELIMINARY	<input type="checkbox"/> OTHER	<input type="checkbox"/> OTHER	
TYPE OF ESTIMATE		TYPE OF WORK															
<input checked="" type="checkbox"/> ORDER OF MAGNITUDE	<input type="checkbox"/> PRELIMINARY TITLE II	<input type="checkbox"/> RI / FS															
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<input type="checkbox"/> TITLE I / PRELIMINARY	<input type="checkbox"/> OTHER	<input type="checkbox"/> OTHER															
BN REMEDIATION PROJECT ESTIMATOR: Abdel Agallouch 702-295-5275 TASK MGR: Jeff Smith 702-295-7775 PROJ MGR: Steve Nacht 702-295-7234		WORK TO BE PERFORMED BY <input checked="" type="checkbox"/> DOE PRIME CONTRACTOR <input type="checkbox"/> NATIONAL LAB <input type="checkbox"/> NTS GENERAL <input type="checkbox"/> SUBCONTRACT <input type="checkbox"/> NTS MAINTENANCE <input type="checkbox"/> OTHER															
<p><u>STATEMENT OF WORK:</u></p> <p>This estimate has been prepared to provide remedial alternative costs for the closure of Corrective Action Unit (CAU) 407, an environmental restoration site listed in the Federal Facilities and Consent Order (FFACO). CAU 407 is specifically described as Roller Coaster Rad Safe Area. Four alternatives will be evaluated for closure of the site: I) No Further Action No associated Costs, or Administrative Controls, II) Closure by Partial Excavation, Disposal, Closure in Place and Administrative Controls, III) Closure by Partial Excavation, Disposal, Closure In Place with Surface Cover, and Administrative Controls and IV) Clean Closure by Excavation and Disposal, and V) Clean closure by partial screening, excavation, and disposal. This estimate will be used to identify the most cost effective alternative for closure of the site while being protective of human health and the environment. Total estimated costs are intended for comparative analysis of remedial field work and field management only. Costs for project management, plan preparation, project support, or other overhead functions are not included.</p> <p><u>SCOPE</u></p> <p>Provide site closure using one of the following alternatives:</p> <ol style="list-style-type: none"> I) NO FURTHER ACTION -NO ASSOCIATED COSTS OR ADMINISTRATIVE CONTROLS II) CLOSURE BY PARTIAL EXCAVATION, DISPOSAL, CLOSURE IN PLACE AND ADMINISTRATIVE CONTROLS III) CLOSURE BY PARTIAL EXCAVATION, DISPOSAL, CLOSURE IN PLACE WITH SURFACE COVER IV) CLEAN CLOSURE BY EXCAVATION AND DISPOSAL V) CLEAN CLOSURE BY PARTIAL SCREENING, EXCAVATION AND DISPOSAL <p><u>BASIS OF ESTIMATE AND ASSUMPTIONS</u></p> <p><u>GENERAL BASIS OF ESTIMATE/ASSUMPTIONS</u></p> <ul style="list-style-type: none"> • These assumptions/basis of estimate apply to all the alternatives listed below. • The site is not an ordnance site. • A bioassay program, health physics support and RCT support will be required for work to be performed in hot areas. Assume PPE requirements will include levels C and D. • Fencing and site monuments/postings will be installed around the site. Existing fence will be reused as much as possible. • Availability and use of fuel onsite <p><u>ALTERNATIVE SPECIFIC BASIS OF ESTIMATE/ASSUMPTIONS</u></p> <p><u>Alternative II: Partial Excavation, Disposal, Closure In place and Administrative Controls.</u></p> <ul style="list-style-type: none"> • All surface contamination greater than background will be removed. Locations will be field screened for radiation after removal. Removal will be limited to a depth of 6-inches. • Excavation and disposal of approximately 1 CY of radiologically impacted soil from 13 surface locations. Excavations to be limited to 2-ft X 2-ft surface area at each location. • Radiologically impacted soil will be containerized in a B-25 box for disposal and shipped to Area 3 RWMS at the NTS. • Assume a total of 16 verification soil samples for laboratory analysis will be required. Samples will be analyzed for gamma spectroscopy, isotopic plutonium, and isotopic uranium. • Waste characterization samples will be required. Assume one composite sample will be analyzed for gamma spectroscopy. 																	
<table style="width:100%; border: none;"> <tr> <td style="border: none;">Review / Concurrence:</td> <td style="border: none;"></td> <td style="border: none;"></td> <td style="border: none;"></td> </tr> <tr> <td style="border: none;">Abdel Agallouch</td> <td style="border: none;">7/29/99</td> <td style="border: none;"></td> <td style="border: none;">7/29/99</td> </tr> <tr> <td style="border: none;">Estimator</td> <td style="border: none;">Date</td> <td style="border: none;">Checked By</td> <td style="border: none;">Date</td> </tr> </table>			Review / Concurrence:				Abdel Agallouch	7/29/99		7/29/99	Estimator	Date	Checked By	Date			
Review / Concurrence:																	
Abdel Agallouch	7/29/99		7/29/99														
Estimator	Date	Checked By	Date														

EST: CAU 407 CADD	BN ENVIRONMENTAL RESTORATION COST ESTIMATE SUMMARY	Prep Date: 7/28/99 Print Date: 7/28/99
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isotopic plutonium, and isotopic uranium.

- The surface of the waste disposal pit will be graded and filled. Diversion ditches will be constructed around the disposal pit to minimize impact from surface water.
- A site plan and survey will be developed for the site.

Alternative III: Closure by Partial Excavation, Disposal, Closure in Place with Surface CAP

- All surface contamination greater than background will be removed. Locations will be field screened for radiation after removal. Removal will be limited to a depth of 6-inches
- Excavation and disposal of approximately 1 CY of radiologically impacted soil from 13 surface locations. Excavations to be limited to 2-ft X 2-ft surface area at each location
- Radiologically impacted soil will be containerized in a B-25 box for disposal and shipped to Area 3 RWMS at the NTS.
- Assume a total of 16 verification soil samples for laboratory analysis will be required. Samples will be analyzed for gamma spectroscopy, isotopic plutonium, and isotopic uranium.
- Waste characterization samples will be required. Assume one composite sample will be analyzed for gamma spectroscopy, isotopic plutonium, and isotopic uranium.
- Assume the cover requirements will be those of a landfill. Therefore, an engineered surface cover will be constructed over the waste disposal pit. Dimensions of the cap will be approximately 50 ft X 100 ft X 2.5 ft.
- A Geosynthetic Clay Liner (GCL) will be required to a permeability less than the surrounding soil (10 X E-05 cm/sec).
- The total volume of material needed to construct the cover will be approximately 600 CY for a total of 40 loads.
- The cover material will be bed lake material available at borrow pit 9 miles from the site.
- A water truck, a dozer, 2 front end loaders, 2 end dump trucks, a grader, a hurricane pump will be needed (both at borrow pit and site) to construct the cover.
- Assume inspections and maintenance of the cover will be conducted for a period of 30 years.

Alternative IV: Clean Closure by Excavation and Disposal

- Total volumes include a 20% expansion factor
- All surface contamination greater than background will be removed. Locations will be field screened for contamination after removal. Removal will be limited to a depth of 6-inches
- On site soil and clean soil from a nearby location will be used to backfill the excavation to minimize surface depression
- Excavation and disposal of approximately 1,856 CY of radiological contaminated soil from the waste disposal pit. Excavation to be 80 ft X 40 ft surface area. The excavation will be sloped from the surface along the length to a maximum of 20 ft at the center. Side walls will be sloped as required for safety and stability.
- Radiologically impacted soil will be containerized in burrito wraps for disposal and shipped to Area 3 RWMS at the NTS. A total of 186 of burrito wraps will be needed.
- Transporting of the waste to Area 3 RWMS will be done by a subcontractor.
- Set up a Radiological Management Area (RMA) is required.
- A total of 30 verification soil samples will be required for both the surface cleanup and excavation. Samples will be analyzed for gamma spectroscopy and isotopic plutonium.
- Assume a total of 12 waste characterization soil samples will be required. Samples will be analyzed for full suite TCLP, gamma spectroscopy, isotopic plutonium.
- Assume backfill material will be imported from a borrow pit (SANDIA's) 6 miles from the site.

Alternative V: Clean Closure by Piling and Screening and partial Removal

- Total volumes include a 20% expansion factor
- The approximate surface area of the trench is about 80 ft by 40 ft
- The top 8 ft of the soil will be excavated, piled and screened in 16 separate 6" thick stockpiles. The total volume to be screened will be approximately 1024 CY
- Assume that screening will be done using fidlers and electras in conjunction with RSL's High Purity Germanium Detector (HPGD). Assume two RSL Technicians will be needed to operate the Device and a scientist for data analysis.
- Assume that the HPGD will be able to identify concentrations as per NDEP's requirements.
- The lower 9 ft of the trench will be excavated and disposed of as radiologically impacted soil and will be containerized in burrito wraps for disposal and shipped to Area 3 RWMS at the NTS. The total volume to be excavated is approximately 832 CY. A total of 84 of burrito wraps will be needed.
- Assume it will take 10 days to excavate the 9 ft section of the trench
- Set up a Radiological Management Area (RMA) is required.
- Transporting of the waste to Area 3 RWMS will be done by a subcontractor.
- A total of 30 verification soil samples will be required for both the surface cleanup and excavation. Samples will be analyzed for gamma spectroscopy and isotopic plutonium.

EST: CAU 407 CADD	BN ENVIRONMENTAL RESTORATION COST ESTIMATE SUMMARY	Prep Date: 7/28/99 Print Date: 7/28/99										
<ul style="list-style-type: none"> • Assume a total of 12 waste characterization soil samples will be required. Samples will be analyzed for full suite TCLP, gamma spectroscopy, isotopic plutonium. • The total backfill material will be approximately 1856 CY. Assume that the 8' of screened material will be used as backfill. In addition borrow pit material will be used to backfill the trench to existing grade. Assume backfill material will be imported from a borrow pit (SANDIA's) 6 miles from the site. 												
<p><u>ESCALATION:</u> Escalation is not included in this estimate. All costs are in FY99 dollars</p>												
<p><u>CONTINGENCY:</u> Contingency costs are not included in this estimate.</p>												
<p><u>COST SUMMARY - TOTAL ESTIMATED COST PER REMEDIAL ALTERNATIVE</u></p>												
<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 80%;">• I) NO FURTHER ACTION -NO ASSOCIATED COSTS OR ADMINISTRATIVE CONTROLS</td> <td style="text-align: right; width: 20%;">\$0</td> </tr> <tr> <td>• II) CLOSURE BY PARTIAL EXCAVATION, DISPOSAL, CLOSURE IN PLACE AND ADMINISTRATIVE CONTROLS</td> <td style="text-align: right;">\$152,091</td> </tr> <tr> <td>• III) CLOSURE BY PARTIAL EXCAVATION, DISPOSAL, CLOSURE IN PLACE WITH SURFACE COVER</td> <td style="text-align: right;">\$309,172</td> </tr> <tr> <td>• IV) CLEAN CLOSURE BY EXCAVATION AND DISPOSAL</td> <td style="text-align: right;">\$1,438,331</td> </tr> <tr> <td>• V) CLEAN CLOSURE BY PARTIAL SCREENING, EXCAVATION AND DISPOSAL</td> <td style="text-align: right;">\$895,451</td> </tr> </table>			• I) NO FURTHER ACTION -NO ASSOCIATED COSTS OR ADMINISTRATIVE CONTROLS	\$0	• II) CLOSURE BY PARTIAL EXCAVATION, DISPOSAL, CLOSURE IN PLACE AND ADMINISTRATIVE CONTROLS	\$152,091	• III) CLOSURE BY PARTIAL EXCAVATION, DISPOSAL, CLOSURE IN PLACE WITH SURFACE COVER	\$309,172	• IV) CLEAN CLOSURE BY EXCAVATION AND DISPOSAL	\$1,438,331	• V) CLEAN CLOSURE BY PARTIAL SCREENING, EXCAVATION AND DISPOSAL	\$895,451
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• II) CLOSURE BY PARTIAL EXCAVATION, DISPOSAL, CLOSURE IN PLACE AND ADMINISTRATIVE CONTROLS	\$152,091											
• III) CLOSURE BY PARTIAL EXCAVATION, DISPOSAL, CLOSURE IN PLACE WITH SURFACE COVER	\$309,172											
• IV) CLEAN CLOSURE BY EXCAVATION AND DISPOSAL	\$1,438,331											
• V) CLEAN CLOSURE BY PARTIAL SCREENING, EXCAVATION AND DISPOSAL	\$895,451											

Appendix D

**Radiological Survey of CAU 407,
CAS TA-23-001-TARC, Roller Coaster RADSAFE Area**



Memorandum

To: Steven Adams

Date: January 20, 1998/9

CS 2/3/99

From: Carl Speer *CS*

Project No. 776710.010202000

Subject: **TRANSMITTAL OF A RADIOLOGICAL SURVEY OF CAU 407, CAS TA-23-001-TARC, ROLLER COASTER RAD SAFE AREA**

Enclosed please find one copy of the report entitled: "Radiological Survey of CAU 407, CAS TA-23-001-TARC, Roller Coaster Rad Safe Area." This report outlines the survey objectives, instruments used, data acquisition and data processing methods, quality control procedures, and a brief review of the data. Also included is the processed radiological survey results and data plots.

If you have any questions, please give me a call at (702) 295-2366.

Attachments

RADIOLOGICAL SURVEY OF CAU 407, CAS TA-23-001-TARC,

Roller Coaster Rad Safe Area

1.0 Objective

The objective of this radiological survey was to provide information on the type, distribution, and locations of surface and shallow subsurface contamination and to show radiological trends to focus characterization and clean up efforts.

2.0 Instruments

- Eberline model ESP-2 Ratemeter (SN. 00589) with 5-inch FIDLER (Field Instrument for the Detection of Low Energy Radiation) detector (SN. 706204)
- NE Technology model Electra (SN. 2339) with model DP6BD alpha/beta probe (SN. 131)

3.0 Data Acquisition

Radiological background locations were selected based on soil characteristics similar to the survey area. Soil areas located approximately 50 meters west of the western fence surrounding the survey area with similar gravel/sand ratios were selected for the soil background measurements. A single background soil measurement was collected for each instrument. Radiological measurements of the background location were performed in the same manner as the site survey described below.

The radiological survey was performed January 23 through 25, 1998 at Corrective Action Site TA-23-001-TARC, Roller Coaster Rad Safe Area. An investigation grid of 150 by 320 feet was established around the posted contamination area with a 24- by 24-foot internal spacing. The grid was marked with wooden stakes and paint to provide visual reference points. Each 24 by 24-ft internal grid square was surveyed with a FIDLER detector by transversing the area at a steady rate while integrating count-rates for 3 minutes. Three 24 by 24-ft areas that indicated elevated readings were subdivided into 6 by 6-ft areas and surveyed by integrating the FIDLER count rate for 30 seconds. Table 1 shows the results of the gamma area integrated count rate for the 24 by 24-ft and the 6 by 6-ft internal spacing. The FIDLER detector was positioned approximately 6 inches from the ground surface during the survey. Discrete locations that indicated elevated gamma readings (hot spots) were counted for 1 minute at a height of 6 inches. The location and measurement of each gamma Hot Spot is shown in Table 2. Alpha and beta measurements were collected near each grid node by placing the detectors directly on the surface of the soil and integrating the count-rate for 60 seconds. Table 3 shows the results of the alpha and beta disintegration rate for each grid node location. Alpha and beta measurements were also collected at each hot spot identified by the FIDLER detector. The location

and measurement of each alpha and beta hot spot are shown in Table 4. Each radiological measurement was recorded on a Radiation Walkover Survey Measurement Form. A total of 50 alpha, 50 beta, and 149 gamma measurements were recorded. Sixteen discrete hot spots were identified by the FIDLER detector.

4.0 Data Processing

The radiological data was processed using the commercial software package SURFER. The raw data from the Radiation Walkover Survey Measurement Form was entered into SURFER as a worksheet. Post maps were generated for the alpha and beta measurements and are shown in Figures 1 and 2 respectively. Figure 3 shows the results of the Area Integration Gamma Survey that indicates general areas that may contain elevated radioactivity. Gamma hot spots are posted as designation numbers in Figure 4 and show the exact location of discrete areas containing elevated radioactivity. A contour plot was generated from SURFER of the gamma area integration data and is included as Figure 5.

5.0 Quality Control

Radiological detection equipment used in this survey was checked daily as described in SQP-ITLV-460. The data collected were checked against source information for transcription errors.

6.0 Data Review

Radiological measurements of the surface soils at CAU 407, TA-23-001-TARC, Roller Coaster Rad Safe Area, indicate the soil is contaminated with alpha, beta and gamma emitters. The elevated measurements were concentrated generally in the eastern half of the fenced area. Some elevated measurements appeared to originate from small rocks or pieces of concrete. Alpha measurements of hot spots are underreported largely due to the inability to position the alpha probe close enough to the affected soil. Other factors affecting these radiological measurements included gamma and beta shine from surrounding soil, changing ambient radon levels, and instrument variations.

Table 1

Integrated Gamma Count Rate

Local Grid Coordinates		Gamma Count Rate
East	North	cpm
012	012	3940
012	036	3800
012	060	3790
012	084	3700
012	108	3680
036	012	3900
036	036	3760
036	060	3740
036	084	3670
036	108	3620
060	012	3690
060	036	3720
060	060	3770
060	084	3660
060	108	3660
084	012	3580
084	036	3740
084	060	3690
084	084	3700
084	108	3660
108	012	3520
108	036	3680
108	060	3640
108	084	3610
108	108	3720
132	012	3540
132	036	3690
132	060	3690
132	084	3650
132	108	3750
156	012	3600
156	036	3750
156	060	3750
156	084	3660
156	108	3710
171	075	3700
171	081	3810
171	087	3900
171	093	4000
177	075	3880
177	081	3990
177	087	3610

Local Grid Coordinates		Gamma Count Rate
East	North	cpm
177	093	3800
180	012	3690
180	036	3780
180	060	3790
180	084	4250
180	108	3700
183	075	6280
183	081	4430
183	087	3910
183	093	3870
189	075	4050
189	081	4400
189	087	4000
189	093	4100
195	027	3720
195	033	3790
195	039	3840
195	045	3860
201	027	3740
201	033	3980
201	039	4430
201	045	5200
204	-036	3610
204	-012	3540
204	012	3620
204	036	4770
204	060	3870
204	084	3850
204	108	3800
207	027	3870
207	033	3910
207	039	5200
207	045	4200
213	027	3370
213	033	4030
213	039	4490
213	045	4800
219	027	3870
219	033	4820
219	039	5850
219	045	4290
225	027	3610
225	033	4950
225	039	5790
225	045	4710
228	-036	3560
228	-012	3700

Local Grid Coordinates		Gamma Count Rate
East	North	cpm
228	012	3590
228	036	7880
228	060	3950
228	084	3890
228	108	3810
231	027	3940
231	033	4180
231	039	4530
231	045	4600
237	027	3800
237	033	4350
237	039	4560
237	045	4590
252	-036	3590
252	-012	3760
252	012	3560
252	036	4290
252	060	3920
252	084	3750
252	108	3770
276	-060	3570
276	-036	3600
276	-012	3760
276	012	3940
276	036	4270
276	060	3720
276	084	3620
276	108	3750
300	-060	3600
300	-036	3620
300	-012	3600
300	012	4390
300	036	4000
300	060	3800
300	084	3800
300	108	3900
324	-060	3530
324	-036	3520
324	-012	3610
324	012	3850
324	036	3910
324	060	3770
324	084	3730
324	108	3890

Table 2

Gamma Hot Spots

Local Grid Coordinates		Gamma Count Rate
East	North	cpm
184	075	185000
194	076	32000
198	042	34100
200	044	41600
201	042	21400
208	036	37000
214	043	23800
220	037	151000
222	034	171000
224	039	118000
228	042	58000
275	024	10400
275	029	63000
288	000	20000
290	018	350000
290	035	31000

Table 3

Alpha and Beta Node Measurements

Local Grid Coordinates		Alpha	Beta
East	North	dpm	dpm
24	24	83.3	1295
48	24	27.8	1325
72	24	62.5	1248
96	24	69.4	1371
120	24	76.4	1258
144	24	55.6	1196
168	24	69.4	1328
192	24	90.3	1356
216	24	118	1172
240	24	48.6	1166
264	24	90.3	1227
288	24	62.5	1313
312	24	90.3	1285
267	33	90.3	1333
222	36	264	1364
289	38	76.4	1270
225	39	188	1377
214	42	139	1518
197	45	104	1285
24	48	97.2	1365
48	48	160	1466
72	48	90.3	1252
96	48	125	1414
120	48	76.4	1337
144	48	90.3	1506
168	48	111	1417
189	48	118	1383
216	48	69.4	1485
240	48	90.3	1475
264	48	55.6	1325
288	48	83.3	1479
312	48	34.7	1261
24	72	27.8	1414
48	72	130	1415
72	72	41.7	1380
96	72	104	1328
120	72	111	1451
144	72	83.3	1331
168	72	41.7	1242
192	72	69.4	1377
216	72	55.6	1464
240	72	62.5	1500
264	72	69.4	1163
288	72	90.3	1224
312	72	41.7	1212

Table 4

Alpha and Beta Hot Spot Measurements

Local Grid Coordinates		Alpha	Beta
East	North	dpm	dpm
286	12	521	1561
188	79	27700	37800
196	44	59600	19900
210	36	246000	106000
258	26	867000	458000

Figure 1

Roller Coaster Rad Safe Area
Corrective Action Unit 407,
Corrective Action Site TA-23-001-TARC

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Alpha Measurements (dpm/100 sq. cm)

Alpha Background = 41.7 dpm

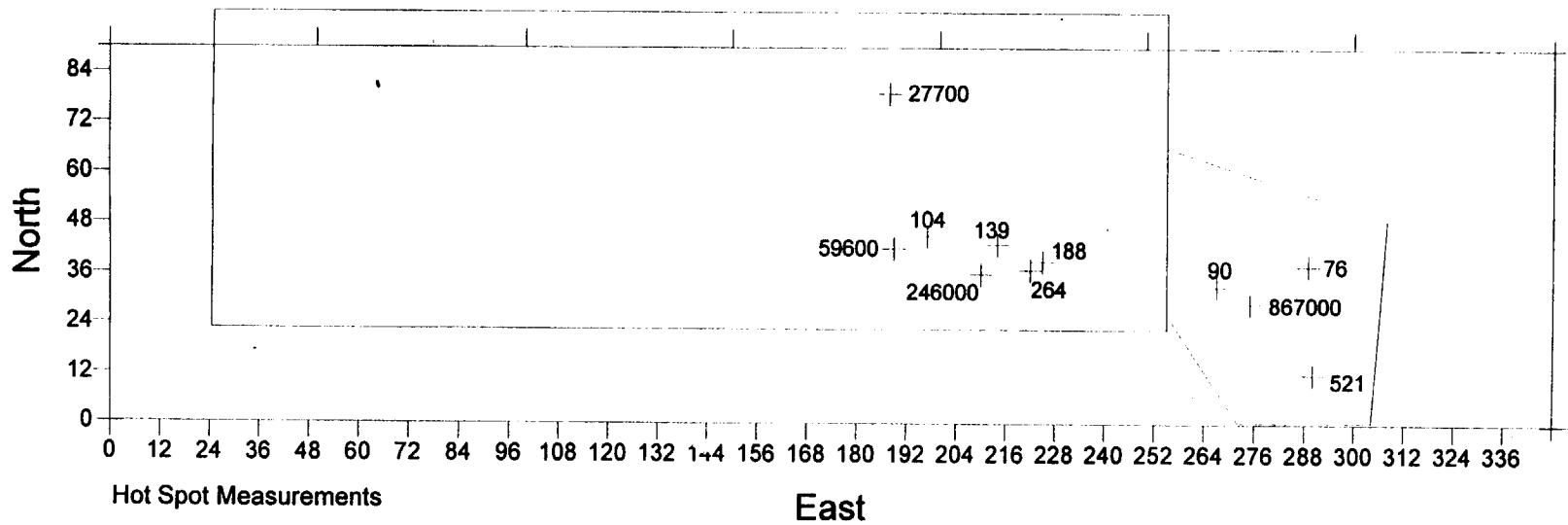
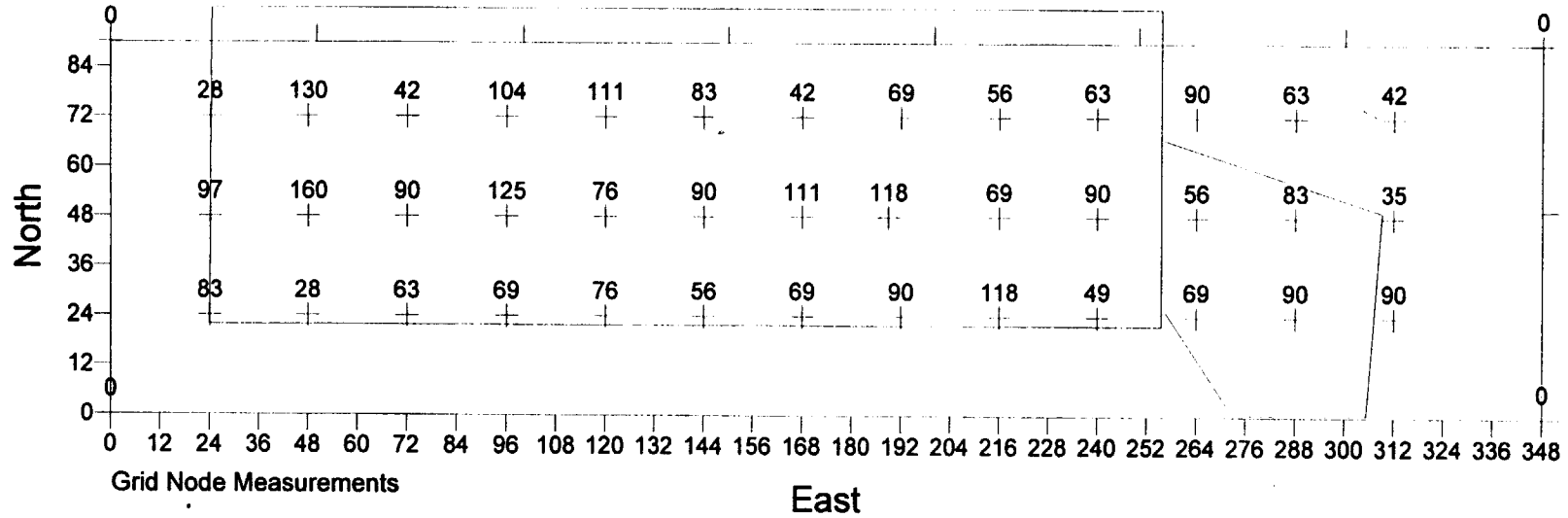


Figure 2
Roller Coaster Rad Safe Area
Corrective Action Unit 407,
Corrective Action Site TA-23-001-TARC
 Beta Measurements (dpm/100 sq. cm)
 Beta Background = 1224 dpm

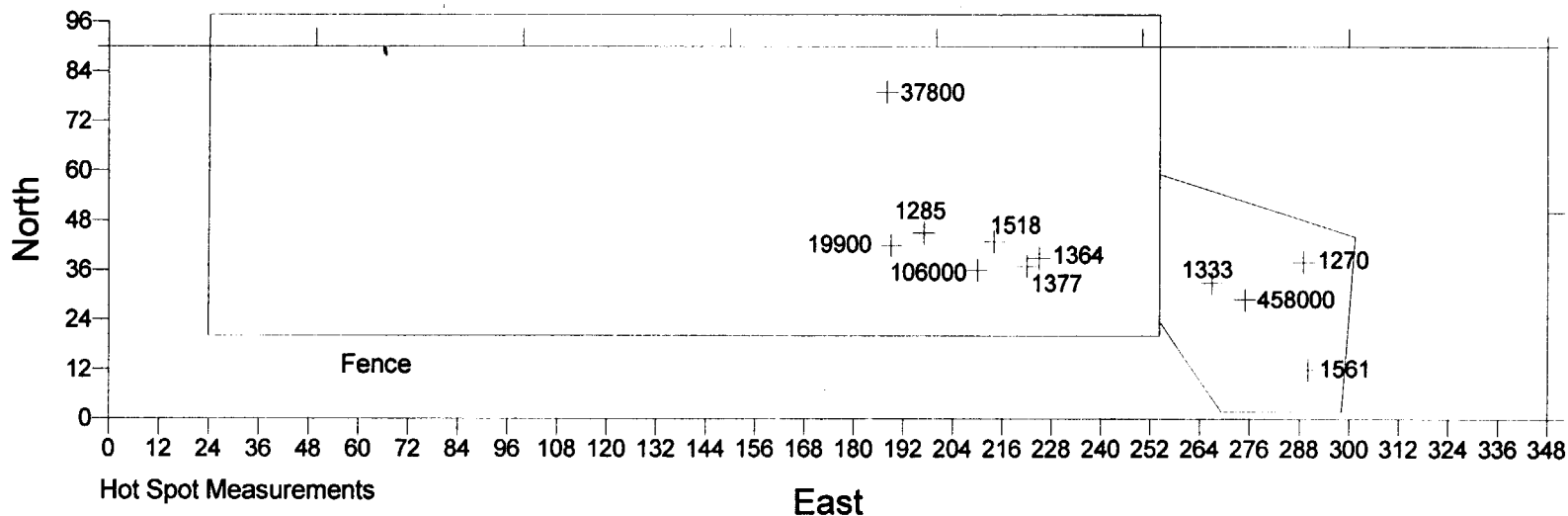
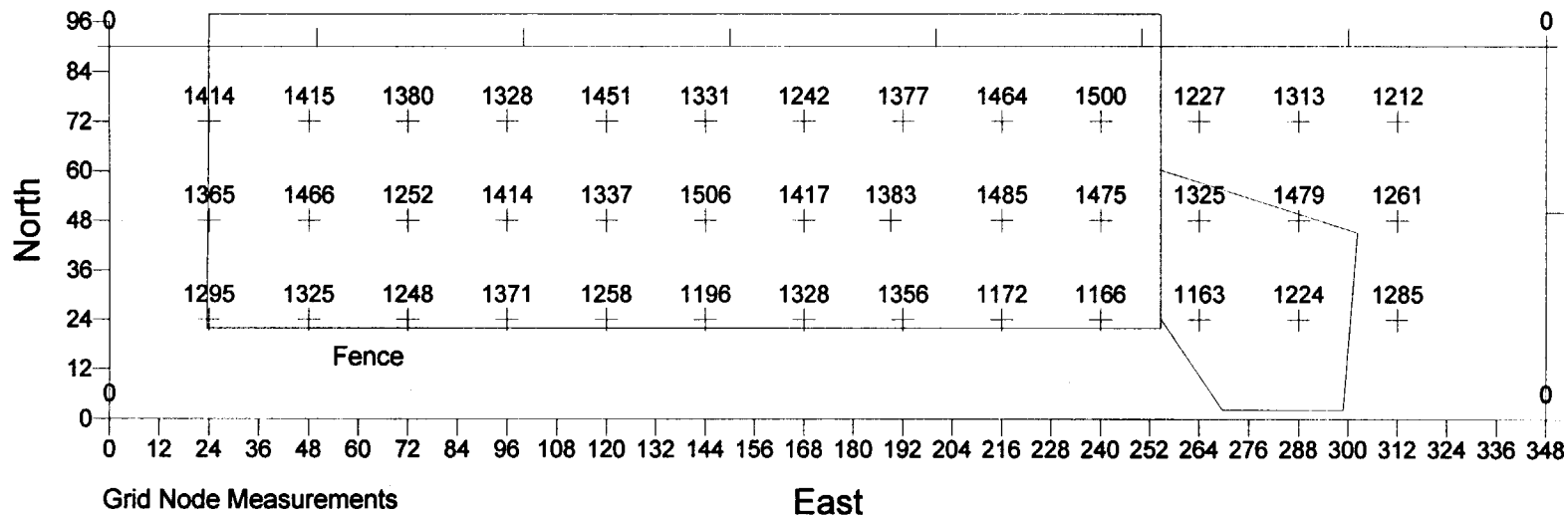
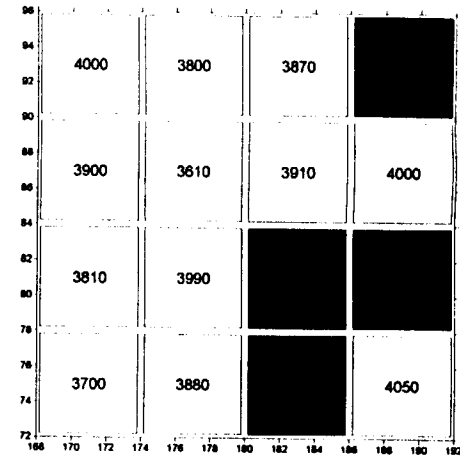
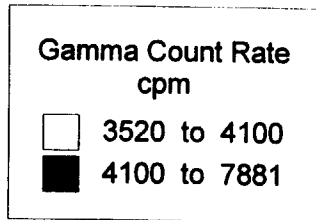
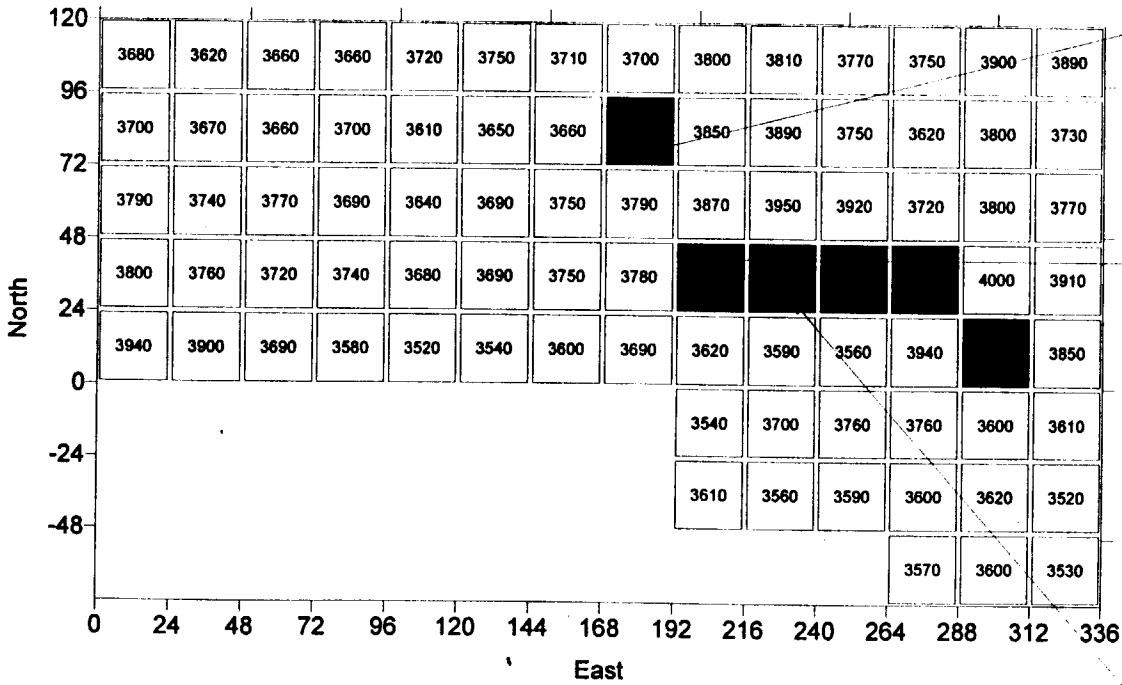


Figure 3

Roller Coaster Rad Safe Area Corrective Action Unit 407, Corrective Action Site TA-23-001-TARC

Area Integration Gamma Count Rate (cpm)
Gamma Background = 3600 cpm



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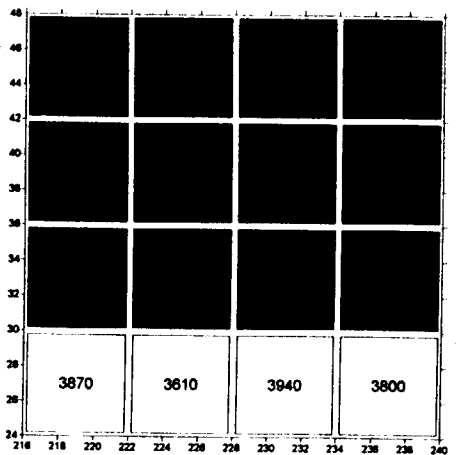
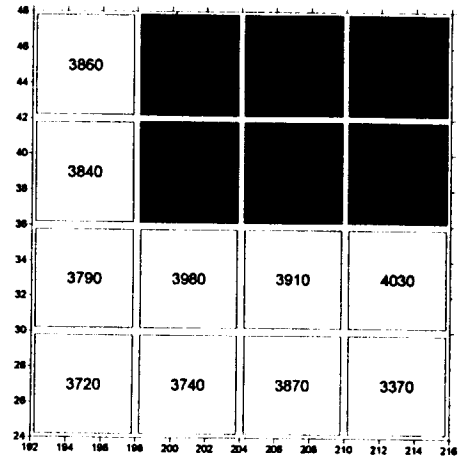
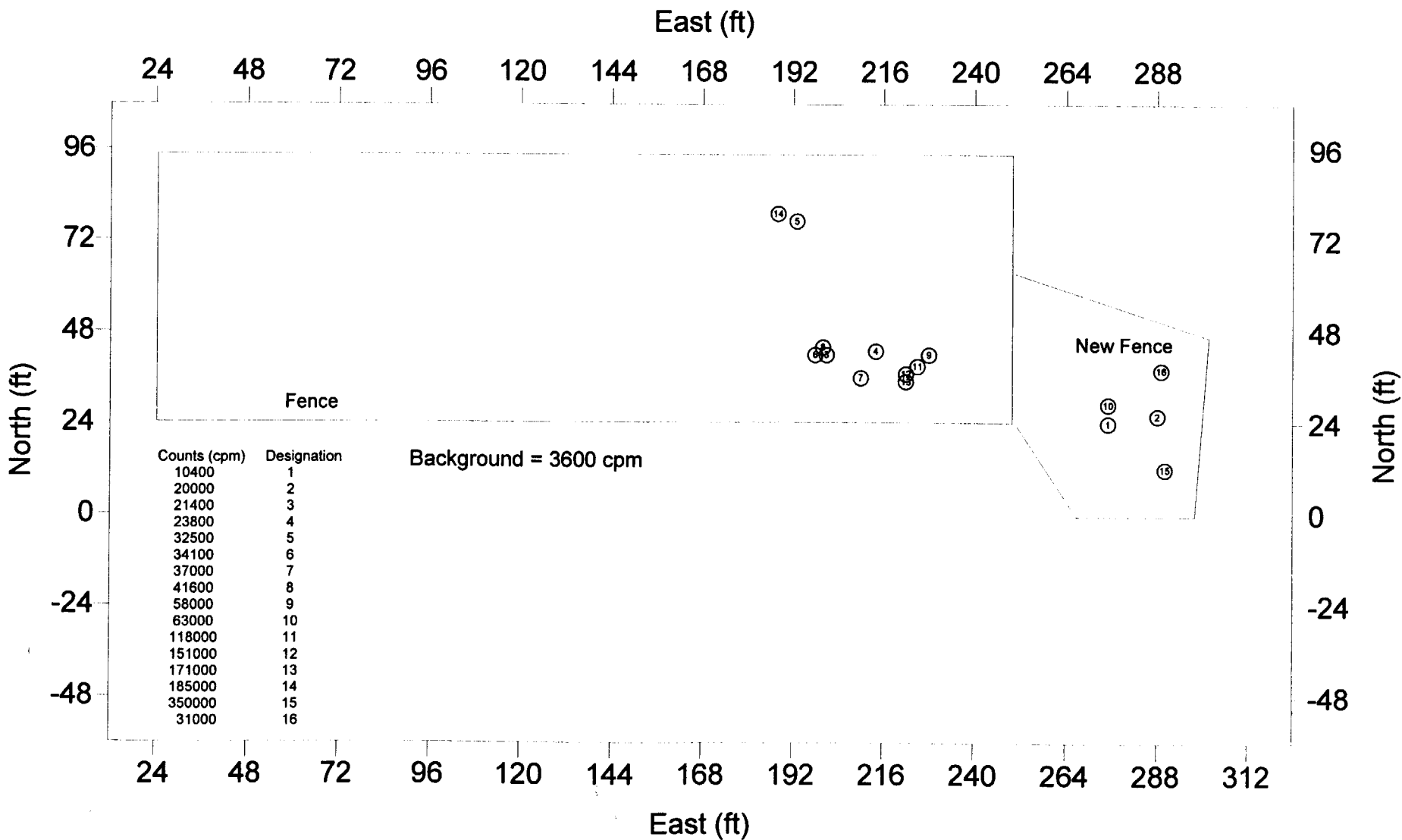


Figure 4
 Roller Coaster Rad Safe Area
 Corrective Action Unit 407,
 Corrective Action Site TA-23-001-TARC
 Hot Spot Gamma Count Rate (CPM)



Appendix E

Roller Coaster RADSAFE Area Dose Assessment

E.1.0 Purpose and Scope

The purpose of the dose assessment is to evaluate the potential dose to hypothetical future land users at the RCRSA for each of the corrective action alternatives. A concentration of residual radioactive material in the RCRSA soil is calculated for each corrective action alternative that will ensure that the basic dose limit of 25 mrem to the hypothetical future land user is not exceeded. The tasks conducted as part of the dose assessment are to discuss the regulatory requirements for corrective action levels, describe the dose calculation methodology, define the hypothetical future land users, list the dose calculation input parameters, and summarize the dose calculation results. The RCRSA dose assessment results will be used to select the corrective action decision.

E.1.1 Corrective Action Levels

Corrective actions at the RCRSA are being conducted to ensure that the residual concentrations of plutonium (Pu), americium (Am), uranium (U) and their decay products in the soil do not exceed the guidelines established in DOE Order 5400.5, *Radiation Protection of the Public and the Environment* (DOE, 1993). In the DOE Order, the corrective action guideline is defined as a residual radionuclide concentration that, given appropriate and reasonable future use scenarios and site parameters, will reasonably ensure that dose limits to the average individual in the critical population will not be exceeded. The DOE Order does not state corrective action levels for Pu, Am, or U but indicates that the corrective action level should be derived on a site-specific basis.

The DOE Order 5400.5 (DOE, 1993) guidelines for corrective action are based upon a radiation dose criterion of 100 mrem/yr. This radiation dose is defined as the effective dose equivalent from external radiation plus the committed effective dose equivalent from internal radiation. The 100-mrem/yr dose criterion is the standard dose rate to ensure protection to members of the public from DOE operations. This criterion includes the dose contribution for the combination of all significant pathways and sources (excluding background).

The corrective actions at the RCRSA are based upon a dose criterion of 25 mrem/yr. This dose criteria is in accordance with proposed 10 CFR 834, *Radiation Protection of the Public and the Environment*. In addition, the 25-mrem/yr dose criterion is for the termination of a license from the

U.S. Nuclear Regulatory Commission (NRC) (CFR, 1998). This dose criterion is more restrictive than the guidelines recommended in DOE Order 5400.5 and proposed 10 CFR 834, and will require lower concentrations of Pu and Am to attain corrective actions (DOE, 1993). Additional details on the acceptable dose criterion are discussed in [Section E.1.2](#).

The dose to hypothetical future land users at the RCRSA is assessed in accordance with the requirements of Chapter IV of DOE Order 5400.5 (DOE, 1993). The methodology for deriving specific property guidelines for allowable levels of residual radioactive material from a basic dose limit of 25 mrem/yr is contained in *A Manual for Implementing Residual Radioactive Material Guidelines: A Supplement to the U.S. Department of Energy Guidelines for Residual Radioactive Material at FUSRAP [Formerly Utilized Sites Remedial Action Program] Sites* (Gilbert et al., 1989). This manual is cited in DOE Order 5400.5 as the manual for implementing DOE guidance on establishing cleanup concentrations for radionuclides in soil using the RESRAD microcomputer code (Gilbert et al., 1989). The version of RESRAD used in this dose assessment is 5.82 (Yu et al., 1993b). Additional information on the methodology used to assess the dose is provided in [Section E.1.4](#). The hypothetical future land uses assumed for the dose assessment are described in detail in [Section E.1.5](#). The dose calculation input parameters on the physical description, hydrological conditions, and contamination zone parameters assumed for the RCRSA dose assessment are addressed [Section E.1.6](#). All of the RESRAD input parameters are listed in [Attachment 1](#) to this appendix. [Section E.1.7](#) summarizes the calculated doses for each corrective action alternative.

E.1.2 Acceptable Dose Criteria

The dose criterion used in this dose assessment is a committed effective dose equivalent of 25 mrem/year. This is the dose rate established by the NRC in Title 10 CFR Part 20 for unrestricted public use of NRC decommissioned facilities. The RCRSA is located on the TTR which is operated by the USAF. The dose criterion for protection of the public from USAF operations is 100 mrem/yr, which is the same as the DOE's. The NRC specific criterion for protection of an occupationally exposed USAF worker is 5,000 mrem/yr. These two criteria are from Title 10 CFR Part 20, (CFR, 1998). The NRC dose criterion of 25 mrem/yr for licensed facility decommissioning can go as high as 500 mrem/yr if it can be demonstrated that further reductions are not technically achievable,

are prohibitively expensive, or would result in net public environmental harm (CFR, 1998). The USAF accepted 25 mrem/yr as the dose criteria for unrestricted use of the Clean Slate sites (Roller Coaster Storage Transportation Test Sites). The USAF has not made a decision on an acceptable dose criterion for the RCRSA.

E.1.3 Radiological Source Term

Storage transportation tests were conducted as Clean Slate 1, 2, and 3 in 1963. These tests resulted in the contamination of near-surface soil at those sites with Pu, Am, and trace quantities of U. The RCRSA was used to decontaminate vehicles, equipment, and individuals participating in the Clean Slate tests. In addition, radiologically contaminated trash and the Double Tracks baseplate was disposed in a waste pit at the RCRSA.

The site was active in 1963 and was used to decontaminate vehicles, equipment, and personnel involved in the Clean Slate tests. The site consists of a hotline area for decontaminating personnel, a vehicle decontamination area, two decontamination sumps, and a waste disposal pit. The radiological contaminants of concern include Pu, Am, and U associated with the source terms. The total surface area of the RCRSA is approximately 2,899 square meters (m²) (30,000 ft²).

In 1998, radiation surveys of the surface and subsurface soil were performed in support of RCRSA site characterization. The radiological surveys of the soil surface demonstrated the presence of 15 locations with elevated concentrations or “hot spots” of Pu, Am, U, and their decay products. The 15 locations with elevated survey instrument count rates are located in six survey grids, each 53.5 m² (576 ft²) for a total surface area of 321 m². The surface area of the RCRSA that is radiologically contaminated was estimated to be 74 m² (792 ft²). For the purpose of this dose assessment it was assumed that the radiological contamination was distributed uniformly over the six survey grids, an area of 321 m² (3,456 ft²).

Radiological surveys of the surface soil showed alpha concentrations ranging from 76 to 867,000 disintegrations per minute/100 square centimeters (dpm/100 cm²), beta concentrations ranging from 1,270 to 458,000 dpm/100 cm², and gamma count rates ranging from 10,400 to 350,000 cpm.

Eighteen surface soil samples, plus five duplicate soil samples, were taken from the 15 hot spot locations and were analyzed by Bechtel Nevada Analytical Services Laboratory using gamma and alpha spectrometry. The plutonium-239/240 ($^{239/240}\text{Pu}$) concentration in the soil samples is extraordinarily variable. Its concentration varied from 0.0993 pCi/g to 159,000 pCi/g. The average $^{239/240}\text{Pu}$ concentration in the hot spot soil samples was 11,446 pCi/g while the median $^{239/240}\text{Pu}$ concentration was only 2.93 pCi/g. Only six of the hot spot soil samples had $^{239/240}\text{Pu}$ concentration exceeding 100 pCi/g and only four had $^{239/240}\text{Pu}$ concentrations exceeding 1,000 pCi/g. The activity concentration of the americium is approximately six to seven percent of the $^{239/240}\text{Pu}$. The activity concentration of the uranium exceeded the background concentration in only two of the 23 samples. A summary of the radioanalysis of the hot spot soil samples is summarized in [Table E.1-1](#).

In addition to the surface soil samples, 10 boreholes were drilled inside the exclusion zone fence at the RCRSA to a depth of 9.1 meters (m) (30 ft). The borehole cores were surveyed using NE Technology Electra gross alpha/beta detectors. Elevated survey instrument count rates were found at the gravel native soil interface at one location in Borehole B-4. Seventy-six soil samples were taken from the ten boreholes. The samples were taken from the fill material native soil interface and where elevated survey instrument count rates were measured. The soil samples were analyzed for Pu, Am, and U using alpha spectrometry. The U concentration in all borehole soil samples is within background. Sixty-three of the borehole samples had background concentrations of plutonium. Seven samples had $^{239/240}\text{Pu}$ concentrations greater than background but less than 5 pCi/g, six samples had $^{239/240}\text{Pu}$ concentrations between 5 and 10 pCi/g, and five samples had concentrations exceeding 10 pCi/g.

Borehole, B-4, drilled in the waste disposal pit, had elevated alpha and beta-gamma contamination associated with trash located at a depth of 3 m (10 ft). A soil sample associated with this trash had a $^{239/240}\text{Pu}$ concentration of 5,200 pCi/g. Other soil in the vicinity of trash was surveyed and found to have a background count rate. Two samples from borehole B-4 exceeded 10 pCi/g. A sample taken from the bottom of the waste disposal pit had a $^{239/240}\text{Pu}$ concentration of 224 pCi/g. Six soil samples taken below these two samples had background concentrations of $^{239/240}\text{Pu}$. One soil sample taken from the bottom of the vehicle decontamination area borehole (B-2), had a $^{239/240}\text{Pu}$ concentration of 51 pCi/g. Three samples taken from Borehole B-4b at the bottom of the waste disposal pit had $^{239/240}\text{Pu}$ concentrations of 24, 12, and 2.4 pCi/g.

**Table E.1-1
Radionuclide Concentration in RCRSA Surface Soil Sample**

Sample Number	Am-241 Concentration (pCi/g)	Pu-239/240 Concentration (pCi/g)	U-235 Concentration (pCi/g)	U-238 Concentration (pCi/g)
112	Not Detected	2.03E+0	Not Detected	9.80E-1
113	Not Detected	4.47E-1	Not Detected	Not Detected
114	Not Detected	4.89E-1	Not Detected	1.05E+0
115	Not Detected	2.28E-1	Not Detected	8.95E-1
116	2.64E-1	2.93E+0	Not Detected	8.68E-1
117	Not Detected	9.93E-2	Not Detected	8.71E-1
118	Not Detected	3.87E-2	Not Detected	9.52E-1
119	Not Detected	4.97E-1	Not Detected	9.20E-1
120	Not Detected	1.38E-1	Not Detected	1.30E+0
121	Not Detected	9.07E-1	Not Detected	8.87E-1
122	1.29E-2	3.97E+3	Not Detected	Not Detected
123	2.35E+0	1.15E+1	Not Detected	8.86E-1
123	2.35E+0	1.69E+1	Not Detected	Not Detected
123 D	3.53E+0	2.87E+1	Not Detected	1.09E+0
123 D	3.53E+0	8.62E+1	Not Analyzed	Not Analyzed
124	1.50E+1	1.31E+2	Not Detected	9.97E-1
124	1.50E+1	3.34E+2	Not Detected	Not Detected
125	8.60E+1	Not Detected	Not Analyzed	Not Analyzed
126	1.19E+3	1.95E+4	Not Analyzed	Not Analyzed
127	4.61E+3	7.94E+4	2.00E+0	5.47E+1
128	7.92E+3	1.59E+5	Not Detected	1.15E+2
129	Not Detected	Not Detected	Not Detected	Not Detected
129 D	Not Detected	Not Detected	Not Detected	Not Detected

The radiological contamination below the ground surface is generally limited to the fill material native soil interface located at the bottom of disposal sumps and pits. For this dose assessment it was assumed that the radiological contamination extends from the ground surface to a depth of 0.61 m (2 ft) over an area of 321 m² (3,456 ft²). This assumption will conservatively bound the true RCRSA source term. Analysis showed that Pu and Am at greater depths do not contribute to the dose.

E.1.4 Dose Calculation Methodology

The radiological dose assessments process estimates the dose to hypothetical future land users by applying mathematical models designed to quantify the transport of radionuclides through the environment and their subsequent intake and exposure to man. Numerous methods are available for calculating the dose to land users exposed to radionuclides in the soil. This section describes how the method used in this dose assessment was selected.

The dose calculation methodology used for computing the corrective action level for Pu, Am, and U contaminated soil at the RCRSA must meet eight specific regulatory and DOE Order criteria (DOE, 1993 and 1998) and 10 CFR 830 (CFR, 1994). If the method does not meet all eight of the regulatory and DOE Order criteria, the method is unacceptable. In addition, there are four other criteria that are specific to the Industrial Sites Project. These 12 criteria are listed below:

- Calculate corrective action levels as a function of the site-specific radionuclide concentrations in the soil (DOE, 1993)
- Compute the corrective action level as a function of the committed effective dose equivalent to the receptor (DOE, 1993)
- Calculate the corrective action level as a function of each individual radionuclide contaminant of potential concern (DOE, 1993)
- Documentation is available that describes the model's equations, and its basis for the calculation (DOE, 1993 and 1998; CFR, 1994).
- Documentation is available on the validation of the method (DOE, 1998; CFR 1994)
- Documentation is available on the independent verification that the method solves the numerical problems as intended by the authors (DOE, 1998; CFR, 1994)

- The method must be capable of calculating the dose from each potential exposure scenario (DOE, 1993)
- The method must be capable of computing the cancer risks to members of the public as a function of the corrective action level and site-specific characteristics (DOE, 1993)
- Documentation is available on the benchmarking of the method against other accepted methods or environmental measurements
- The method must be capable of calculating the contribution of each radionuclide to the Committed Effective Dose Equivalent (CEDE)
- The method should be accepted by the DOE, NRC, and the EPA for calculating corrective action levels for radiologically contaminated soil.
- The method should be capable of performing sensitivity analysis.

A comparison of the 9 codes to the 12 criteria is summarized in [Table E.1-2](#). Of the 9 commercially available codes, only the RESRAD code fulfills all 12 acceptance criteria. Therefore, the RESRAD code was used to perform the dose assessment for supporting the RCRSA corrective action decision.

RESRAD is a pathway analysis code that uses hydrological, meteorological, geochemical, radiological source term, material-related parameters, and the site area, depth and shape to calculate the radiological dose and risk resulting from exposure to residual radioactive material. RESRAD has been accepted and used by the EPA, DOE, and the NRC in calculating corrective action levels. In addition, documentation exists to demonstrate that RESRAD has been benchmarked, validated, verified, and meets all of the quality control and assurance criteria established in DOE Order 414.1, DOE Order 5400.5, and 10 CFR 830 (DOE, 1993 and 1998; CFR, 1994).

E.1.5 Future Land-Uses

Neither the DOE nor the USAF has any specific future plans to use the RCRSA site. Because there are major roads and a groundwater well in the vicinity of the RCRSA site it was assumed that under civilian control the site could be used for industrial purposes.

A residential scenario (rancher/farmer) would not be applicable for the RCRSA because the area of contamination 321 m^2 ($3,456 \text{ ft}^2$), is less than 0.1 acres. It is not reasonable for the residential scenario to be considered for a site this small. For the industrial use scenario to be feasible, supporting

**Table E.1-2
Comparison of Computer Codes to Requirements Criteria**

REQUIREMENTS CRITERION		CODE								
		DECON	GENII	GENII-S	MEPAS	MMSOILS	NTS DOSE	PRESTO - EPA-CPG	RESRAD	RISKCALC
1	Calculate Cleanup Levels	Yes	No	No	No	No	No	No	Yes	No
2	Cleanup Level Based on CEDE	Yes	No	No	No	No	No	No	Yes	No
3	Cleanup Level a Function of Radionuclide	Yes	No	No	No	No	No	No	Yes	No
4	Documentation	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No
5	Validation	No	No	No	Yes	No	No	No	Yes	No
6	Verification	Nos	Yes	Yes	Yes	No	No	No	Yes	No
7	Scenario	No	Yes	No	No	No	Yes	No	Yes	No
8	Cancer Risk from CEDE	No	No	No	Yes	Yes	No	No	Yes	No
9	Benchmarking	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No
10	Exposure Pathway	No	Yes	Yes	Yes	No	Yes	Yes	Yes	No
11	Regulatory Acceptance	No	No	No	Yes	Yes	No	No	Yes	No
12	Sensitivity Analysis	No	No	Yes	No	Yes	No	No	Yes	No
13	Programmatic Acceptance	No	No	No	No	No	No	No	Yes	No

CEDE = Committed Effective Dose Equivalent

infrastructures would have to be prepared (e.g., grading of the ground surfaces, construction of buildings and parking lots, and excavation to install utility and groundwater lines). Therefore, both industrial and construction use scenarios were evaluated. Additional details on these exposure scenarios are described in the following two sections. All of the land-use parameter values used in the RESRAD computations are listed in [Attachment 1](#).

The construction and industrial land-uses will result in disruption of the surface soil. The dose assessment was performed assuming that the soil was not disturbed and that it was mixed to a depth of 0.46 m (18 in.). In every calculation performed, the resultant dose was greater if it was assumed that clean soil added to the surface of the excavation site was mixed to a depth of 0.46 m (18 in.). Therefore, the doses listed in [Section E.1.7](#) assume that the soil is mixed to a depth of 0.46 m (18 in.). [Attachment 2](#) summarize the doses for both mixed and unmixed soil.

E.1.5.1 Construction Worker Scenario

The construction worker scenario assumes an individual works exclusively on the radiologically contaminated areas of the RCRSA. The area on which they work is located on soil with residual Pu and Am contamination at the corrective action concentration. The construction worker is assumed to remain on the RCRSA eight hours per day for 120 days per year. While on the RCRSA, the construction worker receives a radiological exposure and dose through the external exposure, drinking water, inhalation, and soil ingestion exposure pathways. Each of these are described in the following subsections.

External Exposure

The construction worker receives an external dose from the radionuclides present on the surface of the RCRSA. The external dose rate while outdoors is higher than the dose rate indoors. In order to calculate a maximum credible dose to the construction worker, it is assumed that they spend six hours of their work day outdoors and two hours indoors. One required input parameter is known as the shielding factor. It is used in calculating both the external and inhalation dose while the dose receptor is indoors. The inhalation shielding factor account for the fact that the concentration of Pu, Am, and U contaminated dust in the air is lower indoors than outdoors. The external exposure shielding accounts for the reduction of the external dose rate by the floor and walls of the building. In this dose

assessment the shielding factors used for inhalation and external exposure pathways are the RESRAD default values, 0.4 and 0.7, respectively.

Drinking Water Exposure Pathway

During the workday, the construction worker is assumed to obtain all of their drinking water from a groundwater well located on the downgradient boundary of the RCRSA. This groundwater well location will maximize the potential radionuclide concentration in the drinking water. The construction worker is assumed to ingest two liters of water per day while on the RCRSA. This water ingestion rate is greater than the 90 percentile for drinking water ingestion recommended for dose assessments in the *Exposure Factors Handbook* (AIHC, 1994).

Inhalation Exposure Pathway

The inhalation of Pu, Am, and U contaminated particles is an important route for entry into the body. The human respiratory tract model is the set of mathematical expressions that describe the extent to which airborne radionuclides are inhaled, deposited, retained, transported, and their radiation emissions absorbed in the tissues of the respiratory tract. In addition, it describes the fraction of the particles leaving the lung, their transport rate, and their partition to other tissue and organs of the body.

Whether or not airborne radionuclides are inhaled and enter the respiratory tract of people breathing contaminated air is determined by numerous physical, chemical, and biological factors. If the radionuclide is in a particulate form, the size, density, and hygroscopicity will determine the extent to which the material is inhalable (i.e., can be entrained in air inspired through the nose or mouth, and either deposited in the respiratory tract or exhaled). Physical as well as chemical properties will also determine the penetration of inhaled radionuclides, the sites of deposition, the retention times or rates of clearance, and rates of absorption into blood and translocation to other tissues. Other important determinants are physiological factors, including breathing characteristics at the time of intake (e.g., respiratory rate and volume, breathing through the nose or mouth) and whether respiratory tissues are normal or altered as a result of disease, smoking, or exposure to other occupational and environmental toxicants. All of these factors, as well as the radiological properties of the inhaled material, will determine the radiation dose and, in conjunction with the sensitivity of the irradiated tissues, the health risks associated with a given intake.

With the dose from an exposure to airborne radionuclides being determined by so many variables, it would be rare for two individuals exposed under the same conditions to experience the same radiation doses and the same health consequences. Therefore, to protect workers and members of the public against detrimental health effects resulting from exposure to airborne radionuclides, it is necessary to devise and assign consistent and conservative values to a set of parameters that can approximate the conditions and characteristics of the most common exposures encountered by reference populations. The need for a set of referenced parameter values was recognized during the earliest attempts to derive limits for radionuclide exposures, thus beginning the development of dosimetric modeling of the respiratory tract for radiation protection purposes.

The early respiratory models included the Tripartite Conference on Radiation Protection held from 1949 to 1953 (Taylor, 1984), the International Commission Respiratory Protection (ICRP) Publication 2 Model (ICRP, 1960), the Task Group on Lung Dynamics Model (TGLD, 1966) and the lung dosimetry model presented in *ICRP Publication 30* (ICRP, 1979). The 1966 report of the Task Group on Lung Dynamics, slightly modified in *ICRP Publication 30*, was a major scientific accomplishment in that it used and expanded upon the total relevant technical data available at that time. The model was published in 1979 and, with modifications derived from *ICRP Publication 48* (ICRP, 1986), was used to develop the dose conversion factors listed in Federal Guidance Report #11 (Eckerman, et al., 1988). The dose conversion factors in Eckerman et al., (1988) are used in this dose assessment.

The construction worker receives a radiological intake by inhaling radionuclide contaminated soil particles resuspended from the surface soil. The mass loading of Pu, Am, and U contaminated soil in the air is the radiological source term for the inhalation exposure pathway. In this dose assessment the mass loading of contaminated soil in the air is assumed to be 4.08×10^{-5} grams per cubic meter (g/m^3). This mass loading is the value measured during the excavation and truck loading of contaminated soil during the remediation of the Clean Slate 1 site (Bowen, 1997). It is three times the measured average during the spring, summer, and fall at TTR (Shinn, 1994). Assuming this mass loading should conservatively bound the true mass loading.

The dose from inhalation of Pu, Am, and U contaminated dust is a function of the particle size distribution of the dust particles. Particles with activity median aerodynamic diameters (AMAD)

larger than 10 micrometers (μm) are not inhaled into the lungs and will not contribute to the dose. In this dose assessment it was assumed that the average dust particle size in air is 1.0 μm AMAD. Therefore, all of the Pu, Am, and U contaminated dust is inhaled and contributes to the construction worker dose. Studies performed at the Roller Coaster sites demonstrate that the fraction of the particle size distribution in the soil and the air that is in the respirable range is less than 17 percent (Wilson, 1968; Perry, 1966). Assuming a 1 μm AMAD particle size distribution will conservatively over estimate the dose from inhalation of Pu, Am, and U contaminated dust.

The inhalation rate of the construction worker is based upon their activity level and associated breathing rates, which are listed in [Table E.1-3](#). The breathing rates associated with the construction worker's activities are for 24- to 30-year old males (Layton, 1993).

**Table E.1-3
Inhalation Rate for the Construction Worker**

Activity Level	Average Time Spent per Day at this Activity Level (hours/day)^c	Average Breathing Rate During this Activity Level (m³/hour)^b	Total Volume of Air Inhaled During this Activity Level (m³)
Sitting	1	0.65	0.65
Light Work	1.5	0.65	0.975
Moderate Physical Labor	5	1.75	8.75
Hard Physical Labor	0.5	2.66	1.33
Total	8	NA	11.7
Annual Inhalation Intake	960 hours/year	NA	1,404 m ³ /year
RESRAD Input ^a	NA	NA	12,812 m ³ /year

^a RESRAD adjusts the inhalation rate by multiplying it by the fraction of the time the dose receptor is on the site. Therefore, the calculated annual inhalation rate has to be divided by the fraction of time spent on the site.

^b Table 7, 24- to 30-year old males (Layton, 1993).

^c Reasonable worst-case, page 124, Yu et al. (1993a).

Soil Ingestion Pathway

The construction worker may inadvertently ingest radionuclides associated with the surface soil. The radionuclides are inadvertently ingested through the following exposure pathways:

- Soil is resuspended in the air and enters the mouth and then ingested
- Soil becomes attached to food which is then ingested
- Transfer of contaminated soil from hands to the mouth and ingested
- Soil resuspended from dusty clothing or equipment is taken into the mouth and swallowed

Foodstuffs are not grown on the RCRSA. The Pu, Am, and U are not incorporated into the food. But due to the potential dusty conditions on a construction site Pu, Am, and U contaminated soil may become entrained with the food and ingested. The model used in this dose assessment to describe the behavior of radionuclides in the gastrointestinal tract and for the calculation of doses from radionuclides in the lumen of the gut is that presented in ICRP Publication 30 (ICRP, 1979).

There are no federal guidelines on the inadvertent soil ingestion rate for a construction worker. For outdoor activities in the commercial and industrial setting, for example construction or landscaping, a soil ingestion rate of 0.48 grams per day (g/d) is recommended by the EPA for short-term intense activities (EPA, 1991). In this dose assessment, the construction worker is assumed to inadvertently ingest 0.48 g/d of contaminated soil. Assuming a soil ingestion rate of 0.48 g/d for the construction worker should bound any realistic soil ingestion rate.

E.1.5.2 Industrial Worker Scenario

The industrial worker scenario assumes an individual works full time on the RCRSA and exclusively on the radiologically contaminated areas of the RCRSA. The industrial worker is assumed to remain on the RCRSA eight hours per day for 250 days per year. The area on which they work is located on soil with residual Pu, Am, and U contamination at the corrective action concentration. The building in which they work is located on soil with residual Pu, Am, and U contamination at the corrective action concentration. While on the RCRSA, the industrial worker receives a radiological exposure and dose through the external, drinking water, inhalation, and soil ingestion exposure pathways. Each of these pathways are addressed in the following subsections.

External Pathway

While on the site the industrial worker spends half of their time indoors and half outdoors. As stated previously, the dose rate outdoors is higher than the dose rate indoors. Studies demonstrate that the average time spent outdoors is 7 percent, with maximum time outdoors as high as 14.5 percent (AIHC, 1994; Johnson et al., 1992, Lurman et al., 1991). Assuming that the industrial worker spends half their time outdoors should conservatively bound any realistic exposure scenario.

Water Ingestion Pathway

During the workday, the industrial worker is assumed to obtain all of their drinking water from a groundwater well located on the downgradient boundary of the RCRSA. This groundwater well location will maximize the potential radionuclide concentration in the drinking water. The industrial worker is assumed to ingest two liters of water per day while on the RCRSA. This water ingestion rate is greater than the 90 percentile for drinking water ingestion recommended for dose assessments in the *Exposure Factors Sourcebook* (AIHC, 1994).

Inhalation Pathway

The industrial worker receives a radiological intake by inhaling radionuclide contaminated soil particles resuspended from the surface soil. The mass loading of Pu, Am, and U contaminated soil in the air is the radiological source term for the inhalation exposure pathway. For the industrial worker scenario, the mass loading of contaminated soil in the air is assumed to be 1.36×10^{-5} g/m³. It is the measured average during the spring, summer, and fall at TTR (Shinn, 1994). Assuming this mass loading should conservatively bound the true mass loading. In the industrial worker exposure scenario it is assumed that the average dust particle size in air is 1.0 μm AMAD. Therefore, all of the Pu, Am, and U contaminated dust is inhaled and contributes to the industrial worker dose. Assuming a 1 μm AMAD particle size distribution should significantly over estimate the dose from inhalation of Pu, Am, and U contaminated dust.

The inhalation rate of the industrial worker is based upon the activity levels and their associated breathing rates listed in [Table E.1-4](#). The activity levels are based upon a reasonable worst-case scenario presented in Yu et al. (1993a). This case recommends 25 percent of the industrial worker's time is spent sitting down, 60 percent of their time performing light work, 10 percent performing moderate physical labor, and 5 percent of their time performing hard physical labor

(Yu et al., 1993a). The inhalation rates associated with the activities are for 24 to 30-year old males (Layton, 1993).

**Table E.1-4
Inhalation Rate for the Industrial Worker**

Activity Level	Average Time Spent per Day at this Activity Level (hours/day)^c	Average Breathing Rate During this Activity Level (m³/hour)^b	Total Volume of Air Inhaled During this Activity Level (m³)
Sitting	2	0.65	1.30
Light Work	4.8	0.65	3.12
Moderate Physical Labor	0.8	1.75	1.40
Hard Physical Labor	0.4	2.66	1.064
Total	8	NA	6.884
Annual Inhalation Intake	2,000 hours/year	NA	1,720 m ³ /year
RESRAD Input ^a	NA	NA	7,537.98 m ³ /year

^a RESRAD adjusts the inhalation rate by multiplying it by the fraction of the time the dose receptor is on the site. Therefore, the calculated annual inhalation rate has to be divided by the fraction of time spent on the site.

^b Table 7, 24 to 30-year old males (Layton, 1993).

^c Reasonable worst-case, page 124, Yu et al. (1993b).

m³/hour = Cubic meters per hour

In the industrial worker dose assessment the shielding factors used for inhalation and external exposure pathways are the RESRAD default values, 0.4 and 0.7, respectively.

Soil Ingestion Pathway

The industrial worker is also assumed to inadvertently ingest soil contaminated at the corrective action level. The industrial worker is assumed to spend more time indoors and in an environment that has less dust in the air than that assumed for the construction worker. Therefore, the inadvertent soil ingestion rate for the industrial worker is less than that of the construction worker, a rate of 0.3 g/d. This rate is three times the rate recommended by the EPA for an adult in the workplace (EPA, 1990).

E.1.6 Dose Calculation Input Parameters

The RESRAD input parameters are based upon site-specific measurements, industry standards, and/or a federal agency guidelines. All of the RESRAD input parameters are listed in the table in [Attachment 1](#). Attachment 1 identifies whether the input parameter is a referenced or calculated value, lists the reference used to obtain the input value, or the reference used to obtain the calculational parameters.

E.1.7 Dose Calculation Results

Doses were calculated for each of the five corrective action alternatives identified in the RCRSA Corrective Action Decision Document. The five corrective action alternatives are:

- Alternative 1: No further action, no excavation of contaminated soil and no soil cover
- Alternative 2: Closure by partial excavation followed by a clean soil cover
- Alternative 3: Closure by partial excavation and a 2.5-foot thick engineered soil cover
- Alternative 4: Clean closure by excavation and disposal
- Alternative 5: Clean closure by excavation, screening, partial removal and disposal

For this dose assessment Alternatives 1 through 3 were analyzed. There would be no residual radionuclide contamination for Alternatives 4 and 5. Therefore, no dose assessment is needed. The results of the remaining alternatives are described in the following subsections. The dose assessment results are focused on the dose to the construction worker. For all corrective action alternatives the construction worker receives a significantly higher dose than the industrial worker. In addition, as stated in [Section E.1.6](#), it was assumed that the soil was mixed to a depth of 0.46 m (18 in.). This assumption results in a greater calculated dose than assuming the soil is not disturbed.

Alternative 1

Alternative 1 was analyzed assuming that the average total transuranic (TRU) ($^{239/240}\text{Pu}$, ^{241}Am) concentration is 12,309 pCi/g. This total TRU concentration is assumed to have an areal extent of 321 m² and extend down from the ground surface to a depth of 0.61 m (2 ft). The maximum dose to the construction worker is 35.7 mrem/yr. This maximum dose is received during the first year after remediation. After 43 years the dose will be less than 25 mrem/year regardless of the depth of the contamination.

It is more likely that the thickness of the contamination is less than 2 in., and most likely less than 1 in. The surface contamination is believed to be due to Pu, Am, and U contaminated soil that fell off the Double Tracks base plate when it was exhumed from the RCRSA waste disposal pit. If the depth of the Pu, Am, and U contaminated soil is 2 in. thick, the maximum dose to the construction worker occurs during the first year and is 3.9 mrem/year. The soil depth required to give the construction worker a dose of 25 mrem/yr is 0.30 m (1 ft).

If the total TRU concentration is 12,309 pCi/g in the assumed contaminated area at RCRSA and it does not extend to a depth of greater than 1 ft, then Alternative 1 should be the recommended alternative.

Alternative 2

Alternative 2 was analyzed assuming that the average total TRU concentration is 12,309 pCi/g over an area of 321 m² and to a depth of 0.61 m (2 ft) below the ground surface. Alternative 2 consists of excavating the surface contaminated soil and replacing it with clean soil. A series of RESRAD calculations were performed to determine the dose to the construction worker as a function of the excavated soil. It was assumed that the soil was excavated, the excavated soil was replaced with clean soil, and that the clean and contaminated soil was mixed to a depth of 0.46 m (18 in.). The total TRU concentration from 0.46 m to 0.61 m is 12,309 pCi/g.

Using the assumptions listed above, the soil would have to be excavated down to a depth of 0.15 m (6 in.) to ensure that the construction worker did not receive a dose in excess of 25 mrem/yr during the first year subsequent to soil excavation. Any soil excavation greater than 0.15 m would result in still lower doses.

If the soil is excavated down to 0.05 m (2 in.) the dose during the first year is 31.7 mrem/yr. After 24 years, the dose to the construction worker would be less than 25 mrem/year if the soil is excavated down to 0.05 m (2 in.).

If the soil is excavated down to a depth of 0.1 m (4 in.) the dose during the first year subsequent to remediation is 27.8 mrem/yr. In 10 years the dose to the construction worker would be less than 25 mrem/yr.

Alternative 3

Alternative 3 was analyzed assuming that the average total TRU concentration is 12,309 pCi/g, the average concentration found in the RCRSA “hot spots.” This total TRU concentration is assumed to extend down from the ground surface to a depth of 0.61 m (2 ft). An engineered cap 0.762 m thick (2.5 ft) is assumed to be placed over the soil surface. With no excavation the dose during the first year subsequent to remediation is zero. The maximum dose of 5.26 mrem/yr does not occur for 762 years. If an engineered cap becomes the recommended alternative, then no excavation is warranted. The 0.762 m (2.5 ft) thick cap will provide sufficient protection to the construction worker.

E.1.7.1 Discussion

The radionuclide that contributes most significantly to the construction worker dose is ^{241}Am , approximately 66 percent of the total dose, regardless of the depth of excavation. The contribution to the dose from each exposure pathway remains constant, regardless of the depth of excavation. The soil ingestion pathway contributes 64 percent of the total dose, inhalation contributes 25 percent of the total dose, and external exposure contributes 11 percent. The maximum dose from exposure to radon and its decay products is 6.0×10^{-6} mrem/yr and it does not occur for 1,000 years. The maximum dose from ingestion of drinking water is $< 1.0 \times 10^{-3}$ mrem/yr and does not occur for 1,530 years.

The maximum annual dose to the construction worker as a function of the excavation depth is presented in [Table E.1-5](#). The maximum annual dose to the construction worker as a function of the thickness of the contamination is listed in [Table E.1-6](#). A summary of the radiological dose assessment for the construction worker scenario is presented in the tables in [Attachment 2](#). The enclosed tables present the dose to the construction worker for Alternatives 1 through 3. These tables summarize the dose to the construction worker for excavation of 2, 4, 6, 8, 12, and 16 in. of surface soil. The tables in [Attachment 2](#) also list the dose from each radionuclide for each exposure pathway.

The DOE, NRC, and EPA use dose-based standards for determining the concentration of residual radioactive material allowed on land to be release to the public. All dose-based standards will have uncertainty associated with the cleanup standard adopted. This uncertainty exists because the annual dose of 25 mrem is derived using inherently conceptual and mathematical models that relate exposure

**Table E.1-5
 Maximum Dose to Hypothetical Construction Worker for the RCRSA^a**

Proposed Corrective Action	Committed Effective Dose Equivalent (mrem/yr)
Assumed Existing Site Condition	35.7
Soil Excavation of 2 in.	31.8
Soil Excavation of 4 in.	27.8
Soil Excavation of 8 in.	20.1

^a The radionuclide contamination is assumed to have an average total TRU concentration of 12,309 pCi/g and extends to a depth of two feet.

**Table E.1-6
 Maximum Dose to Hypothetical Construction Worker for the RCRSA as a Function
 of the Depth of the Radiological Contamination in the Soil^a**

Depth of the Radiological Contamination (in.)	Committed Effective Dose Equivalent (mrem/yr)
2	3.8
4	7.7
6	11.7
8	15.6
12	23.4
16	31.1

^a The soil is assumed to have an average total TRU concentration of 12,309 pCi/g, no soil excavation is assumed.

and risk to concentrations of radioactive material in the soil. The parameter values used in the RESRAD calculations were assigned based on site data and conservative industry standards. Each parameter value used in the RESRAD calculations was chosen from the most conservative, pessimistic, and upper-bound extremes of the range of plausible values. Uncertainty values are not presented for the calculated doses. Generally, the doses calculated by RESRAD exceed the 95th percentile when compared with spreadsheet calculations using the same dose methodology.

The parameter values chosen for the RESRAD dose calculations are very conservative. The exposure pathway that contributes most significantly to the dose is the inadvertent ingestion of Pu and Am contaminated soil. The soil ingestion dose was about 64 percent of the total dose for each of the

corrective action alternatives and for each assumed depth of soil contamination. The parameters that most significantly effect the calculated soil ingestion dose is the soil ingestion rate, the area of contamination, and the ingestion dose conversion factors. The conservatism associated with the selection of the parameter value for each of these parameters are discussed below.

The construction work was assumed to ingest 0.48 g/d of Pu, Am, and U contaminated soil. This value is recommended by the EPA for outdoor activities in the commercial/industrial setting (e.g., construction or landscaping). The EPA recommended value is not based on soil ingestion rate measurements for individuals working in the outdoor commercial or industrial setting but is based upon assumptions and estimates. Only one study has been published on measured rates of inadvertent soil ingestion by adults (Calabrese et al., 1990). The study demonstrated that the median soil ingestion rate was far less than 0.001 g/d, the 80th percentile is about 0.1 g/d, and the 100th percentile is 0.213 g/d. The soil ingestion rate used in this dose assessment is greater than twice the maximum adult soil ingestion rate measured.

The dose to the construction worker is highly dependent on the area of contamination. The dose assessment assumed that the area of contamination is 321 m². The area of contamination may be as low as 74 m². Based upon the RESRAD computations for Alternative 1, the dose from 74 m² is less than two percent of that from the larger area. Assuming a contaminated area of 321 m² may overestimate the true dose by as much as a factor of 55. The true dose may be 55 times less than the calculated dose, based only upon the assumed area of contamination. If the contaminated area is less than 190 m², then the maximum annual dose to the construction worker will be less than 25 mrem/yr, even with a total TRU concentration of 13,309 pCi/g to a depth of 0.61 m (2 ft).

The dose conversion factors used in this dose assessment are from Federal Guidance Report #11 (Eckerman et al., 1988). For Pu and Am these dose conversion factors are the same as those in Publication 48 of the International Commission on Radiological Protection (ICRP, 1986). The ICRP has revised their model used to describe the gastrointestinal tract and how the dose from radionuclides in the lumen of the gut is calculated. The newer model is described in ICRP Publication 67 (ICRP, 1993). In addition, the fraction of the Am that passes from the gastrointestinal tract to the blood, f_1 , has been changed by the ICRP from those given in ICRP Publication 48 (ICRP, 1986). The new dose conversion factor for Pu, 3.33×10^{-5} mrem/pCi, is 1.6 times smaller

than the dose conversion factor listed in Eckerman, et al. (1988). The dose conversion factor for Am, 7.40×10^{-4} mrem/pCi, is 2 times smaller than the dose conversion factor listed in Eckerman et al. (1988).

The calculated doses to the hypothetical future land users should conservatively bound the dose to any individual working on the RCRSA in the future. The true dose to a construction worker on the RCRSA should be 2 to 440 times less than the doses calculated in this dose assessment.

E.1.8 Conclusions

The dose assessment demonstrates that the recommended corrective action alternative is highly dependent on the area of the contamination and the depth distribution of the Pu and Am in the surface soil. If the area of the contamination is significantly less than the 321 m², than the maximum dose will be significantly lower than the calculated dose. The concentration of Pu, Am, and U in the surface soil is anticipated to drop off significantly at a very shallow depth. If either of these assumptions are true, Alternative 1, the no action alternative, should be the recommended corrective action.

If the area of contamination is not significantly less than 321 m² or if the concentration of Pu and Am is not significantly reduced at depths just below the soil surface, then Alternative 2 should be recommended. However, the recommended corrective action is not entirely dependent on the output of the dose assessment. In addition, DOE Order 5400.5 requires that a cost risk benefit analysis for each corrective action alternative be performed. The risk assessment evaluates the risk to the workers performing the remediation and the risk to the workers and members of the public from transporting the waste to the disposal unit. The cost of each corrective alternative must be balanced against the risk incurred from the tasks associated with remediation and the risk reduction to the hypothetical future land users. The cost risk benefit analysis is to be performed in accordance with guidance published by DOE in *Applying the ALARA Process for Radiation Protection of the Public and Environmental Compliance with 10 CFR Parts 834 and DOE Order 5400.5 ALARA Program Requirements* (DOE, 1997).

E.2.0 References

AIHC, see American Industrial Health Council.

American Industrial Health Council. 1994. *Exposure Factors Sourcebook*. Washington, DC.

Bowen, J.L. 1997. *Analysis of Ambient Airborne Particulate Matter for Plutonium Clean Slate 1 During Excavation and Truck Loading Tonopah Test Range May, 1997 - June, 1997*, DRI Document 6357-683-7562.1D1. Reno, NV: Desert Research Institute.

CFR, see *Code of Federal Regulations*.

Calabrese, E.J., E.J. Stanek, III, C.E. Gilbert, and R.M. Barnes. 1990. "Preliminary Adult Soil Ingestion Estimates: Results of a Pilot Study." In *Regulatory Toxicology and Pharmacology*, 12:88-95.

Code of Federal Regulations. 1994. Title 10 CFR Part 830.120, "Quality Assurance Requirements." Washington, DC: U.S Government Printing Office.

Code of Federal Regulations. 1998. Title 10 CFR Part 20, "Standards for Protection Against Radiation." Washington, DC: U.S. Government Printing Office.

DOE, see U.S. Department of Energy.

Eckerman, K.F., A.B. Wolbarst, and C.B. Richardson. 1988. *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*, Federal Guidance Report No. 11. Oak Ridge, TN: Oak Ridge National Laboratory.

EPA, see U.S. Environmental Protection Agency.

Gilbert, T.L., C. Yu, Y.C. Yuan, A.J. Zieler, M.J. Jusko, and A. Wallo III. 1989. *A Manual for Implementing Residual Radioactive Material Guidelines: A Supplement to the U.S. Department of Energy Guidelines for Residual Radioactive Material at FUSRAP [Formerly Utilized Sites Remedial Action Program] Sites*, ANL/ES-160. Argonne, IL: Argonne National Laboratory.

ICRP, see International Commission on Radiological Protection.

International Commission on Radiological Protection. 1960. *Recommendation of the International Commission on Radiological Protection Report of Committee II on Permissible Dose for Internal Radiation (1959)*, Publication 2. Oxford, UK: Pergamon Press.

International Commission on Radiological Protection. 1979. *Limits for Intakes of Radionuclides by Workers*, Publication 30. Oxford, UK: Pergamon Press.

- International Commission on Radiological Protection. 1986. *The Metabolism of Plutonium and Related Elements*, Publication 48. Oxford, UK: Pergamon Press.
- Johnson, T.M., M. McCoy, J.E. Capel, L. Wijnberg, and W. Ollison. 1992. "A Comparison of Ten Time/Activity Databases: Effects of Geographic Location, Temperature, Demographic, Group, and Diary Recall Method." In *AWMA Conference Proceedings*.
- Layton, D.W. 1993. "Metabolically Consistent Breathing Rates for use in Dose Assessments." In *Health Phys.*, 64(1): 23-36.
- Lurman, F.W., M.J. St. Denis, A.M. Winer, and S.D. Colome. 1991. "Benzene Population Exposure in Southern California: Application of the REHEX Model." As submitted to Atmospheric Environment.
- NRC, see U.S. Nuclear Regulatory Commission.
- Perry, J.K. 1966. *Operation Roller Coaster Project Officers Report - Project 2.6d Special Particulate Analysis (Soil)*, Report POR-2509. Golden, CO: Colorado School of Mines Research Foundation, Inc.
- Shinn, J.H. 1994. Memorandum from J. H. Shinn to R. Smiecinski (U.S. Department of Energy) entitled, "Mass Loading Data from Tonopah Test Range," 14 September. Livermore, CA: Lawrence Livermore National Laboratory.
- Task Group on Lung Dynamics. 1966. "Deposition and Retention Models for Internal Dosimetry of the Human Respiratory Tract." In *Health Phys.*, 12 (2): 173 - 207.
- Taylor, L.S. 1984. The Tri-Partite Conference on Radiation Protection - Canada, United States (1949 - 1953), *U.S. DOE Report HVO-270 (DE 84016028)*. Washington, DC: U.S. Department of Energy, Office of Scientific and Technical Information.
- TGLD, see Task Group on Lung Dynamics.
- U.S. Department of Energy. 1993. *Radiation Protection of the Public and the Environment*, DOE Order 5400.5. Washington, DC.
- U.S. Department of Energy. 1997. *Applying the ALARA Process for Radiation Protection of the Public and Environmental Compliance with 10 CFR Part 834 and DOE 5400.5 ALARA Program Requirements*, Vols. 1 and 2, Draft. Washington, DC.
- U.S. Department of Energy. 1998. *Quality Assurance*, DOE Order 414.1. Washington, DC.
- U.S. Environmental Protection Agency. 1990. "Risk Assessment Guidance for Superfund," Vol. I, Human Health Evaluation Manual," Part A, OSWER Directive 9285.6-01. Washington, DC.

U.S. Environmental Protection Agency. 1991. "Risk Assessment Guidance for Superfund," Vol. I, Human Health Evaluation Manual, Supplemental Guidance - Standard Default Exposure Factors, OSWER Directive 9285.6-03. Washington, DC.

Wilson, R. H. 1968. *Operation Roller Coaster Project Officers Report - Project 4.1. Plutonium Intake by Animals Exposed to a Non-Nuclear Detonation of a Plutonium-Bearing Weapon Simulant*, POR-2512. Rochester, NY: University of Rochester Atomic Energy Project.

Yu, C., A.J. Zieler, J.-J. Cheng, Y.C. Yuan, L.G. Jones, D.J. LePoire, Y.Y. Wang, C.O. Loureiro, E. Enanapragasm, E. Faillace, A. Wallo III, W.A. Williams, and H. Peterson. 1993a. *Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil*, Publication ANL/EAIS-8. Argonne, IL: Argonne National Laboratory.

Yu, C., C. Loureiro, J.-J. Cheng, L.G. Jones, Y.Y. Wang, Y.P. Chia, and E. Faillace. 1993b. *Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD*, Version 5.0, ANL/EAD/LD-2. Argonne, IL: Argonne National Laboratory.

Attachment 1

Parameters Used in the Roller Coaster RADSAFE Area Dose/Corrective Action Level Calculations

Table 1
Parameter Values Used in the RESRAD Code for Calculating Dose to
Industrial and Construction Worker on the Roller Coaster RADS SAFE Area Site
(Page 1 of 6)

Parameter	Unit	RCRSA Scenario 1 Value	RCRSA Scenario 4 Value	RCRSA Scenario 6 Value	RCRSA Scenario 10 Value	RCRSA Scenario 12 Value	Source
Days on site per year Industrial worker Construction worker	d/yr	250 120	250 120	250 120	250 120	250 120	Conservative Assumption listed in DOE/NV, 1998.
Dose Limit	mrem/yr	25	25	25	25	25	10 CFR Part 20 Subpart D (CFR, 1998).
Dose conversion factors for inhalation	mrem/pCi						ICRP Publication 30 (ICRP, 1979) and ICRP Publication 48 (ICRP, 1986). The dose conversion factors for uranium and plutonium are from Federal Guidance Report #11, Class Y. For all other isotopes it is the RESRAD default value.
Ac-227+D		6.72E+0	6.72E+0	6.72E+0	6.72E+0	6.72E+0	
Am-241		4.44E-1	4.44E-1	4.44E-1	4.44E-1	4.44E-1	
Np-237+D		5.40E-1	5.40E-1	5.40E-1	5.40E-1	5.40E-1	
Pa-231		1.28E-0	1.28E-0	1.28E-0	1.28E-0	1.28E-0	
Pb-210+D		2.32E-2	2.32E-2	2.32E-2	2.32E-2	2.32E-2	
Pu-238		2.88E-1	2.88E-1	2.88E-1	2.88E-1	2.88E-1	
Pu-239		3.08E-1	3.08E-1	3.08E-1	3.08E-1	3.08E-1	
Pu-240		3.08E-1	3.08E-1	3.08E-1	3.08E-1	3.08E-1	
Pu-241+D		4.96E-3	4.96E-3	4.96E-3	4.96E-3	4.96E-3	
Pu-242		2.93E-1	2.93E-1	2.93E-1	2.93E-1	2.93E-1	
Ra-226+D		8.60E-3	8.60E-3	8.60E-3	8.60E-3	8.60E-3	
Ra-228+D		5.08E-3	5.08E-3	5.08E-3	5.08E-3	5.08E-3	
Th-228+D		3.45E-1	3.45E-1	3.45E-1	3.45E-1	3.45E-1	
Th-229+D		2.16E+0	2.16E+0	2.16E+0	2.16E+0	2.16E+0	
Th-230		3.26E-1	3.26E-1	3.26E-1	3.26E-1	3.26E-1	
Th-232		1.64E+0	1.64E+0	1.64E+0	1.64E+0	1.64E+0	
U-233		6.59E-1	6.59E-1	6.59E-1	6.59E-1	6.59E-1	
U-234		1.32E-1	1.32E-1	1.32E-1	1.32E-1	1.32E-1	
U-235+D		1.23E-1	1.23E-1	1.23E-1	1.23E-1	1.23E-1	
U-236		1.25E-1	1.25E-1	1.25E-1	1.25E-1	1.25E-1	
U-238+D		1.18E-1	1.18E-1	1.18E-1	1.18E-1	1.18E-1	

Table 1
Parameter Values Used in the RESRAD Code for Calculating Dose to
Industrial and Construction Worker on the Roller Coaster RADSAFE Area Site
(Page 2 of 6)

Parameter	Unit	RCRSA Scenario 1 Value	RCRSA Scenario 4 Value	RCRSA Scenario 6 Value	RCRSA Scenario 10 Value	RCRSA Scenario 12 Value	Source
Dose conversion factors for ingestion	mrem/pCi						ICRP Publication 30 (ICRP, 1979) and ICRP Publication 48 (ICRP, 1986). The dose conversion factors for uranium and plutonium are from Federal Guidance Report #11, Class Y. For all other isotopes it is the RESRAD default value.
Ac-227+D		1.48E-2	1.48E-2	1.48E-2	1.48E-2	1.48E-2	
Am-241		3.64E-3	3.64E-3	3.64E-3	3.64E-3	3.64E-3	
Np-237+D		4.44E-3	4.44E-3	4.44E-3	4.44E-3	4.44E-3	
Pa-231		1.06E-3	1.06E-3	1.06E-3	1.06E-3	1.06E-3	
Pb-210+D		6.85E-5	6.85E-5	6.85E-5	6.85E-5	6.85E-5	
Pu-238		4.96E-5	4.96E-5	4.96E-5	4.96E-5	4.96E-5	
Pu-239		5.18E-5	5.18E-5	5.18E-5	5.18E-5	5.18E-5	
Pu-240		5.18E-5	5.18E-5	5.18E-5	5.18E-5	5.18E-5	
Pu-241+D		7.66E-7	7.66E-7	7.66E-7	7.66E-7	7.66E-7	
Pu-242		4.92E-5	4.92E-5	4.92E-5	4.92E-5	4.92E-5	
Ra-226+D		1.33E-3	1.33E-3	1.33E-3	1.33E-3	1.33E-3	
Ra-228+D		1.44E-3	1.44E-3	1.44E-3	1.44E-3	1.44E-3	
Th-228+D		8.08E-4	8.08E-4	8.08E-4	8.08E-4	8.08E-4	
Th-229+D		4.03E-3	4.03E-3	4.03E-3	4.03E-3	4.03E-3	
Th-230		5.48E-4	5.48E-4	5.48E-4	5.48E-4	5.48E-4	
Th-232		2.73E-3	2.73E-3	2.73E-3	2.73E-3	2.73E-3	
U-233		2.65E-5	2.65E-5	2.65E-5	2.65E-5	2.65E-5	
U-234		2.61E-5	2.61E-5	2.61E-5	2.61E-5	2.61E-5	
U-235+D		2.67E-5	2.67E-5	2.67E-5	2.67E-5	2.67E-5	
U-236		2.47E-5	2.47E-5	2.47E-5	2.47E-5	2.47E-5	
U-238+D		2.38E-5	2.38E-5	2.38E-5	2.38E-5	2.38E-5	
Area of contaminated zone > 50pCi/g	m ²	3.21E+2	3.21E+2	3.21E+2	3.21E+2	3.21E+2	Calculated value. Based upon Fig. A.2-1 Sampling Locations, Draft CAU 407 CAIP and Figures 1-3 in Speer, 1999.
Thickness of contaminated zone	m	0.61	0.61	0.61	0.61	0.61	Assumes soil contamination to a depth of 0.46 m. Characterization measurements at RCRSA shows no contamination between surface and gravel/soil interface except at one point.
Time since placement of material	years	0	0	0	0	0	This conservative assumption, assumes no radioactive decay. As time since material placement is increased the concentration of the radionuclides decreases.
Times for calculation: 0, 1, 10, 50, 100, 250, 500, 1000, 5000, and 10000.	years	-	-	-	-	-	User input values to establish dose over the time frame of interest (i.e., 1000 years). However, with long half-life radionuclides such as plutonium, the relative difference in dose between time A and B is minimized.

Table 1
Parameter Values Used in the RESRAD Code for Calculating Dose to
Industrial and Construction Worker on the Roller Coaster RADS SAFE Area Site
 (Page 3 of 6)

Parameter	Unit	RCRSA Scenario 1 Value	RCRSA Scenario 4 Value	RCRSA Scenario 6 Value	RCRSA Scenario 10 Value	RCRSA Scenario 12 Value	Source
Radionuclide concentration in soil	pCi/g	<u>top 46 cm</u>					Calculated value based on RCRSA characterization data, the isotopic ratios in the Roller Coaster Tests source term, and dilution with various thicknesses of clean soil on the surface (Bechtel Nevada, 1996).
Am-241		<u>8.63E+2</u>	<u>7.69E+2</u>	<u>6.75E+2</u>	<u>4.88E+2</u>	<u>3.00E+2</u>	
Pu-238		<u>8.65E+1</u>	<u>7.70E+1</u>	<u>6.80E+1</u>	<u>4.90E+1</u>	<u>3.00E+1</u>	
Pu-239		<u>1.04E+4</u>	<u>9.32E+3</u>	<u>8.13E+3</u>	<u>5.91E+3</u>	<u>3.64E+3</u>	
Pu-240		<u>9.92E+2</u>	<u>8.84E+2</u>	<u>7.76E+2</u>	<u>5.60E+2</u>	<u>3.45E+2</u>	
Pu-241		<u>6.98E+3</u>	<u>4.19E+3</u>	<u>3.68E+3</u>	<u>2.66E+3</u>	<u>1.63E+3</u>	
45 -61 cm							
Am-241		<u>8.63E+2</u>	<u>8.63E+2</u>	<u>8.63E+2</u>	<u>8.63E+2</u>	<u>8.63E+2</u>	
Pu-238		<u>8.65E+1</u>	<u>8.65E+1</u>	<u>8.65E+1</u>	<u>8.65E+1</u>	<u>8.65E+1</u>	
Pu-239		<u>1.04E+4</u>	<u>1.04E+4</u>	<u>1.04E+4</u>	<u>1.04E+4</u>	<u>1.04E+4</u>	
Pu-240		<u>9.92E+2</u>	<u>9.92E+2</u>	<u>9.92E+2</u>	<u>9.92E+2</u>	<u>9.92E+2</u>	
Pu-241		<u>6.98E+3</u>	<u>6.98E+3</u>	<u>6.98E+3</u>	<u>6.98E+3</u>	<u>6.98E+3</u>	
Cover depth	m						Set of assumptions on future corrective actions.
Initial Cover Depth		0	0.05	0.10	0.20	0.40	
Final Cover Depth		0	0	0	0	0	
Density of contaminated, saturated, and unsaturated zone	g/cm ³	1.5	1.5	1.5	1.5	1.5	Bechtel Nevada, 1998.
Contamination zone erosion rate	m/yr	3.74E-4	3.74E-4	3.74E-4	3.74E-4	3.74E-4	Calculated value based on site specific data from Shinn et al., 1986.
Total porosity of contamination zone, unsaturated zone, and saturated zone	-	0.35	0.35	0.35	0.35	0.35	DOE/NV, 1997.
Effective porosity of the contaminated, unsaturated, and saturated zone	-	0.35	0.35	0.35	0.35	0.35	DOE/NV, 1997.
Hydraulic conductivity of the contaminated, unsaturated, and saturated zone	m/yr	1000	1000	1000	1000	1000	Yu et al. 1993 (Table 5.4, page 31).

Table 1
Parameter Values Used in the RESRAD Code for Calculating Dose to
Industrial and Construction Worker on the Roller Coaster RADSAFE Area Site
 (Page 4 of 6)

Parameter	Unit	RCRSA Scenario 1 Value	RCRSA Scenario 4 Value	RCRSA Scenario 6 Value	RCRSA Scenario 10 Value	RCRSA Scenario 12 Value	Source
Hydraulic gradient	-	1E-4	1E-4	1E-4	1E-4	1E-4	Wille, 1998a. Wille, 1998b.
"b" parameter of the contaminated, unsaturated, and saturated zone	-	4.05	4.05	4.05	4.05	4.05	Yu et al., 1993 (Table 13.1, value for sand).
Evapotranspiration coefficient	-	0.68	0.68	0.68	0.68	0.68	Calculated value. 1. Yu et al., 1993 (p. 72). 2. Culp and Howard, 1994 (p. 2-3).
Precipitation	m/yr	0.127	0.127	0.127	0.127	0.127	Culp and Howard, 1994 (p. 2-5).
Irrigation	m/yr	1.53	1.53	1.53	1.53	1.53	Calculated value. 1. Culp and Howard, 1994 (precipitation rate). 2. Yu et al., 1993 (p.68).
Irrigation mode	-	Ditch	Ditch	Ditch	Ditch	Ditch	RESRAD default. No agriculture exposure pathway, therefore this parameter has no effect on calculated doses.
Runoff coefficient	-	0.2	0.2	0.2	0.2	0.2	RESRAD default. Yu et al., 1993 (Page 66).
Watershed area for pond	m ²	321	321	321	321	321	Same as area of contamination. Surface water groundwater is not or expected to be a contamination median. Therefore, the contribution from groundwater and its pathways are zero, and the magnitude of the value present here does not effect the dose calculations.
Accuracy for water/soil computations	none	1.00E-3	1.00E-3	1.00E-3	1.00E-3	1.00E-3	Default RESRAD value having no bearing on direct exposures and air pathway exposure scenarios.
Well pumping rate	m ³ /yr	491	491	491	491	491	Calculated value, the product of the contaminated area times the irrigation rate.
Water table drop rate	m/yr	2.4E-3	2.4E-3	2.4E-3	2.4E-3	2.4E-3	Calculated value. DOE/NV, 1997 (Plate 3).
Well pump intake depth (below water table).	m	10	10	10	10	10	RESRAD default. Yu et al., 1993 (p. 86).

Table 1
Parameter Values Used in the RESRAD Code for Calculating Dose to
Industrial and Construction Worker on the Roller Coaster RADSAFE Area Site
 (Page 5 of 6)

Parameter	Unit	RCRSA Scenario 1 Value	RCRSA Scenario 4 Value	RCRSA Scenario 6 Value	RCRSA Scenario 10 Value	RCRSA Scenario 12 Value	Source
Model: nondispersion (ND) or mass balance (MB)	-	ND	ND	ND	ND	ND	RESRAD default. These models deal with how the on-site groundwater pathways are handled within the RESRAD code. Groundwater is not or expected to be a contamination median. Therefore, the contribution for groundwater and its pathways is zero.
Number of unsaturated zones	-	1	1	1	1	1	IT Corporation, 1996.
Unsaturated zone thickness	m	90	90	90	90	90	Calculated value. 1. DOE/NV, 1997. 2. Remote Sensing Laboratory, 1994.
Distribution coefficient (all zones)							Yu et al., 1993 (Table 32.1, Page 105; values for sand). For Am-241: Hansen, 1996.
Uranium isotopes	cm ³ /g	35	35	35	35	35	
Plutonium isotopes	cm ³ /g	550	550	550	550	550	
Americium isotopes	cm ³ /g	35	35	35	35	35	
Actinium isotopes	cm ³ /g	450	450	450	450	450	
Neptunium isotopes	cm ³ /g	5	5	5	5	5	
Protactinium isotopes	cm ³ /g	550	550	550	550	550	
Lead isotopes	cm ³ /g	270	270	270	270	270	
Radium isotopes	cm ³ /g	500	500	500	500	500	
Thorium isotopes	cm ³ /g	3200	3200	3200	3200	3200	
Inhalation rate	m ³ /yr						1. Layton, 1993. 2. Yu et al., 1993 (Page 124, reasonable worst-case).
Industrial worker		7.358E3	7.358E3	7.358E3	7.358E3	7.358E3	
Construction worker		1.28E4	1.28E4	1.28E4	1.28E4	1.28E4	
Mass loading for inhalation	g/m ³						Site specific data from: Shinn, 1994.
Industrial worker		1.36E-5	1.36E-5	1.36E-5	1.36E-5	1.36E-5	
Construction worker		4.08E-5	4.08E-5	4.08E-5	4.08E-5	4.08E-5	
Exposure duration	years	20	20	20	20	20	User assumption, has no effect on calculated dose.
Shielding factor, dust inhalation	-	0.4	0.4	0.4	0.4	0.4	RESRAD default. Yu et al., 1993 (Page 112).
Shielding factor, external gamma radiation	-	0.7	0.7	0.7	0.7	0.7	RESRAD default. Yu et al., 1993 (Page 129).

Table 1
Parameter Values Used in the RESRAD Code for Calculating Dose to
Industrial and Construction Worker on the Roller Coaster RADS SAFE Area Site
(Page 6 of 6)

Parameter	Unit	RCRSA Scenario 1 Value	RCRSA Scenario 4 Value	RCRSA Scenario 6 Value	RCRSA Scenario 10 Value	RCRSA Scenario 12 Value	Source
Fraction of time spent indoors Industrial worker Construction worker	-	0.1142 0.027397	0.1142 0.027397	0.1142 0.027397	0.1142 0.027397	0.1142 0.027397	Calculated value. Industrial worker, 4 hours/day, 250 days/year Construction worker, 2 hours/day, 120 days/year
Fraction of time spent outdoors (on site) Industrial worker Construction worker		0.1142 0.08219	0.1142 0.08219	0.1142 0.08219	0.1142 0.08219	0.1142 0.08219	Calculated value. Industrial worker, 4 hours/day, 250 days/year Construction worker, 6 hours/day, 120 days/year
Shape factor flag, external gamma	-	1	1	1	1	1	RESRAD default. Yu et al., 1993 (Page 133).
Soil ingestion rate RESRAD Input Industrial worker Construction worker	g/yr	10.95 175	10.95 175	10.95 175	10.95 175	10.95 175	RESRAD default. Yu et al., 1993 (Page 115). 0.2 g/d for Industrial Worker, twice the rate recommended by EPA, 0.48 g/d for construction worker, outdoor maximum recommended by EPA
Water ingestion rate RESRAD Input Industrial worker Construction worker	L/yr	250 500	250 500	250 500	250 500	250 500	2 L/d reasonable worst case water intake rate, >90 percentile for tap water in Roseberry and Burmaster (1992) referenced in <i>Exposure Factors Handbook</i> (AIHC, 1994)
Depth of soil mixing layer	m	0.46	0.46	0.46	0.46	0.46	DOE/NV, 1998.
Average annual wind speed (10 knots)	m/s	5.1	5.1	5.1	5.1	5.1	DOE/NV, 1998.
Summary of pathways selected external gamma inhalation milk ingestion plant ingestion meat ingestion aquatic drinking water soil ingestion radon	NA	Y Y N N N N Y Y Y	Y Y N N N N Y Y Y	Y Y N N N N Y Y Y	Y Y N N N N Y Y Y	Y Y N N N N Y Y Y	Scenario dependent.

^a Scenario specific data is noted in the parameter column. All other data is pertinent to all scenarios.

^b DT = Double Track Site; CS1, CS2, CS3 = Clean Slate Site 1,2,3; PR57 = Project 57 Site.

Attachment 1 References

AIHC, see American Industrial Health Council.

American Industrial Health Council. 1994. *Exposure Factors Sourcebook*. Washington, DC.

Bechtel Nevada. 1996. *In Situ Radiological Surveying at the Double Tracks Site*, DOE/NV/11718-013. Las Vegas, NV: Remote Sensing Laboratory.

Bechtel Nevada. 1998. *Clean Slate 2 and 3 Material Testing Laboratory Data*. Las Vegas, NV.

CFR, see *Code of Federal Regulations*.

Code of Federal Regulations. 1998. Title 10 CFR Part 20, "Standards for Protection Against Radiation." Washington, DC: U.S. Government Printing Office.

Culp, T., and D. Howard. 1994. *1993 Site Environmental Report Tonopah Test Range, Tonopah, Nevada*, SAND94-1292. Albuquerque, NM: Sandia National Laboratories.

Hansen, W. 1996. Personal communication to S.R. Adams (IT Corporation) entitled, "U.S. Department of Energy Headquarters Review/Lessons Learned for the Double Tracks Subproject," 17 October. Las Vegas, NV.

ICRP, see International Commission on Radiological Protection.

International Commission on Radiological Protection. 1979. *Limits for Intakes of Radionuclides by Workers*, Publication 30. Oxford, UK: Pergamon Press.

International Commission on Radiological Protection. 1986. *The Metabolism of Plutonium and Related Elements*, Publication 48. Oxford, UK: Pergamon Press.

IT Corporation. 1996. *Underground Test Area Subproject Phase I Data Analysis Task: Regional Geologic Model Data Documentation Package*, ITLV/10972-186. Las Vegas, NV.

Layton, D.W. 1993. "Metabolically Consistent Breathing Rates for Use in Dose Assessments." In *Health Physics*, 64(1): 23-26.

Remote Sensing Laboratory. 1994. *An Aerial Radiological Survey of the Tonopah Test Range*. Nellis Air Force Base, NV.

Shinn, J.H., D.N. Homan, and C.B. Hofmann. 1986. *A Summary of Plutonium Aerosol Studies: Resuspension at the Nevada Test Site*, UCRL-90746. Livermore, CA: Lawrence Livermore National Laboratory.

Shinn, J.H. 1994. Memorandum from J.H. Shinn to R. Smiecinski (U.S. Department of Energy) regarding, "Mass Loading Data from Tonopah Test Range," 14 September. Livermore, CA: Lawrence Livermore National Laboratory.

Speer, C.L. 1999. Letter from C.L. Speer to S.R. Adams (IT Corporation) regarding, "Transmittal of a Radiological Survey of CAU 407, CAS TA-23-001-TARC, Roller Coaster RADS SAFE Area." Las Vegas, NV: IT Corporation.

U.S. Department of Energy, Nevada Operations Office. 1997. *Regional Groundwater Flow and Tritium Transport Modeling and Risk Assessment of the Underground Test Area, Nevada Test Site, Nevada*, DOE/NV-477. Las Vegas, NV.

U.S. Department of Energy, Nevada Operations Office. 1998. Transmittal entitled, "*Soil Related Information, Attachment A: Air Force Land Uses*," 7 January. Las Vegas, NV.

Willie, L.E. 1998a. Memorandum entitled, "*Vertical Gradient in the Unsaturated Zone at the Clean Slate 1, 2, and 3 Sites*." Las Vegas, NV: IT Corporation.

Willie, L.E. 1998b. Memorandum entitled, "*Vertical Gradient in the Unsaturated Zone at the Project 57 Site*." Las Vegas, NV: IT Corporation.

Yu, C., A.J. Zieler, J.-J. Cheng, Y.C. Yuan, L.G. Jones, D.J. LePoire, Y.Y. Wang, C.O. Loureiro, E. Enanapragasm, E. Faillace, A. Wallo III, W.A. Williams, and H. Peterson. 1993. *Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil*, Publication ANL/EAIS-8. Argonne, IL: Argonne National Laboratory.

Attachment 2

Roller Coaster RADSAFE Area RESAD Input

Attachment 2. Part 2.
Roller Coaster RADSAFE Area
Construction Worker Scenario Doses

CAU 407 CADD
Appendix E
Revision: 0
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Maximum Annual Dose to a Construction Worker on the Roller Coaster RADSAFE Area (mrem/year)

Scenario #1 - No excavaton of Surface Contaminated Soil

Isotope	External	External	Inhalation		Soil		Water	TOTAL
	Exposure	Exposure	0 - 46 cm	46 - 61 cm	0 - 46 cm	45 - 61 cm	0- 61 cm	
Am-241	3.40E+00	1.33E-09	8.55E-01	0	1.93E+01	0	0	2.36E+01
Pu-238	1.26E-03	5.20E-10	5.60E-02	0	2.64E-02	0	0	8.36E-02
Pu-239	2.82E-01	2.14E-05	7.23E+00	0	3.33E+00	0	0	1.08E+01
P-240	1.40E-02	1.28E-09	6.84E-01	0	3.16E-01	0	0	1.01E+00
Pu-241	8.04E-03	1.47E-07	5.23E-02	0	2.21E-02	0	0	8.25E-02
TOTAL	3.70E+00	2.16E-05	8.88E+00	0	2.30E+01	0	0	3.56E+01

Scenario #1 Corrective Action Level for Total TRU = (25/35.6) x 12,309 =	8.65E+03 pCi/g
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Scenario #3 - Excavaton of 0.05 m of Surface Contaminated Soil, Replace with Clean Soil

Isotope	External	External	Inhalation		Soil		Water	TOTAL
	Exposure	Exposure	0 - 46 cm	46 - 61 cm	0 - 46 cm	45 - 61 cm	0- 61 cm	
Am-241	3.06E-01	1.33E-09	7.60E-01	0	1.72E+01	0	0	1.82E+01
Pu-238	9.04E-05	5.20E-10	4.97E-02	0	2.34E-02	0	0	7.33E-02
Pu-239	9.09E-02	2.14E-05	6.43E+00	0	2.96E+00	0	0	9.48E+00
P-240	8.59E-04	1.28E-09	6.08E-01	0	2.81E-01	0	0	8.90E-01
Pu-241	2.51E-03	1.47E-07	4.65E-02	0	1.97E-02	0	0	6.87E-02
TOTAL	4.00E-01	2.16E-05	7.89E+00	0	2.04E+01	0	0	2.87E+01

Scenario #3 Corrective Action Level for Total TRU = (25/28.7) x 12,309 =	1.07E+04 pCi/g
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Scenario #4 - Excavaton of 0.05 m of Surface Contaminated Soil, Replace with Clean Soil, and Mix to a Depth of 0.46 m

Isotope	External	External	Inhalation		Soil		Water	TOTAL
	Exposure	Exposure	0 - 46 cm	46 - 61 cm	0 - 46 cm	45 - 61 cm	0- 61 cm	
Am-241	3.03E+00	1.33E-09	7.62E-01	0	1.72E+01	0	0	2.10E+01
Pu-238	1.12E-03	5.20E-10	4.98E-02	0	2.35E-02	0	0	7.44E-02
Pu-239	2.52E-01	2.14E-05	6.45E+00	0	2.97E+00	0	0	9.66E+00
P-240	1.25E-02	1.28E-09	6.10E-01	0	2.81E-01	0	0	9.03E-01
Pu-241	7.17E-03	1.47E-07	4.67E-02	0	1.97E-02	0	0	7.35E-02
TOTAL	3.30E+00	2.16E-05	7.91E+00	0	2.05E+01	0	0	3.17E+01

Scenario #4 Corrective Action Level for Total TRU = [(25/31.7) x 10971]/.891=	9.71E+03 pCi/g
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Scenario #5 - Excavaton of 0.1 m of Surface Contaminated Soil, Replace with Clean Soil

Isotope	External	External	Inhalation		Soil		Water	TOTAL
	Exposure	Exposure	0 - 46 cm	46 - 61 cm	Ingestion	Ingestion	Ingestion	
	0 - 46 cm	46 - 61 cm	0 - 46 cm	46 - 61 cm	0 - 46 cm	45 - 61 cm	0- 61 cm	
Am-241	2.92E-02	1.33E-09	6.65E-01	0	1.50E+01	0	0	1.57E+01
Pu-238	2.08E-05	5.20E-10	4.35E-02	0	2.05E-02	0	0	6.40E-02
Pu-239	3.30E-02	2.14E-05	5.63E+00	0	2.59E+00	0	0	8.25E+00
P-240	1.67E-04	1.28E-09	5.32E-01	0	2.46E-01	0	0	7.78E-01
Pu-241	7.68E-04	1.47E-07	4.07E-02	0	1.72E-02	0	0	5.87E-02
TOTAL	6.32E-02	2.16E-05	6.91E+00	0	1.79E+01	0	0	2.49E+01

Scenario #5 Corrective Action Level for Total TRU = (25/24.9) x 12,309 =	1.24E+04 pCi/g
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Scenario #6 - Excavaton of 0.10 m of Surface Contaminated Soil, Replace with Clean Soil and Mix to a Depth of 0.46 m

Isotope	External	External	Inhalation		Soil		Water	TOTAL
	Exposure	Exposure	0 - 46 cm	46 - 61 cm	Ingestion	Ingestion	Ingestion	
	0 - 46 cm	46 - 61 cm	0 - 46 cm	46 - 61 cm	0 - 46 cm	45 - 61 cm	0- 61 cm	
Am-241	2.66E+00	1.33E-09	6.69E-01	0	1.51E+01	0	0	1.84E+01
Pu-238	9.93E-04	5.20E-10	4.40E-02	0	2.07E-02	0	0	6.57E-02
Pu-239	2.20E-01	2.14E-05	5.63E+00	0	2.59E+00	0	0	8.43E+00
P-240	1.10E-02	1.28E-09	5.35E-01	0	2.47E-01	0	0	7.93E-01
Pu-241	6.30E-03	1.47E-07	4.10E-02	0	1.73E-02	0	0	6.46E-02
TOTAL	2.90E+00	2.16E-05	6.91E+00	0	1.80E+01	0	0	2.78E+01

Scenario #6 Corrective Action Level for Total TRU = [(25/27.8) x 9583]/.783 =	1.10E+04 pCi/g
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Scenario #7 - Excavaton of 0.15 m of Surface Contaminated Soil, Replace with Clean Soil

Isotope	External	External	Inhalation		Soil		Water	TOTAL
	Exposure	Exposure	0 - 46 cm	46 - 61 cm	Ingestion	Ingestion	Ingestion	
	0 - 46 cm	46 - 61 cm	0 - 46 cm	46 - 61 cm	0 - 46 cm	45 - 61 cm	0- 61 cm	
Am-241	2.79E-03	1.33E-09	5.70E-01	0	1.29E+01	0	0	1.34E+01
Pu-238	4.78E-06	5.20E-10	3.73E-02	0	1.76E-02	0	0	5.49E-02
Pu-239	1.20E-02	2.14E-05	4.82E+00	0	2.22E+00	0	0	7.05E+00
P-240	3.26E-05	1.28E-09	4.56E-01	0	2.11E-01	0	0	6.67E-01
Pu-241	2.35E-04	1.47E-07	3.49E-02	0	1.47E-02	0	0	4.99E-02
TOTAL	1.51E-02	2.16E-05	5.92E+00	0	1.53E+01	0	0	2.13E+01

Scenario #7 Corrective Action Level for Total TRU = (25/21.3) x 12,309 =	1.45E+04 pCi/g
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Scenario #8 - Excavaton of 0.15 m of Surface Contaminated Soil, Replace with Clean Soil and Mix to a Depth of 0.46 m

Isotope	External	External	Inhalation		Soil		Water	TOTAL
	Exposure	Exposure	0 - 46 cm	46 - 61 cm	Ingestion	Ingestion	Ingestion	
	0 - 46 cm	46 - 61 cm	0 - 46 cm	46 - 61 cm	0 - 46 cm	45 - 61 cm	0- 61 cm	
Am-241	2.29E+00	1.33E-09	5.76E-01	0	1.30E+01	0	0	1.59E+01
Pu-238	8.47E-04	5.20E-10	3.75E-02	0	1.77E-02	0	0	5.60E-02
Pu-239	1.90E-01	2.14E-05	4.87E+00	0	2.24E+00	0	0	7.31E+00
P-240	9.45E-03	1.28E-09	4.61E-01	0	2.13E-01	0	0	6.83E-01
Pu-241	5.42E-03	1.47E-07	3.53E-02	0	1.49E-02	0	0	5.56E-02
TOTAL	2.49E+00	2.16E-05	5.98E+00	0	1.55E+01	0	0	2.40E+01

Scenario #8 Corrective Action Level for Total TRU = [(25/23.96) x 8294]/.674 =	1.28E+04 pCi/g
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Scenario #9 - Excavaton of 0.20 m of Surface Contaminated Soil, Replace with Clean Soil

Isotope	External	External	Inhalation		Soil		Water	TOTAL
	Exposure	Exposure	0 - 46 cm	46 - 61 cm	Ingestion	Ingestion	Ingestion	
Am-241	0 - 46 cm	46 - 61 cm	0 - 46 cm	46 - 61 cm	0 - 46 cm	45 - 61 cm	0- 61 cm	
Am-241	2.67E-04	1.33E-09	4.75E-01	0	1.07E+01	0	0	1.12E+01
Pu-238	1.10E-06	5.20E-10	3.11E-02	0	1.46E-02	0	0	4.57E-02
Pu-239	4.36E-03	2.14E-05	4.02E+00	0	1.85E+00	0	0	5.87E+00
P-240	6.36E-06	1.28E-09	3.80E-01	0	1.75E-01	0	0	5.55E-01
Pu-241	7.18E-05	1.47E-07	2.91E-02	0	1.23E-02	0	0	4.14E-02
TOTAL	4.70E-03	2.16E-05	4.93E+00	0	1.28E+01	0	0	1.77E+01

Scenario #9 Corrective Action Level = (25 mre/yr)/ 17.71) x 12309 pCi/g =	1.74E+04 pCi/g
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Scenario #10 - Excavaton of 0.20 m of Surface Contaminated Soil, Replace with Clean Soil and Mix to a Depth of 0.46 m

Isotope	External	External	Inhalation		Soil		Water	TOTAL
	Exposure	Exposure	0 - 46 cm	46 - 61 cm	Ingestion	Ingestion	Ingestion	
Am-241	0 - 46 cm	46 - 61 cm	0 - 46 cm	46 - 61 cm	0 - 46 cm	45 - 61 cm	0- 61 cm	
Am-241	1.92E+00	1.33E-09	4.83E-01	0	1.09E+01	0	0	1.33E+01
Pu-238	7.15E-04	5.20E-10	3.17E-02	0	1.49E-02	0	0	4.73E-02
Pu-239	1.60E-01	2.14E-05	4.09E+00	0	1.88E+00	0	0	6.13E+00
P-240	7.92E-03	1.28E-09	3.86E-01	0	1.78E-01	0	0	5.72E-01
Pu-241	4.55E-03	1.47E-07	2.96E-02	0	1.25E-02	0	0	4.66E-02
TOTAL	2.09E+00	2.16E-05	5.02E+00	0	1.30E+01	0	0	2.01E+01

Scenario #10 Corrective Action Level for Total TRU = [(25/20.11) x 6957]/.566 =	1.53E+04 pCi/g
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Scenario #11 - Excavaton of 0.30 m of Surface Contaminated Soil, Replace with Clean Soil

Isotope	External	External	Inhalation		Soil		Water	TOTAL
	Exposure	Exposure	0 - 46 cm	46 - 61 cm	Ingestion	Ingestion	Ingestion	
	0 - 46 cm	46 - 61 cm	0 - 46 cm	46 - 61 cm	0 - 46 cm	45 - 61 cm	0- 61 cm	
Am-241	2.44E-06	1.33E-09	2.85E-01	0	6.43E+00	0	0	6.72E+00
Pu-238	5.81E-08	5.20E-10	1.87E-02	0	8.79E-03	0	0	2.74E-02
Pu-239	5.74E-04	2.14E-05	2.41E+00	0	1.11E+00	0	0	3.52E+00
P-240	2.42E-07	1.28E-09	2.28E-01	0	1.05E-01	0	0	3.33E-01
Pu-241	6.71E-06	1.47E-07	1.75E-02	0	7.37E-03	0	0	2.48E-02
TOTAL	5.83E-04	2.16E-05	2.96E+00	0	7.66E+00	0	0	1.06E+01

Scenario #11 Corrective Action Level = (25 mre/yr)/ 10.62) x 12309 pCi/g =	2.90E+04 pCi/g
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Scenario #12 - Excavaton of 0.3 m of Surface Contaminated Soil, Replace with Clean Soil and Mix to a Depth of 0.46 m

Isotope	External	External	Inhalation		Soil		Water	TOTAL
	Exposure	Exposure	0 - 46 cm	46 - 61 cm	Ingestion	Ingestion	Ingestion	
	0 - 46 cm	46 - 61 cm	0 - 46 cm	46 - 61 cm	0 - 46 cm	45 - 61 cm	0- 61 cm	
Am-241	1.18E+00	1.33E-09	2.97E-01	0	6.71E+00	0	0	8.19E+00
Pu-238	4.38E-04	5.20E-10	1.94E-02	0	9.14E-03	0	0	2.90E-02
Pu-239	9.82E-02	2.14E-05	2.52E+00	0	1.16E+00	0	0	3.77E+00
P-240	4.88E-03	1.28E-09	2.38E-01	0	1.10E-01	0	0	3.53E-01
Pu-241	2.80E-03	1.47E-07	1.82E-02	0	7.69E-03	0	0	2.87E-02
TOTAL	1.29E+00	2.16E-05	3.09E+00	0	7.99E+00	0	0	1.24E+01

Scenario #12 Corrective Action Level for Total TRU = [(25/12.37) x 4281]/.348 =	2.49E+04 pCi/g
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Scenario #13 - Excavaton of 0.4 m of Surface Contaminated Soil, Replace with Clean Soil

Isotope	External	External	Inhalation		Soil		Water	TOTAL
	Exposure	Exposure	0 - 46 cm	46 - 61 cm	Ingestion	Ingestion	Ingestion	
	0 - 46 cm	46 - 61 cm	0 - 46 cm	46 - 61 cm	0 - 46 cm	45 - 61 cm	0- 61 cm	
Am-241	2.23E-08	1.33E-09	9.50E-02	0	2.14E+00	0	0	2.24E+00
Pu-238	3.07E-09	5.20E-10	6.22E-03	0	2.93E-03	0	0	9.15E-03
Pu-239	7.48E-05	2.14E-05	8.04E-01	0	3.70E-01	0	0	1.17E+00
P-240	9.18E-09	1.28E-09	7.60E-02	0	3.51E-02	0	0	1.11E-01
Pu-241	6.23E-07	1.47E-07	5.82E-03	0	2.46E-03	0	0	8.27E-03
TOTAL	7.55E-05	2.16E-05	9.87E-01	0	2.55E+00	0	0	3.54E+00

Scenario #13 Corrective Action Level = (25 mre/yr/3.541) x 12309 pCi/g =	8.69E+04 pCi/g
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Scenario #14 - Excavaton of 0.4 m of Surface Contaminated Soil, Replace with Clean Soil and Mix to a Depth of 0.46 m

Isotope	External	External	Inhalation		Soil		Water	TOTAL
	Exposure	Exposure	0 - 46 cm	46 - 61 cm	Ingestion	Ingestion	Ingestion	
	0 - 46 cm	46 - 61 cm	0 - 46 cm	46 - 61 cm	0 - 46 cm	45 - 61 cm	0- 61 cm	
Am-241	4.45E-01	1.33E-09	1.12E-01	0	2.53E+00	0	0	3.08E+00
Pu-238	1.61E-04	5.20E-10	7.12E-03	0	3.35E-03	0	0	1.06E-02
Pu-239	3.68E-02	2.14E-05	9.44E-01	0	4.34E-01	0	0	1.41E+00
P-240	1.83E-03	1.28E-09	8.90E-02	0	4.11E-02	0	0	1.32E-01
Pu-241	1.05E-03	1.47E-07	6.83E-03	0	2.89E-03	0	0	1.08E-02
TOTAL	4.85E-01	2.16E-05	1.16E+00	0	3.01E+00	0	0	4.65E+00

Scenario #14 Corrective Action Level for Total TRU = [(25/4.652) x 1606]/.13 =	6.64E+04 pCi/g
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Scenario #15 - Excavaton of 0.46 m of Surface Contaminated Soil, Replace with Clean Soil Dose in year 0, the year of maximum dose for all other Scenarios

Isotope	External	Soil		Water	TOTAL
	Exposure	Inhalation	Ingestion	Ingestion	
	46 - 61 cm	46 - 61 cm	45 - 61 cm	0- 61 cm	
Am-241	1.33E-09	0	0	0	1.33E-09
Pu-238	5.20E-10	0	0	0	5.20E-10
Pu-239	2.14E-05	0	0	0	2.14E-05
P-240	1.28E-09	0	0	0	1.28E-09
Pu-241	1.42E-07	0	0	0	1.42E-07
TOTAL	2.16E-05	0	0	0	2.16E-05

Scenario #15 Corrective Action Level = (25 mre/yr/2.16E-5) x 12309 pCi/g =	1.43E+10 pCi/g
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**Scenario #16 - Excavaton of .46 m of Surface Contaminated Soil, Replace with Clean Soil
Dose in year 261.5, the year of maximum dose for Scenario #15**

Isotope	External	Soil		Water	TOTAL
	Exposure	Inhalation	Ingestion	Ingestion	
	46 - 61 cm	46 - 61 cm	45 - 61 cm	0- 61 cm	
Am-241	1.84E-14	3.44E-09	7.75E-08	0	8.09E-08
Pu-238	1.54E-09	4.59E-04	2.16E-04	0	6.75E-04
Pu-239	5.12E-05	4.46E-01	2.14E-01	0	6.60E-01
P-240	1.01E-08	4.31E-02	1.99E-02	0	6.30E-02
Pu-241	1.83E-08	1.17E-07	2.39E-06	0	2.53E-06
TOTAL	5.12E-05	4.90E-01	2.34E-01	0	7.24E-01

Scenario #16 Corrective Action Level = (25 mre/yr/.724) x 12309 pCi/g =	4.25E+05 pCi/g
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Scenario #17 - Same as Scenario #1 Except there is a 0.762 m (2.5 feet) engineered cap over the site. Dose in year 0 is 1.994E-9 mrem/year. Listed below is the dose in the maximum year, 762 years, dose = 5.235 mrem/year

Isotope	External	Soil		Water	TOTAL
	Exposure	Inhalation	Ingestion	Ingestion	
	0 - 61 cm	0 - 61 cm	0 - 61 cm	0- 61 cm	
Am-241	4.19E-06	1.05E-06	2.38E-05	0	2.90E-05
Pu-238	3.67E-06	6.16E-05	2.91E-05	0	9.44E-05
Pu-239	1.25E-01	3.21E+00	1.48E+00	0	4.81E+00
P-240	5.87E-03	2.86E-01	1.32E-01	0	4.24E-01
Pu-241	1.17E-06	2.94E-07	6.63E-06	0	8.10E-06
TOTAL	1.31E-01	3.50E+00	1.61E+00	0	5.23E+00

Scenario #17 Corrective Action Level = (25 mre/yr/5.23) x 12309 pCi/g =	5.88E+04 pCi/g
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Scenario #18 - Same as Scenario #7 Except there is a 0.762 m (2.5 feet) engineered cap over the site. Dose in year 0 is 9.554E-11 mrem/year. Listed below is the dose in the maximum year, 1928 years, dose = 0.4478 mrem/year

Isotope	External	Soil		Water	TOTAL
	Exposure	Inhalation	Ingestion	Ingestion	
	0 - 61 cm	0 - 61 cm	0 - 61 cm	0- 61 cm	
Am-241	4.98E-12	2.39E-12	1.22E-11	7.42E-03	7.42E-03
Pu-238	1.69E-07	3.63E-09	2.26E-08	0.00E+00	1.95E-07
Pu-239	3.50E-04	2.78E-01	1.28E-01	0.00E+00	4.06E-01
P-240	4.93E-07	2.26E-02	1.05E-02	0.00E+00	3.31E-02
Pu-241	8.84E-09	4.24E-13	2.16E-12	1.39E-03	1.39E-03
TOTAL	3.50E-04	3.00E-01	1.38E-01	8.81E-03	4.48E-01

Scenario #18 Corrective Action Level = (25 mre/yr/.448) x 12309 pCi/g =	6.87E+05 pCi/g
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Radiological Source Terms for Construction Worker

Average Concentration After Excavation, Replacing Excavated Soil with Clean Soil, and Mixing to a Depth of 0.46 meters (pCi/g)						
0.0 m	0.05 m	0.1 m	0.15 m	0.2 m	0.3	0.4 m
1.000	0.891	0.783	0.674	0.565	0.348	0.130

Isotope	Concentration After Mixing to .46 m with Clean Cover Depth (meters)						
	0	0.05	0.1	0.15	0.2	0.3	0.4
Am-241	863.00	769.00	675.00	581.00	488.00	300.00	113.00
Pu-238	86.50	77.00	68.00	58.00	49.00	30.00	11.00
Pu-239	10454.00	9318.00	8132.00	7045.00	5909.00	3636.00	1364.00
Pu-240	992.00	884.00	776.00	668.00	560.00	345.00	129.00
Pu-241	4698.00	4187.00	3677.00	3166.00	2655.00	1634.00	613.00
Total Dose to Worker =	35.58	31.70	27.50	23.96	20.11	12.37	4.65
Fraction of 25 mrem/yr =	1.42	1.27	1.10	0.96	0.80	0.49	0.19
Source Term Multiplier =	0.70	0.79	0.91	1.04	1.24	2.02	5.37

Isotope	Source Term (pCi/g) Required to Obtain 25 mrem/year for Initial Depth of Clean Cover (m)							
	0	0.05	0.1	0.15	0.2	0.3	0.4	0.46
Am-241	6.06E+02	6.06E+02	6.14E+02	6.06E+02	6.07E+02	6.06E+02	6.07E+02	9.99E+08
Pu-238	6.08E+01	6.07E+01	6.18E+01	6.05E+01	6.09E+01	6.06E+01	5.91E+01	1.00E+08
Pu-239	7.35E+03	7.35E+03	7.39E+03	7.35E+03	7.35E+03	7.35E+03	7.33E+03	1.21E+10
Pu-240	6.97E+02	6.97E+02	7.05E+02	6.97E+02	6.96E+02	6.97E+02	6.93E+02	1.15E+09
Pu-241	3.30E+03	3.30E+03	3.34E+03	3.30E+03	3.30E+03	3.30E+03	3.29E+03	5.44E+09
Total TRU	8.65E+03	8.65E+03	8.71E+03	8.65E+03	8.65E+03	8.65E+03	8.63E+03	1.42E+10

Note - Total TRU is defined by Bechtel Nevada Remote Sensing Laboratory as the concentration of the Am-241 + Pu-239 + Pu-240

For all depths less than the soil mixing depth of 0.46 m, the source term is uniformly mixed in the top 0.46 m. However, when the source term is below the mixing layer, none of the radiological source term is brought closer to the surface.

Attachment 2. Part 1.
 Roller Coaster RADSAF Area
 Radiological Source Terms for RESRAD Input

Total TRU Concentration in soil, after mixing to 0.46 m, that will result in 25 mrem/yr to a Construction Worker, as a Function of the Depth of Clean Cover Applied Prior to Mixing,	
Depth of Clean Cover (m)	Total TRU Concentration (pCi/g)
0	8.649E+03
0.05	8.652E+03
0.1	8.712E+03
0.15	8.654E+03
0.2	8.649E+03
0.3	8.649E+03
0.4	8.631E+03

Note - Initial Depth of Contamination is assumed to be 0.61 m

Dose to Construction Worker With .46 m of Soil Excavated and Replaced with Clean Soil (mrem/year)		
Isotope	Concentration (pCi/g)	Dose (mrem/yr)
Am-241	863	8.090E-08
Pu-238	86.5	6.756E-04
Pu-239	10454	6.787E-01
Pu-240	992	6.297E-02
Pu-241	4698	2.509E-06
Total TRU	12309	7.42E-01
Total Dose to Worker =		7.42E-01
Fraction of 25 mrem/yr =		2.97E-02
Source Term Multiplier =		3.37E+01
Total TRU for 25 mrem/yr =		4.15E+05

Note - Initial Depth of Contamination is assumed to be 0.61 m

Attachment 2. Part 1.
 Roller Coaster RADSAF Area
 Radiological Source Terms for RESRAD Input

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The Initial Source Term (pCi/g), from the soil surface to 0.61 m and prior to mixing to 0.45 m, that will result in 25 mrem/yr to the Construction Worker after the Soil is mixed to a depth of 0.46 m							
Thickness of Clean Soil Cover Prior to Soil Mixing (m)							
Isotope	0	0.05	0.1	0.15	0.2	0.3	0.4
Am-241	6.06E+02	6.80E+02	7.84E+02	9.00E+02	1.07E+03	1.74E+03	4.66E+03
Pu-238	6.08E+01	6.81E+01	7.90E+01	8.98E+01	1.08E+02	1.74E+02	4.53E+02
Pu-239	7.30E+03	8.24E+03	9.45E+03	1.09E+04	1.30E+04	2.11E+04	5.62E+04
Pu-240	7.00E+02	7.82E+02	9.01E+02	1.03E+03	1.23E+03	2.00E+03	5.31E+03
Pu-241	3.30E+03	3.70E+03	4.27E+03	4.90E+03	5.84E+03	9.49E+03	2.53E+04
Total TRU	8.61E+03	9.71E+03	1.11E+04	1.28E+04	1.53E+04	2.49E+04	6.62E+04

If no soil is excavated, then a Total TRU concentration of 8,610 pCi/g will result in 25 mrem/year to the construction worker after the soil is mixed to a depth of 0.45 m

If the soil is excavated to a depth of 0.05 m (2 inches) then a Total TRU concentration of 9,710 pCi/g will result in 25 mrem/yr to the construction worker after the soil is mixed to a depth of 0.45 m

If the soil is excavated to a depth of 0.1 m (4 inches) then a Total TRU concentration of 11,100 pCi/g will result in 25 mrem/yr to the construction worker after the soil is mixed to a depth of 0.45 m

If the soil is excavated to a depth of 0.15 m (6 inches) then a Total TRU concentration of 12,800 pCi/g will result in 25 mrem/yr to the construction worker after the soil is mixed to a depth of 0.45 m

If the soil is excavated to a depth of 0.2 m (8 inches) then a Total TRU concentration of 15,300 pCi/g will result in 25 mrem/yr to the construction worker after the soil is mixed to a depth of 0.45 m however, the initial Total TRU concentration is only 12,309 pCi/g. Therefore, any excavation beyond 6 inches will result in less than 25 mrem/yr to the construction worker.

Attachment 2. Part 1.
Roller Coaster RADSAF Area
Radiological Source Terms for RESRAD Input

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Initial Concentration (pCi/g) required to give 25 mrem/year to the Construction Worker after the top 0.46 m of the soil is mixed, as a function of the depth of the initial radioactive contamination (meters)						
Isotope	Depth of the Initial Radioactive Contamination (meters)					
	0.05	0.10	0.15	0.20	0.30	0.40
Am-241	5.56E+03	2.79E+03	1.85E+03	1.39E+03	9.27E+02	6.95E+02
Pu-238	5.57E+02	2.80E+02	1.86E+02	1.39E+02	9.29E+01	6.96E+01
Pu-239	6.74E+04	3.39E+04	2.25E+04	1.69E+04	1.12E+04	8.43E+03
Pu-240	6.40E+03	3.21E+03	2.13E+03	1.60E+03	1.07E+03	7.99E+02
Pu-241	3.03E+04	1.52E+04	1.01E+04	7.57E+03	5.05E+03	3.79E+03
Total TRU	7.94E+04	3.99E+04	2.65E+04	1.98E+04	1.32E+04	9.92E+03

If the Total TRU concentration is 12,309 pCi/g then the thickness of the contamination has to exceed 0.30 meters (1 foot) before the dose to the construction worker will exceed 25 mrem/year

If the total TRU contamination at the RCRSA is 0.05 m (2 inches) thick, its concentration has to exceed 79,400 pCi/g before the dose to the construction worker will exceed 25 mrem/year

If the total TRU contamination at the RCRSA is 0.1 m (4 inches) thick, its concentration has to exceed 39,900 pCi/g before the dose to the construction worker will exceed 25 mrem/year

If the total TRU contamination at the RCRSA is 0.15 m (6 inches) thick, its concentration has to exceed 26,500 pCi/g before the dose to the construction worker will exceed 25 mrem/year

If the total TRU contamination at the RCRSA is 0.2 m (8 inches) thick, its concentration has to exceed 19,800 pCi/g before the dose to the construction worker will exceed 25 mrem/year

If the total TRU contamination at the RCRSA is 0.3 m (1 foot) thick, its concentration has to exceed 13,200 pCi/g before the dose to the construction worker will exceed 25 mrem/year

If the total TRU contamination at the RCRSA is 0.4 m (16 inches) thick, its concentration has to exceed 9,920 pCi/g before the dose to the construction worker will exceed 25 mrem/year

Appendix F

Roller Coaster RADSAFE Area ALARA Analysis

The as low as is reasonably achievable (ALARA) analysis has been conducted for corrective actions identified at the Roller Coaster RADSAFE Area (RCRSA), Corrective Action Unit (CAU) 407. The ALARA analysis includes calculating the radiological dose to the identified hypothetical future land users and the radiological and occupational risk to the general public and remediation workers during corrective actions along with the costs associated with the corrective actions. The goal of the ALARA analysis is to identify the corrective action alternative (CAA) that has the greatest positive net benefit (or least net negative benefit) after its completion.

Safety shot experiments were conducted at Clean Slate 1, 2, and 3 in 1963. These experiments resulted in the contamination of near-surface soil at those sites with plutonium and americium. The RCRSA was used to decontaminate vehicles, equipment, and individuals participating in the Clean Slate experiments. In addition, radiologically contaminated trash and the Double Tracks baseplate was disposed in a waste pit at the RCRSA. Site characterizations were completed at the RCRSA in 1998. Data obtained during site characterization were used extensively in the ALARA analysis. In addition, data and experience gained in the 1995 Double Tracks characterization and 1996 interim corrective action were used in the ALARA analysis when appropriate.

The RCRSA Corrective Action Decision Document identified and evaluated five CAAs. These CAAs are:

- The no further action alternative
- Soil excavation to a depth sufficient to ensure the hypothetical future land user does not receive a dose exceeding 25 millirem per year (mrem/yr), loading and transporting the contaminated soil to the Nevada Test Site (NTS) for disposal, and replacement of the contaminated soil volume with clean soil
- Excavation of the surface contaminated soil, loading and transporting the contaminated soil to the Nevada Test Site (NTS) for disposal, and placement of an engineered cover over the RCRSA
- Clean closure by excavation, screening of the soil, separating the contaminated and noncontaminated soil, replacement of contaminated soil volume with clean soil, and loading and transporting the contaminated soil to the NTS for disposal
- Clean closure by excavation of the gravel/soil mixture to the native soil boundary, replacement of the contaminated soil volume with clean soil, and loading and transporting the contaminated soil to the Nevada Test Site (NTS) for disposal

The ALARA analysis consists of four parts:

- Dose calculations used to determine the dose to the hypothetical future land-use scenario individual for various CALs

- Dose and risk calculations used to determine the risk associated with conducting the corrective action activities at the site for the various CALs
- Cost to complete the four corrective action alternatives plus the no further action CAA
- Comparing and evaluating the results from the first three parts to arrive at the CAA that provided the greatest net benefit, or least net negative benefit.

Based on the results from the ALARA analysis, the no further action has the least negative benefit. However, the U. S. Department of Energy has agreed that corrective actions be performed. The CAA chosen is the excavation of the surface contaminated soil, loading and transporting the contaminated soil to the Nevada Test Site (NTS) for disposal, and placement of an engineered cover over the RCRSA.

Appendix G
NDEP Comment Review Sheets

NEVADA ENVIRONMENTAL RESTORATION PROJECT
DOCUMENT REVIEW SHEET
(Page 1 of 1)

1. Document Title/Number: Corrective Action Decision Document for Corrective Action Unit 407: Roller Coaster RADSAFE Area, TTR, Nevada			2. Document Date: August 1999	
3. Revision Number: Draft Rev. 0			4. Originator/Organization: IT Corporation	
5. Responsible DOE/NV ERP Subproject Mgr.: Janet Appenzeller-Wing			6. Date Comments Due:	
7. Review Criteria: Full				
8. Reviewer/Organization/Phone No.: Michael D. McKinnon, NDEP, 486-2874			9. Reviewer's Signature:	
10. Comment Number/ Location	11. Type*	12. Comment	13. Comment Response	14. Accept
1) Section 2.2, Page 7, Last Bullet		<i>"...The geologic and geotechnical results revealed that the soil beneath the RCRSA is comprised of sand with discontinuous gravel lenses with a low migration potential..."</i> NDEP is unsure of the intent of this statement. Does it mean the sand and gravel will not migrate? Does it mean that contaminants in this medium will not migrate? If the latter is intended, with sand and gravel being highly permeable, the statement does not make sense.	The intent was to indicate that the COCs will not migrate. The text "with a low migration potential." was deleted.	Yes

^a Comment Types: M = Mandatory, S = Suggested.

Return Document Review Sheets to DOE/NV Environmental Restoration Division, Attn: QAC, M/S 505.

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