Sandia National Laboratories/New Mexico

PROPOSAL FOR RISK-BASED NO FURTHER ACTION ENVIRONMENTAL RESTORATION SITE 193 SABOTAGE TEST AREA OPERABLE UNIT 1335

August 1997

Environmental Restoration Project

United States Department of Energy
Albuquerque Operations Office

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ENVIRONMENTAL RESTORATION SITE 193
SABOTAGE TEST AREA
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Prepared by
Sandia National Laboratories/New Mexico
Environmental Restoration Project
Albuquerque, New Mexico

Prepared for
the U. S. Department of Energy

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ACRONYMS AND ABBREVIATIONS

CEARP	Comprehensive Environmental Assessment and Response Program
Co-60	Cobalt 60
COC	constituents of concern
COPEC	constituents of potential ecological concern
Cs-137	Cesium 137
DoD	Department of Defense
DOU	Document of Understanding
DU	depleted uranium
EPA	U.S. Department of Energy
ER	Environmental Restoration
HE	high explosives
HMX	octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HQ	hazard quotient(s)
HSWA	Hazardous and Solid Waste Amendments
KAFB	Kirtland Air Force Base
LAS	Lockheed Analytical Services
μR	microrem
mg/kg	milligram(s) per kilogram
mrem	millirem
NFA	no further action
OU	Operable Unit
pCi/g	picocurie(s) per gram
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
RME	reasonable maximum exposure
SMO	Sample Management Office
SNL/NM	Sandia National Laboratories/New Mexico
TAL	Target Analyte List
TEDE	total effective dose equivalent
TNT	trinitrotoluene
U-238	Uranium 238
UO_2	uranium oxide
UXO	unexploded ordnance
VCM	voluntary corrective measure

1.0 INTRODUCTION

1.1 Description of ER Site 193

Environmental Restoration (ER) Site 193, known as the Sabotage Test Area and part of Operable Unit (OU) 1335, is listed in the Hazardous and Solid Waste Amendments (HSWA) Module IV (EPA August 1993) of the Sandia National Laboratories/New Mexico (SNL/NM) Resource Conservation and Recovery Act (RCRA) Hazardous Waste Management Facility Permit (NM5890110518-1) (EPA 1992).

The Sabotage Test Area is located near the southwestern corner of Kirtland Air Force Base (KAFB), within the triangle formed by Magazine Road, Isleta Road, and University Ranch Road (Figures 1 and 2). The site occupies approximately 0.6 acres in South Thunder Range and is located southwest of Building 9964, the former control bunker for the site. Figure 3 is an aerial photograph of the Sabotage Test Area around Building 9964.

The Sabotage Test Area is essentially flat, with a very slight slope to the west. The surficial geology at the site is characterized by a veneer of aeolian sediments that are underlain by alluvial fan or alluvial deposits. Based on drilling records of similar deposits at KAFB, the alluvial materials are highly heterogeneous, composed primarily of medium to fine silty sands with frequent coarse sand, gravel, and cobble lenses, and probably extend to the water table. Depth to groundwater at the site is approximately 350 feet below ground surface. Local groundwater flow is generally to the west/northwest. The nearest production well, KAFB-4, is located approximately 5.5 miles to the north of the site. The nearest groundwater monitor well is TRE-1, which is located approximately 1,400 feet east of the site (SNL/NM August 1996).

Vegetation consists predominantly of grasses including grama, muhly, dropseed, and galleta. Shrubs commonly associated with the grasslands include sand sage, winter fat, saltbrush, and rabbitbush. Cacti are common, and include cholla, pincushion, strawberry, and prickly pear.

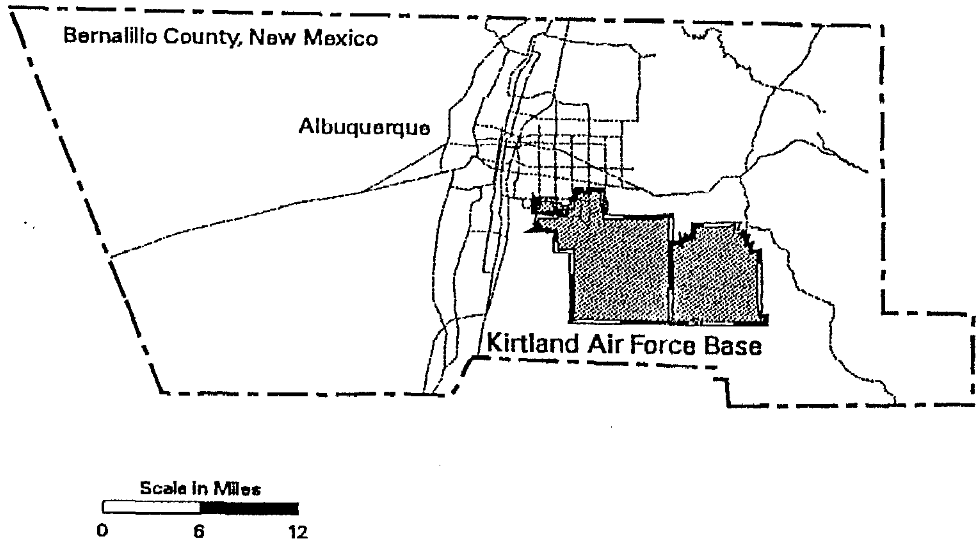
For a more detailed discussion regarding the local setting at ER Site 193, refer to the Draft RCRA Facility Investigation (RFI) Work Plan for OU 1335, Southwest Test Area (SNL/NM March 1996).

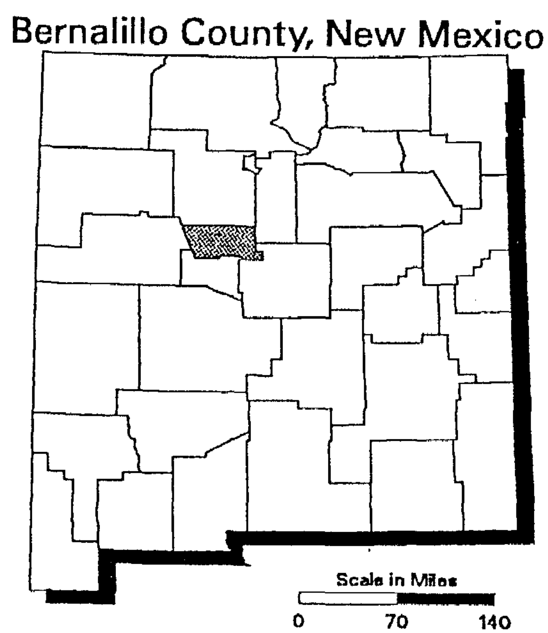
1.2 No Further Action Basis

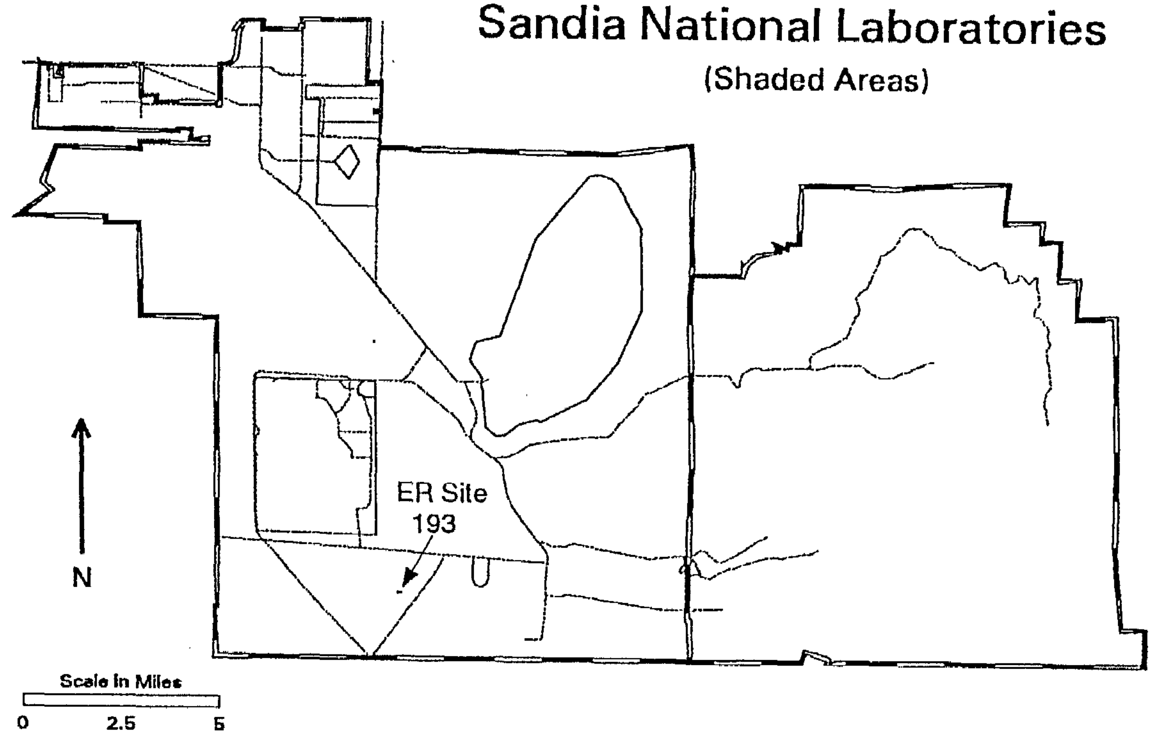
Review and analysis of the ER Site 193 soil sample analytical data indicate that concentrations and activities of constituents of concern (COC) detected in soils at this site are less than (1) SNL/NM or other applicable background concentrations, or (2) proposed subparts or other action levels, or (3) derived risk assessment action levels. Thus, ER Site 193 is being proposed for a no further action (NFA) decision based on voluntary corrective measures (VCM) verification and confirmatory sampling data and risk assessment demonstrating that COCs that may have been released from the site into the environment pose an acceptable level of risk

SNL EGIS DEPT 6682 DAHelfrich GIS MAP-ID = 970076 nmloc_dh.aml 18-NOV-1996

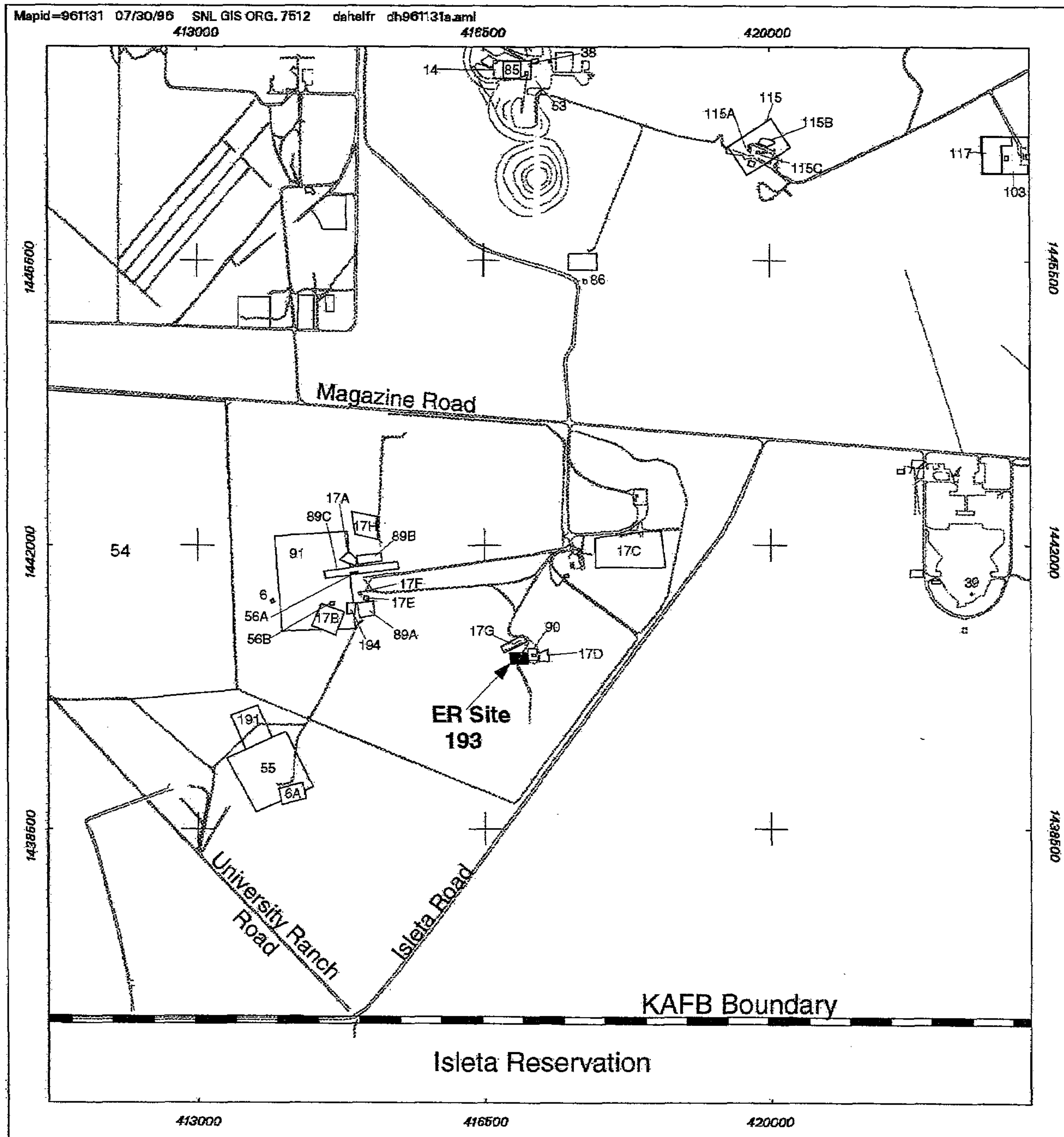
Figure 1
The Location of Kirtland Air Force Base and Sandia National Laboratories







Source: SNL EGIS Database



Legend

Roadway

KAFB Boundary

ER Site 193

Other ER Sites

Figure 2
Location of ER Site 193,
Sabotage Test Area

0 1000 2000
Scale in Feet

0 240 480
Scale in Meters

Sandia National Laboratories, New Mexico
Environmental Restoration Geographic Information System

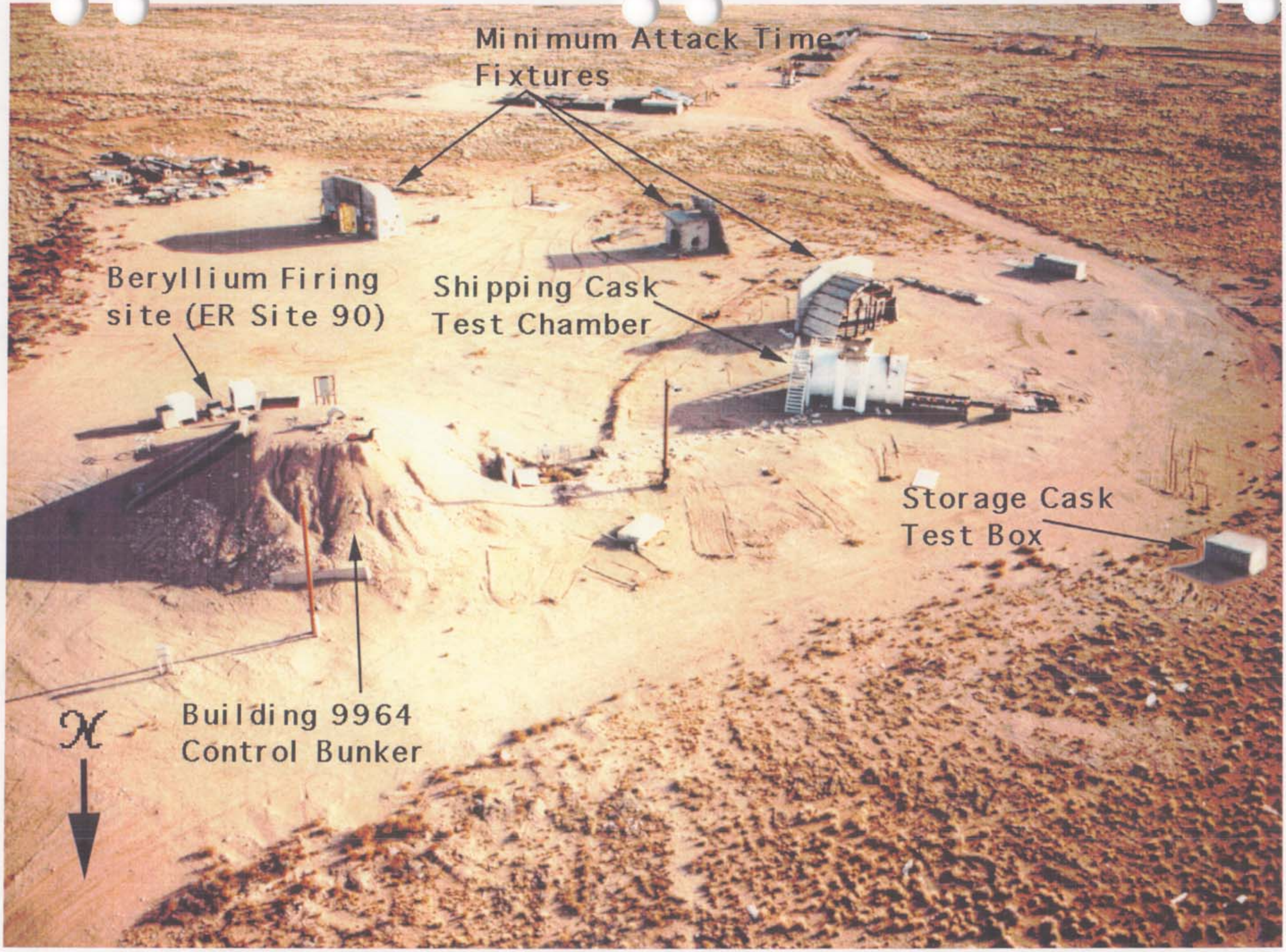


Figure 3. Aerial Photograph of ER Site 193, Sabotage Test Area.

under current and projected future land use, NFA Criterion 5 of the ER Document of Understanding (DOU) (NMED 1996).

2.0 HISTORY OF ER SITE 193

2.1 Historical Operations

2.1.1 Tests Conducted

Building 9964 was constructed in 1967 as a control bunker for the 2-foot shock tube and the Beryllium Firing Site, both shown in Figure 3. Test activities not associated with ER Site 193 were investigated as part of the ER Site 17 (Scrapyards) and ER Site 90 (Beryllium Firing Site) investigations in OU 1335. The three types of tests conducted at the Sabotage Test Area are described below. The test site is no longer active.

Minimum Attack Time Tests

In the mid- to late 1970s, studies were conducted to determine how effective different types of attacks might be on storage structures similar to those used to store nuclear weapons. High explosives (HE) charges and various types of equipment were evaluated. The primary purpose of the tests was to determine how quickly hostile personnel could penetrate the buildings, which were built of reinforced concrete, and gain access to controlled materials. The tests involving equipment use did not generate any hazardous residues. The HE tests used different types of shaped and tamped explosive charges in the 50 pound range or smaller. All of the explosives burned completely during the tests or were removed according to personnel conducting the tests (SNL/NM 1995a). A Department of Defense (DoD) study on explosives shows that explosive tests involving less than 2,000 pounds of HE do not produce any unexploded residues if the HE successfully detonates (goes "high order") (DoD 1992). Based on interviews and site records, all HE was completely consumed during the tests, therefore, no sampling for residual HE was conducted at the site. The locations of the Minimum Attack Time test fixtures are shown in Figure 3

The explosives used in the Minimum Attack Time tests varied, but mostly consisted of 2,4,6-trinitrotoluene (TNT), hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), and possibly octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) compounds.

Shipping Cask Tests

Tests were conducted from 1979 to 1981 to determine how much radioactive material would be released from a terrorist attack on a nuclear fuel rod shipping cask (Sandoval 1983). Three tests were conducted at ER Site 193. In the first two tests, a shaped charge including 30 to 40 pounds of HE was detonated against a simulated fuel cask with simulated fuel rods (Sandoval 1983). Both tests were open air tests, and materials including depleted uranium (DU), zirconium, lead, and stainless steel were dispersed across the site (Sandoval 1982 and Sandoval 1983). A third test was conducted in a chamber (3 meters in diameter by 6 meters long) that fully contained the assembly and all the resulting debris (Sandoval 1983). In this test, a full-scale shipping cask and simulated fuel rods were subjected to an explosive charge to assess the potential damage from a terrorist attack. The location of the shipping cask test chamber is shown in Figure 3. The simulated fuel assembly consisted of 258 kilograms of DU in zircalloy tubing, 1.2 meters in length. Figure 4 shows the shipping cask being loaded into the containment chamber prior to the test. Materials dispersed within the chamber included DU, zirconium, lead, and stainless steel (Sandoval 1983).

Storage Cask Test

A test was conducted in approximately 1981 to study how much radioactive material would be released from a terrorist attack on a nuclear fuel rod storage cask (Philbin 1988). This test was conducted in a steel box that measured approximately 8 feet by 10 feet with one open side. The location of the storage cask test box is shown in Figure 3. A dry storage cask with steel walls, containing fuel elements simulated by DU (reportedly about 12 kilograms), was subjected to a detonation from a shaped charge. Five of the nine simulated cells within the storage cask were penetrated during the tests, and about 100 grams of uranium oxide (UO_2) were not recovered after the test (SNL/NM 1995b and Philbin 1988). The DU and other metals, which were fragmented and vaporized during the test, were dispersed inside the steel box and to the west out of the open side of the box.

2.1.2 Constituents of Concern

ER Site 193 is an explosive testing site that dispersed aerosolized metals and potentially discharged wastewater to the surrounding soils. COCs include heavy metals and DU, which may be present in the soils around the Sabotage Shipping Cask test chamber and the Storage Cask test box.

The HE devices used in the Minimum Attack Time tests and the Shipping Cask and Storage Cask tests are classified, but were most likely shaped or tamped charges composed of Composition B explosives (60 percent RDX and 40 percent TNT). Interviewees indicate that all tests were performed above-grade, and the weight of the explosive material used for the tests was between 30 and 50 pounds. The interviewees also stated that all explosives used in the tests were fully consumed upon detonation (Sandoval 1983; SNL/NM 1995c; and DoD 1992); therefore, HE is not considered a COC for this site.

Metals potentially released from the Storage Cask test, conducted in 1981, include DU, lead, and the alloying agents of stainless steel, such as chromium, nickel, and cadmium (Sandoval 1983 and SNL/NM 1995d). The DU and other metals, which were fragmented and vaporized during the test, were dispersed inside the steel box and to the west out of the open side of the box.

DU, lead, and the alloying agents of stainless steel also were potentially released from three Shipping Cask tests conducted from 1979 to 1981 (Sandoval 1983). Two of the tests were open air tests that may have dispersed COCs across the site. A third test was conducted within a Shipping Cask test chamber. The materials used in the test were fully contained within the

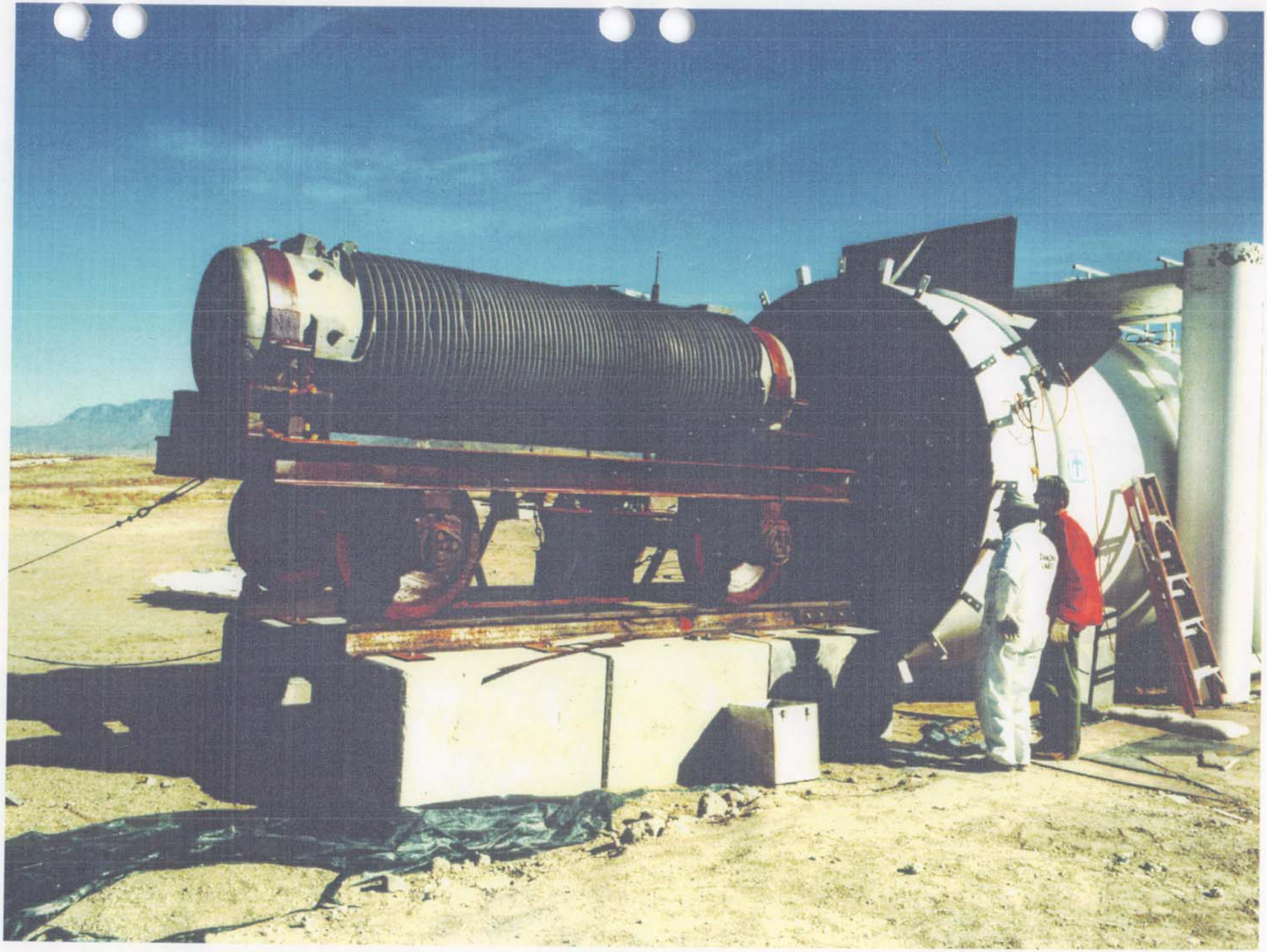


Figure 4. Shipping Cask Test Chamber

chamber. Not all of the material was recovered, however, since the chamber was rinsed out after the test and water may have been discharged to the soil around the chamber (SNL/NM 1995d).

The primary intent of the Shipping Cask and Storage Cask tests was to fully account for all released radioactive materials following a terrorist attack, so material was carefully removed from all surfaces in the Shipping Cask test chamber and the Storage Cask test box immediately following the tests. About 100 grams of DU released from the Storage Cask test box was not recovered after the test (SNL/NM 1995b).

The COCs listed above were identified from process knowledge, interviews, and site records. Because the potential exists for other metals to have been released during the Shipping Cask and Storage Cask tests, the COC list, for risk analysis purposes, was expanded to include the eight RCRA metals, as well as beryllium and nickel. Likewise, because the potential exists for other radionuclides to have been released, the radionuclide COC list, for risk analysis purposes, was expanded to include additional radionuclides besides DU.

2.2 Previous Audits, Inspections, and Findings

The Comprehensive Environmental Assessment and Response Program (CEARP) Phase I Report (DOE 1987) and the RCRA Facility Assessment (RFA) report (EPA 1987) first identified ER Site 193 as a potential release site and listed the site because "the surrounding building/site may be contaminated with lead or depleted uranium." The Coyote Canyon Test Complex Environmental Assessment (SNL/NM and DOE 1992) listed ER Site 193 as a Radioactive Materials Management Area because of tests that involved DU.

3.0 EVALUATION OF RELEVANT EVIDENCE

3.1 Unit Characteristics and Operating Practices

ER Site 193 is no longer an active site.

3.2 Results of SNL/NM ER Project Sampling/Surveys

3.2.1 Summary of Prior Investigations

The following information, presented in chronological order, was used to evaluate ER Site 193:

- Interviews with former site employees: John Weber (SNL/NM 1995b) and Floyd Matthews (SNL/NM 1995c and SNL/NM 1995d).
- Draft RFI Work Plan and Sampling and Analysis Plan for OU 1335, Southwest Test Area (SNL/NM March 1996).
- Results of four surveys, including an archeological/cultural resources survey (DOE 1996a), a sensitive or special status species or environments survey (DOE 1996a), a UXO/HE survey (SNL/NM 1994), and a radiological survey (RUST Geotech Inc. 1994).
- VCM activities performed during February and March 1995 and June 1996.
- Post-cleanup (verification) surface soil sampling performed subsequent to VCM activities in February and March 1995 and June 1996.
- Confirmatory surface soil sampling conducted in 1995.
- Photographs and field notes collected at the site by SNL/NM ER staff.

3.2.2 Cultural Resources Survey

A cultural resources inventory of the Sabotage Test Area was completed in 1994 as part of the Environmental Assessment of the Environmental Restoration Project at SNL/NM (DOE 1996a). No cultural resources were identified at or in the vicinity of ER Site 193.

3.2.3 Sensitive-Species Survey

A sensitive-species survey of the Sabotage Test Area was conducted in 1994 as part of the Environmental Assessment of the Environmental Restoration Project at SNL/NM (DOE 1996a). No sensitive species were identified at or in the vicinity of ER Site 193.

3.2.4 UXO/HE Survey

An unexploded ordnance (UXO)/HE visual surface survey of the Sabotage Test Area was conducted by KAFB Explosive Ordnance Disposal personnel in November 1993. No UXO/HE or ordnance debris was identified at or in the vicinity of ER Site 193 (SNL/NM 1994).

3.2.5 Radiological Surveys

A surface radiation survey of the Sabotage Test Area was conducted by RUST Geotech Inc. in January 1994. The survey covered approximately 0.5 acres of flat alluvial terrain with several steel and concrete structures. A gamma scan survey was performed on 6 foot centers (100 percent coverage) over the surface of ER Site 193. No radiation above background levels was detected to the west of the open side of the Storage Cask test box, indicating that this area was cleaned up to background activities after the tests were conducted. Radiation levels slightly above background were detected in a few locations to the east of the Storage Cask test box and to the west and north of the Shipping Cask test chamber. Background gamma exposure rates ranged from 11 to 12 microrem (μR)/hour. Gamma anomalies with activities at or above 1.3 times local background levels in the area east of the Storage Cask test box and to the west and north of the Shipping Cask test chamber included six soil point sources (14-28 μR/hour); three soil area sources (11-16 μR/hour); and one fragment point source (20-28 μR/hour) (Figure 5) (RUST Geotech Inc. 1994). A detailed summary of the gamma anomalies shown in Figure 5 is presented in Table 1.

3.2.6 VCM Sampling

VCM activities were performed at ER Site 193 during February and March 1995. During this time, all of the soil point sources (193E1-SP, 193E4-SP, 193E5-SP, 193E6-SP, 193E7-SP, and 193E9-SP), the fragment point source (193E10-FP), and two of the soil source areas (193E2-SA and 193E3-SA) identified during the radiological survey were remediated. In June 1996, the remaining soil source area (193E8-SA), near the Sabotage Storage Cask test box, was remediated after a backhoe was used to remove a large concrete block that covered a portion of the soil source area (Figure 5). After the removal of radiologically contaminated soils, seven post-cleanup (verification) samples, including one duplicate at the 193E loss sample location (Figure 6), were collected from areas exhibiting the highest residual gamma radiation readings (Figure 6) and were analyzed on site by SNL/NM Department 7713, Radiation Protection Sample Diagnostics Laboratory, for radiological constituents using gamma spectroscopy. Gamma spectroscopy analysis was performed on the samples to verify that the residual radionuclide concentrations met risk-based action levels. The results of the gamma spectroscopy analysis are presented in Table 2 and have been included in the Risk Assessment Analysis (Section 6.1).

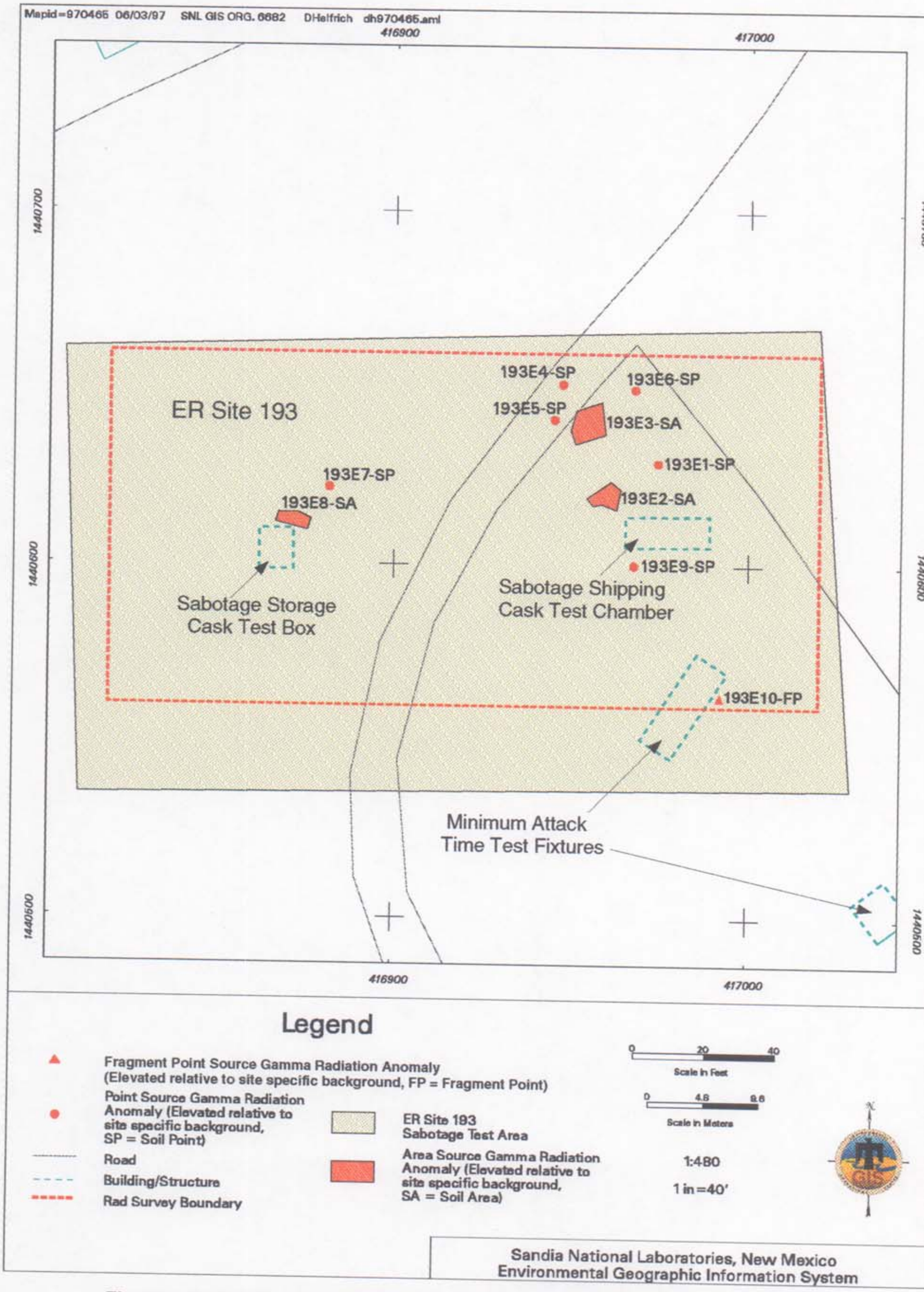


Figure 5 Phase I Survey Radiation Anomalies at ER Site 193, Sabotage Test Area

Table 1
Detailed Summary of Radioactive Anomalies at ER Site 193

Anomaly					Area Background		Description/Comment
ID	Type Code[a]	Area (ft^2)	cps	µR/hr	cps	µR/hr	
193E1	SP	3.1	400	28	100	11	
193E2	SA	44.4	100-140	11-14	100	11	3 feet north of railcar
193E3	SA	81.4	100-300	11-22	90	11	Multiple hot spots
193E4	SP	3.1	160	15	90	11	
193E5	SP	3.1	325	24	100	11	
193E6	SP	3.1	180	16	100	11	
193E7	SP	3.1	150	14	100	11	Light-purple soil
193E8	SA	33.8	100-190	11-16	90	11	Multiple hot spots
193E9	SP	3.1	275	21	90	11	
193E10	FP	3.1	400	28	100	11	4- by 18-inch metal fragment; 4- by 6-inch piece of foam-like material

[a]Type Codes: SA = Soil Area Source, SP = Soil Point Source, FP = Fragment Point Source
cps = counts per second
µR/hr = microroentgen per hour

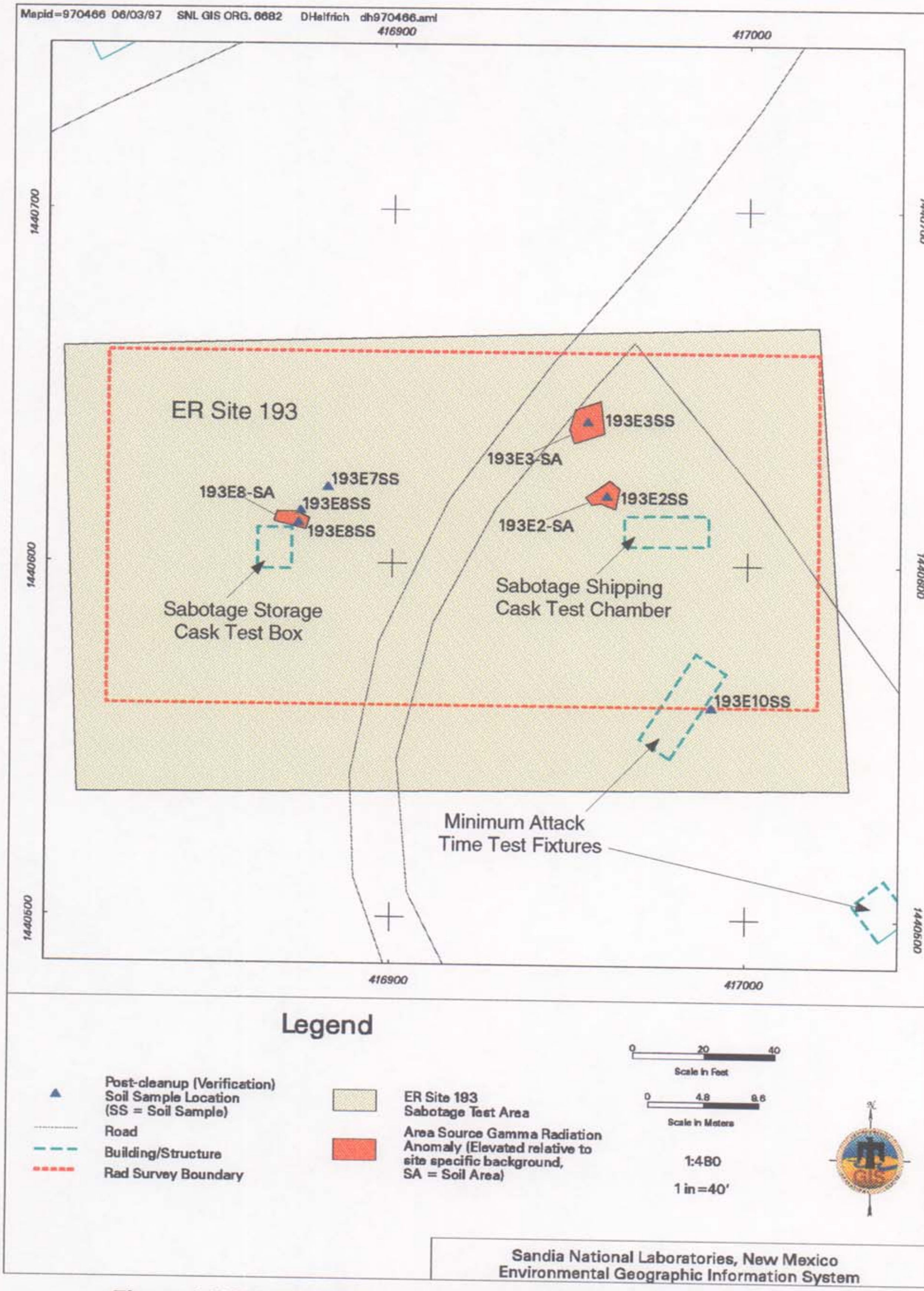


Figure 6 VCM Post-Cleanup (Verification) Surface Soil Sample Locations at ER Site 193, Sabotage Test Area

Table 2
Summary of ER Site 193 VCM Verification Surface Soil Sample Analytical Results

Sample Attributes			Radiological Activities (pCi/g)					
Sample Number	ER Sample ID	Sample Depth (inches)	Co-60	Cs-137	Ra-228	Th-232	U-238/Th-234[a]	U-235
500235-02	193E2-SS	4 - 7	ND	0.0353	0.62	0.446	0.698	ND
500235-01	193E3-SS	3 - 6	ND	0.0734	0.786	0.803	1.33	ND
500235-03	193E8-SS	4 - 7	ND	ND	0.706	0.537	7.55	0.124
500235-05	193E7-SS	6 - 9	ND	1.68	0.868	0.622	0.766	ND
630124-15	193E8-SS	4 - 7	ND	ND	0.898	0.866	30.4	0.45
500118-05	193E10-SS	0 - 6	ND	0.917	0.552	0.462	1.18	ND
500118-06	193E10-SD	0 - 6	ND	0.98	0.69	0.526	1.82	ND
SNL/NM Southwest Area Background Level (pCi/g)			NA	0.664	1.01	1.01	1.4	0.16

[a]The greater of the two activities (U-238 or Th-234) was used. Secular equilibrium was assumed due to the short half-life of Th-234
NA = Not applicable
ND = Not detected above the minimum detectable activity (MDA)
pCi/g = Picocuries per gram.
Radiological constituents analyzed by gamma spectroscopy: Co = Cobalt; Cs = Cesium; Ra = Radium;
SD = Surface soil duplicate sample
SS = Surface soil sample
Th = Thorium
U = Uranium

3.2.7 Confirmatory Sampling

Although the likelihood of hazardous waste releases at ER Site 193 is considered low, confirmatory soil sampling was conducted by SNL/NM in 1995 to determine whether COCs were present at levels exceeding background at the site. The confirmatory soil sampling program was performed in accordance with the rationale and procedures described in the OU 1335 Sampling and Analysis Plan, and the Draft RFI Work Plan (SNL/NM March 1996). Five-foot grids were centered on the Sabotage Shipping Cask test chamber and the Sabotage Storage Cask test box, and 20 sampling locations were selected using a random number generator. A total of 22 samples, including 2 duplicate samples, were collected from the locations shown on Figure 7. All samples were routed to the appropriate analytical laboratories by the SNL/NM Sample Management Office (SMO). SNL/NM chain-of-custody and sample documentation procedures were employed and followed for all samples collected. Of the 22 samples collected, 100 percent were analyzed on site at the ER Chemistry Laboratory for radiological constituents and metals. Five duplicate samples, including one for quality assurance (QA), were analyzed by an off-site Contract Laboratory Program laboratory for 20 percent verification analyses. ER Site 193 samples were analyzed by SNL/NM Department 7713, Radiation Protection Sample Diagnostics Laboratory, for radiological constituents using gamma spectroscopy; by SNL/NM Department 7584, ER Chemistry Laboratory, for Target Analyte List (TAL) metals using inductively coupled plasma (U.S. Environmental Protection Agency [EPA] Method 6010, modified for the target metals); and by Lockheed Analytical Services (LAS) of Las Vegas, Nevada, for TAL metals (EPA Method 6010/7000), for cesium using gamma spectroscopy, and for isotopic uranium using LAS laboratory Method LAL-0108.

3.2.7.1 On-Site and Off-Site TAL Metals Results

On-Site Analyses: ER Chemistry Lab

Table 3 presents a summary of the TAL metals results for the 22 surface soil samples collected during confirmatory sampling at ER Site 193. The table provides the ER sample ID, the analyte, the highest measured concentration of each specific analyte, the SNL/NM Southwest Area background concentration, and the proposed RCRA Subpart S action level for soils (55 FR 30865). On-site TAL metals results for all samples collected during confirmatory sampling are presented in Section 6.2. The table provided in Section 6.2 gives the ER sample ID, the sample depth, the concentration of each specific analyte for all 22 samples, the method detection limit, the practical quantitation limit, the SNL/NM Southwest Area background level, and the proposed RCRA Subpart S action level (55 FR 30865).

The concentrations of all metals detected that are COCs for this site were either below the corresponding SNL/NM Southwest Area background concentrations or below the proposed RCRA Subpart S action level for soils, with the exception of beryllium. Beryllium was present in ER Sample ID 193-GR-003-0-SS-02 at a concentration of 0.68 milligrams per kilogram (mg/kg), slightly above the SNL/NM Southwest Area background 95th percentile of 0.65 mg/kg. The proposed RCRA Subpart S action level is 0.2 mg/kg. With the 95th percentile, it is expected that

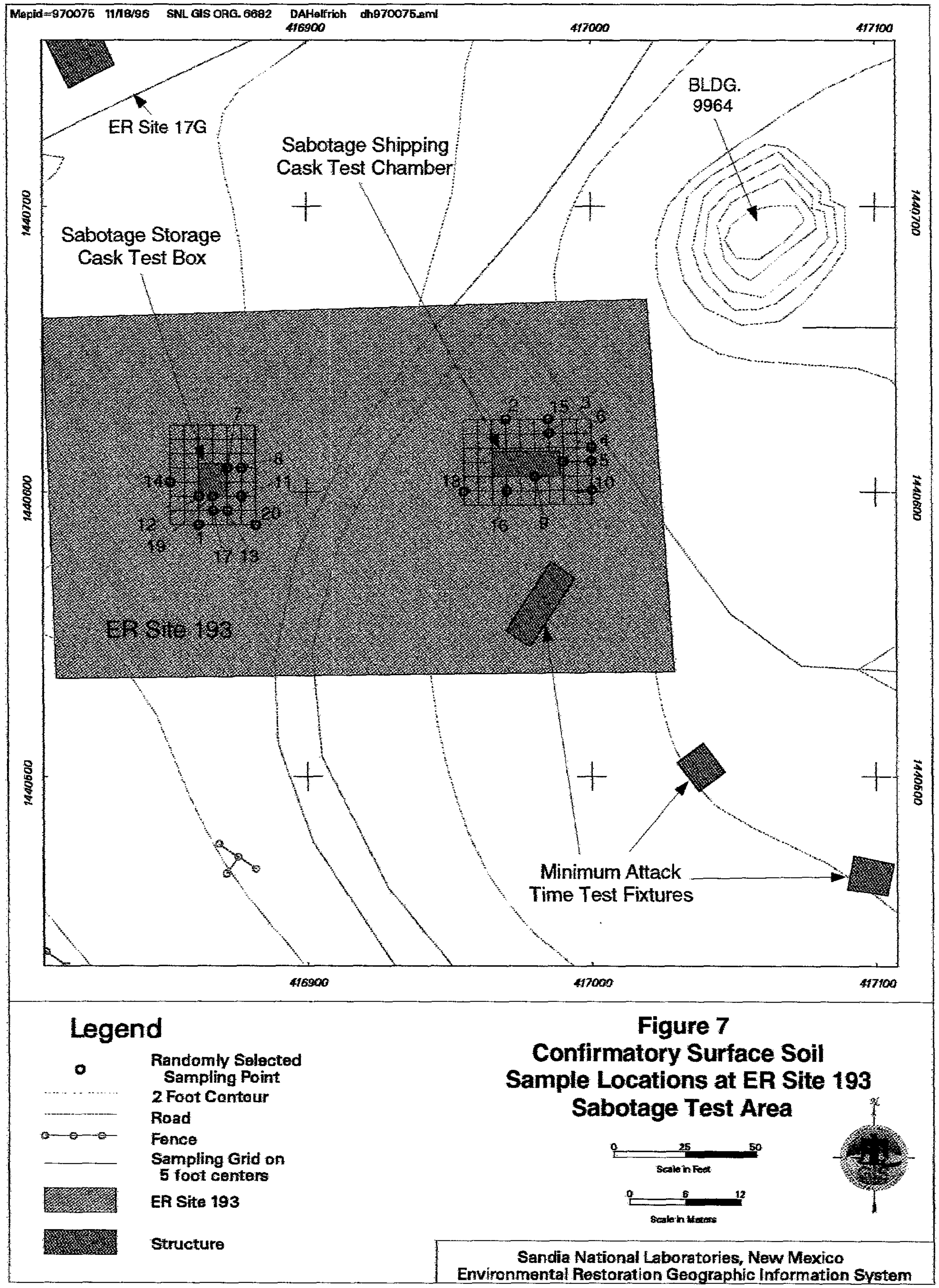


Figure 7
Confirmatory Surface Soil Sample Locations at ER Site 193 Sabotage Test Area

Table 3
Summary of On-Site Confirmatory TAL Metals Analytical Results for ER Site 193

Sample Number	ER Sample ID	Analyte[a]	Highest Measured Concentration (mg/kg)	SNL/NM Southwest Area Surface Soil Background Level (mg/kg)	Proposed RCRA Subpart S Action Level (mg/kg)
NA	NA	Ag	ND	<1	200
NA	193-GR-003-0-SS-02	Al	13000	NA	—
NA	NA	As	ND	5.6	0.5
NA NA	193-GR-005-0-SS-02 193-GR-020-0-SS-02	Ba	150	130	4000
NA	193-GR-003-0-SS-02	Be	0.68	0.65	0.2
NA	193-GR-018-0-SS-02	Ca	68000	NA	—
NA	NA	Cd	ND	<1	40
NA	NA	Co	ND	5.2	—
NA	193-GR-002-0-SS-02	Cr	12	17.3	400[b]
NA	193-GR-006-0-SS-02	Cu	49	15.4	—
NA	193-GR-003-0-SS-02	Fe	14000	NA	—
NA	193-GR-006-0-SS-02	Hg	0.07J	<0.25	20
NA	193-GR-003-0-SS-02	Mg	4200	NA	—
NA	193-GR-002-0-SS-02	Mn	330	NA	10000
NA	NA	Ni	ND	11.5	2000
NA	193-GR-010-0-SS-02	Pb	51	21.4	400[c]
NA	NA	Sb	ND	3.9	30
NA	NA	Se	ND	<1	400
NA	NA	Tl	ND	<1.1	—
NA	193-GR-004-0-SS-02	V	18J	20.4	600
NA	193-GR-020-0-SS-02	Zn	53	62	20000

[a]TAL metals by inductively coupled plasma (EPA Method 6010, modified for the target metals)
[b]Proposed Subpart S action level for hexavalent chromium
[c]No proposed Subpart S action level for lead in soil; 400 mg/kg is EPA proposed action level
J = Concentrations of metal detected in sample is less than the practical quantitation limit but greater than the method detection limit
NA = Not applicable (no laboratory sample number was assigned to samples analyzed on site)
ND = Not detected in concentrations above laboratory method detection limit
mg/kg = milligrams per kilogram
SS = Surface soil sample
SSD = Duplicate surface soil sample
— = No SNL/NM background concentration or proposed Subpart S action level available for analyte

5 percent of the natural population of any constituent will exist above the 95th percentile value. In addition, the concentration of beryllium measured was still substantially less than the maximum value (1.6 mg/kg) of the range of naturally occurring beryllium concentrations used to calculate the 95th percentile value, or the SNL/NM Southwest Area background level, for beryllium. Based on this, the result is interpreted as a background value; however, to be conservative, this value was included in the risk assessment analysis (Section 6.1). Beryllium was not detected above background in any of the other 21 samples in concentrations exceeding the SNL/NM Southwest Area background 95th percentile.

Off-Site Analyses: Lockheed Analytical Services

Table 4 presents a summary of the TAL metals results for the five duplicate confirmatory surface soil samples sent off site for 20 percent verification analyses. The table provides the sample number, the ER sample ID, the analyte, the highest measured concentration of each specific analyte, the SNL/NM Southwest Area background concentration, and the proposed RCRA Subpart S action level for soils (55 FR 30865). Off-site TAL metals results for the five duplicate samples collected during confirmatory sampling are presented in Section 6.3. The table provided in Section 6.3 gives the sample ID, the ER sample ID, the sample depth, the concentration of each specific analyte for all five duplicate samples, the method detection limit, the practical quantitation limit, the SNL/NM Southwest Area background level, and the proposed RCRA Subpart S action level (55 FR 30865).

The concentrations of all metals detected that are COCs for this site were either below the corresponding SNL/NM Southwest Area background levels or below the proposed RCRA Subpart S action level for soils. Beryllium was not detected in any of the five duplicate samples analyzed at the off-site laboratory; however, the reporting detection limit was greater than both the SNL/NM Southwest Area background value and the proposed RCRA Subpart S action level (Section 6.3). The corresponding on-site analyses of the same five duplicate samples showed no beryllium concentrations above the SNL/NM Southwest Area background 95th percentile of 0.65 mg/kg (Section 6.2).

3.2.7.2 Radiological Results

Table 5 presents a summary of the on-site and off-site radiological results for the surface soil samples collected during confirmatory sampling at ER Site 193. The table provides, for both on-site and off-site samples, the lab sample number, the ER sample ID, the radionuclide, the highest measured activity of each specific radionuclide, and the SNL/NM Southwest Area background activity. Twenty-two samples were analyzed on site, and six duplicate samples were analyzed off site for 20 percent verification analyses. The on-site samples were analyzed by SNL/NM Department 7713, Radiation Protection Sample Diagnostics Laboratory, for radiological constituents using gamma spectroscopy. The off-site samples were analyzed for cesium using gamma spectroscopy and for isotopic uranium using LAS laboratory method LAL-0108. On-site and off-site radiological results for all samples collected during confirmatory sampling are presented in Sections 6.4 and 6.5, respectively. The tables provided in Sections 6.4 and 6.5 give the laboratory sample number, the ER sample ID, the sample depth,

Table 4
Summary of Off-Site Confirmatory TAL Metals Analytical Results for ER Site 193

Sample Number	ER Sample ID	Analyte[a]	Highest Measured Concentration (mg/kg)	SNL/NM Southwest Area Surface Soil Background Level (mg/kg)	RCRA Proposed Subpart S Action Level (mg/kg)
NA	NA	Ag	ND	<1	200
024984-08	193-GR-020-0-SS-08	Al	9900	NA	—
024981-08 024984-08	193-GR-005-0-SS-08 193-GR-020-0-SS-08	As	3.3	5.6	0.5
024984-08	193-GR-020-0-SS-08	Ba	140	130	4000
NA	NA	Be	ND	0.65	0.2
024984-08	193-GR-020-0-SS-08	Ca	57000	NA	—
NA	NA	Cd	ND	<1	40
NA	NA	Co	ND	5.2	—
024985-08	193-GR-020-0-SSD-08	Cr	9.9	17.3	400[b]
024985-08	193-GR-020-0-SSD-08	Cu	9.8	15.4	—
024984-08	193-GR-020-0-SS-08	Fe	13000	NA	—
NA	NA	Hg	ND	<0.25	20
024984-08	193-GR-020-0-SS-08	K	2800	NA	—
024984-08	193-GR-020-0-SS-08	Mg	3900	NA	—
024984-08	193-GR-020-0-SS-08	Mn	220	NA	10000
NA	NA	Na	ND	NA	—
024983-08	193-GR-015-0-SS-08	Ni	8.3	11.5	2000
024983-08	193-GR-015-0-SS-08	Pb	32	21.4	400[c]
NA	NA	Se	ND	<1	400
NA	NA	Sb	ND	3.9	30
NA	NA	Tl	ND	<1.1	—
024981-08	193-GR-005-0-SS-08	V	21	20.4	600
024985-08	193-GR-020-0-SSD-08	Zn	42	62	20000

[a]TAL metals by EPA Methods 6010/7000
[b]Proposed Subpart S action level for hexavalent chromium
[c]No proposed Subpart S action level for lead in soil; 400 mg/kg is EPA proposed action level
mg/kg = milligrams per kilogram
NA = Not applicable (no laboratory sample number was assigned to samples analyzed on site)
ND = Not detected in concentrations above laboratory method detection limit
SS = Surface soil sample
SSD = Duplicate surface soil sample
— = No SNL/NM background concentration or proposed Subpart S action level available for analyte

Table 5
Summary of On-Site and Off-Site Confirmatory Radiochemical Results for ER Site 193

Sample Number	ER Sample ID	Radionuclide	Highest Measured Activity (pCi/g)	SNL/NM Southwest Area Background Surface Soil Activity (pCi/g)
On Site: SNL/NM Radiation Protection Sample Diagnostics Laboratory				
50067302	193-GR-002-0-SS-01	Co-60	0.341	—
50070404	193-GR-005-0-SS-02	Cs-137	1.77	0.664
50067305	193-GR-006-0-SS-01	Ra-228	0.874	1.01
50067301	193-GR-001-0-SS-01	Th-232	0.847	1.01
NA	NA	U-234	ND	1.6
NA	NA	U-235	ND	0.16
50067301	193-GR-001-0-SS-01	U-238	4.1	1.4
Off Site: Lockheed Analytical Services				
025887-06	193-GR-016-0-SS-01	Cs-137	1.75	0.664
025887-04	193-GR-008-0-SS-01	U-233/234	1.17	1.6
025887-04	193-GR-008-0-SS-01	U-235	0.12	0.16
025887-04	193-GR-008-0-SS-01	U-238	6.65	1.4

NA = Not applicable, or SNL/NM background concentration not available
ND = Not detected in sample above minimum detectable activity (MDA)
pCi/g = picocuries per gram
SS = Surface soil sample
— = No SNL/NM background concentration available

the activities of each specific radionuclide for all samples, and the SNL/NM Southwest Area background activity. Radiochemical results show activities of Cobalt 60 (Co-60), Cesium 137 (Cs-137), and Uranium 238 (U-238) to be above SNL/NM Southwest Area background activities. Seven sample analyses, four on site (ER sample ID: 193-GR-002-0-SS-01, 193-GR-005-0-SS-02, 193-GR-006-0-SS-01, and 193-GR-016-0SS-01) and three off site (ER sample ID: 193-GR-002-0-SS-01, 193-GR-006-0-SS-01, and 193-GR-016-0-SS-01), showed activities of Cs-137 exceeding SNL/NM Southwest Area background levels. The maximum reported value (1.77 picocuries per gram [pCi/g] by the Department 7713 laboratory, ER sample ID: 193-GR-005-0-SS-02) is approximately three times background. U-238 was detected in one on-site (ER sample ID: 193-GR-001-0-SS-01) and three off-site (ER sample ID: 193-GR-001-0-SS-01, 193-GR-008-0-SS-01, and 193-GR-013-0-SS-01) sample analyses in activities exceeding background. The maximum reported value (6.65 pCi/g by LAS, ER sample ID: 193-GR-008-0-SS-01) is approximately five times the SNL/NM Southwest Area background activity. Co-60 was detected in two samples (0.341 pCi/g, ER sample ID: 193-GR-002-0-SS-01 and 0.113 pCi/g, ER sample ID: 193-GR-015-0-SS-02) analyzed by the on-site Department 7713 laboratory. The levels of Cs-137, U-238, and Co-60 are discussed in the ER Site 193 Risk Assessment Analysis contained in Section 6.1 of this NFA proposal.

Complete metals and radiochemical soil sample analytical data packages are archived in the SNL/NM ES&H Records Center and are readily available for review.

3.2.7.3 *Quality Assurance/Quality Control Results*

QA/quality control (QC) samples collected during confirmatory sampling consisted of one aqueous equipment blank and one aqueous field blank. Both blanks were sent off site for TAL metals analysis at LAS. Results of analysis showed concentrations of copper, iron, and zinc in both the equipment blank and the field blank (Section 6.3). No other metals or COCs were detected in the two blanks.

Two sets of duplicate soil samples were collected during confirmatory sampling. Both sets of samples (ER sample ID: 193-GR-010-0-SSD-06 and 193-GR-020-0-SSD-07) were analyzed on site at the ER Chemistry Laboratory (Section 6.2). One set of the duplicate samples was sent off site (ER sample ID: 193-GR-020-0-SSD-08) as part of the 20 percent verification analyses (Section 6.3). Concentrations of TAL metals in the two sets of samples analyzed on site were in good agreement with those detected in the equivalent primary samples, except for calcium and lead in the pair of samples from location number 10. Concentrations of TAL metals in the set of duplicate samples sent off site for analysis were in good agreement as well, except for calcium.

Validation and comparison of Level II and Level III data to published background data were completed in 1996 and confirmed that Data Validation Level I and Data Validation Level II reviews conducted by the SNL/NM SMO were accurate and that the data are acceptable for use in this NFA proposal.

3.3 Gaps in Information

Process knowledge, site files, and personnel interviews were used to identify the most likely COCs at ER Site 193 and helped to select the types of analyses performed on soil samples. While the history of past releases at the site is incomplete, analytical data from VCM verification sampling, confirmatory sampling, and radiological screening are sufficient to determine whether significant releases of COCs occurred at the site.

3.4 Risk Evaluation

The following subsections summarize the results of the risk assessment process for both human and ecological risk related factors.

3.4.1 Human Health Risk Assessment

ER Site 193 has been recommended for industrial land use (DOE 1996b). A complete discussion of the risk assessment process, results, and uncertainties is provided in Section 6.1, the ER Site 193 Risk Assessment Analysis. Due to the presence of beryllium in concentrations above SNL/NM Southwest Area background levels, and several radionuclides present in activities above SNL/NM Southwest Area background, it was necessary to perform a human health risk assessment analysis for the site. The risk assessment process provides a quantitative evaluation of the potential adverse human health effects caused by constituents in the site's soil. The risk assessment analysis presents the hazard index and excess cancer risk for both industrial land-use and residential land-use scenarios. The excess cancer risk from nonradioactive COCs and radioactive COCs is not considered to be additive (EPA 1989).

The main contributor to the nonradiological industrial land-use scenario risk assessment for ER Site 193 was arsenic. For the radiological risk assessment, the primary contributor was Co-60, a relatively short-lived radionuclide. Using conservative assumptions and employing a reasonable maximum exposure (RME) approach to the risk assessment, the calculations for the nonradiological COCs show that for the industrial land-use scenario the hazard index is 0.2, significantly less than the numerical standard of 1.0 suggested by risk assessment guidance (EPA 1989). The estimated cancer risk (3×10^{-5}) is in the middle of the suggested range of acceptable risk of 10^{-4} to 10^{-6} (EPA 1989). The incremental hazard index is 0.17, and the incremental cancer risk is 2.6×10^{-5}. Incremental risk is determined by subtracting the risk associated with background from the potential risk associated with the COCs. Incremental risk calculations indicate insignificant contribution to risk from the nonradiological COCs under an industrial land-use scenario.

The incremental total effective dose equivalent (TEDE) and corresponding estimated cancer risk from the radioactive components are much less than EPA guidance values. The estimated incremental TEDE is 2.8 millirem (mrem)/year for the industrial land-use scenario, much less than the EPA draft numerical guidance of 15 mrem/year. The corresponding estimated excess cancer risk value is 4×10^{-5} for the industrial land-use scenario, much less than calculated risk values from naturally occurring radiation and from intakes considered to be within background levels.

The residential land-use scenarios for this site are provided only for comparison in the Risk Assessment Analysis (Section 6.1). The uncertainties associated with the calculations are considered small relative to the conservativeness of the risk assessment analysis. It is therefore concluded, based upon the risk assessment analysis, that ER Site 193 does not have significant potential to affect human health under an industrial land-use scenario.

3.4.2 Ecological Risk Assessment

To provide a "worst case" scenario, ecological risk analysis for ER Site 193 was performed using the highest measured concentration for each analyte or the highest measured activity for each radionuclide, where available. When a sample analytical result was reported by the laboratory as a "non-detect," a laboratory method detection limit was used to calculate risk in place of an actual measured concentration. In these cases, the higher detection limit between the on-site and the off-site laboratories was used for conservatism.

Four constituents of potential ecological concern (COPEC) and three identified for ER Site 193 (arsenic, cadmium, selenium, and silver) were not detected in any of the soil samples analyzed at either the on-site or off-site laboratories. As a result, the detection limits from the on-site ER Chemistry Laboratory were used to perform the risk analysis because they were consistently higher than the corresponding detection limits from the off-site laboratory.

Overall, although exposure modeling indicated potential ecological risks at ER Site 193, further examination of detection limits used in place of the actual measured analyte concentrations, comparison to SNL/NM background concentrations, and average exposure concentrations indicate that ecological risks to receptors associated with ER Site 193 are considered insignificant, except for selenium. The high detection limits used (50 mg/kg for the on-site lab and 10 mg/kg for the off-site lab) in the ecological risk analysis for selenium produced hazard quotients (HQ) greater than 1. When a detection limit of 50 mg/kg is used, HQs are greater than 1 for the plant (50), the deer mouse (15), and the owl (3). When the lower detection limit of 10 mg/kg is used, the HQ for the owl is reduced to less than 1 (0.6), and the HQs for the plant and the deer mouse are reduced to 10 and 3, respectively.

Risk analysis results showed potential ecological risk for selenium; however, the site history, process knowledge, and interviews all indicate that selenium was not used in test components or tests performed at the site, nor was it initially a COPEC. It was introduced as a COPEC, along with the other seven RCRA metals, to provide a conservative risk analysis for ER Site 193.

4.0 RATIONALE FOR NO FURTHER ACTION DECISION

ER Site 193 is being proposed for an NFA determination for the following reasons:

- VCM activities were performed at ER Site 193 during February and March 1995. During this time, all of the soil point sources, the fragment point source, and two of the soil source areas identified during the RUST Geotech walk-over gamma radiation survey were remediated. In June 1996, the remaining soil source area identified during the gamma radiation walk-over survey was remediated after a backhoe was used to remove a large concrete block which covered a portion of the soil source area. After the removal of point sources and radiologically contaminated soils, seven post-cleanup (verification) samples were collected from areas exhibiting the highest residual gamma radiation readings and were analyzed on site using gamma spectroscopy. Results showed that three radionuclides (Cs-137, U-238/Thorium-234, and U-235) were present in activities exceeding SNL/NM Southwest Area background levels. The maximum measured activity of each was included in the risk analysis performed for the site.

- Twenty-two confirmatory surface soil samples were collected and analyzed on site for TAL metals and radionuclides by gamma spectroscopy. Twenty percent of the samples were sent off site for verification analyses for TAL metals, Cs-137 by gamma spectroscopy, and isotopic uranium.

  Beryllium was the only metal that exceeded SNL/NM Southwest Area background levels. It was detected slightly above background in one sample analyzed on site at the ER Chemistry Laboratory. Although the value is interpreted as background, it was included in the risk assessment analysis. Beryllium was not detected in any of the other 21 samples in concentrations exceeding the SNL/NM Southwest Area background 95th percentile.

  Co-60, Cs-137, and U-238 were all detected in activities exceeding SNL/NM Southwest Area background levels in samples analyzed both on site and off site. The maximum measured activity of each was used in the risk analysis performed for the site.

- Using conservative assumptions and employing an RME approach to the risk assessment, the calculations for the nonradiological COCs show that for the industrial land-use scenario the hazard index is 0.2, significantly less than the numerical standard of 1.0 suggested by risk assessment guidance (EPA 1989). The estimated cancer risk (3×10^{-5}) is in the middle of the suggested range of acceptable risk of 10^{-4} to 10^{-6} (EPA 1989). The incremental hazard index is 0.17, and the incremental cancer risk is 2.6×10^{-5} for an industrial land-use scenario. Incremental risk calculations indicate insignificant contribution to risk from the nonradiological COCs under an industrial land-use scenario.

The incremental TEDE and corresponding estimated cancer risk from the radioactive components are much less than EPA guidance values. The estimated incremental TEDE is 2.8 mrem/year for the industrial land-use scenario, much less than the EPA draft numerical guidance of 15 mrem/year. The corresponding estimated excess cancer risk value is 4×10^{-5} for the industrial land-use scenario, much less than calculated risk values from naturally occurring radiation and from intakes considered to be within background levels.

The uncertainties associated with the calculations are considered small relative to the conservativeness of the risk assessment analysis. It is therefore concluded, based upon the risk assessment analysis, that ER Site 193 does not have significant potential to affect human health under an industrial land-use scenario.

- Ecological risks to receptors associated with ER Site 193 are considered insignificant, except for selenium. All analytical results for selenium (both on-site and off-site laboratory analysis) were non-detects; however, the high detection limits used (50 mg/kg for the on-site lab and 10 mg/kg for the off-site lab) in the ecological risk analysis for selenium produced HQs greater than 1. When a detection limit of 50 mg/kg is used, HQs are greater than 1 for all three modeled receptors. When a detection limit of 10 mg/kg is used, the HQ for one of the receptors, the owl, is reduced to less than 1.

  Although risk analysis results show potential ecological risk for selenium, the site history, process knowledge, and interviews all indicate that selenium was not used in test components or tests performed at the site. It was introduced as a COPEC, along with the other seven RCRA metals, to provide a conservative risk analysis for ER Site 193.

Based upon the information cited above, additional investigations are unwarranted and unnecessary. SNL/NM has demonstrated that ER Site 193 has been characterized and remediated in accordance with current applicable state or federal regulations, and the available data indicate that contaminants pose an acceptable level of risk under current and projected future land use (Criterion 5 of Section 1.2). ER Site 193 is therefore recommended for an NFA determination.

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6.0 ANNEXES

6.1	ER Site 193 Risk Assessment Analysis
6.2	On-Site Confirmatory TAL Metals Results for ER Site 193
6.3	Off-Site Confirmatory TAL Metals Results for ER Site 193
6.4	On-Site Confirmatory Radiochemical Results for ER Site 193
6.5	Off-Site Confirmatory Radiochemical Results for ER Site 193

Section 6.1
ER Site 193 Risk Assessment Analysis

ER SITE 193: RISK ASSESSMENT ANALYSIS

I. Site Description and History

ER Site 193 is an explosive test site that dispersed aerosolized metals and potentially discharged wastewater to the surrounding soils. Constituents of concern (COC) are heavy metals and depleted uranium (DU) which could have been released to the soils around the Sabotage Shipping Cask test chamber and the Storage Cask test box.

The high explosives (HE) devices used in the Minimum Attack Time tests and the Shipping Cask and Storage Cask tests are classified, but were most likely shaped or tamped charges composed of Composition B explosives (60% RDX and 40% TNT). Interviewees indicate that all tests were performed above-grade and the weight of the explosive material used for the tests was between 30 and 50 pounds. The interviewees also stated that all explosives used in the tests were fully consumed upon detonation (Sandoval, 1983; SNL/NM, 1995a; and USDOD, 1992); therefore, HE is not considered a COC for this site.

Metals potentially released from the Storage Cask test, conducted in 1981, include DU, lead, and the alloying agents of stainless steel, such as chromium, nickel, and cadmium (Sandoval, 1983 and SNL/NM, 1995b). The DU and other metals that were fragmented and vaporized during the test were dispersed inside the steel box and to the west out of the open side of the box.

DU, lead, and the alloying agents of stainless steel also were potentially released from three Shipping Cask tests conducted from 1979 to 1981 (Sandoval, 1983). Two of the tests were open air tests that may have dispersed COCs across the site. A third test was conducted within a Shipping Cask test chamber. The materials used in the test were fully contained within the chamber. Not all of the material was recovered, however, since the chamber was rinsed out with water after the test and may have been discharged to the soil around the chamber (SNL/NM, 1995b).

The primary intent of the Shipping Cask and Storage Cask tests was to fully account for all released radioactive materials following a terrorist attack, so material was carefully removed from all surfaces in the Shipping Cask test chamber and the Storage Cask test box immediately following the tests. About 100 grams of DU released from the Storage Cask test box was not recovered after the test (SNL/NM, 1995c).

The COCs listed above were identified from process knowledge, interviews, and site records. Because the potential exists for other metals to have been released during the Shipping Cask and Storage Cask tests, the COC list, for risk analysis purposes, was expanded to include the eight RCRA Metals, as well as beryllium and nickel. Likewise, because the potential exists for other radionuclides to have been released, the radioactive COC list, for risk analysis purposes, was expanded to include additional radionuclides other than just DU.

II. Human Health Risk Assessment Analysis

Risk assessment of this site includes a number of steps which culminate in a quantitative evaluation of the potential adverse human health effects caused by constituents located at the site. The steps to be discussed include:

Step 1.	Site data are described which provide information on the potential COCs, as well as the relevant physical characteristics and properties of the site.
Step 2.	Potential pathways by which a representative population might be exposed to the COCs are identified.
Step 3.	The potential intake of these COCs by the representative population is calculated using a tiered approach. The tiered approach includes screening steps, followed by potential intake calculations and a discussion or evaluation of the uncertainty in those calculations. Potential intake calculations are also applied to background screening data.
Step 4.	Data are described on the potential toxicity and cancer effects from exposure to the COCs and associated background constituents and subsequent intake.
Step 5.	Potential toxicity effects (specified as a Hazard Index) and cancer risks are calculated for nonradiological COCs and background. For radiological COCs, the incremental total effective dose equivalent (TEDE) and incremental estimated cancer risk are calculated by subtracting applicable background concentrations directly from maximum on-site contaminant values. This background subtraction only occurs when a radiological COC occurs as contamination and exists as a natural background radionuclide.
Step 6.	These values are compared with standards established by the United States (U.S.) Environmental Protection Agency (USEPA) and U.S. Department of Energy (USDOE) to determine if further evaluation, and potential site clean-up, is required. Nonradiological COC risk values are also compared to background risk so that an incremental risk may be calculated.
Step 7.	Discussion of uncertainties in the previous steps.

II.1 Step 1. Site Data

Site history and characterization activities are used to identify potential COCs. The identification of COCs and the sampling to determine the concentration levels of those COCs across the site are described in the ER Site 193 No Further

Action Proposal. In order to provide conservatism in this risk assessment, the calculation uses only the maximum concentration value of each COC determined for the entire site. Chemicals that are essential nutrients such as iron, magnesium, calcium, potassium, and sodium were not included in this risk assessment (USEPA, 1989). Both radioactive and nonradioactive COCs are evaluated. The nonradioactive COCs evaluated are metals.

II.2 Step 2. Pathway Identification

ER Site 193 has been designated with a future land-use scenario of industrial (USDOE and USAF, 1996)(see Appendix 1 for default exposure pathways and parameters). Because of the location and the characteristics of the potential contaminants, the primary pathway for human exposure is considered to be soil ingestion for chemical COCs and direct gamma exposure for radiological. The inhalation pathway for both chemicals and radionuclides is included because of the potential to inhale dust and volatiles. No contamination at depth was determined and therefore no water pathways to the groundwater are considered. Depth to groundwater at Site 193 is approximately 350 feet below ground surface. Because of the lack of surface water or other significant mechanisms for dermal contact, the dermal exposure pathway is considered to not be significant. No intake routes through plant, meat, or milk ingestion are considered appropriate for the industrial land-use scenario. However, plant uptake is considered for the residential land-use scenario.

PATHWAY IDENTIFICATION

Chemical Constituents	Radionuclide Constituents
Soil Ingestion	Soil Ingestion
Inhalation (Dust and volatiles)	Inhalation (Dust and Volatiles)
Plant uptake (Residential only)	Plant uptake (Residential only)
	Direct Gamma

II.3 Steps 3-5. Calculation of Hazard Indices and Cancer Risks

Steps 3 through 5 are discussed in this section. These steps include the discussion of the tiered approach in eliminating potential COCs from further consideration in the risk assessment process and the calculation of intakes from all identified exposure pathways, the discussion of the toxicity information, and the calculation of the hazard indices and cancer risks.

The risks from the COCs at ER Site 193 were evaluated using a tiered approach. First, the maximum concentrations of COCs were compared to the SNL/NM background screening level for this area (IT, 1996). If a SNL/NM-specific screening level was not available for a constituent, then a background value was obtained, when possible, from the U.S. Geological Survey (USGS) National Uranium Resource Evaluation (NURE) program (USGS, 1994).

The maximum concentration of each COC was used in order to provide a conservative estimate of the associated risk. If any nonradiological COCs were above both the SNL/NM background screening levels or the USGS background value, all nonradiological COCs were considered in further risk assessment analyses.

For radiological COCs that exceeded the SNL/NM background screening levels, background values were subtracted from the individual maximum radionuclide concentrations. Those that did not exceed these background levels were not carried any further in the risk assessment. This approach is consistent with USDOE orders. Radioactive COCs that did not have a background value and were detected above the analytical minimum detectable activity (MDA) were carried through the risk assessment at their maximum levels. This step is performed (rather than carry the below-background radioactive COCs through the risk assessment and then perform a background risk assessment to determine incremental TEDE and estimated cancer risk) to prevent the "masking" of radiological contamination that may occur if on-site background radiological COCs exist in concentrations far enough below the assigned background level. When this "masking" occurs the final incremental TEDE and estimated cancer risk are reduced and, therefore, provide a non-conservative estimate of the potential impact on an on-site receptor. This approach is also consistent with the regulatory approach (40 CFR Part 196, 1994) which sets a TEDE limit to the on-site receptor in excess of background. The resultant radioactive COCs remaining after this step are referred to as background-adjusted radioactive COCs.

Second, if any nonradiological COC failed the initial screening step, the maximum concentration for each nonradiological COC was compared with action levels calculated using methods and equations promulgated in the proposed Resource Conservation and Recovery Act (RCRA) Subpart S (40 CFR Part 264, 1990) and Risk Assessment Guidance for Superfund (RAGS) (USEPA, 1989) documentation. If there are 10 or fewer COCs and each has a maximum concentration less than one-tenth of the action level, then the site would be judged to pose no significant health hazard to humans. If there are more than 10 COCs, the Subpart S screening procedure was skipped.

Third, hazard indices and risk due to carcinogenic effects were calculated using Reasonable Maximum Exposure (RME) methods and equations promulgated in RAGS (USEPA, 1989). The combined effects of all nonradiological COCs in the soils were calculated. The combined effects of the nonradiological COCs at their respective background concentrations in the soils were also calculated. For toxic compounds, the combined effects were calculated by summing the individual hazard quotients for each compound into a total Hazard Index. This Hazard

Index is compared to the recommended standard of 1. For potentially carcinogenic compounds, the individual risks were summed. The total risk was compared to the recommended acceptable risk range of 10^{-4} to 10^{-6}. For the radioactive COCs, the incremental TEDE was calculated and the corresponding incremental cancer risk estimated using USDOE's RESRAD computer code.

II.3.1 Comparison to Background and Action Levels

Nonradioactive ER Site 193 COCs are listed in Table 1, radioactive COCs are listed in Table 2. Both tables show the associated 95th percentile or UTL background levels (IT, 1996).

The SNL/NM background levels have not yet been approved by the USEPA or the NMED but are the result of a comprehensive study of joint SNL/NM and U.S. Air Force data from the Kirtland Air Force Base (KAFB). The report was submitted for regulatory review in early 1996. The values shown in Table 1 supersede the background values described in an interim background study report (IT, 1994).

Several compounds have maximum measured values greater than background screening levels. Therefore all nonradiological COCs were retained for further analysis with the exception of lead. The maximum concentration value for lead is 51 mg/kg. The USEPA intentionally does not provide any toxicological data on lead and therefore no risk parameter values can be calculated. However, USEPA guidance for the screening value for lead for an industrial land-use scenario is 2000 mg/kg (USEPA, 1996a); for a residential land-use scenario, the USEPA screening guidance value is 400 mg/kg (USEPA, 1994a). The maximum concentration value for lead at this site is less than both of those screening values and therefore lead is eliminated from further consideration in this risk assessment.

Because several nonradiological COCs had concentrations greater than their respective SNL/NM background 95th percentile or UTL, the site fails the background screening criteria and all nonradiological COCs proceed to the proposed Subpart S action level screening procedure.

Table 3 shows the nonradioactive COCs compared to the proposed Subpart S action level for soils. The table compares the maximum concentration values to 1/10 of the proposed Subpart S action level. This methodology was guidance given to SNL/NM from the USEPA (USEPA, 1996b). This is the second screening process in the tiered risk assessment approach. Several nonradioactive COCs had concentration values greater than 1/10 of the proposed Subpart S action level. Because of these COCs, the site fails the proposed Subpart S screening criteria and a Hazard Index value and cancer risk value must be calculated for all of the nonradioactive COCs.

Table 1. Nonradioactive COCs at ER Site 193 and Comparison to the Background Screening Values.

COC name	Maximum concentration (mg/kg)	SNL/NM 95th % or UTL Level (mg/kg)	Is maximum COC concentration less than or equal to the applicable SNL/NM background screening value?
Arsenic	50 ND	5.6	No
Barium	150	130	No
Beryllium	0.68	0.65	No
Cadmium	10 ND	<1	No
Chromium, total*	12	1	No
Lead	51	21.4	No
Mercury	0.07J	<0.25^	No
Nickel	8.3	11.5	Yes
Selenium	50 ND	<1	No
Silver	10 ND	<1	No

*total chromium assumed to be chromium VI (most conservative)
ND - not detected
^ - uncertainty due to detection limits

Table 2. Radioactive COCs at ER Site 193 and Comparison to the Background Screening Values.

COC name	Maximum concentration (pCi/g)	SNL/NM 95th % or UTL Level (pCi/g)	Is maximum COC concentration less than or equal to the applicable SNL/NM background screening value?
Co-60	0.34	NC	No
Cs-137	1.77	0.664	No
Ra-228	0.87	1.01	Yes
Th-232	0.84	1.01	Yes
U-238	30.4*	1.4	No
U-235	0.45*	0.16	No
U233/234	3.8*	1.6	No

NC - not calculated
* The maximum U-238 and U-235 activities at ER Site 193 were detected in a gamma spectroscopy analysis of the soil sample from location 193E8SS (Figure 6); these values were used in the radiologic risk calculation.
** U-234 concentration calculated using uranium isotopic ratios from waste characterization samples taken during the surface radiological voluntary corrective measures project.

Table 3. Comparison of ER Site 193 Nonradioactive COC Concentrations to Proposed Subpart S Action Levels.

COC name	Maximum concentration (mg/kg)	Proposed Subpart S Action Level (mg/kg)	Is individual contaminant less than 1/10 the Action Level?
Arsenic	50 ND	0.5	**No**
Barium	150	6000	Yes
Beryllium	0.68	0.2	**No**
Cadmium	10 ND	80	**No**
Chromium, total*	12	400	Yes
Mercury	0.07J	20	Yes
Nickel	8.3	2000	Yes
Selenium	50 ND	400	Yes
Silver	10 ND	400	Yes

* total chromium assumed to be chromium VI (most conservative)
ND - not detected

II.3.2 Identification of Toxicological Parameters

Tables 4 and 5 show the COCs that have been retained in the risk assessment and the values for the toxicological information available for those COCs. Dose conversion factors (DCFs) used in determining the incremental TEDE values for the individual pathways were the default values provided in the RESRAD computer code as developed in the following:

- For ingestion and inhalation, DCFs are taken from Federal Guidance Report No. 11, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion* (USEPA, 1988a).

- The DCFs for surface contamination (contamination on the surface of the site) were taken from USDOE/EH-0070, *External Dose-Rate Conversion Factors for Calculation of Dose to the Public* (USDOE, 1988).

Table 4. Nonradioactive Toxicological Parameter Values for ER Site 193 COCs

COC name	RfD_o (mg/kg/d)	RfD_{inh} (mg/kg/d)	Confidence	Sf_o (kg-d/mg)	Sf_{inh} (kg-d/mg)	Cancer Class ^
Arsenic	0.0003	--	M	1.5	15.1	A
Barium	0.07	0.000143	M	--	--	D
Beryllium	0.005	--	L	4.3	8.4	B2
Cadmium	0.0005	0.0000571	H	--	6.3	B1
Chromium, total*	0.005	--	L	--	42	A
Mercury	0.0003	0.0000857	--	--	--	D
Nickel	0.02	--	--	--	--	D
Selenium	0.005	--	H	--	--	D
Silver	0.005	--	L	--	--	D

* total chromium assumed to be chromium VI (most conservative)
RfD_o - oral chronic reference dose in mg/kg-day
RfD_{inh} - inhalation chronic reference dose in mg/kg-day
Confidence - L = low, M = medium, H = high
SF_o - oral slope factor in $(mg/kg\text{-}day)^{-1}$
SF_{inh} - inhalation slope factor in $(mg/kg\text{-}day)^{-1}$
^ USEPA weight-of-evidence classification system for carcinogenicity:

A - human carcinogen
B1 - probable human carcinogen. Limited human data are available
B2 - probable human carcinogen. Indicates sufficient evidence in animals and inadequate or no evidence in humans.
C - possible human carcinogen
D - not classifiable as to human carcinogenicity
E - evidence of noncarcinogenicity for humans

-- information not available

Table 5. Radiological Toxicological Parameter Values for ER Site 193 COCs

COC name	Sf_{ev} (g/pCi-yr)	SF_o (1/pCi)	Sf_{inh} (1/pCi)	Cancer Class^
Co-60	9.8×10^{-6}	1.9×10^{-11}	6.9×10^{-11}	A
Cs-137	2.1×10^{-6}	3.2×10^{-11}	1.9×10^{-11}	A
U-238	5.7×10^{-8}	6.2×10^{-11}	1.2×10^{-8}	A
U-235	2.7×10^{-7}	4.7×10^{-11}	1.3×10^{-8}	A
U-233/234	2.1×10^{-11}	4.4×10^{-11}	1.4×10^{-8}	A

Sf_{ev}- external volume exposure slope factor (risk/yr per pCi/g)
SF_o - oral (ingestion) slope factor (risk/pCi)
SF_{inh} - inhalation slope factor (risk/pCi)
^ USEPA weight-of-evidence classification system for carcinogenicity:

A - human carcinogen
B1 - probable human carcinogen. Limited human data are available
B2 - probable human carcinogen. Indicates sufficient evidence in animals and inadequate or no evidence in humans.
C - possible human carcinogen
D - not classifiable as to human carcinogenicity
E - evidence of noncarcinogenicity for humans

- The DCFs for volume contamination (exposure to contamination deeper than the immediate surface of the site) were calculated using the methods discussed in, *Dose-Rate Conversion Factors for External Exposure to Photon Emitters in Soil* (Health Physics 28:193-205) (Kocher, D.C., 1983), and ANL/EAIS-8, *Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil* (Yu, C., et al., 1993a).

II.3.3 Exposure Assessment and Risk Characterization

Section II.3.3.1 describes the exposure assessment for this risk assessment. Section II.3.3.2 provides the risk characterization including the Hazard Index value and the excess cancer risk for both the potential nonradiological COCs and associated background; industrial and residential land-uses. The incremental TEDE and incremental estimated cancer risk are provided for the background-adjusted radiological COCs; industrial and residential land-uses.

II.3.3.1 Exposure Assessment

Appendix 1 shows the equations and parameter values used in the calculation of intake values and the subsequent Hazard Index and excess cancer risk values for the individual exposure pathways. The appendix shows the parameters for both industrial and residential land-use scenarios. The equations are based on RAGS (USEPA, 1989). The parameters are based on information from RAGS (USEPA, 1989) as well as other USEPA guidance documents and reflect the RME approach advocated by RAGS (USEPA, 1989). For radionuclides, the coded equations provided in the RESRAD computer code were used to estimate the excess dose and cancer risk for the individual exposure pathways. Further discussion of this process is provided in Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0 (Yu, C., et al., 1993b).

Although the designated land-use scenario is industrial for this site, the risk and TEDE values for a residential land-use scenario are also presented. These residential risk and TEDE values are presented only to provide perspective on the potential for risk to human health under the more restrictive land-use scenario.

II.3.3.2 Risk Characterization

Table 6 shows that for the ER Site 193 nonradioactive COCs, the Hazard Index value is 0.2 and the excess cancer risk is 3 x 10^{-5} for the designated industrial land-use scenario. The numbers presented included exposure from soil ingestion and dust inhalation for the nonradioactive COCs. Table 7 shows that for the ER Site 193 associated nonradiological background constituents, the Hazard Index is 0.02 and the excess cancer risk is 5 x 10^{-6} for the designated industrial land-use scenario.

For the radioactive COCs, contribution from the direct gamma exposure pathway is included. The incremental TEDE for industrial land-use is 2.8 mrem/yr and the estimated excess cancer risk is 4 x 10^{-5}.

For the residential land-use scenario, the Hazard Index value increases to 29 and the excess cancer risk is 6 x 10^{-4}. The numbers presented included exposure from soil ingestion, dust and volatile inhalation, and plant uptake. Although USEPA (1991) generally recommends that inhalation not be included in a residential land-use scenario, this pathway is included because of the potential for soil in Albuquerque, NM, to be eroded and, subsequently, for dust to be present even in predominantly residential areas. Because of the nature of the local soil, other exposure pathways are not considered (see Appendix 1).

Table 6. Nonradioactive Risk Assessment Values for ER Site 193 COCs.

COC Name	Maximum concentration (mg/kg)	Industrial Land-Use Scenario		Residential Land-Use Scenario	
		Hazard Index	Cancer Risk	Hazard Index	Cancer Risk
Arsenic	ND	0.16	3E-5	2.86	6E-4
Barium	150	0.00	--	0.02	--
Beryllium	0.68	0.00	1E-6	0.00	5E-6
Cadmium	10 ND	0.02	4E-9	8.17	6E-9
Chromium, total*	12	0.00	3E-8	0.01	5E-8
Mercury	0.07J	0.00	--	0.12	--
Nickel	8.3	0.00	--	0.01	--
Selenium	50 ND	0.01	--	17.59	--
Silver	10 ND	0.00	--	0.41	--
TOTAL		**0.2**	**3E-5**	**29**	**6E-4**

* total chromium assumed to be chromium VI (most conservative)
-- information not available
ND - not detected

Table 7. Nonradioactive Risk Assessment Values for ER Site 193 Background Constituents.

Constituent Name	Background concentration (mg/kg)	Industrial Land-Use Scenario		Residential Land-Use Scenario	
		Hazard Index	Cancer Risk	Hazard Index	Cancer Risk
Arsenic	5.6	0.02	4E-6	0.32	6E-5
Barium	130	0.00	--	0.02	--
Beryllium	0.65	0.00	1E-6	0.00	5E-6
Cadmium	<1	--	--	--	--
Chromium, total*	1	0.00	3E-9	0.00	4E-9
Mercury	<0.25	--	--	--	--
Nickel	11.5	0.00	--	0.02	--
Selenium	<1	--	--	--	--
Silver	<1	--	--	--	--
TOTAL		**0.02**	**5E-6**	**0.4**	**7E-5**

-- information not available

* total chromium assumed to be chromium VI (consistent with Table 6)

Table 7 shows that for the ER Site 193 associated nonradiological background constituents, the Hazard Index increases to 0.4 and the excess cancer risk is 7×10^{-5}.

For the radioactive COCs, contribution from the direct gamma exposure pathway is included. The incremental TEDE for residential land-use is 7.7 mrem/yr and the estimated excess cancer risk is 1×10^{-4}.

II.4 Step 6. Comparison of Risk Values to Numerical Standards.

The risk assessment analyses considered the evaluation of the potential for adverse health effects for both an industrial land-use scenario, which is the designated land-use scenario for this site, and also a residential land-use scenario.

For the industrial land-use scenario, the Hazard Index calculated for the nonradioactive COCs is 0.2; this is much less than the numerical standard of 1 suggested in RAGS (USEPA, 1989). The excess cancer risk is estimated at 3×10^{-5}. In RAGS, the USEPA suggests that a range of values (10^{-6} to 10^{-4}) be used as the numerical standard; the value calculated for this site is in the middle of the suggested acceptable risk range. Therefore, for an industrial land-use scenario, the Hazard Index risk assessment values are significantly less than the established numerical standards and the excess cancer risk is in the middle of the suggested acceptable risk range. This risk assessment also determined risks considering background concentrations of the potential nonradiological COCs for both the industrial and residential land-use scenarios. For the industrial land-use scenario, the Hazard Index is 0.02. The excess cancer risk is estimated at 5×10^{-6}. Incremental risk is determined by subtracting risk associated with background from potential nonradiological COC risk . These numbers are not rounded before the difference is determined and therefore may appear to be inconsistent with numbers presented in tables and discussed within the text. The incremental Hazard Index is 0.17 and the incremental cancer risk is 2.6×10^{-5} for the industrial land-use scenario.

For the radioactive components of the industrial land-use scenario, the calculated incremental TEDE is 2.8 mrem/yr. In accordance with proposed USEPA guidance, the standard being utilized is an incremental TEDE of 15 mrem/yr (40 CFR Part 196, 1994) for the probable land-use scenario (industrial in this case); the calculated dose value for ER Site 193 for an industrial land-use is well below this standard. The estimated excess cancer risk is 4×10^{-5}. The cancer risk from the nonradioactive COCs and the radioactive COCs is not additive, as noted in RAGS (USEPA, 1989).

For the residential land-use scenario, the calculated Hazard Index for the nonradioactive COCs is 29, which is greater than the numerical guidance. The excess cancer risk is estimated at 6 x 10^{-4}; this value is also above the suggested acceptable risk range. The Hazard Index for associated background for the residential land-use scenario is 0.4. The excess cancer risk is estimated at 7 x 10^{-5}. For the residential land-use scenario, the incremental Hazard Index is 28.8 and the incremental cancer risk is 5.4 x 10^{-4}.

The incremental TEDE from the radioactive components is 7.7 mrem/yr. In accordance with proposed USEPA guidance, the standard being utilized is an incremental TEDE of 75 mrem/yr (40 CFR Part 196, 1994) for a complete loss of institutional controls (residential land-use in this case); the calculated dose values for ER Site 193 for the residential land-use is well below this standard. It should also be noted that, consistent with the proposed guidance (40 CFR Part 196, 1994), ER Site 193 should be eligible for unrestricted radiological release as the residential scenario resulted in an incremental TEDE to the on-site receptor of less than 15 mrem/yr. The associated estimated excess cancer risk is 1 x 10^{-4}. The cancer risk from the nonradioactive COCs and the radioactive COCs is not additive, as noted in RAGS (USEPA, 1989).

II.5 Step 7 Uncertainty Discussion

The data used to characterize ER Site 193, Sabotage Test Area, was provided by 22 surface soil samples collected at two of the three sub-sites. No sampling was conducted at the third sub-site because only high explosives were involved. Interviewees and site records indicate that all explosives used in the tests were fully consumed upon detonation (Sandoval, 1983; SNL/NM, 1995a; and USDOD, 1992), therefore no HE residue remains. The number of samples were proposed in the RFI Work Plan for OU 1335 and the site-specific Sampling and Analysis Plan for ER Site 193. The 22 samples were collected from random locations on gridded areas at the most probable release points of the two sub-sites. The number of samples was deemed sufficient to establish whether residues from the above-ground tests were detectable at the site. The COCs for the site are depleted uranium and metals. The soil samples were analyzed for TAL metals by USEPA Method 6010, mercury by USEPA Method 7471, and isotopic uranium by Lockheed Analytical Laboratories Method 0108-26879. Samples also were analyzed by gamma spectroscopy at the SNL/NM on-site radiological laboratory. QA/QC samples for the sampling event consisted of a field blank and an equipment rinsate blank analyzed for the site COCs. All the samples were analyzed by on-site SNL/NM laboratories except for the isotopic uranium analyses, the QA/QC samples, and splits from 20% of the samples which were sent to an off-site CLP laboratory for analysis. This complies with the 100% on-site analyses with 20% off-site confirmation analyses approach defined in the OU 1335 RFI Work Plan. The data provided by the CLP laboratory is considered definitive data suitable for use in a risk assessment analysis.

The conclusion from the risk assessment analysis is that the potential effects caused by potential nonradiological COCs on human health are within the acceptable range compared to established numerical standards for the industrial land-use scenario. Calculated incremental risk between potential nonradiological COCs and associated background indicate small contribution of risk from nonradiological COCs when considering the industrial land-use scenario.

For the radiological COCs the conclusion from the risk assessment is that the potential effects on human health, for the industrial land-use scenario, are well within the proposed standard (40 CFR Part 196, 1994) and are a small fraction of the estimated 290 mrem/yr received due to natural background (NCRP, 1987).

The potential effects on human health, for the nonradiological COCs, are greater when considering the residential land-use scenario. Incremental risk between potential nonradiological COCs and associated background also indicates a increased contribution of risk from the nonradiological COCs. The increased effects on human health are primarily the result of including the plant uptake exposure pathway. Constituents that posed little to no risk considering an industrial land-use scenario (some of which are below background screening levels), contribute a significant portion of the risk associated with the residential land-use scenario. These constituents bioaccumulate in plants. Because Site 193 is designated as an industrial land-use area (USDOE and USAF, 1996), the likelihood of significant plant uptake in this area is highly unlikely. The uncertainty in this conclusion is considered to be small.

For the radiological COCs the conclusion from the risk assessment is that the potential effects on human health, for the residential land-use scenario, is well within the proposed standard (40 CFR Part 196, 1994) and is a small fraction of the estimated 290 mrem/yr received due to natural background (NCRP, 1987).

Because of the location, history of the site, and the future land-use (USDOE and USAF, 1996), there is low uncertainty in the land-use scenario and the potentially affected populations that were considered in making the risk assessment analysis. Because the COCs are found in surface and near-surface soils and because of the location and physical characteristics of the site, there is little uncertainty in the exposure pathways relevant to the analysis.

An RME approach was used to calculate the risk assessment values, which means that the parameter values used in the calculations were conservative and that the calculated intakes are likely overestimates. Maximum measured values of the concentrations of the COCs and minimum value of the 95th UTL or percentile background concentration value, as applicable, of background concentrations associated with the COCs were used to provide conservative results.

Table 4 shows the uncertainties (confidence) in the nonradiological toxicological parameter values. There is a mixture of estimated values and values from the Health Effects Assessment Summary Tables (HEAST) (USEPA, 1996c) and Integrated Risk Information System (IRIS) (USEPA, 1988b, 1994b) data bases. Where values are not provided, information is not available from HEAST, IRIS, or USEPA regions. Because of the conservative nature of the RME approach, the uncertainties in the toxicological values are not expected to be of high enough concern to change the conclusion from the risk assessment analysis.

The nonradiological risk assessment values are within the acceptable range for the industrial land-use scenario compared to the established numerical standards. Though the residential land-use Hazard Index and excess cancer risk are above the numerical standards, it has been determined that future land-use at this locality will not be residential (USDOE and USAF, 1996). The radiological incremental TEDE is a very small fraction of estimated background TEDE for both the industrial and residential land-use scenarios and both are well within proposed standards (40 CFR Part 196, 1994). The overall uncertainty in all of the steps in the risk assessment process is considered insignificant with respect to the conclusion reached.

II.6 Summary

ER Site 193, an explosive test site, had relatively minor contamination consisting of some inorganic nonradioactive and radioactive compounds. Because of the location of the site on KAFB, the designated industrial land-use scenario (USDOE and USAF, 1996) and the nature of the contamination, the potential exposure pathways identified for this site included soil ingestion and dust and volatile inhalation for chemical constituents and soil ingestion, dust and volatile inhalation, and direct gamma exposure for radionuclides. Plant uptake was included as an exposure pathway for the residential land-use scenario. This site is designated for industrial land-use (USDOE and USAF, 1996); the residential land-use scenario is provided for perspective only.

The main contributor to the nonradiological industrial land-use scenario risk assessment was arsenic. For the radiological risk assessment the primary contributor was Co-60, a relatively short-lived radionuclide.

Using conservative assumptions and employing a RME approach to the risk assessment, the calculations for the nonradiological COCs show that for the industrial land-use scenario the Hazard Index (0.2) is significantly less than the accepted numerical guidance from the USEPA. The estimated cancer risk (3×10^{-5}) is in the middle of the suggested acceptable risk range. The incremental Hazard Index is 0.17 and the incremental cancer risk is 2.6×10^{-5} for the industrial land-use scenario. Incremental risk calculations indicate insignificant contribution to risk from the nonradiological COCs considering an industrial land-use scenario.

The incremental TEDE and corresponding estimated cancer risk from the radioactive components are much less than USEPA guidance values; the estimated incremental TEDE is 2.8 mrem/yr for the industrial land-use scenario. This value is much less than the numerical guidance of 15 mrem/yr in draft USEPA guidance. The corresponding estimated excess cancer risk value is 4×10^{-5} for the industrial land-use scenario.

The calculations for the nonradiological COCs show that for the residential land-use scenario the Hazard Index (29) is greater than the accepted numerical guidance from the USEPA. The estimated cancer risk (6×10^{-4}) is above the upper end of the suggested acceptable risk range. The increased effects on human health are primarily the result of the inclusion of the plant uptake exposure pathway. .Nonradiological constituents that posed little to no risk considering an industrial land-use scenario (some of which are below background screening levels), contribute a significant portion of the risk associated with the residential land-use scenario. These constituents bioaccumulate in plants. Because ER Site 193 is an industrial site (USDOE and USAF, 1996), the likelihood of significant plant uptake in this area is highly unlikely. For the residential land-use scenario, the incremental Hazard Index is 28.8 and the incremental cancer risk is 5.4×10^{-4}. Increased risk from the nonradiological COCs was evident considering residential land-use, due to plant uptake, but future use will be restricted to industrial land-use.

The incremental TEDE and corresponding estimated cancer risk from the radioactive components are much less than USEPA guidance values; the estimated incremental TEDE is 7.7 mrem/yr for the residential land-use scenario. This value is much less than the numerical guidance of 75 mrem/yr in draft USEPA guidance. The corresponding estimated excess cancer risk value is 1×10^{-4} for the residential land-use scenario.

The uncertainties associated with the calculations are considered small relative to the conservativeness of the risk assessment analysis. It is therefore concluded that this site does not have significant potential to affect human health under an industrial land-use scenario.

III. Ecological Risk Assessment

III.1 Introduction

This section addresses the ecological risks associated with exposure to constituents of potential ecological concern (COPECs) in soils from SNL/NM ER Site 193. The ecological risk assessment process performed for this site is a screening level assessment which follows the methodology presented in IT (1997) and SNL/NM (1997). The methodology was based on screening level guidance presented by USEPA (USEPA, 1992; 1996d; 1996e) and by Wentsel, et al. (1996) and is consistent with a phased approach. This assessment utilizes conservatism in the estimation of ecological risks, however, ecological relevance and professional judgment are also incorporated as recommended by USEPA (1996d) and Wentsel et al., (1996) to insure that the predicted exposures of selected ecological receptors reasonably reflect those expected to occur at the site.

III.2 Ecological Pathways

Site 193 lies within the area of the South Thunder Range (STR) which was previously surveyed for sensitive species during the spring and summer of 1992 and 1993 (Sullivan and Knight, 1994). The area surrounding the site consists of desert grassland vegetation. The topography is flat and there are no major drainages or surface water features in the area. The South Thunder Range lies in an internal drainage basin; therefore, off-site surface water drainage is not connected to the Rio Grande. Complete ecological pathways may exist at this site through the exposure of plants and wildlife to COPECs in surface and subsurface soil. No threatened, endangered, or other special status species are known to occur at the site. Scattered individuals of the grama grass cactus (*Pediocactus papyracanthus*) occur in the grassland habitats of the South Thunder Range (Sullivan and Knight, 1994; IT, 1995). This species had once been listed as endangered by the New Mexico Forestry and Resource Conservation Division (NMFRCD) and as a C2 candidate for federal listing by the U.S. Fish and Wildlife Service, but has since been removed from both special status categories by the respective agencies. The Santa Fe milkvetch (*Astragalus feensis*), designated a rare and sensitive plant by the NMFRCD, occurs on low hills within the STR (Sullivan and Knight, 1994), but is not expected to occur at the site due to its affinity for the limestone-derived soils which are not present at the site.

III.3 Constituents of Potential Ecological Concern (COPECs)

The COPECs at this site are DU, lead, and the alloying agents of stainless steel, such as chromium, nickel, and cadmium. These COPECs were identified from process knowledge, interviews, and site records. Because the potential exists for other metals and radionuclides to have been released during the Shipping and Storage Cask tests, the list of COPECs, for ecorisk assessment purposes, was expanded to include all eight RCRA metals, as well as beryllium and nickel, and additional radionuclides other than just DU. Only surface and subsurface samples collected to a depth of 5 ft were evaluated in the ecological risk assessment (IT, 1997).

Four of the eight RCRA metals (arsenic, cadmium, selenium, and silver) were not detected in any soil samples submitted to either the on-site or off-site laboratories. The laboratory detection limits for these four analytes did, however, exceed the corresponding SNL/NM background UTLs or 95th percentiles, and therefore could not be excluded from the list of COPECs for ecorisk assessment. Chemicals that are essential nutrients such as iron, magnesium, calcium, potassium, and sodium were not included in this risk assessment per USEPA 1989. Radionuclides detected at above background activities at this site were cesium-137, cobalt-60, uranium-233/234, uranium-235, and uranium-238.

III.4 Receptors and Exposure Modeling

A non-specific perennial plant was used as the receptor to represent plant species at the site. Two wildlife receptors (the deer mouse and the burrowing owl) were used to represent wildlife use of the site. Exposure modeling for the wildlife receptors was limited to the food ingestion pathway. Inhalation and dermal contact were considered insignificant pathways with respect to ingestion. Drinking water was also considered an insignificant pathway because of the lack of surface water at this site. The deer mouse was modeled as an omnivore (50 percent of the diet as plants and 50 percent as soil invertebrates) and the burrowing owl as a strict predator on small mammals (100 percent of the diet as deer mice). Both were modeled with soil ingestion comprising 2 percent of the total dietary intake. Table 8 presents the species-specific factors used in modeling exposures in the wildlife receptors. Although home range is also included in this table, exposures for this screening-level assessment were modeled using an area use factor of 1, implying that all food items and soil ingested are from the site being investigated.

The maximum measured COPEC concentrations from both surface and subsurface soil samples were used to conservatively estimate potential exposures and risks to plants and wildlife at this site.

Table 9 presents the transfer factors used in modeling the concentrations of COPECs through the food chain. Table 10 presents the maximum concentrations of non-radioactive COPECs in soil, the derived concentrations in the various food-chain elements, and the modeled dietary exposures for each of wildlife receptor species.

With respect to the radionuclides, both internal and external dose was estimated for the deer mouse and the burrowing owl using dose models developed by Pacific Northwest Laboratory (USDOE, 1995). A description of the model can be found in IT, 1997 and USDOE, 1995. Exposure to parent radionuclide and relevant decay chain daughters was assessed. Maximum detected activities used in the exposure models were:

Table 8. Exposure Factors for Ecological Receptors at Environmental Restoration Site 193, Sandia National Laboratories, New Mexico

Receptor species	Class/Order	Trophic level	Body weight (kg)[a]	Food intake rate (kg/d)[b]	Dietary Composition[c]	Home range (acres)
Deer Mouse (*Peromyscus maniculatus*)	Mammalia/ Rodentia	Omnivore	0.0239[d]	0.00372	Plants: 50% Invertebrates: 50% (+ Soil at 2% of intake)	0.27[e]
Burrowing owl (*Speotyto cunicularia*)	Aves/ Strigiformes	Carnivore	0.155[f]	0.0173	Rodents: 100% (+ Soil at 2% of intake)	34.6[g]

[a]Body weights are in kilograms wet weight.
[b]Food intake rates are estimated from the allometric equations presented in Nagy (1987). Units are kilograms dry weight per day.
[c]Dietary compositions are generalized for modeling purposes. Default soil intake value of 2% of food intake.
[d]From Silva and Downing (1995).
[e]From USEPA (1993), based on the average home range measured in semi-arid shrubland in Idaho.
[f]From Dunning (1993).
[g]From Haug et al. (1993).

Table 9. Transfer Factors Used in Exposure Models for Constituents of Potential Ecological Concern at Environmental Restoration Site 193, Sandia National Laboratories, New Mexico

Constituent of Potential Ecological Concern	Soil-to-Plant Transfer Factor	Soil-to-Invertebrate Transfer Factor	Food-to-Muscle Transfer Factor
Arsenic	4.00×10^{-2} a	1.00×10^{0} b	2.00×10^{-3} a
Barium	1.50×10^{-1} a	1.00×10^{0} b	2.00×10^{-4} c
Beryllium	1.00×10^{-2} a	1.00×10^{0} b	1.00×10^{-3} a
Cadmium	5.50×10^{-1} a	6.00×10^{-1} d	5.50×10^{-4} a
Chromium (total)	4.00×10^{-2} c	1.30×10^{-1} e	3.00×10^{-2} c
Lead	9.00×10^{-2} c	4.00×10^{-2} d	8.00×10^{-4} c
Mercury	1.00×10^{0} c	1.00×10^{0} b	2.50×10^{-1} a
Selenium	5.00×10^{-1} c	1.00×10^{0} b	1.00×10^{-1} c
Silver	1.00×10^{0} c	2.50×10^{-1} d	5.00×10^{-3} c

[a]From Baes et al. (1984).
[b]Default value.
[c]From NCRP (1989b).
[d]From Stafford et al. (1991).
[e]From Ma (1982).

Table 10. Media Concentrations for Constituents of Potential Ecological Concern at Environmental Restoration Site 193, Sandia National Laboratories, New Mexico.

Constituent of Potential Ecological Concern	Soil[a] (maximum)	Plant Foliage[a,b]	Soil[a,b] Invertebrate	Deer Mouse Tissues[a,c]
Arsenic	5.00×10^{1} ND	2.00×10^{0}	5.00×10^{1}	1.69×10^{-1}
Barium	1.50×10^{2}	2.25×10^{1}	1.50×10^{2}	5.58×10^{-2}
Beryllium	6.80×10^{-1}	6.80×10^{-3}	6.80×10^{-1}	1.12×10^{-3}
Cadmium	1.00×10^{1} ND	5.50×10^{0}	6.00×10^{0}	1.02×10^{-2}
Chromium (total)	1.20×10^{1}	4.80×10^{-1}	1.56×10^{0}	1.18×10^{-1}
Lead	5.10×10^{1}	4.59×10^{0}	2.04×10^{0}	1.08×10^{-2}
Mercury	7.00×10^{-2} J	7.50×10^{-2}	7.50×10^{-2}	5.98×10^{-2}
Selenium	5.00×10^{1} ND	2.50×10^{1}	5.00×10^{1}	1.21×10^{1}
Silver	1.00×10^{1} ND	1.00×10^{1}	2.50×10^{0}	1.01×10^{-1}

[a]Milligrams per kilogram. All are based on dry weight of the media.
[b]Product of the soil concentration and the corresponding transfer factor.
[c]Product of the average concentration in food times the food-to-muscle transfer factor times the wet weight-dry weight conversion factor of 3.125 (from USEPA, 1993).
ND - not detected, the maximum detection limits were used for conservatism.
J - estimated concentration.

- Cs-137 and daughters- 1.77 pCi/g
- Co-60- 0.34 pCi/g
- U-233/234- 3.8 pCi/g
- U-235 and daughter- 1.45 pCi/g
- U-238 and daughters- 30.4 pCi/g.

III.5 Toxicity Benchmarks

Benchmark toxicity values for the plant and wildlife receptors are presented in Table 11. For plants, the benchmark soil concentrations are based on the Lowest-Observed-Adverse-Effect-Level (LOAEL) with the adverse effect being a 20 percent reduction of growth. For wildlife, the toxicity benchmarks are based on the No-Observed-Adverse-Effect-Level (NOAEL) for chronic oral exposure (with emphasis on reproductive effects) in a taxonomically similar test species. Total chromium was assumed to be primarily composed of chromium III, and mercury was assumed to be inorganic in form. Insufficient toxicity information was found to estimate the NOAELs for beryllium and silver in the burrowing owl.

The benchmark used for exposure of terrestrial receptors to radiation was 0.1 rad/day. This value has been recommended by IAEA (1992) for the protection of terrestrial populations. Because plants and insects are less sensitive to radiation than vertebrates (Whicker and Schultz, 1982), the dose of 0.1 rad per day should also offer sufficient protection to other components within the terrestrial habitat of Site 193.

III.6 Risk Characterization

The maximum soil concentrations and estimated dietary exposures were compared to plant and wildlife benchmark values, respectively. The results of these comparisons for non-radioactive COPECs are presented in Table 12. The maximum measured soil concentrations or the highest detection limits (used in place of actual measured concentrations when the lab reported a non-detect) for all COPECs, except barium, beryllium, and mercury, exceeded their respective plant benchmark values.

Hazard quotients (HQs) are used to quantify the comparison between benchmarks for wildlife exposure. In the deer mouse, HQs exceeded one for arsenic (HQ = 31.5), barium (HQ = 1.39), and selenium (HQ = 1.53) In the burrowing owl, the HQ for mercury (HQ = 1.07) and selenium (HQ = 3.3) exceeded one.

Table 11. Toxicity Benchmarks for Ecological Receptors at Environmental Restoration Site 193, Sandia National Laboratories, New Mexico

		Mammalian NOAELs (mg/Kg/d)			Avian NOAELs (mg/Kg/d)		
Constituent of Potential Ecological Concern	Plant Benchmark (mg/Kg)[a]	Mammalian Test Species[b]	Test Species NOAEL[c]	Deer Mouse NOAEL[d]	Avian Test Species[e]	Test Species NOAEL[e]	Burrowing Owl NOAEL[f]
Arsenic	10	Lab mouse	0.126	0.133	Mallard	5.14	5.14
Barium	500	Lab rat	5.1	9.98	Chicks	20.8	20.8
Beryllium	10	Lab rat	0.66	1.29	---[g]	---	---
Cadmium	3	Lab rat	1[h]	1.89	Mallard	1.45	1.45
Chromium (total)	1	Lab rat	3.28	6.42	Black duck	1	1
Lead	50	Lab rat	8	15.7	American kestrel	3.85	3.85
Mercury	0.3	Lab rat	0.032	0.0626	Mallard	0.0064	0.0064
Selenium	1	Lab rat	0.2	0.391	Screech owl	0.44	0.44
Silver	2	Lab rat[h]	17.8[i]	34.8	---	---	---

[a]From Will and Suter (1995).
[b]From Sample et al. (1996), except where noted. Body weights (in kilograms) for NOAEL conversion are: lab mouse, 0.030; lab rat, 0.350 (except where noted); and mink, 1.0.
[c]From Sample et al. (1996), except where noted.
[d]Based on NOAEL conversion methodology presented in Sample et al. (1996), using a deer mouse body weight of 0.239 kilograms and a mammalian scaling factor of 0.25.
[e]From Sample et al. (1996).
[f]Based on NOAEL conversion methodology presented in Sample et al. (1996). The avian scaling factor of 0.0 was used, making the NOAEL independent of body weight.
[g]--- designates insufficient toxicity data.
[h]Body weight of lab rat was 0.303 Kg for NOAEL conversion (Sample et al. 1996)
[i]From USEPA (1997).

Table 12. Comparisons to Toxicity Benchmarks for Ecological Receptors at Environmental Restoration Site 193, Sandia National Laboratories, New Mexico

Constituent of Potential Ecological Concern	Plant Hazard Quotient	Deer Mouse Hazard Quotient	Burrowing Owl Hazard Quotient
Arsenic	**5.00×10^{0}**	**3.15×10^{1}**	2.53×10^{-2}
Barium	3.00×10^{-1}	**1.39×10^{0}**	1.64×10^{-2}
Beryllium	6.80×10^{-2}	4.30×10^{-2}	---[a]
Cadmium	**3.33×10^{0}**	1.02×10^{-2}	1.62×10^{-2}
Chromium (total)	**1.20×10^{1}**	3.06×10^{-2}	3.99×10^{-2}
Lead	**1.02×10^{0}**	4.31×10^{-2}	2.98×10^{-2}
Mercury	2.50×10^{-1}	1.90×10^{-1}	**1.07×10^{0}**
Selenium	**5.00×10^{1}**	**1.53×10^{1}**	**3.30×10^{0}**
Silver	**5.00×10^{0}**	2.88×10^{-2}	---

Bold text indicates hazard quotient greater than one.
[a]--- designates insufficient toxicity data available for risk estimation purposes.
* Table provides HQs for the soil concentrations provided in Table 10.

With reference to the radioactive COPECs, the total radiation dose to the mouse and owl was estimated to be approximately 3.8 x 10^{-4} (Tables 13 and 14, respectively). This value is considerably less than the benchmark of 0.1 rad/day. The radionuclides present in the soils at ER Site 193 should not be hazardous to the terrestrial receptors associated with the site.

Table 13. Internal and External Dose Rates for Mice Exposed to Radionuclides at Environmental Restoration Site 193, Sandia National Laboratories, New Mexico

Radionuclide	Maximum Concentration (pCi/g)	Internal Dose (rad/d)	External Dose (rad/d)	Total Dose (rad/d)
Cs-137 + D	1.77	1.75 x 10^{-5}	8.07 x 10^{-5}	9.82 x 10^{-5}
Co-60	0.34	6.04 x 10^{-8}	6.50 x 10^{-5}	6.51 x 10^{-5}
U-233/234	3.8	2.10 x 10^{-5}	1.81 x 10^{-8}	2.10 x 10^{-5}
U-235 + D	0.45	2.33 x 10^{-6}	6.53 x 10^{-6}	8.86 x 10^{-6}
U-238 + D	30.4	1.39 x 10^{-4}	5.03 x 10^{-5}	1.89 x 10^{-4}
Total		1.80 x 10^{-4}	2.02 x 10^{-4}	3.82 x 10^{-4}

pCi/g - picocuries per gram
+ D - includes decay daughters

Table 14. Internal and External Dose Rates for Owl Exposed to Radionuclides at Environmental Restoration Site 193, Sandia National Laboratories, New Mexico

Radionuclide	Maximum Concentration (pCi/g)	Internal Dose (rad/d)	External Dose (rad/d)	Total Dose (rad/d)
Cs-137 + D	1.77	1.49 x 10^{-5}	8.07 x 10^{-5}	9.56 x 10^{-5}
Co-60	0.34	7.99 x 10^{-8}	6.50 x 10^{-5}	6.50 x 10^{-5}
U-233/234	3.8	1.50 x 10^{-5}	1.81 x 10^{-8}	1.50 x 10^{-5}
U-235 + D	0.45	1.67 x 10^{-6}	6.53 x 10^{-6}	8.20 x 10^{-6}
U-238 + D	30.4	9.98 x 10^{-5}	5.03 x 10^{-5}	1.50 x 10^{-4}
Total		1.31 x 10^{-4}	2.02 x 10^{-4}	3.33 x 10^{-4}

pCi/g - picocuries per gram
+ D - includes decay daughters

III.7 Uncertainties

Many uncertainties are associated with the characterization of ecological risks at ER Site 193. These uncertainties result in the use of assumptions in estimating risk which may lead to an overestimation or underestimation of the true risk present at the site. For this screening level risk assessment, assumptions are made that are more likely to overestimate risk rather than to underestimate it. These conservative assumptions are used to be more protective of the ecological resources potentially affected by the site. Conservatisms incorporated into this risk assessment include the use of the maximum measured soil concentration or maximum detection limit to evaluate risk, the use of wildlife toxicity benchmarks based on NOAEL values, the use of maximum transfer factors found in the literature for modeling plant and mouse tissue concentrations, the use of earthworm-based transfer factors or a default factor of 1.0 for modeling COPECs in soil invertebrates, and the use of 1.0 as the use factor for wildlife receptors regardless of seasonal use or home range size. Uncertainties associated with the estimation of risk to ecological receptors following exposure to radiation are primarily related to those inherent in the dose models and related exposure parameters. As an example, the external dose model is based on the assumption that the receptors are underground in soil uniformly contaminated with the maximum detected activity of each radioactive COPEC. Assumptions used in the radiation dose model will err significantly on the side of conservatism.

III.8 Summary

Potential risks were indicated for all three ecological receptors at ER Site 193. However, use of the maximum measured soil concentration or the maximum detection limit (used in place of actual measured concentrations when the lab reported a non-detect) to evaluate risk provided the "worst case" scenario for the risk assessment and may not reflect actual site conditions. Maximum measured concentrations of chromium (total) and lead exceeded their respective plant benchmark values by a factor of less than 13. Detection limit values for arsenic, cadmium, selenium, and silver also resulted in predicted hazards to vegetation. With reference to the deer mouse, arsenic (highest detection limit used), barium, and selenium (highest detection limit used) were found to be potentially hazardous. Of these, arsenic and selenium produced HQs greater than 1.0 in the deer mouse using the higher detection (on-site lab) limits of the two analytical labs. Mercury and selenium were the COPECs that resulted in an HQ greater than 1.0 in the burrowing owl.

Detection limits associated with the on-site laboratory were used in this screening assessment because they were generally higher than those reported by the off-site laboratory for samples collected from the same site. Use of the higher detection limit for arsenic from the on-site laboratory (50 mg/kg) produced a HQ of 5. Use of the maximum detected concentration for arsenic reported by the off-site laboratory of 3.3 mg/kg would have resulted in a prediction of no ecological risk because this concentration is less than the background screening concentration of 5.6 mg/kg. Likewise, the higher detection limit of cadmium (10 mg/kg) from the on-site laboratory was used for the screening evaluation, which produced a HQ of 3.3 for the plant. The lower detection limit from the off-site laboratory (1 mg/kg) is within the range of the background concentrations.

Higher detection limits for selenium (50 mg/kg) from the on-site laboratory produced HQs greater than one for plant, the deer mouse, and the owl. When the lower detection limit of the off-site lab was used (10 mg/kg), it produced a HQ of less than one for the owl, and the HQs for the plant and the deer mouse were reduced to 10 and 3, respectively. The higher detection limit of the on-site lab for silver (10 mg/kg) produced a HQ of 5 for the plant. The lower detection limit of the on-site lab (2 mg/kg) produced a HQ of one. Using an estimated concentration of 0.07 mg/kg for mercury, a HQ of 1.07 was calculated for the owl. However, the estimated concentration of mercury (0.07 mg/kg) is within SNL/NM background.

As mentioned earlier, the use of maximum detected concentrations also resulted in predictions of ecological risk to plants exposed to chromium and lead and to mice exposed to barium. Although the maximum measured concentration for barium in soil from ER Site 193 indicated potential risk to the deer mouse, the average soil concentration from 27 data points for the site (103 mg/kg) is within the range of background. Using the average barium concentration in soil, no ecological risks would be predicted for the site. Similarly, the maximum total chromium concentration in soil of 12 mg/kg is less than the background concentration of total chromium (17.3 mg/kg; the background concentration reported in Table 1 is for chromium VI and not total chromium). No ecological risk from total chromium is therefore expected. Use of the maximum detected concentration of lead in ER Site 193 soil (51 mg/Kg) resulted in a HQ of 1.02 for plants. Out of the 27 data points for lead, 12 were nondetects and 12 had values lower than 30 mg/Kg. Using the average lead concentration in the exposure calculations would result in a HQ less than unity. Based on these comparisons, ecological risks associated with exposure to barium, total chromium, and lead are not expected to be significant.

Total radiation dose was not predicted to be hazardous to ecological receptors associated with the site. This is true for both internal and external exposure. Based on these results, cesium-137 and its daughters, cobalt-60, uranium-233/234, uranium-235 and its daughters, and uranium-238 and its daughters can be justified for elimination as a COPECs at Site 193.

Overall, although exposure models indicated potential ecological risks, further examination of detection limits, background concentrations, and average exposure concentrations indicate that ecological risks to receptors associated with ER Site 193 are insignificant, except for selenium. The high detection limits used (50 mg/kg, on-site lab and 10 mg/kg, off-site lab) in the ecological risk assessment for selenium produced HQs greater than one. When a detection limit of 50 mg/kg is used, HQs are greater than one for the plant (50), the deer mouse (15), and the owl (3). When the lower detection limit of 10 mg/kg is used, the HQ for the owl is reduced to less than one (0.6), and the HQs for the plant and the deer mouse are reduced to 10 and 3, respectively.

Risk analysis results showed potential ecological risk for selenium; however, the site history, process knowledge, and interviews all indicate that selenium was not used in test components or tests performed at the site, nor was it initially a COPEC. It was introduced as a COPEC, along with the other seven RCRA metals, to provide a conservative risk analysis for ER Site 193.

IV. References

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APPENDIX 1.

Sandia National Laboratories Environmental Restoration Program

EXPOSURE PATHWAY DISCUSSION FOR CHEMICAL AND RADIONUCLIDE CONTAMINATION

BACKGROUND

Sandia National Laboratories (SNL) proposes that a default set of exposure routes and associated default parameter values be developed for each future land-use designation being considered for SNL/NM Environmental Restoration (ER) project sites. This default set of exposure scenarios and parameter values would be invoked for risk assessments unless site-specific information suggested other parameter values. Because many SNL/NM ER sites have similar types of contamination and physical settings, SNL believes that the risk assessment analyses at these sites can be similar. A default set of exposure scenarios and parameter values will facilitate the risk assessments and subsequent review.

The default exposure routes and parameter values suggested are those that SNL views as resulting in a Reasonable Maximum Exposure (RME) value. Subject to comments and recommendations by the USEPA Region VI and NMED, SNL proposes that these default exposure routes and parameter values be used in future risk assessments.

At SNL/NM, all Environmental Restoration sites exist within the boundaries of the Kirtland AFB. Approximately 157 potential waste and release sites have been identified where hazardous, radiological, or mixed materials may have been released to the environment. Evaluation and characterization activities have occurred at all of these sites to varying degrees. Among other documents, the SNL/ER draft Environmental Assessment (DOE, 1996) presents a summary of the hydrogeology of the sites, the biological resources present and proposed land use scenarios for the SNL/NM ER sites. At this time, all SNL/NM ER sites have been tentatively designated for either industrial or recreational future land use. The NMED has also requested that risk calculations be performed based on a residential land use scenario. All three land use scenarios will be addressed in this document.

The SNL/NM ER project has screened the potential exposure routes and identified default parameter values to be used for calculating potential intake and subsequent hazard index, risk and dose values. EPA (EPA, 1989a) provides a summary of exposure routes that could potentially be of significance at a specific waste site. These potential exposure routes consist of:

- Ingestion of contaminated drinking water;
- Ingestion of contaminated soil;

- Ingestion of contaminated fish and shell fish;
- Ingestion of contaminated fruits and vegetables;
- Ingestion of contaminated meat, eggs, and dairy products;
- Ingestion of contaminated surface water while swimming;
- Dermal contact with chemicals in water;
- Dermal contact with chemicals in soil;
- Inhalation of airborne compounds (vapor phase or particulate), and;
- External exposure to penetrating radiation (immersion in contaminated air; immersion in contaminated water and exposure from ground surfaces with photon-emitting radionuclides).

Based on the location of the SNL ER sites and the characteristics of the surface and subsurface at the sites, we have evaluated these potential exposure routes for different land use scenarios to determine which should be considered in risk assessment analyses (the last exposure route is pertinent to radionuclides only). At SNL/NM ER sites, there does not presently occur any consumption of fish, shell fish, fruits, vegetables, meat, eggs, or dairy products that originate on-site. Additionally, no potential for swimming in surface water is present due to the high-desert environmental conditions. As documented in the RESRAD computer code manual (ANL, 1993), risks resulting from immersion in contaminated air or water are not significant compared to risks from other radiation exposure routes.

For the industrial and recreational land use scenarios, SNL/NM ER has therefore excluded the following four potential exposure routes from further risk assessment evaluations at any SNL/NM ER site:

- Ingestion of contaminated fish and shell fish;
- Ingestion of contaminated fruits and vegetables;
- Ingestion of contaminated meat, eggs, and dairy products; and
- Ingestion of contaminated surface water while swimming.

That part of the exposure pathway for radionuclides related to immersion in contaminated air or water is also eliminated.

For the residential land-use scenario, we will include ingestion of contaminated fruits and vegetables because of the potential for residential gardening.

Based on this evaluation, for future risk assessments, the exposure routes that will be considered are shown in Table 1. Dermal contact is included as a potential exposure pathway in all land use scenarios. However, the potential for dermal exposure to inorganics is not considered significant and will not be included. In general, the dermal exposure pathway is generally considered to not be significant relative to water ingestion and soil ingestion pathways but will be considered for organic components. Because of the lack of toxicological parameter values for this pathway, the inclusion of this exposure pathway into risk assessment calculations may not be possible and may be part of the uncertainty analysis for a site where dermal contact is potentially applicable.

Table 1. Exposure Pathways Considered for Various Land Use Scenarios

Industrial	Recreational	Residential
Ingestion of contaminated drinking water	Ingestion of contaminated drinking water	Ingestion of contaminated drinking water
Ingestion of contaminated soil	Ingestion of contaminated soil	Ingestion of contaminated soil
Inhalation of airborne compounds (vapor phase or particulate)	Inhalation of airborne compounds (vapor phase or particulate)	Inhalation of airborne compounds (vapor phase or particulate)
Dermal contact	Dermal contact	Dermal contact
External exposure to penetrating radiation from ground surfaces	External exposure to penetrating radiation from ground surfaces	Ingestion of fruits and vegetables
		External exposure to penetrating radiation from ground surfaces

EQUATIONS AND DEFAULT PARAMETER VALUES FOR IDENTIFIED EXPOSURE ROUTES

In general, SNL/NM expects that ingestion of compounds in drinking water and soil will be the more significant exposure routes for chemicals; external exposure to radiation may also be significant for radionuclides. All of the above routes will, however, be considered for their appropriate land use scenarios. The general equations for calculating potential intakes via these routes are shown below. The equations are from the Risk Assessment Guidance for Superfund (RAGS): Volume 1 (EPA, 1989a and 1991). These general equations also apply to calculating potential intakes for radionuclides. A more in-depth discussion of the equations used in performing radiological pathway analyses with the RESRAD code may be found in the RESRAD Manual (ANL, 1993). Also shown are the default values SNL/NM ER suggests for use in Reasonable Maximum Exposure (RME) risk assessment calculations for industrial, recreational, and residential scenarios, based on EPA and other governmental agency guidance. The pathways and values for chemical contaminants are discussed first, followed by those for radionuclide contaminants. RESRAD input parameters that are left as the default values provided with the code are not discussed. Further information relating to these parameters may be found in the RESRAD Manual (ANL, 1993).

<u>Generic Equation for Calculation of Risk Parameter Values</u>
The equation used to calculate the risk parameter values (i.e., Hazard Quotient/Index, excess cancer risk, or radiation total effective dose equivalent [dose]) is similar for all exposure pathways and is given by:

Risk (or Dose) = Intake x Toxicity Effect (either carcinogenic, noncarcinogenic, or radiological)

$$= C \times (CR \times EFD/BW/AT) \times \text{Toxicity Effect} \quad (1)$$

where

- C = contaminant concentration (site specific);
- CR = contact rate for the exposure pathway;
- EFD = exposure frequency and duration;
- BW = body weight of average exposure individual;
- AT = time over which exposure is averaged.

The total risk/dose (either cancer risk or hazard index) is the sum of the risks/doses for all of the site-specific exposure pathways and contaminants.

The evaluation of the carcinogenic health hazard produces a quantitative estimate for excess cancer risk resulting from the COCs present at the site. This estimate is evaluated for determination of further action by comparison of the quantitative estimate with the potentially acceptable risk range of 10^{-4} to 10^{-6}. The evaluation of the noncarcinogenic health hazard produces a quantitative estimate (i.e., the Hazard Index) for the toxicity resulting from the COCs present at the site. This estimate is evaluated for determination of further action by comparison of this quantitative estimate with the EPA standard Hazard Index of unity (1). The evaluation of the health hazard due to radioactive compounds produces a quantitative estimate of doses resulting from the COCs present at the site.

The specific equations used for the individual exposure pathways can be found in RAGS (EPA, 1989) and the RESRAD Manual (ANL, 1993). Table 2 shows the default parameter values suggested for used by SNL at ER sites, based on the selected land use scenario. References are given at the end of the table indicating the source for the chosen parameter values. The intention of SNL is to use default values that are consistent with regulatory guidance and consistent with the RME approach. Therefore, the values chosen will, in general, provide a conservative estimate of the actual risk parameter. These parameter values are

Table 2. Default Parameter Values for Various Land Use Scenarios

Parameter	Industrial	Recreational	Residential
General Exposure Parameters			
Exposure frequency (d/y)	***	***	***
Exposure duration (y)	30[a,b]	30[a,b]	30[a,b]
Body weight (kg)	70[a,b]	56[a,b]	70 adult[a,b] 15 child
Averaging Time (days) for carcinogenic compounds (=70 y x 365 d/y) for noncarcinogenic compounds (=ED x 365 d/y)	25550[a] 10950	25550[a] 10950	25550[a] 10950
Soil Ingestion Pathway			
Ingestion rate	100 mg/d[c]	6.24 g/y[d]	114 mg-y/kg-d[a]
Inhalation Pathway			
Inhalation rate (m^3/yr)	5000[a,b]	146[d]	5475[a,b,d]
Volatilization factor (m^3/kg)	chemical specific	chemical specific	chemical specific
Particulate emission factor (m^3/kg)	1.32E9[a]	1.32E9[a]	1.32E9[a]
Water Ingestion Pathway			
Ingestion rate (L/d)	2[a,b]	2[a,b]	2[a,b]
Food Ingestion Pathway			
Ingestion rate (kg/yr)	NA	NA	138[b,d]
Fraction ingested	NA	NA	0.25[b,d]
Dermal Pathway			
Surface area in water (m^2)	2[b,e]	2[b,e]	2[b,e]
Surface area in soil (m^2)	0.53[b,e]	0.53[b,e]	0.53[b,e]
Permeability coefficient	chemical specific	chemical specific	chemical specific

*** The exposure frequencies for the land use scenarios are often integrated into the overall contact rate for specific exposure pathways. When not included, the exposure frequency for the industrial land use scenario is 8 h/d for 250 d/y; for the recreational land use, a value of 2 hr/wk for 52 wk/y is used (EPA, 1989b); for a residential land use, all contact rates are given per day for 350 d/y.

[a] RAGS, Vol 1, Part B (EPA, 1991).

[b] Exposure Factors Handbook (EPA, 1989b)

[c] EPA Region VI guidance.

[d] For radionuclides, RESRAD (ANL, 1993) is used for human health risk calculations; default parameters are consistent with RESRAD guidance.

[e] Dermal Exposure Assessment, 1992.

suggested for use for the various exposure pathways based on the assumption that a particular site has no unusual characteristics that contradict the default assumptions. For sites for which the assumptions are not valid, the parameter values will be modified and documented.

Summary

SNL proposes the described default exposure routes and parameter values for use in risk assessments at sites that have an industrial, recreational or residential future land-use scenario. There are no current residential land-use designations at SNL ER sites, but this scenario has been requested to be considered by the NMED. For sites designated as industrial or recreational land-use, SNL will provide risk parameter values based on a residential land-use scenario to indicate the effects of data uncertainty on risk value calculations or in order to potentially mitigate the need for institutional controls or restrictions on Sandia ER sites. The parameter values are based on EPA guidance and supplemented by information from other government sources. The values are generally consistent with those proposed by Los Alamos National Laboratory, with a few minor variations. If these exposure routes and parameters are acceptable, SNL will use them in risk assessments for all sites where the assumptions are consistent with site-specific conditions. All deviations will be documented.

References

ANL, 1993, Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0, ANL/EAD/LD-2, Argonne National Laboratory, Argonne, IL.

DOE, Environmental Assessment of the Environmental Restoration Project at Sandia National Laboratories/New Mexico, US. Dept. of Energy, Kirtland Area Office, 1996.

EPA, 1989a, Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, EPA/540-1089/002, US Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.

EPA, 1989b, Exposure Factors Handbook, EPA/600/8-89/043, US Environmental Protection Agency, Office of Health and Environmental Assessment, Washington, D.C.

EPA, 1991, Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part B), EPA/540/R-92/003, US Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.

EPA, 1992, Dermal Exposure Assessment: Principles and Applications, EPA/600/8-91/011B, Office of Research and Development, Washington, D.C.

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ADDITIONAL /SUPPORTING DATA

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