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Date: September 12, 2008
Refer To: EP2008-0485

James P. Bearzi, Bureau Chief
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Drive East, Building 1
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Subject: Submittal of the Corrective Measures Evaluation Report for Material Disposal Area G, Consolidated Unit 54-013(b)-99, at Technical Area 54

Dear Mr. Bearzi:

Enclosed please find two hard copies with electronic files of the "Corrective Measures Evaluation Report for Material Disposal Area G, Consolidated Unit 54-013(b)-99, at Technical Area 54." This document is being submitted in accordance with the schedule of deliverables and requirements of the Compliance Order on Consent. As you are aware, an enhanced groundwater monitoring network is currently being installed around the perimeter of Material Disposal Area G. Groundwater data from this network will be available and will be shared with your office beginning in early- to mid-fiscal year 2009.

If you have any questions, please contact Steve Paris at (505) 606-0915 (smparis@lanl.gov) or Ed Worth at (505) 606-0398 (eworth@doeal.gov).

Sincerely,

Bruce G Schappell for SGS
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Enclosures: 1) Two hard copies with electronic files - Corrective Measures Evaluation Report for Material Disposal Area G, Consolidated Unit 54-013(b)-99, at Technical Area 54 (EP2008-0485)

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LA-UR-08-5781
September 2008
EP2008-0485

Corrective Measures Evaluation Report for Material Disposal Area G, Consolidated Unit 54-013(b)-99, at Technical Area 54

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by the Environmental Programs Directorate

LA-UR-08-5871
EP2008-0485

Corrective Measures Evaluation Report for Material Disposal Area G, Consolidated Unit 54-013(b)-99, at Technical Area 54

September 2008

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EXECUTIVE SUMMARY

This report documents the corrective measures evaluation (CME) of Material Disposal Area (MDA) G, Consolidated Unit 54-013(b)-99, located within Area G of Technical Area 54, at Los Alamos National Laboratory. Consolidated Unit 54-013(b)-99 consists of nine solid waste management units: 54-013(b), 54-014(b), 54-014(c), and 54-014(d), 54-015(k), 54-017, 54-018, 54-019, and 54-020. Consolidated Unit 54-013(b)-99 consists of inactive subsurface units established within the boundary of Area G for the disposal of low-level radioactive waste (LLW), radioactively contaminated infectious waste, asbestos-contaminated material, and polychlorinated biphenyls. Consolidated Unit 54-013(b)-99 also includes subsurface units used for the retrievable storage of transuranic waste. The MDA G corrective active units comprising Consolidated Unit 54-013(b)-99 are collocated within Area G with Resource Conservation and Recovery Act (RCRA)-regulated landfill and subsurface storage units and U.S. Department of Energy (DOE)-regulated LLW disposal units. This CME is part of a comprehensive, integrated approach to remediation and closure of all subsurface units at Area G.

The goal of the CME report is to recommend a corrective measure alternative for closure of the Consolidated Unit 54-013(b)-99 solid waste management units and to address releases from them in compliance with the March 1, 2005, Compliance Order on Consent (Consent Order). The performance assessment and composite analysis for Area G will establish the technical requirements for closure needed to meet the performance objectives for radiological protection of the public from radionuclides disposed of at the site. These technical requirements will be incorporated into the design of the final remedy during the corrective measure implementation (CMI) phase of the project.

This CME report screens 12 corrective measures alternatives based on their ability to meet regulatory threshold and other qualitative screening criteria. Four of the 12 alternatives evaluated met the screening criteria and were retained: (1) monitoring and maintenance of the existing cover combined with a soil vapor extraction (SVE) system; (2) construction of an engineered evapotranspiration (ET) cover combined with a SVE system for the removal of vapor-phase volatile organic compounds (VOCs); (3) partial waste excavation, ex situ treatment and disposal of excavated waste, monitoring and maintenance of an engineered ET cover, and extraction of vapor-phase organic compounds using an SVE system; and (4) complete excavation and off-site disposal of all MDA G waste combined with an SVE system. The alternatives must meet the cleanup objectives of the Consent Order, RCRA closure standards, and DOE performance objectives for LLW disposal sites. The alternatives also assume that the subsurface RCRA units will be closed using alternative closure requirements developed through the CME and CMI processes.

The recommended corrective measure alternative is an engineered ET cover, partial excavation of Pit 28, maintenance and monitoring, combined with a SVE system for removing vapor-phase VOCs. This alternative best satisfies the Consent Order requirements and DOE Orders 435.1 and 5400.5.

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1.0 INTRODUCTION

This report documents the corrective measures evaluation (CME) of Material Disposal Area (MDA) G, Consolidated Unit 54-013(b)-99, at Los Alamos National Laboratory (LANL or the Laboratory). MDA G is located within the boundaries of Area G at Technical Area 54 (TA-54) (Figures 1.0-1 and 1.0-2).

Area G is a 63-acre waste management and disposal area that contains 334 active and inactive waste management units (Figure 1.0-3). Area G contains 36 pits, 294 shafts, and 4 trenches (Table 1.0-1).

Consolidated Unit 54-013(b)-99 contains nine inactive subsurface solid waste management units (SWMUs): 54-013(b), 54-014(b), 54-014(c), 54-014(d), 54-015(k), 54-017, 54-018, 54-019, and 54-020 (Figure 1.0-3). Table 1.0-2 identifies and describes each SWMU, including the type of waste it manages or stores. MDA G contains 229 of the 334 subsurface waste management units at Area G (Table 1.0-1). These disposal units include 32 pits, 193 shafts, and 4 trenches and include low-level radioactive waste (LLW) mixed with hazardous constituents (mixed LLW or MLLW) and transuranic (TRU) waste. The remaining 105 SWMUs include Resource Conservation and Recovery Act (RCRA)-regulated landfill and storage units and U.S. Department of Energy (DOE)-regulated LLW disposal units. This CME is part of a comprehensive, integrated approach to remediation and closure of all subsurface disposal units at Area G, including the MDA G corrective action units, RCRA landfill units, and DOE LLW units.

The goal of the CME report is to recommend a corrective measure alternative for closure of the Consolidated Unit 54-013(b)-99 solid waste management units and to address releases from them in compliance with the March 1, 2005, Compliance Order on Consent (the Consent Order). The performance assessment and composite analysis for Area G will establish the technical requirements for closure needed to meet the performance objectives for radiological protection of the public from radionuclides disposed of at the site. These technical requirements will be incorporated into the design of the final remedy during the corrective measure implementation (CMI) phase of the project.

Hazardous constituents are subject to the corrective action provisions of the RCRA and the New Mexico Hazardous Waste Act (NMHWA), as described in the Consent Order. The MDA G SWMUs also contain LLW managed by the DOE pursuant to the Atomic Energy Act of 1954. Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to the New Mexico Environment Department (NMED) in accordance with DOE policy.

Preclosure plans for Area G waste disposal units include the cessation of operations (including aboveground waste storage operations overlying MDA G), decontamination and decommissioning (D&D) of all structures, retrieval and final off-site disposition of retrievably stored TRU waste (including that stored within MDA G) in accordance with DOE Order 435.1, final disposition of LLW, and regulatory closure of permitted units in accordance with the Laboratory's Hazardous Waste Facility Permit. The costs associated with the performance of these activities are not included in the evaluation of corrective measure alternatives in this CME report.

This CME report screens 12 corrective measure alternatives based on their ability to meet regulatory threshold and other qualitative screening criteria and recommends one alternative for implementation. The CME process also involves the public in selecting and implementing the corrective measure alternative to ensure that the proposed remedy addresses public concerns about the site. Public outreach activities that have occurred to date are presented in Appendix B.

This CME report is organized according to Consent Order requirements. Table 1.0-3 summarizes the Consent Order requirements and identifies where the applicable requirements are addressed within this document. Section 2 provides a brief site history, describes the relationship between Area G and MDA G, discusses the waste inventory, and summarizes the results of previous investigations. Section 3 describes surface and subsurface site conditions. The conceptual site model (including a description of sources, pathways, and receptors) is summarized in section 4. Section 5 details the regulatory criteria for the CME, including applicable cleanup standards, risk-based screening levels (SLs), and risk-based cleanup goals for each pertinent medium at MDA G. It also discusses the process by which criteria from the Consent Order were used for screening, evaluating, and selecting the corrective measures alternatives. The corrective measures technologies are presented, screened, and optimized in section 6. Corrective measures alternatives are identified and described in section 7 and evaluated in section 8. The selection of the recommended corrective measures alternative is discussed in section 9. The design criteria to meet cleanup objectives are presented in section 10, the proposed schedule is provided in section 11, and references and map data sources are presented in section 12.

2.0 BACKGROUND INFORMATION

TA-54 is situated in the east-central portion of the Laboratory on Mesita del Buey between Pajarito Canyon to the south and Cañada del Buey to the north (Figure 1.0-2). TA-54 includes four MDAs designated as G, H, J, and L; a waste characterization, container storage, and transfer facility; active radioactive waste storage and disposal operations at Area G; active hazardous and mixed-waste storage operations at Area L; and administrative and support areas (Figure 1.0-2). The transfer facility is located at the western end of TA-54. MDAs H and J are located approximately 500 ft and 1000 ft southeast of the transfer facility, respectively. MDA L is located approximately 1 mil southeast of the transfer facility. MDA G is located within Area G approximately 0.5 mi southeast of MDA L.

Area G, a 63-acre area containing active and inactive waste disposal units, lies within the boundaries of TA-54 (Figure 1.0-2). MDA G [Consolidated Unit 54-013(b)-99] is located within Area G and consists of SWMUs 54-013(b), 54-014(b), 54-014(c), 54-014(d), 54-015(k), 54-017, 54-018, 54-019, and 54-020 (Figure 1.0-3). The SWMUs that comprise MDA G contain 229 inactive subsurface waste management units including 32 pits, 193 shafts, and 4 trenches (Tables 1.0-1 and 1.0-2). These disposal units range in depth from 8 ft to 65 ft below the original ground surface.

The 229 inactive waste management units within MDA G are subject to the corrective action provisions of the Consent Order. Pit 29 and Shaft 124 are hazardous waste disposal units subject to RCRA closure requirements (Table 1.0-1 and Figure 1.0-3). Two other shafts (145 and 146) are regulated as RCRA storage units. The RCRA closure of the Area G landfill units and subsurface storage units will be coordinated with CMI for the MDA G SWMUs in accordance with 40 Code of Federal Regulations (CFR) 264.110(c). The CME process for MDA G will also establish the alternative closure requirements for the Area G landfill and subsurface storage units.

The following subsections provide a summary of the history and previous investigations of MDA G. Further information about the site conditions at MDA G is presented in the approved investigation work plan and report and the approved supplemental sampling investigation work plan and report for MDA G (LANL 2004, 087833, pp. 14-21; LANL 2005, 090513, pp. 9, 11-16; LANL 2006, 094803, pp. 2-3; LANL 2007, 096110, p. 1). These four documents also provide additional information about the waste disposal units, waste inventory, previous characterization activities, analytical results, and assessments of potential current-day risk to human and ecological receptors.

2.1 Site History

During the 1950s, TA-54 was selected for underground disposal of Laboratory-derived waste (Rogers 1977, 005707, pp. G-1-G-2; Rogers 1977, 005708, p. G-1). MDAs G, H, J, and L were created within TA-54 for this purpose (Figure 1.0-2).

Area G contains 334 subsurface waste management units (including 229 inactive disposal units that comprise MDA G) (Figure 1.0-3). In 1971, Area G began use for the retrievable storage of TRU waste. In 1986, Area G began to segregate MLLW for treatment and temporary storage or for off-site disposal. Area G is the only active LLW and polychlorinated biphenyl (PCB) waste disposal facility at the Laboratory. Operations at Area G include storage and characterization of TRU and mixed TRU waste destined for off-site disposal at the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico and the storage of MLLW destined for off-site treatment and/or disposal.

As a result of the waste management operations at Area G, the active and inactive waste management units are subject to the requirements of several different regulatory programs. The waste management units of Area G can be placed in five categories: LLW disposal units, TRU waste storage units, RCRA-regulated waste disposal units, corrective action units, and container storage units (CSUs) (Table 1.0-1).

MDA G has been used as the Laboratory's primary radioactive disposal facility from 1957. Initially DOE authorized MDA G for the disposal of LLW and certain radioactively contaminated infectious waste, asbestos-contaminated material, and PCBs, and for the temporary placement of TRU waste. Hazardous and mixed waste was disposed of in pits, trenches, and shafts at MDA G until 1990. Solid and liquid waste were also disposed of at MDA G. MDA G contains 229 inactive subsurface waste management units (Figure 1.0-3). Tables 2.1-1 through 2.1-3 summarize the operational history, unit dimensions, waste volumes, and description of waste received at each pit, trench, and shaft at MDA G (LANL 2005, 090513, pp. 53–55).

During active operations (i.e., when waste was being received), the pits and trenches were open to the atmosphere and the shafts were covered and locked with steel lids. When operations ceased, the remaining capacity of the pits, shafts, and trenches was backfilled with clean crushed tuff. Portions of the waste disposal units at MDA G have been covered with asphalt, and much of the surface above MDA G is currently being utilized for the active storage of RCRA interim-status MLLW and TRU waste (LANL 1992, 007669, pp. 5-179).

2.2 MDA G Waste and Inventory

Radioactively contaminated infectious waste, asbestos-contaminated material, LLW, and PCBs were disposed of at MDA G. MDA G is also used for temporary retrievable storage of TRU waste. The total estimated volumes and activities of radioactive waste disposed of or stored at MDA G between 1957 and July 1990 are summarized in Table 2.2-1. Because of incomplete records, the quantities of hazardous and radioactive constituents in the waste have been extrapolated (LANL 2005, 094156).

2.2.1 LLW and MLLW

The pits and shafts of Area G were used mainly for the disposal of LLW. Three subsurface pits and 98 shafts at Area G (exclusive of the MDA G units) are regulated as LLW disposal units pursuant to DOE Order 435.1 (Figure 1.0-3). These units are not identified as SWMUs and are not subject to corrective actions under the Consent Order. Consistent with implementing a comprehensive, integrated strategy for Area G closure, these units will be included in the CMI plan.

Between 1971 and 1987, some MLLW (hazardous and radioactive) may have been disposed of in the pits and shafts of MDA G. These units have been identified as SWMUs and are subject to the Consent Order (Table 1.0-2). Documentation indicates that the Laboratory generated an average of 55 m^3/yr of MLLW between the mid-1980s and the mid-1990s. Therefore, it is estimated that approximately 1800 m^3 of MLLW was disposed of at MDA G.

Because the waste was disposed of before the effective date of RCRA's mixed waste regulations, it is not subject to RCRA disposal requirements. However, MLLW removed from MDA G would be subject to RCRA's newly generated waste requirements.

Pit 29 and Shaft 124, two waste disposal units known as the Area G landfill units, are subject to RCRA closure requirements because they were used for the disposal of MLLW after the effective date of the RCRA hazardous waste management regulations (Figure 1.0-3). These two subsurface RCRA-regulated disposal units will be closed as RCRA landfills. Pursuant to 40 CFR 264.110(c), the alternative closure requirements of these units will be established by the CME process for MDA G. The CMI plan for MDA G will fulfill the requirements for a closure plan and postclosure plan for the landfill units as specified in 40 CFR §§ 264.112 and 264.118.

2.2.2 PCB-Contaminated, Asbestos, and Radioactively Contaminated Infectious Waste

Some of the Area G LLW disposal units were authorized for the disposal of radioactively contaminated asbestos and PCBs, which are regulated under the Toxic Substances Control Act (TSCA). No documentation is available on the concentrations or types of PCBs present. However, 200 kg of PCBs has been estimated to be present within the waste disposal units of MDA G (Tables 2.1-1 and 2.1-3).

The type and volume of radioactively contaminated infectious waste and asbestos are unknown. DOE has requested that the U.S. Environmental Protection Agency (EPA) coordinate TSCA closure requirements with those mandated by the Consent Order (DOE 2006, 098527).

2.2.3 TRU and Mixed TRU Waste

At Area G, TRU and mixed TRU waste are stored in surface and subsurface units and await characterization, certification, and shipment to WIPP for disposal. Some of this waste is contained within the SWMUs at MDA G. Table 2.2-2 summarizes the TRU waste currently contained at Area G.

Pre-1970 waste with TRU elements is assumed to contain hazardous constituents (LANL 2004, 087833, pp. G-3–G-9). Waste disposal records indicate that significant portions of the TRU waste generated at the Laboratory after 1970 are mixed with hazardous constituents. The mixed TRU waste consists of combustible and noncombustible fractions. Combustible waste includes items such as rags, plastic, paper, and rubber. Examples of noncombustible waste include glass, scrap metal, graphite, salts, and equipment such as glove boxes. Other categories or types of waste that were generated are cement paste, generated when treated liquid waste or sludges were solidified in cement before disposal; chemical treatment sludge; and PCB-contaminated waste.

The TRU and mixed TRU waste disposed of or stored within the SWMUs of MDA G are subject to the requirements of the Consent Order (Tables 1.0-1 and 1.0-2). Some TRU and mixed TRU waste are also stored aboveground and in CSUs at MDA G. This waste is managed in accordance with the Laboratory's RCRA operating permit and/or interim-status requirements.

If the pre-1970 waste with TRU elements was excavated for off-site disposal, it may meet the current regulatory definition for mixed TRU waste and would be subject to RCRA and TRU requirements for newly generated mixed waste.

If DOE determines that retrieval of portions of the post-1970 TRU waste is impractical and/or unsafe for workers, DOE may propose incorporating this waste into the corrective actions at MDA G through regulatory options available within DOE Order 435.1.

2.3 Summary of Previous Investigations

MDA G has been the subject of several site investigations. The first investigation was conducted in 1985, following receipt by the Laboratory of a Compliance Order from the New Mexico Environmental Improvement Division (NMEID, now the NMED). A Phase I RCRA facility investigation (RFI) was conducted at the MDA G between 1993 and 1995. A Consent Order site investigation was concluded in 2007. All three investigations are summarized in the following sections and in the approved investigation report (LANL 2005, 090513) and addendum to the investigation report (LANL 2007, 096110). These investigations comprised a comprehensive approach to characterize potential releases from all subsurface disposal units at Area G, including the MDA G corrective action units, RCRA landfill units, and DOE LLW disposal units. NMED approved the investigation report (NMED 2007, 096716). Relevant data from these investigations are included in the sections that follow, as appropriate.

The investigation report addendum (LANL 2007, 096110) concluded that the contaminants in the subsurface of MDA G pose no potential unacceptable present-day risk or dose to human health or the environment. However, the report recommended a CME to ensure future releases from MDA G do not pose a potential unacceptable risk/dose to receptors.

2.3.1 1985 Physical Investigations

In 1985, the Laboratory received a Compliance Order from NMEID that addressed numerous waste management issues at the Laboratory (NMEID 1985, 075885, pp. 1–9). An investigation in and around MDA G was performed and focused on six tasks outlined in the 1985 Compliance Order. The results and outcomes of these six tasks are described in a hydrogeologic assessment of Areas G and L in TA-54 (IT Corporation 1987, 076068, pp. 6-2–6-7).

2.3.2 Phase I RFI

In 1993, 1994, and 1995, ambient-air, channel-sediment, surface-flux, and subsurface-core samples were collected at MDA G during a Phase I RFI. Figure 2.3-1 shows the locations of the boreholes for the subsurface samples. In addition, quarterly pore-gas samples have been collected since 1985. The results of these previous investigations are summarized in the historical investigation report of the approved work plan for MDA G (LANL 2004, 087833, Appendix B, pp. B-5–B-18).

During the Phase I RFI, the following samples were collected and analyzed:

- 59 surface channel sediment samples in surrounding canyons
- 156 core samples from 10 vertical boreholes and 10 angled boreholes in the mesa

- 142 tritium surface flux samples
- 281 (including field duplicates) volatile organic compound (VOC) surface-flux samples consisting of 227 ambient-air samples for tritium and 16 ambient-air samples for VOCs
- 48 subsurface pore-gas samples for VOCs
- 13 subsurface pore-gas samples for tritium

In channel sediments, beryllium, cadmium, cobalt, mercury, selenium, and silver were retained as chemicals of potential concern (COPCs) because of elevated detection limits above background values (BVs). Five radionuclides, including tritium, cobalt-60, plutonium-238, plutonium-239, and americium-241, were detected in channel sediment samples above BVs (LANL 1998, 059730, pp. 44–45) and were identified as COPCs (Figure 2.3-2). Methoxychlor was also identified as a COPC (Figure 2.3-3).

In ambient-air samples, elevated levels of tritium, plutonium-238, plutonium-239, americium-241, acetone, and methanol were detected (Tables 2.3-1 and 2.3-2). Slightly elevated levels of uranium isotopes were also detected. Locations of the ambient-air sampling stations are shown in Figure 2.3-4.

Tritium; methylene chloride; 1,1,1-trichloroethane (TCA); tetrachloroethene (PCE); and 1,1,2-trichlorotrifluoroethane (Freon 113) (Eklund 1995, 056033, pp. 3-9, 3-18, 4-2–4-9, and 4-12) were detected in flux-gas samples. Locations of tritium high-flux areas are shown in Figure 2.3-5, and tritium and VOC surface flux chamber sampling locations are shown in Figure 2.3-6.

Volatile organic compound surface flux was measured across Area G in two surveys conducted in August 1993 and August 1994 using a surface flux chamber and EMFLUX surface adsorbent cartridges (Figure 2.3-7). Details of the surface flux chamber investigations are reported in Eklund (1995, 056033, pp. iv–7-1). Details of the EMFLUX surface adsorbent cartridges investigations are presented in three reports prepared by Quadrel Services (Quadrel Services 1993, 063868, pp. 9–11; Quadrel Services 1994, 063869, pp. 3-21) and Trujillo et al. (1998, 058242, pp. 18–21). During the summers of 1993 and 1994, tritium flux was measured at 142 locations on and near the surface of Area G (Eklund 1995, 056033, pp. 3-11–3-17) (Figure 2.3-7). Sixteen VOCs were detected in 1993 mesa-top surface flux studies: acetone, benzene, carbon disulfide, carbon tetrachloride, chloroform, chloromethane, 1,1-dichloroethane, 1,1-dichloroethene, methylene chloride, PCE, toluene, TCA, trichloroethene (TCE), trichlorofluoromethane (Freon 11), Freon 113, and xylene. Fewer VOCs were detected in the 1994 samples: acetone, 1,1-dichloroethane, 1,1-dichloroethene, methylene chloride, PCE, toluene, TCA, TCE, Freon 113, and xylene.

Additionally, in 1994, 16 ambient-air samples were collected for 8 d at two sampling locations along the northern perimeter of Area G. Surface flux and ambient-air sampling results indicated VOCs and tritium were being released into the atmosphere from the subsurface (LANL 2005, 090513, p. 4).

Borehole soil and tuff samples identified 43 COPCs: antimony, cadmium, cyanide, mercury, molybdenum, selenium, silver, thallium, vanadium, tritium, cobalt-60, strontium-90, cesium-137, europium-152, thorium-230, uranium-234, uranium-235, uranium-238, plutonium-238, plutonium-239, americium-241, acetone, aldrin, Aroclor-1254, benzene, benzo(a)pyrene, benzo(g,h,i)perylene, bis(2-ethylhexyl)phthalate, butanone[2-], butylbenzylphthalate, chlordane[gamma-], di-n-butylphthalate, di-n-octylphthalate, ethylbenzene, heptachlor epoxide, methylene chloride, methylnaphthalene[2-], naphthalene, pyrene, PCE, toluene, trimethylbenzene[1,2,4-], and xylene (total) (Figures 2.3-8, 2.3-9, and 2.3-10).

The pore-gas monitoring data for MDA G indicate that VOCs are COPCs in pore gas. TCA is the dominant VOC detected. The highest TCA concentration measured was 167 parts per million by volume (ppmv). Table 2.3-3 summarizes the detected VOCs in MDA G pore-gas samples from 1999 to 2002, with sampling locations shown in Figure 2.3-11.

In 2003, 13 subsurface pore-gas samples were collected from two boreholes located next to the tritium disposal shafts (locations 54-01110 and 54-01111) and analyzed for tritium. A review and analysis of the data indicate that tritium has been released into the tuff beneath the disposal units (LANL 2005, 090513, p. 4). Table 2.3-4 summarizes the pore-gas tritium results for these two boreholes (LANL 2004, 087833, Appendix B, p. B-75).

2.3.3 2005 Field Investigation

Thirty-nine boreholes were drilled in accordance with the approved MDA G work plan (LANL 2004, 087833) (Figure 2.3-12). Thirty-seven boreholes were drilled using a hollow-stem auger rig either to refusal or to the target depth specified in the work plan. Two boreholes were drilled to a depth of 556 ft and 700 ft below ground surface (bgs) with an air-rotary rig to determine whether perched water was present. One of these boreholes was abandoned at 556 ft when drilling problems prevented the target depth of 700 ft from being reached. A replacement borehole was drilled at an adjacent location to a depth of 700 ft.

Continuous core was collected from the 37 shallow boreholes to characterize the stratigraphy beneath the site. Samples of the core were analyzed for target analyte list metals, cyanide, nitrates, explosive compounds, dioxins, furans, perchlorate, VOCs, and radionuclides. The sampling, which focused on fracture characterization, included the collection of fracture fill material and surrounding intact tuff (Table 2.3-5). Geotechnical and geochemical samples were collected from the deep boreholes to measure chloride-ion concentration, matric potential, and moisture content. Pore-gas samples for tritium and VOCs were collected to evaluate the nature and extent of vapor-phase VOCs and tritium in pore water beneath MDA G.

The soil and rock sample results indicated a number of inorganic and organic chemicals were detected at trace levels beneath the former disposal units and were consistent with the results obtained during the Phase I RFI (sampling locations are shown in Plates 1 and 2).

The only organic chemicals detected in core samples were trace levels of several dioxin and furan congeners. Inorganic chemicals detected above BVs did not show any discernable patterns or trends and did not indicate a release from the historical waste units at MDA G.

Naturally occurring and anthropogenic radionuclides were confirmed at levels above BVs in soil and rock samples collected beneath MDA G. The anthropogenic radionuclides detected sporadically across the site included americium-241, plutonium-238, plutonium-239, and strontium-90. Naturally occurring radionuclides detected above BVs included thorium isotopes, uranium-234, uranium-235, and uranium-238. Naturally occurring radionuclides were detected at concentrations within the natural variability in the subsurface tuff (Plate 3).

The pore-gas sample results confirmed the presence of VOCs, consisting primarily of chlorinated VOCs, in the vadose zone beneath MDA G. Data collected during the Phase I RFI, quarterly monitoring, and the 2005 investigation indicate the highest VOC concentrations are beneath the eastern and south-central portions of MDA G and are limited at depth by the Cerros del Rio basalt at approximately 630 ft. The dominant subsurface vapor contaminant is TCA. Tritium was also detected in pore gas. The highest concentrations were detected in samples from locations in the eastern and south-central portions of MDA G, coinciding with the highest vapor concentrations of VOCs (Tables 2.3-6 and 2.3-7).

Subsurface samples collected to a depth of 700 ft beneath MDA G did not identify perched water zones. Gravimetric moisture analyses showed moisture levels ranging from 0.2% to 27.2% by weight (Table 2.3-8). Laboratory matric potential readings confirmed all samples collected beneath MDA G contained moisture levels below saturation. Perched groundwater was not detected in the 39 boreholes, including the borehole completed to a depth of 700 ft. Perched groundwater is unconfined and separated from an underlying main body of groundwater by an unsaturated zone. Not finding perched groundwater, however, does not preclude the possibility of concentrated preferential flow, including lateral flow.

2.3.4 2007 Field Investigation (Addendum to 2005 Field Investigation)

The Laboratory extended four existing boreholes (BH-2 [location 54-24361], BH-10 [location 54-24370], BH-26 [location 54-24386], and BH-34 [location 54-24394], shown in Figure 2.3-12), to define the vertical extent of VOC pore-gas contamination (LANL 2007, 096110, p. v). Table 2.3-9 shows a typical port construction summary. An existing borehole, BH-37 (location 54-24397), was also extended to determine the vertical profile of tritium concentrations in the vapor phase at this location.

The pore-gas sampling confirmed the results of the Phase I RFI, previous quarterly monitoring, and the 2005 investigation: the highest VOC concentrations are beneath the eastern portions of MDA G. VOC concentrations are highest in the Tshirege Member of the Bandelier Tuff and decrease markedly in the underlying stratigraphic units. Concentrations of VOCs are lowest in the deepest unit sampled, the Cerros del Rio basalt. TCA is the dominant subsurface VOC vapor contaminant in the eastern and central portions of MDA G, while TCE is dominant in the western portions of MDA G (Table 2.3-10). Tritium is detected in BH-37, with concentrations peaking at 50 ft bgs near the base of the nearby tritium shafts, and decreasing as the sampling depth increases to 239.75 ft bgs (Table 2.3-11).

The vertical distribution of VOC and tritium concentrations indicated no current threat of groundwater contamination, but the report recommended future pore-gas monitoring. The pore-gas sampling data supported the adequacy of the existing subsurface vapor-monitoring network to track contaminants in pore gas.

3.0 SITE CONDITIONS

The site conditions at Area G are described in detail in the approved investigation work plan (LANL 2004, 087833, pp. 14–21) and the investigation report (LANL 2005, 090513, pp. 9–15). The following subsections summarize the surface and subsurface conditions at Area G.

3.1 Surface Conditions

Area G, which encompasses the MDA G disposal units at TA-54, is located in the eastern area of Mesita del Buey, a 100-ft- to 140-ft-high, finger-shaped mesa that trends southeast. The elevation of Mesita del Buey ranges from 6605 ft to 6748 ft above sea level (asl) at Area G and varies in width from 500 ft to 1000 ft. The topography at Area G is relatively flat and narrow, with steep sides draining into Cañada del Buey to the north and Pajarito Canyon to the south. The north-facing slope of the mesa has a gentler gradient than the south-facing slope. The south-facing slope of Mesita del Buey is almost vertical near the rim and slopes more gently toward the canyon floor approximately 100 ft below.

The surface of Area G is regularly modified to accommodate ongoing waste storage and management operations. A very limited portion of the area can be considered undisturbed with respect to vegetation, erosional features, and soil formation. Most of Area G consists of asphalt-paved roads and storage areas, graded roads, buildings, utilities, stormwater drainages, shaft caps, and vegetated pit and trench covers.

3.1.1 Soil

The soil of Mesita del Buey is derived from the weathering of the Tshirege Member tuffs (phenocrysts and phenocryst fragments, devitrified glass, and minor lithic fragments) and from wind-blown sources. Soil on the flanks of the mesa is developed on Tshirege Member tuffs and colluvium with additions from wind-blown and water-transported sources. Native soil has been disturbed by waste management operations over much of the surface of Mesita del Buey, but where present, native soil is generally thickest near the center of the mesa and thinner toward the edges.

In general, soil on the mesa surface is thin and poorly developed and tends to be sandy near the surface and more clay-like beneath the surface. More highly developed soil profiles exist on the north-facing slopes and tend to be richer in organic matter. Soil profiles on the south-facing slopes tend to be poorly developed. Soil-forming processes have been identified along fractures in the upper part of the mesa, and the translocation of clay minerals from surface soil into fractures. A discussion of soil in the Los Alamos area can be found in the approved installation work plan for the former Environmental Restoration Project (LANL 1998, 062060, pp. 2-6–2-21).

The original soil near Area G was poorly developed, as is typical of soil derived from Bandelier Tuff and formed under semiarid climate conditions (Nyhan et al. 1978, 005702, p. 24). In general, undisturbed soil on the mesa tops consists of the Carjo loam, the Hackroy loam, and the Seaby loam. At Area G, natural or undisturbed surficial soil cover is limited as a result of disposal unit and cover construction.

Canyon bottoms near Area G (Cañada del Buey and Pajarito Canyon) are covered with colluvium and alluvium that has eroded from the tuff and soil on the mesa top and canyon walls. The canyon rims and slopes are composed of soil from the Hackroy-Rock outcrop complex; the canyon bottoms are composed of the Tocal, a very fine, sandy loam. Since disposal activities began, Cañada del Buey has experienced a period of accretion, and eroded soil areas at TA-54 have been deposited on the canyon bottom and stream banks. Potentially, this soil may be redistributed downstream during storm runoff events. The drainages between the mesa and canyon bottoms were sampled during the Phase I RFI; the canyon bottoms will be investigated under separate canyon investigation work plans.

3.1.2 Surface Water

No perennial streams flow on Mesita del Buey; water flows only as stormwater and snowmelt runoff on the mesa and in small drainages off the mesa to the north and the south. Stormwater flows at a number of points along the perimeter of TA-54, (LANL 2002, 074009, pp. 37–43). Therefore, flooding at the site is not a concern. As a result of runoff, surface erosion occurs primarily as shallow sheet erosion on the relatively flat parts of the mesa and as channel erosion in major drainages from the mesa top. Runoff from summer storms reaches a maximum in less than 2 h and lasts less than 24 h. By contrast, runoff from spring snowmelt occurs over a period of several weeks at a low discharge rate. The amount of eroded material transported in runoff is generally higher during summer rainfall events than during snowmelt (Hollis et al. 1997, 063131, p. 2-33).

3.1.3 Historical Preservation and Archaeology

Known archaeological sites exist in the immediate vicinity of Area G. The site has been thoroughly characterized for archaeological sites and structures that may be subject to historical preservation (LANL 1992, 007669).

3.2 Subsurface Conditions

A detailed description of the stratigraphy beneath Area G is presented in the approved work plan (LANL 2004, 087833, pp. 16–19) and was confirmed through borehole logging discussed in the investigation report (LANL 2005, 090513, pp. 11–15). The borehole logs confirm that the general stratigraphy beneath Area G is consistent with what was encountered during previous drilling at Area G and with the regional geology described by Broxton and Reneau (1995, 049726, pp. 8–19). The stratigraphy encountered is summarized in section 3.2.1. The locations of surface and subsurface structures and subsurface utilities are shown in Figure 3.2-1.

3.2.1 Stratigraphy Beneath Mesita del Buey

The locations and depths of previously drilled regional wells (R-20, R-21, R-22, and R-32) also confirmed the stratigraphy beneath Area G, including the units of the Bandelier Tuff (Figure 3.2-2) and the underlying Cerros del Rio basalts. The regional aquifer is located within the Santa Fe Group, the Puye Formation, and the Cerros del Rio basalts.

With reference to the Bandelier Tuff, the term *welding* is used to distinguish between tuff that is less compacted (or uncompacted) and porous (nonwelded) and that which is more compacted and dense (welded). In the field, the degree of welding in tuff is quantified by the degree of flattening of pumice fragments (a higher degree of flattening and elongation equals a higher degree of welding). Petrographically, welded tuff shows adhesion (welding) of grains, but nonwelded tuff does not. The term *devitrified* is applied to tuff whose volcanic glass has crystallized.

3.2.1.1 Tshirege Member (Qbt)

The Tshirege Member of the Bandelier Tuff is a compound-cooling unit that resulted from several successive ash-flow deposits separated by periods of inactivity, which allowed for partial cooling of each unit. The properties related to water flow and contaminant migration (e.g., density, porosity, degree of welding, fracture content, and mineralogy) vary both vertically and laterally as a result of localized emplacement temperature, thickness, gas content, and composition.

Tshirege Member Unit 2

Unit 2 of the Tshirege Member of the Bandelier Tuff is a competent, resistant unit that forms the surface of Mesita del Buey. Its thickness varies from 36 ft to 65 ft (11 m to 19.8 m) at Area G. Where it is exposed, unit 2 forms nearly vertical cliffs on the sides of the mesa. The rock is described as a moderately welded ash-flow tuff composed of crystal-rich, devitrified pumice fragments in a matrix of ash, shards, and phenocrysts (primarily potassium feldspar [sanidine] and quartz).

Unit 2 is extensively fractured as a result of contraction during post-depositional cooling. The cooling-joint fractures are visible on mesa edges and on the walls of pits. In general, the fractures dissipate at the bottom of unit 2. On average, fractures in unit 2 are nearly vertical. The mean spacing between fractures ranges from 1.9 ft to 2.6 ft (0.6 m and 8.8 m), and the fracture width ranges from less than 0.03 in. to 0.51 in. (1 mm to 13 mm), with a median width of 0.12 in. (3 mm). The fractures are typically filled with clays to a depth of about 9.9 ft (3 m); smectites are the dominant clay minerals present. Smectites are known for their tendency to swell when water is present and for their ability to strongly bind certain elements, both of which have implications for the transport of metals and radionuclides in fractures. Opal and calcite may be found throughout the fractured length, usually in the presence of tree and plant roots (live and decomposed); the presence of both the minerals and the roots indicates some water at depth in fractures.

At the base of unit 2 is a series of thin (less than 3.9-in.- [10-cm-] thick) discontinuous, crystal-rich, fine- to coarse-grained surge deposits. Bedding structures are often observed in these deposits. The surge beds ejected during a volcanic event mark the base of unit 2.

Tshirege Member Unit 1v

Tshirege Member unit 1v is a vapor-phase-altered cooling unit underlying unit 2. This unit forms sloping outcrops, which contrast with the near-vertical cliffs of unit 2. Unit 1v is further subdivided into units 1v(u) and 1v(c).

Unit 1v(u). The uppermost portion of unit 1v is devitrified and vapor-phase-altered ash-fall and ash-flow tuff; it has been designated unit 1v(u), where *u* signifies upper. Its thickness varies from 3 ft to 35 ft (0.9 m to 10.7 m) at Area G. Unit 1v(u) is unconsolidated at its base and becomes moderately welded nearer the overlying unit 2. Only the more prominent cooling fractures originating in unit 2 continue into the more welded upper section of unit 1v(u) but die out in the lower, less consolidated section. More typically, fractures in unit 2 do not extend into unit 1v(u).

Unit 1v(c). Beneath unit 1v(u) is unit 1v(c), where *c* stands for colonnade, named for the columnar jointing visible in cliffs formed from this unit. 1v(c) is a poorly welded, devitrified ash-flow tuff at its base and top; it becomes more welded in its interior. Unit 1v(c) varies in thickness from 6 ft to 32 ft (1.8 m to 9.8 m) at Area G.

Tshirege Member Unit 1g

The basal contact of unit 1 v(c) is marked by a rapid change (within 0.7 ft [0.2 m] vertically) from devitrified (crystallized) matrix in unit 1 v(c) to vitric (glassy) matrix in the underlying unit 1g. Vitric pumices in unit 1g stand out in relief on weathered outcrops, but devitrified pumices above this interval are weathered out. In outcrop, this devitrification interval forms a prominent erosional recess termed the *vapor-phase notch*. No depositional break is associated with the vapor-phase notch; the abrupt transition indicates this feature is the base of the devitrification that occurred in the hot interior of the cooling ash-flow sheet after emplacement.

Unit 1g is a vitric, pumiceous, nonwelded ash-flow tuff underlying the devitrified unit 1 v(c). Unit 1g varies in thickness from 30 ft to 88 ft (9.1 m to 26.8 m) at Area G. Few fractures are observed in the visible outcrops of this unit, and weathered cliff faces have a distinctive Swiss-cheese appearance because of the softness of the tuff. The uppermost 5 ft to 20 ft (1.5 m to 6.1 m) of unit 1g are iron-stained and slightly welded. This portion of unit 1g is resistant to erosion, helping to preserve the vapor-phase notch in the outcrops. A distinctive pumice-poor surge deposit forms the base of unit 1g.

Tsankawi Pumice Bed

The Tsankawi Pumice Bed is the basal air-fall deposit of the Tshirege Member of the Bandelier Tuff. It is a thin bed of gravel-sized vitric pumice. The maximum thickness of the Tsankawi Pumice Bed is 2 ft (0.6 m) at Area G.

3.2.1.2 Cerro Toledo Interval (Qct)

The Cerro Toledo interval consists of thin beds of tuffaceous sandstone, paleosol, siltstone, ash, and pumice fall; it separates the Tshirege and Otowi Members of the Bandelier Tuff. The Cerro Toledo interval also includes localized gravel- and cobble-rich fluvial deposits predominantly derived from intermediate composition lava eroded from the Jemez Mountains west of the Pajarito Plateau. This interval varies in thickness from 0.5 ft to 32 ft (0.2 m to 9.8 m) at Area G.

3.2.1.3 Otowi Member (Qbo)

The Otowi Member tuff has a maximum penetrated thickness of 62 ft (18.9 m) at Area G, although in some locations it was not encountered. The tuffs are massive, nonwelded, pumice-rich, and mostly vitric ash flows. The pumice is fully inflated, supporting tubular structures, which have not collapsed as a result of welding. The matrix is an unsorted mix of glass shards, phenocrysts, perlite clasts, and minute, broken pumice fragments.

The Guaje Pumice Bed (Qbog) is the basal air-fall deposit of the Otowi Member of the Bandelier Tuff. The maximum thickness of the unit at Area G is 5 ft (1.5 m). The pumice bed is nonwelded but brittle, and the pumice tubes are partially filled with silica cement.

3.2.1.4 Cerros del Rio Basalts (Tb 4)

In the vicinity of TA-54, the Cerros del Rio basalts lie directly beneath the Otowi Member of the Bandelier Tuff. In well R-32, the basalts are 636 ft (193.9 m) thick (LANL 2003, 079602); in well R-22 they are 983 ft (299.6 m) thick (Ball et al. 2002, 071471). In both wells, the regional water table occurs within these basalts. Borehole cores at Area G show the basalts consist of both angular rubble and dense, fractured masses, with zones of moderately to very porous lavas. Deeper drilling at R-22 showed a wide variety of lithologies within the basalts, including massive flows, interflow rubble or scoria zones, sediment, and paleosol (Ball et al. 2002, 071471). One borehole (BH 15-3 [54-25105]) penetrated 282 ft (85.9 m) of the Cerros del Rio basalts.

3.2.1.5 Puye Formation (Tpf, Tpp) and Older Fanglomerate

The Puye Formation is a conglomerate deposit derived primarily from volcanic rock to the west, with varying lithologies, including stream channel and overbank deposits, ash and pumice beds, debris flows and lahar deposits. Well tests on the Pajarito Plateau confirm the unit is very heterogeneous with both high- and low-permeability zones present (Nylander et al. 2003, 076059.49, pp. 4-17–4-20). The formation is poorly lithified, and as such is unlikely to sustain open fractures.

The Puye Formation thins from west to east beneath TA-54. At supply well PM-2, the Puye Formation (including fanglomerate, pumiceous units, and ancestral Rio Grande deposits) is approximately 800 ft (243.8 m) thick; at well R-23 it is completely absent (LANL 2003, 079601). Drilling across the Pajarito Plateau indicates the Puye Formation is frequently underlain by alluvial fan deposits similar in lithology to the Puye but considerably older. These deposits are of considerable thickness at PM-2, were penetrated at R-22 (approximately 80 ft [24.4 m] thick), and were absent at R-23. The Puye Formation was also encountered at R-16 (351 ft [106.9 m] thick), where the water table occurs within the Puye Formation (LANL 2003, 076061).

3.2.1.6 Totavi Lentil Deposits (Tpt)

The Totavi Lentil is an ancestral Rio Grande deposit consisting of coarse gravel and sand with abundant quartzite. The deposit has been alternatively conceptualized as a series of distinct north-south trending ribbons as well as a continuous thin sheet at the base of the Puye Formation. Like the overlying Puye Formation it has both high- and low-permeability zones (Nylander et al. 2003, 076059.49, pp. 4-17–4-20).

3.2.1.7 Santa Fe Group (Tsf, Tf, and Ts) and Santa Fe-Age Basalts (Tb 1 and Tb 2)

The Santa Fe Group is an alluvial-fan deposit comprised of medium to fine sand and clay. Numerous north-south trending faults are present in the Santa Fe Group. Santa Fe Group rocks are deep below Area G (1500 ft [457.2 m] bgs at PM-2) and were not penetrated by wells R-20, R-32, or R-22 (Ball et al. 2002, 071471; LANL 2003, 079600; LANL 2003, 079602). Most water supply wells on the eastern edge of the Pajarito Plateau and elsewhere in the basin are completed in these rocks. The Santa Fe Group units have the lowest permeability of all the units in the regional aquifer.

Basaltic lava flows occurred when the Santa Fe Group was deposited; these basalts occur both within the Santa Fe Group and within the pre-Puye Formation sands, gravels, and conglomerates penetrated by wells R-20 and R-22 (Ball et al. 2002, 071471; LANL 2003, 079600). These old basalts appear to have fewer open fractures than the younger Cerros del Rio basalts.

3.2.2 Hydrogeology

The proposed hydrogeologic conceptual model for the Pajarito Plateau (LANL 1998, 059599, pp. 53–55) is presented in Figure 3.2-3. Additional information about the locations and designations of Mesita del Buey drainage sections is illustrated in Figure 3.2-4. The following sections provide an overview of infiltration rates and groundwater occurrence in the vicinity of Area G.

Mesita del Buey is one of the drier mesas at the Laboratory and on the Pajarito Plateau. Infiltration occurs into the shallow subsurface mostly during snowmelts or intense summer thunderstorms. Evapotranspiration (ET) removes moisture from the shallow subsurface of the mesa. Net infiltration on Mesita del Buey is reported to range up to 0.24 in/yr (6 mm/yr) (Birdsell et al. 2005, 092048, Table 1). Shallow percolation may be slightly higher in focused recharge areas such as depressions and channels that collect runoff. Some moisture that percolates through the top of the mesa is evaporated through the sides of the mesa. The rate of percolation into the subsurface of the mesa is approximately 0.04 in./yr (1 mm/yr) (Hollis et al. 1997, 063131, pp. 2-67–2-70). The conceptual site model for contaminant migration through the unsaturated zone is presented in detail in Appendix E of the MDA G CME plan, Revision 2 (LANL 2007, 098608), and is summarized in section 4.2.1 of this report.

Generally, moisture content in the upper 100 ft (30 m) of tuff at MDA G is less than 12% by volume in areas undisturbed by disposal pits, shafts, and trenches, and, most notably, the asphalt cover. Where disposal activities have disturbed some areas, the near-surface moisture content may increase up to approximately 25% because of the absence of plant transpiration and the suppression of evaporation by the installation of extensive areas with asphalt surfacing (Krier et al. 1997, 056834, p. 35). At these moisture contents, most of the fractures beneath MDA G are dry, and pore water occurs in the tuff matrix.

Although intermediate-depth perched groundwater has been observed in locations elsewhere on the Pajarito Plateau (Robinson et al. 2005, 091682), these perched zones are generally observed beneath wet canyons and none were observed during drilling of the regional wells in the direct vicinity of Area G (R-20, R-21, R-22, and R-32) (Ball et al. 2002, 071471; Kleinfelder 2003, 090047; LANL 2003, 079600; LANL 2003, 079602). Well R-22 is located 500 ft (152 m) east of Area G on Mesita del Buey and characterizes the subsurface conditions below Area G. No intermediate-depth perched groundwater was observed in 700 ft (213 m) of drilling in the deepest Area G borehole to date (location 54-25105) (LANL 2005, 090513, p. 15). Intermediate-depth perched water does occur in wells R-23 and R-23i, located in Pajarito Canyon east of Area G (LANL 2003, 079601; Kleinfelder 2006, 092495). This water is thought to be localized beneath the canyon floor and results from infiltration along the canyon, which has a large drainage area.

The regional aquifer of the Pajarito Plateau is the only local aquifer capable of supplying municipal water on a large scale for the Laboratory, Los Alamos County, and other municipalities in the Española Basin (Purtymun 1984, 006513, p. 1). The regional aquifer extends throughout the Española Basin (an area roughly 2300 mi^2) and reaches its maximum thickness beneath the Pajarito Plateau (over 9800 ft thick) (Cordell 1979, 076049, pp. 59-64). Depths to the regional aquifer range between 1200 ft along the western edge of the Pajarito Plateau and about 600 ft along the eastern edge. Beneath Area G, the water-table elevation is approximately 5830 ft (5767 ft asl at well R-22; 5860 ft asl at well R-32) or approximately 930 ft bgs in the Cerros del Rio basalts (Figure 3.2-5).

The structure of the groundwater flow in the regional aquifer near Area G (Figure 3.2-6) indicates that contaminants reaching the regional aquifer will be transported to the southeast toward the Rio Grande. A recent analysis of the regional-aquifer monitoring network near TA-54 demonstrated that contaminants originating at Area G and potentially arriving at the regional aquifer will not travel toward the production wells on the Pajarito Plateau (LANL 2007, 098548). A combination of the existing and two additional regional monitoring wells (proposed in the report) provide high probability for successful detection of contaminants originating from Area G and flowing toward the Rio Grande (LANL 2007, 098548).

4.0 CONCEPTUAL SITE MODEL

Conceptual site models are based on existing site knowledge and data. They describe potential contaminants, exposure pathways, transport mechanisms to potential receptors, current and reasonably foreseeable land uses, and uncontaminated media that may become contaminated in the future because of contaminant migration (EPA 1989, 008021, pp. 4-10). The current conceptual site model for MDA G is presented in detail in Appendix E of the MDA G CME plan, Revision 2 (LANL 2007, 098608) and is summarized in the following section. The potential sources, pathways, and receptors are illustrated schematically in Figure 4.0-1, presented in Figure 3.2-3 and summarized below.

4.1 Sources

The known sources of environmental contamination, documented in the approved MDA G investigation report (LANL 2005, 090513, Appendix G, pp. G-27–G-30) are as follows:

- vapor-phase releases of tritium and VOCs from subsurface SWMUs;
- inorganic chemicals, radionuclides , and organic chemicals in drainage channel sediment; and
- inorganic chemicals and radionuclides present in the tuff below the disposal units.

Minor secondary sources of contamination occur where VOCs partition into soil moisture. Tritium vapor may equilibrate with soil moisture to form a secondary source of tritium contamination.

4.2 Pathways

4.2.1 Contaminant Transport Pathways

As described in the approved investigation report (LANL 2005, 090513, pp. G-4–G-5), the relevant release and transport processes are a function of chemical-specific properties, the physical form and/or container associated with a waste, and the nature of the transport process.

The conceptual site model includes the following modes of contaminant release:

- leaching (dissolution) by water infiltrating at the ground surface, then seeping through the covers and into the waste volume;
- volatilization or vaporization and diffusion of certain contaminants within the waste;
- incorporation into plants whose roots grow into the waste;
- excavation by animals burrowing into the waste; and
- exposure of waste because of erosional processes (wind, water, and mass wasting).

Contaminants released from the disposed waste may be redistributed within and beyond the site by the following primary transport pathways:

- vapor-phase transport of volatile chemicals (VOCs and tritium) into the surrounding unsaturated zone with potential for transport to the regional aquifer;
- vapor-phase transport of volatile chemicals (VOCs and tritium) into the atmosphere;
- surface-water transport of contaminated surface soil as eroded sediment into adjacent canyons by runoff;
- airborne transport of small particulates brought to the surface by biointrusion or erosion;
- unsaturated transport of contaminants with infiltrating water through the thick (900 ft to 1000 ft) unsaturated zone;
- saturated-zone transport if contaminants reach the regional aquifer; and
- biointrusive transport via plant roots and burrowing animals.

The pathway through the unsaturated zone below MDA G is of concern because contaminants may eventually reach the regional aquifer, which is the water supply for Los Alamos County and the Laboratory. The primary modes of transport below MDA G are vapor-phase, diffusion-dominated transport of VOCs and unsaturated transport of contaminants with infiltrating water. Unsaturated liquid phase flow and transport are currently being evaluated with unsaturated zone flow and transport simulation models. Current site characterization data indicate that the tuff beneath MDA G is predominately unsaturated, and that moisture content is consistent with mesa-top infiltration rates of 1 mm/yr or less (Kwicklis et al. 2005, 092049, p. 672). Unsaturated-zone flow and transport simulations indicated predominantly vertical transport. Travel times for liquid-phase (aqueous) unsaturated-zone transport are predicted to be approximately 10,000 yr for peak concentrations of nonadsorbing species to reach the regional aquifer (Newman 1996, 059118, p. 1; Newman et al. 1997, 059371, p. 19; Birdsell et al. 1999, 069792, p. 73; Collins et al. 2005, 092028, pp. 2-85–2-94). However, the first arrival of extremely low concentrations by this method is simulated to occur in about 100 yr. Moisture content increases slightly above the Cerros del Rio basalt, especially in the Guaje Pumice Bed. The contrast in hydrologic properties between the pumice and basalt may cause some lateral spreading along the paleotopography of the Cerros del Rio basalt, which slopes to the south towards Pajarito Canyon. This and other heterogeneities in the geology may increase the length of the flow path to the regional aquifer but would also concentrate flow, increasing the volumetric water content, increasing the local flux rate and, potentially, decreasing the travel time to the regional aquifer. In 1995, a very small volume of water (approximately 1 cup) was produced within the Cerros del Rio basalt during drilling of the borehole at location 54-01016 at MDA L. Three porous-cup lysimeters, one at the depth of the observed saturation and two at deeper depths, were subsequently installed in this borehole to monitor water that might accumulate. These lysimeters were monitored annually through 2005, and no further accumulation of free water occurred over 10 yr of monitoring (LANL 2003, 087572.1114, p. 6). Greater percolation rates likely exist beneath the canyon because of channelized canyon runoff and perched alluvial water. If contaminants are laterally diverted atop the basalt to beneath the canyon, faster transport rates toward the regional aquifer could occur. Although trace levels of tritium and technetium-99 have been detected in well R-22, which is next to Area G, they are attributed to infiltration from channelized canyon flow. The conceptual site model for contaminant migration through the unsaturated zone is presented in more detail in Appendix E of the MDA G CME plan, Revision 2 (LANL 2007, 098608). Various modeling studies that support this summary are also referenced in that appendix.

In addition to unsaturated-zone monitoring, groundwater monitoring near MDA G will be used to sample the regional aquifer and perched intermediate zones in accordance with the Laboratory's Interim Facility-Wide Groundwater Monitoring Plan (IFWGMP) (LANL 2007, 096665). Regional aquifer samples are currently collected at wells R-20, R-21, R-22, R-23, and R-32, and perched intermediate zone water from Pajarito Canyon is collected at well R-23i. In addition, at TA-54, five new regional monitoring wells and two new perched intermediate monitoring wells in Pajarito Canyon were proposed (LANL 2007, 098548) to further bolster the monitoring network. This report was approved by NMED and requires the Laboratory to install five new regional wells and two new perched-intermediate wells around TA-54 starting in 2008. The locations of existing and planned wells for the enhanced monitoring network are shown in Figures 4.2-1 and 4.2-2. The combined monitoring network, including unsaturated zone monitoring, will supply data to determine whether any corrective measure implemented is effective at reducing infiltration and preventing migration of contaminants to the regional aquifer. The intermediate-depth monitoring wells will provide additional information on contamination in perched intermediate water, if it is present, beneath Pajarito Canyon.

Vapor-phase transport accounts for the observed migration to depth of VOCs in pore gas within the Bandelier Tuff. Extensive analyses of the VOCs in pore gas beneath MDA L (also on Mesita del Buey) have shown that vapor-phase transport accounts for the migration of VOCs, for which vapor-phase concentrations are in equilibrium with water concentrations as determined by Henry's law partitioning. Vapor migration of VOCs in the subsurface can be described by diffusive behavior, which is unaffected by preferential air flow or barometric pumping within the mesa (Stauffer et al. 2005, 090537). Diffusion theoretically spreads contamination in a spherical direction along concentration gradients. However, topography plays an important role in vapor transport at TA-54. With low vapor concentrations occurring at the top and sides of the mesas, the steepest concentration gradients are toward the surface. These steep gradients preferentially lead to vapor transport toward these external boundaries rather than downward toward the regional aquifer.

Tritium is transported in the subsurface at TA-54 through a multiphase coupled process. Primarily, it is transported by the diffusion of water vapor. However, as tritiated water vapor diffuses away from a source area, it readily equilibrates with tritium-free pore water already in the unsaturated zone. The relatively rapid process of vapor-phase diffusion (in the case of tritium, the vapor is water vapor) is effectively slowed by the presence of pore water, which acts as a reservoir for tritium that partitions from the vapor. This interaction with pore water results in a lower effective water-vapor diffusion coefficient than would be observed if no liquid pore water was present. This conceptual site model is based on observations of tritium in the subsurface at both MDA G and TA-53 (Vold 1996, 070155; Stauffer 2003, 080930). Data and modeling results indicate that the effective vapor-phase diffusion coefficient for tritium is 25 times lower than for the VOCs at TA-54, primarily because those VOCs do not partition as readily into pore water. Diffusion of tritium toward the surface leads to some surface flux of tritium to the atmosphere in water vapor. In addition, radioactive decay of tritium (half-life of 12.3 yr) decreases tritium mass as it migrates through the unsaturated zone. Any tritium reaching the regional aquifer by water-vapor diffusion would be directly below the disposal site because this pathway is the shortest diffusive pathway, and the tritium would partition into the groundwater. The most significant migration of tritium, both to the surface and downward toward the regional aquifer, will occur near the tritium shafts where subsurface vapor concentrations are the highest.

It is possible that a vapor plume of either VOCs or tritium could reach the Guaje Pumice Bed, which is generally present atop the Cerros del Rio basalt at TA-54. Because this unit has higher moisture content than overlying tuff units, vapor diffusion through the pumice may be slower. VOC or tritium vapors that reach the Guaje Pumice Bed will partition into the pore water. If lateral flow occurs in the Guaje Pumice Bed atop a dipping basalt unit, this flow could reach Pajarito Canyon where enhanced liquid-phase flow might occur. However, flow rates along this dipping surface are likely to be quite low because of unsaturated permeability relationships.

Stratigraphy is a less important control for vapor-phase transport than for liquid-phase transport because of the tendency of the plume to spread in all directions, rather than being gravity driven. Rapid transport by advective vapor flow is not a likely transport mechanism within the fractured Cerros del Rio basalt because vapor-phase densities are low enough that gravity-driven downward flow in fractures should not occur. Additionally, if vapor-phase transport of VOCs were to reach the regional aquifer by diffusing through the fractured Cerros del Rio basalt, the effect of partitioning calculated using Henry's law would result in very low mass loadings to the regional groundwater based on current detected vapor concentrations (LANL 2005, 092591; LANL 2007, 096409). In the event that VOC vapor-phase transport causes low concentrations to reach the regional aquifer, the area of migration would be centered beneath MDA G because stratigraphy would have minimal effect on the direction of migration.

Several activities and studies are proposed to address uncertainties associated with vapor-phase transport and its impact on the regional aquifer. A pilot test is being performed to address the radius and depth of pressure influence of soil vapor extraction (SVE) wells, the rate of extraction of VOCs, and rebound time (LANL 2007, 099777). Air permeability tests will be used to assess and provide site-specific data for numerical transport models. Vapor sampling of VOCs and tritium and three-dimensional mapping will identify multiple source areas and changes in concentration with time.

A better understanding of saturated-zone transport pathways will be achieved by regional groundwater monitoring in accordance with the Laboratory's 2007 IFWGMP (LANL 2007, 096665). The groundwater monitoring wells (Figures 4.2-1 and 4.2-2) will allow sampling at the regional aquifer and potential perched-intermediate zones intercepted in Pajarito Canyon to determine if VOCs, tritium or other contaminants from MDA G have reached the regional aquifer or a potential intermediate perched zone in the canyon. Appendix F of the MDA G CME plan, Revision 2 (LANL 2007, 098608) contains analytical calculations demonstrating that groundwater-screening criteria in the regional aquifer are not likely to be exceeded for VOCs and tritium if water fluxes through the surface cover remain at or below the design rate of 1 mm/yr.

The two other contaminant transport pathways of the conceptual site model are biointrusion and surface water. Any corrective measures alternative selected will address these two pathways.

4.2.2 Exposure Pathways

The risk assessment (LANL 2005, 090513, Appendix G, pp. G-11–G-12) identified human exposure pathways to contaminants by incidental soil ingestion, inhalation of suspended soil (dust), dermal absorption, and external irradiation. Inhalation of gas-phase contaminants, such as tritium and/or VOCs emanating from the site into the atmosphere, is also a potential means of exposure. In addition, plant uptake and animal burrowing may lead to additional exposure pathways. Diffusive releases of vapor- and gas-phase contaminants may be another route of exposure.

Ecological receptors may be exposed through soil ingestion, inhalation of suspended soil (dust), dermal absorption, and external irradiation as well as through plant-root uptake and the food web. In addition, the receptors may be exposed to concentrations of gas-phase contaminants in subsurface burrows. The ecological pathways conceptual exposure model for MDA G identifies the primary exposure pathways to animals as being dietary uptake of contaminated channel sediment and respiratory uptake of vapor-phase contaminants. The primary exposure pathway to plants is root uptake.

4.3 Receptors

Receptors in the immediate area that could be potentially exposed to contamination from MDA G include humans (site workers at Area G and TA-54) and biota at the site. No evaluation of a construction worker is included in this assessment because no intrusive activity is anticipated at MDA G following closure. Should such work occur, an evaluation will be performed to address this scenario, and those performing the evaluation will work with facility management to ensure the safety of workers and to limit their exposure.

Other human receptors include those living downwind or downgradient of the site. Receptors may also include inadvertent intruders. In evaluating dose and risk impacts from potential contaminant releases to members of the public, it is common practice to place receptors either along the site boundary or at the site fence line.

The hillside areas of Mesita del Buey have fully intact terrestrial biotic communities and therefore include a full suite of potential terrestrial receptors (LANL 2005, 090513, Appendix G, p. G-14). Area G is managed in a way that limits ecological receptors to invasive plants, small mammals, birds, and invertebrates. The mesa top is fenced off from the surrounding hillsides to limit access to the area by large animals (e.g., deer, elk, and mountain lions); some limitations may also apply to foxes, coyotes, raccoons, bobcats, or other medium-size mammals. Although the mesa top and hillsides differ in community composition and character, the terrestrial functional feeding groups expected on the Pajarito Plateau are not likely to be currently found in and around Area G because it is highly industrialized and part of the area is paved.

The risk assessment identified 10 terrestrial receptors appropriate for numerical screening against contaminant concentrations in soil or channel sediment (LANL 2005, 090513, Appendix G, pp. G-4–G-12). These terrestrial receptors include the following:

- plants
- earthworm (soil-dwelling invertebrate)

- American robin (avian invertebrate eater, avian omnivore, and avian herbivore)
- American kestrel (avian carnivore [also serves as a surrogate for the Mexican spotted owl])
- deer mouse (mammalian omnivore)
- montane shrew (mammalian insectivore)
- desert cottontail (mammalian herbivore)
- red fox (mammalian carnivore)
- little brown Myotis bat (flying mammalian insectivore [also serves as a surrogate for the spotted bat])
- Botta's pocket gopher (burrowing mammalian herbivore)

5.0 REGULATORY CRITERIA

The subsurface units at MDA G are subject to several sets of regulatory requirements. The MDA G units are subject to corrective action requirements under the Consent Order, including cleanup standards, SLs, and risk-based cleanup goals for nonradioactive contaminants. Area G, including the MDA G units, is a LLW disposal facility regulated by DOE under Order 435.1. The LLW disposal units are subject to closure requirements under DOE Order 435.1, including long-term performance objectives for radiological protection of the public. The Area G landfill units and subsurface RCRA storage are subject to closure under RCRA rather than corrective action under the Consent Order. Closure of these units will be coordinated with corrective action through the use of alternative closure requirements. These various requirements are discussed in the following sections.

5.1 Cleanup Standards, Risk-Based SLs, and Risk-Based Cleanup Goals

The cleanup and SLs described in section VIII of the Consent Order were followed for determining the recommended corrective measure alternative. The cleanup levels are based on the New Mexico Water Quality Control Commission's (NMWQCC's) groundwater and surface water standards and on NMED's screening levels for protection of human health; the levels are consistent with the EPA's National Oil and Hazardous Substance Pollution Contingency Plan, 40 CFR Section 300.430(e)(2)(i)(A)(*2*).

NMED has selected a human health target risk level of 10^{-5} and a hazard index (HI) of 1.0 as cleanup goals for establishing site-specific cleanup levels. NMED and the EPA have soil screening levels (SSLs), the EPA has maximum contaminant levels (MCLs), and the NMWQCC has groundwater and surface water standards, which are described below.

Screening for ecological risk for determination of the recommended corrective measures alternative used the ecological screening levels (ESLs) (LANL 2004, 087630; LANL 2005, 090032).

Table 5.1-1 presents a listing of the regulatory standards regarding cleanup for specific media.

5.1.1 Groundwater

As required by NMED in a letter dated April 5, 2007 (NMED 2007, 095999), the "Technical Area 54 Well Evaluation and Network Recommendations" (LANL 2007, 098548) was submitted to NMED. This report was approved by NMED and requires the Laboratory to install five new regional wells and two new perched intermediate wells around TA-54 beginning in 2008. Requirements from the approved plan will be incorporated into the remedy selected for MDA G. The corrective measure alternative chosen will be required to meet the groundwater standards in Section VIII.A of the Consent Order. These standards include the NMWQCC groundwater standards, including alternative abatement standards (20.6.2.4103 New Mexico Administrative Code [NMAC]), and the EPA drinking water MCLs under the federal Safe Drinking Water Act (42 United States Code [U.S.C.] §§ 300f to 300j-26) or the NMWQCC (20.7.10 NMAC). If both a NMWQCC standard and an MCL have been established for an individual substance, the lower of the two levels is considered the cleanup level for that substance.

NMED uses the most recent version of the EPA Region 6 human health medium-specific screening level (HHMSSL) for tap water as the SL, if either a NMWQCC standard or an MCL has not been established for a specific substance. If no NMWQCC groundwater standard or MCL has been established for a contaminant for which toxicological information is published, the Laboratory will use a target excess cancer risk level of 10^{-5} and/or HI of 1.0 as the basis for proposing a cleanup level for the contaminant. If the naturally occurring (background) concentration of a contaminant exceeds the standard, the cleanup level defaults to the background concentration for that specific contaminant.

5.1.2 Soil

NMED has specified SSLs that are based on a target total excess cancer risk of 10^{-5} and for noncarcinogenic contaminants a target HI of 1.0 for residential and industrial land use. Residential and industrial SSLs are from NMED's "Technical Background Document for Development of Soil Screening Levels, Revision 4.0" (NMED 2006, 092513). If an NMED SSL has not been established for a contaminant for which toxicological information is published, the Laboratory uses the most recent version of the EPA Region 6 HHMSSL for residential and industrial land use. These SSLs will be used as cleanup levels as specified in the Section VIII.B.1 of the Consent Order if an excavation alternative is selected.

5.1.3 Surface Water

No permanent surface water is present at MDA G. Discharges of stormwater from MDA G, which are subject to permitting under Section 402 of the federal Clean Water Act will be included in a stormwater discharge permit issued by EPA (currently in draft form). Therefore, surface water cleanup levels are not applicable to corrective measures at MDA G.

5.1.4 Pore Gas

No regulatory standards apply to VOCs in pore gas. VOC results from pore-gas sampling were screened to evaluate whether concentrations of VOCs in subsurface pore gas are of concern as a potential source of groundwater contamination (LANL 2007, 096110, Appendix E, p. E-4). Because no SLs for pore gas address potential for groundwater contamination, the screening evaluation was based on groundwater cleanup levels contained in the Consent Order and in Henry's law constants that describe the equilibrium relationship between vapor and water concentrations. The source of the Henry's law constants was the NMED SSL technical background document (NMED 2006, 092513). If Henry's law constants were not available from this source, they were obtained from the Pennsylvania Department of Environmental Protection chemical- and physical-properties database (http://www.dep.state.pa.us/physicalproperties/Default.htm). The following dimensionless form of Henry's law constant was used:

$$H' = \frac{C_{air}}{C_{water}}$$ **Equation 5-1**

where C_{air} is the volumetric concentration of contaminant in air and C_{water} is the volumetric concentration of contaminant in water. Equation 5-1 can be used to calculate the following screening value:

$$SV = \frac{C_{air}}{1{,}000 \times H' \times SL}$$ **Equation 5-2**

where C_{air} is the concentration of VOC in the pore-gas sample (µg/m^3), H′ is the dimensionless Henry's law constant, *SL* is the screening level (µg/L) and 1000 is a conversion factor from L to m^3. The SLs are based on the NMWQCC's groundwater standards or the EPA MCLs, whichever is lower. As specified in the Consent Order, if no MCL or NMWQCC standard is available, the EPA Region 6 HHMSSL for tap water SL is used (adjusted to 10^{-5} risk for carcinogens). The numerator in Equation 5-2 is the actual concentration of VOC in pore gas, and the denominator represents the concentration in pore gas needed to exceed the SL. Therefore, if the screening value is less than 1, the concentration of VOC in pore gas is not sufficiently high to cause the SL to be exceeded, even if the VOC plume were in contact with groundwater.

Equation 5.2 was used to screen the VOC pore-gas data for the supplemental investigation at MDA G. The screening was performed using the maximum detected value from the deepest stratigraphic unit sampled, which is the Cerros del Rio basalt. Data from the deepest unit are used in the screening because this unit is closest to the regional aquifer. Sixteen VOCs having MCLs, NMWQCC standards and/or HHMSSLs were detected in samples collected from the Cerros del Rio basalt at MDA G (LANL 2007, 096110, Appendix E, p. E-14). These results show that the screening value (SV) is below 1 in every case. Based on these screening results, the VOCs detected in subsurface pore gas at MDA G do not appear to be a potential source of groundwater contamination at present.

5.2 Consent Order Criteria

The revised CME plan identifies an initial set of corrective measure alternatives for MDA G (LANL 2007, 098608, p. 17) based on evaluation of specific information on site conditions, including the contaminant inventory, the design of the disposal units, the environmental setting, and the nature and extent of contamination.

A range of corrective measures alternatives is screened and evaluated to determine what corrective measure(s) is most appropriate at MDA G to ensure protection of human health and the environment in the future. For this evaluation, the capability to control the release of potentially harmful quantities of contaminants from the site is assessed in accordance with NMED, EPA, and DOE risk/dose assessment guidance. A range of alternatives, including closure under DOE Order 435.1, source removal, containment, and contaminant removal, is assessed. The containment alternatives are evaluated to ensure that contaminant concentrations do not exceed cleanup levels if the material in the subsurface disposal units is left in place. The benefits, costs, and implementation risks of the alternatives are compared with the no further action alternative as a baseline.

Numerous criteria are used in this report to determine the recommended corrective measure alternative for MDA G. Sections VII.D.4.a and VII.D.4.b of the Consent Order provide threshold and balancing criteria for screening and evaluation of corrective measures, respectively. These criteria are presented in sections 5.2.1 and 5.2.2 of this report. Additionally, Section XI.F.10 of the Consent Order provides evaluation criteria for the corrective measure alternatives, as summarized in section 5.2.3. Section XI.F.11 of the Consent Order mandates justifying the recommended corrective measure alternative based on a fourth set of criteria listed in section 5.2.4. Figure 5.2-1 presents a flow chart of the selection process used to determine the recommended corrective measure alternative using all four sets of criteria.

5.2.1 Threshold Criteria

As described in Section VII.D.4.a of the Consent Order, all corrective measure alternatives were screened for further analysis based on the following threshold criteria. To be selected, the alternative must

1. be protective of human health and the environment;
2. attain media cleanup standards;
3. control the source or sources of releases to reduce or eliminate, to the extent practicable, further releases of contaminants that may pose a threat to human health and the environment; and
4. comply with applicable standards for management of waste.

The screening process was applied to 11 corrective measures alternatives as discussed in section 7.

5.2.2 Balancing Criteria

Section VII.D.4.b of the Consent Order identifies balancing criteria to be applied upon screening of the initial set of corrective measure alternatives. These balancing criteria include

1. long-term reliability and effectiveness,
2. reduction of toxicity, mobility, or volume,
3. short-term effectiveness,
4. implementability, and
5. cost.

These criteria closely overlap with the evaluation criteria described in Section XI.F.9 of the Consent Order. Therefore, these criteria were combined with the evaluation criteria outlined in section 5.2.3. The combined criteria were used to evaluate four corrective measure alternatives that passed the initial screening described in section 6.

5.2.3 Evaluation Criteria

Section XI.F.10 of the Consent Order required the evaluation of corrective measure alternatives based on the following criteria:

1. applicability
2. technical practicability
3. effectiveness
4. implementability
5. human health and ecological protectiveness
6. cost

The overlap between the balancing criteria presented in section 5.2.2 with these evaluation criteria was addressed by discussing the balancing criteria within the six corresponding evaluation criteria. Section 8 evaluates the four corrective measure alternatives that passed the initial screening, presented in section 6, in terms of these criteria.

5.2.4 Selection Criteria

Based on the evaluation of the four final corrective measure alternatives, one alternative was selected as the recommended corrective measure alternative. Compliance of this alternative with a final set of criteria described in Section XI.F.11 of the Consent Order is detailed in section 9 of this report. The criteria used in the final selection were as follows:

1. achieve cleanup objectives in a timely manner
2. protect human and ecological receptors
3. control or eliminate the sources of contamination
4. control migration of released contaminants
5. manage remediation waste in accordance with state and federal regulations

The justification for the recommended corrective measure alternative includes the supporting rationale for the remedy selection, based on the factors listed in sections 7 and 8 and a discussion of short- and long-term objectives for the site and the benefits and possible hazards of the alternative.

5.3 DOE Closure Requirements

Low-level radioactive and mixed waste disposal operations at Area G followed the requirements set by DOE Order 5820.2, “Radioactive Waste Management,” and those requirements subsequently set by DOE Order 5820.2A, “Radioactive Waste Management.” On July 9, 1999, DOE Order 5820.2A was cancelled and replaced by DOE Order 435.1, “Radioactive Waste Management.” The objective of these orders is to ensure that all radioactive waste at DOE sites is managed in a manner that protects the health and safety of both workers and the public and the environment.

DOE Order 435.1 does not set specific closure system design criteria but establishes performance objectives for the closed facility. The objectives and limits are as follows:

- Doses to representative member of the public shall not exceed 25 mrem in a year total effective dose equivalent (TEDE) from all exposure pathways, excluding the dose from radon and its progeny in air.
- Dose to representative members of the public via the air pathway shall not exceed 10 mrem in a year TEDE, excluding the dose from radon and its progeny in air.
- Release of radon shall be less than an average flux of 20 $pCi/m^2/s$ at the surface of the disposal facility.

5.4 RCRA Closure Requirements

As specified in the draft Hazardous Waste Facility Permit issued by NMED on August 27, 2007, closure of the Area G landfill units and subsurface RCRA storage units will be coordinated with the corrective action for MDA G being conducted under the Consent Order. Pursuant to 40 CFR 264.110(c), the Area G landfill units and subsurface RCRA storage units will be closed under alternative closure requirements established under the Consent Order rather than the closure requirements of 40 CFR 264 Subparts G and N. The alternative closure requirements for the Area G landfill units and subsurface RCRA storage units will be established using the CME process for MDA G contained in Section VII.D of the Consent Order. Upon NMED's selection of the remedy for MDA G, the Laboratory will prepare and submit a CMI plan. The CMI plan will fulfill the requirements for a closure plan and postclosure plan for the Area G landfill units and subsurface RCRA storage units specified in 40 CFR §§ 264.112 and 264.118.

6.0 CORRECTIVE MEASURE TECHNOLOGIES

The revised MDA G CME plan (LANL 2007, 098608, p. 17) provides an initial subset of alternatives/alternative groupings that will meet the corrective measure goals. Most of the alternatives identified in the CME plan could incorporate a variety of specific technologies to accomplish the corrective actions. To provide additional detail in presenting corrective measure alternatives, this CME report initially identifies and screens potential technologies by type. Applicable technologies are combined into a preliminary list of alternatives, presented in section 7 and further screened using a comparative analysis.

6.1 Preliminary List of Technologies

General types of corrective measure technologies potentially appropriate to MDA G site conditions and waste types were taken from the comprehensive technology list developed by the Federal Remediation Technologies Roundtable (Table 3.2, available at http://www.frtr.gov/matrix2/appd_b/append_b.html).

For waste disposed of at MDA G, potentially appropriate technologies from the comprehensive technology list fall into the four general categories listed below and shown in the left-most column of Figure 6.1-1:

- containment
- in situ treatment
- excavation/retrieval
- ex situ treatment

Only technologies that would be appropriate for MDA G site conditions were considered and consequently presented in the CME report.

Within the treatment categories, subcategories include biological, chemical, physical, and thermal treatment. To be effective, technologies must address the site conditions at MDA G, all or a significant portion of the waste matrices present at MDA G (potentially including contaminated environmental media), and the primary contaminants at MDA G, as discussed in section 4.2.1 and summarized in the approved investigation report (LANL 2005, 090513).

6.1.1 Containment Technologies

Containment technologies are intended to limit migration of contaminants or limit infiltration into the vadose zone. Such technologies include the surface and subsurface barriers discussed below.

6.1.1.1 Vertical Barriers

Vertical barrier technologies are considered of limited benefit for MDA G applications, since the absence of near-surface groundwater limits lateral migration of most contaminants. In addition, some of these types of barriers have limited effectiveness against semivolatile organic compounds (SVOCs) and pesticides and no expected effectiveness against VOCs. Reducing the lateral component of vapor-phase transport of a few volatile contaminants at the site (e.g., TCA and tritium) is one potential application for vertical barriers at MDA G, but downward migration of these contaminants may be enhanced as a result.

The following vertical barrier technologies were considered when preparing the CME.

Slurry Wall/Grout Curtain

Slurry walls are formed using slurried bentonite clays or cement-grout or other barrier materials that are placed in narrow, deep trenches or in a series of adjacent open boreholes surrounding the perimeter or at the migrating edge of a disposal site. Slurry walls are commonly used to intercept contaminants that migrate laterally. The arid environment at MDA G is not compatible with the use of bentonite clays, which become cracked and permeable when desiccated (Pearlman 1999, 102747, p. 16), and the porous nature of grout materials will not significantly impede vapor-phase transport of volatile COPCs at MDA G. Also, lateral migration of contaminants (except vapor phase VOCs) is limited at MDA G, so this technology was not retained for further consideration.

Rock-Grout Mixing

Rock-grout barriers are formed by drilling adjacent deep shafts around the perimeter of a disposal site and mixing the cut rock with injected grout as the shaft is drilled. Like slurry walls, rock-grout mixing is used to intercept contaminants that migrate laterally. Lateral migration of contaminants, except vapor-phase VOCs, is limited at MDA G and the porous nature of grout materials will not impede vapor-phase transport of volatile COPCs at MDA G. In addition, rock-grout barriers require a mixing area, produce substantial spoils, and crack because of freeze-thaw cycles (Pearlman 1999, 102747, pp. 4-5). This technology was not retained for further consideration because lateral migration of contaminants, other than VOCs, is not expected at MDA G.

Synthetic Membrane

A synthetic membrane, such as a geosynthetic liner, can be placed in a vertical trench. The membrane forms a barrier that impedes/restricts the lateral and vertical migration of contaminants. Although this technology may be adapted to impede lateral and vertical migration of contaminants at MDA G, the synthetic membrane will degrade and be ineffective in the early stages of the closure period (USACE 1998, 102742, pp. 6-7–6-8). This technology was not retained for further consideration because of a lack of effectiveness demonstrated very early in the DOE stability period.

Reactive Barrier

A chemically active material can be placed in a vertical orientation around the waste disposal area or the reactive materials can be incorporated into another barrier technology. The reactive chemical is chosen for the ability to adsorb or chemically degrade one or more of the COPCs (such as activated carbon for adsorption of TCA). However, because the barrier technology is primarily demonstrated in the liquid phase, its applicability to MDA G is not considered effective. Therefore, this technology was not retained for further consideration (ESL 2004, 102753, p. 2-3).

6.1.1.2 Deep Subsurface Horizontal Barriers

The purpose of a horizontal barrier is typically to contain downward aqueous-phase contaminant transport. Such a barrier is suitable for sites with known significant infiltration from the surface. In addition, this technology is not cost effective on a large scale (Pearlman 1999, 102747, p. 40). A deep horizontal barrier is not appropriate for addressing the release and transport pathways of potential concern at MDA G. Therefore, technologies in this category were not retained for further consideration.

6.1.1.3 Near-Surface Horizontal Barriers

Near-surface horizontal barriers created by a soil-grout mixture or vitrification could enhance existing covers at MDA G by controlling intrusion into the waste by plants, animals, or people and by reducing infiltration of water. Therefore, this technology is retained for further consideration. Additional engineering or modeling studies are required to determine whether, and to what extent, the physical and hydrological properties of the existing cover materials can be improved over the short- and long-term by implementing this technology.

Soil-Grout Mix

A concrete-grout mixture containing soil or crushed tuff may be used to replace a subsurface portion of the existing cover materials over disposal units at MDA G. This barrier can be safely constructed and has the potential to decrease the permeability to water and/or penetrability by plants and animals (EPA 2006, 102752, p. 7). This technology was retained for further consideration.

Vitrification

In situ vitrification is the process of using electrical resistance to heat soil or rock to temperatures high enough to melt them. When the melted materials cool, a glass-like material forms. In situ vitrification produces an impermeable, impenetrable horizontal barrier and has been demonstrated to a depth of 30 ft (EPA 2006, 102752, pp. 32–34). Current operational cover soil at MDA G is limited to about a 4.9-ft to 6.6-ft (1.5-m to 2-m) thickness over waste. To act as a horizontal barrier over the waste units, the technology has to be used in existing cover materials or in materials to be added as part of a more comprehensive cover system at MDA G. Soil-grout mixing can provide similar benefits more cost effectively and without the added concern of mobilizing volatile waste from the application of extreme heating. This technology was not retained for further consideration for general horizontal barrier use, although it may be used for specific waste immobilization (see section 6.1.2.4).

6.1.1.4 Surface Barriers

Barriers placed on the surface of disposal sites provide protection against the infiltration of water, provide resistance to water and wind erosion, prevent or minimize intrusion into waste by plants or animals, act as a deterrent to inadvertent human intrusion, and limit flux of gas-phase contaminants, such as radon. The existing 3-ft-minimum surface covers at MDA G have provided effective protection against infiltration. Enhancements to existing covers could readily allow MDA G to meet the evaluation criteria for protecting human health and the environment. Enhancements will probably be drawn from the following readily available surface barrier technologies.

Asphalt Cover

Asphalt provides a substantial barrier to surface erosion processes but has been shown at another Laboratory site (MDA AB, Area 2 [LANL 1999, 063918, pp. 16–20]) to trap moisture that will otherwise be evaporated or transpired from the subsurface. Because maintaining low moisture content is a desirable feature for MDA G, an asphalt cover will not be suitable for this site. This technology was not retained for further consideration.

Compacted-Clay Cover

Compacted-clay covers have successfully controlled excess infiltration at RCRA-regulated landfills located in humid environments. However, clay liners are far less effective in arid and semiarid climates because the clay tends to dry out and crack, allowing moisture to flow directly into disposal units (Mulder and Haven 1995, 071297, p. 4). Therefore, compacted-clay covers are not suitable for MDA G. This technology was not retained for further consideration.

Multilayer Cover

Multilayer covers consist of layers of different geologic and synthetic materials placed in a specific order to control potentially detrimental processes and conditions at a site (e.g., infiltration, erosion, and biotic intrusion). RCRA Subtitle C covers fit into this category. Multilayer covers may be compromised if differential settlement occurs or if their components are not suited for the site. Application of conventional multilayer covers is problematic at sites with potential for differential settlement, such as sites where waste has been placed without engineered uniform compaction and sites where clay components can become desiccated and crack.

At MDA G, the variation between the settlement potential of excavated disposal units and their surroundings may be significant, and deeper waste units may have the greatest differential settling. Although subsidence at MDA G may potentially be a long-term occurrence, its impact on the synthetic or geosynthetic membrane component(s) of a multilayer cover may be significant and go unnoticed from the surface. The arid nature of the MDA G climate is also considered incompatible with typical clay component layers of the RCRA Subtitle C multilayer cover, because of the cracking that occurs in clays with desiccation in an arid environment. This technology was not retained for further consideration.

ET Cover

Evapotranspiration covers are designed to provide infiltration protection for arid environments, where materials such as clays and synthetic/geosynthetic membranes are less reliable. ET covers may consist of a single, vegetated soil layer, or may be designed with multiple layers of geologic materials suited to achieve the necessary ET criteria. Suitable native vegetation is a significant component for most ET covers to aid in the dewatering of the cover material(s). The vegetated ET cover was developed explicitly for landfills located in arid and semiarid environments such as the Laboratory (Barnes et al. 1990, 070209, pp. 1201–1202). The earliest research in this area was conducted at a test site within 1 mi of MDA G (Nyhan et al. 1984, 008797, pp. 361–366; Nyhan 1989, 006876; Nyhan et al. 1989, 006874). Cover system design guidance has also been developed that provides requirements and considerations for design of cover systems at the Laboratory (ITRC 2003, 091330; LANL 2006, 094803). An engineered ET cover could enhance the existing MDA G cover. This technology has been retained for further consideration.

Biotic Barriers

Various materials have been used to control the intrusion of plants and/or animals into landfills. Installation of horizontal barriers below the surface of the cover and constructed of cobble-sized rocks or pea gravel inhibits deep-rooting plants and discourages burrowing animals. Chainlink fencing installed below the surface of a cover has been successfully used at a Laboratory site to discourage burrowing animals while having no observable impact on beneficial vegetation (LANL 1999, 063919, pp. E-1–E-2). Either of these subsurface biotic barriers may be used as a stand-alone technology or may be incorporated into enhanced cover designs considered for MDA G. This technology has been retained for further consideration.

6.1.2 In Situ Treatment Technologies

In situ waste treatment technologies are used to reduce the mobility and/or toxicity of waste or to increase their stability without removing the waste from their disposal location. The different in situ methods (biological and physical) discussed in this section are appropriate for different contaminants and disposal environments.

6.1.2.1 Biological Treatment Technologies

Biological methods, using various microorganisms, have been effective in metabolizing a variety of organic contaminants and also in changing solubility of certain inorganic chemical and radioactive species in low concentrations in wastewater treatment processes. However, biological treatment technologies have not been shown to be effective in treating the predominant waste forms specific to the inventory at MDA G (i.e., paper, metals, plastics, personal protective equipment [PPE]). In addition, biological treatment applies best to groundwater and there is no known groundwater contamination at MDA G (FRTR 2004, 102751, pp. 36-39, 42-45). Biodegradation would play a role in the use of SVE for treatment as part of a potential remedy, but biological treatment is not a viable technology for treatment of any other type of waste at MDA G. This technology was not retained for consideration for potential treatment of waste at MDA G because of the nature of the material needing treatment.

6.1.2.2 Chemical Treatment Technologies

Available in situ chemical treatments (i.e., soil washing and chemical oxidation) were not considered appropriate for MDA G. The nature of the waste contained at MDA G does not lend itself to chemical treatment, which generally is used to treat organic and inorganic waste. Although both organic and inorganic waste is stored at MDA G, the radioactive component of the waste cannot be effectively treated with chemical treatment technologies. Soil washing requires a significant amount of water flowing through the waste and could potentially mobilize contaminants into the groundwater. Chemical oxidation has a very small area of influence in the vadose zone (EPA 2006, 102752, p. 9). Because of these issues, these technologies were not retained for further consideration in this corrective measures evaluation.

6.1.2.3 Physical Treatment Technologies

In situ physical treatment technologies include methods to remove mobile contaminants, to increase mobility of contaminants, to further stabilize contaminants, and to destroy contaminants in-place. Most in situ treatments have the advantage over ex situ methods of reducing potential exposure to workers. The decision to use in situ treatment potentially can vary from waste unit to waste unit at MDA G based on the types and orientations of waste, their potential to produce future risks, and the availability of other options. The following subsections present the in situ physical treatment technologies considered.

Soil-Gas Venting

Passive soil-gas venting consists of open boreholes drilled into the contaminated matrix, which allow the release of subsurface vapors and gases to the atmosphere or through a treatment system. This technology is primarily applicable to VOCs. Soil venting is potentially applicable for the VOCs present in pore gas at MDA G (Mickelson 2002, 102750, section 1.2). This technology has been retained for further consideration.

Soil-Vapor Extraction

Soil vapor extraction introduces the use of a force to soil-gas venting to accelerate the removal of subsurface gases or vapors. The force may be in the form of air pressure injected into one or more boreholes, a vacuum that pulls the vapor from one or more boreholes, or a steep diffusion force that removes the gas or vapor from an area. This technology commonly requires a treatment system for the vapor extracted from the subsurface. SVE is a viable alternative when pore spaces between soil grains are sufficiently connected to allow adequate airflow or the rock is somewhat fractured. The tuff found beneath MDA G is sufficiently permeable to use SVE for the removal of VOCs, based on SVE studies in tuff at nearby MDA L (LANL 2006, 094152; Stauffer et al. 2007, 097871). Therefore, SVE is retained for further consideration. A pilot study of SVE is currently being conducted at MDA G to evaluate its effectiveness. The report detailing the findings of the pilot study will be provided to NMED by October 31, 2008, and a final decision concerning its applicability for use as a treatment technology for MDA G can then be made.

Pneumatic Fracturing

Pneumatic fracturing uses the injection of a fluid under pressure to create open fractures in an area in which a contaminant plume exists. Opening flow paths allows access to the contaminated media for removal or treatment (EPA 2001, 102740, p. 1). Pneumatic fracturing has the potential for introducing large amounts of water through these new cracks into a formation that has optimal low moisture content and is not desirable. This technology was not retained for further consideration.

Electrokinetic Soil Treatment

Electrokinetic soil treatment is an in situ process for continuously removing ionic or charged species from soil, including heavy metals, radionuclides, and ionized organic chemicals. The technology is implemented by passing a direct current through the soil. The effectiveness of this technology is dramatically reduced in soil with low moisture content (Evanko and Dzombak 1997, 102743, p. 29). In addition, the use of direct current in the vicinity of the waste is problematic because of buried metal objects. This technology was not retained for further consideration.

Electroacoustic Treatment

In situ electroacoustic soil decontamination is an emerging technology used for decontaminating soil containing organic chemicals. However, its viability has primarily been demonstrated on waste in soil not in other materials such as those found at MDA G (Muralidhara et al. 1990, 102735, pp. iv, 95). This technology was not retained for further consideration.

Dynamic Compaction

Dynamic compaction is used to compact and consolidate waste in place to reduce the potential for settling or sinking over time. The technology has been successfully demonstrated on landfills where subsidence (settling) over large areas is possible, leading to potentially significant run-on and infiltration of surface water (EPA 2002, 102739, p. 1). The technology is potentially applicable for the larger horizontally oriented waste units (the pits) at MDA G, if potential subsidence needs to be reduced, in conjunction with a cover technology. This technology was retained for further consideration.

Waste Stabilization

The infiltration and movement of surface water into/through MDA G waste disposal units and the potential for subsidence of waste and overburden may be reduced by injecting grout into or around waste to reduce the porosity within and between objects. In one method, grout is injected into holes drilled through the waste, while the waste is simultaneously pulverized and mixed with grout. This approach is only applicable for bulk-managed, soil-like waste. A second waste stabilization method involves the direct injection of grout into void spaces surrounding waste. This method would be more appropriate for the waste present in the MDA G disposal shafts (EPA 1996, 102748, p. 4). This technology was retained for further consideration.

6.1.2.4 Thermal Treatment Technologies

Thermal treatment technologies have been developed and implemented to decompose heat sensitive contaminants into less toxic or less mobile forms or to enhance the extractability of a contaminant by heating it into a vapor phase. Heat is generated or delivered using microwave radiation, radio frequency radiation, or thermal-radiation energy or through direct conductance of electricity or injection of already heated materials (such as steam).

Vitrification

Several in situ vitrification technologies exist for solidifying waste masses in the ground. In situ vitrification uses electrical resistance to heat soil or rock (and waste materials) to temperatures high enough to melt them. When the melted materials cool, a glass-like material is formed. In situ vitrification produces an essentially impermeable mass and has been demonstrated to a depth of 30 ft. The surface-down melt-in method has the potential to trap volatilized gases under the melted mass and has been prone to catastrophic release in some situations. An alternative method that simultaneously melts waste and matrix between two electrodes at all depths has been shown to achieve similar results more safely. Parallel electrodes are successively moved to create multiple melt planes until the necessary application coverage is achieved.

In situ stabilization technologies (jet grouting) generally achieve similar performance objectives more cost effectively than in situ vitrification without the risk of mobilizing volatile waste, but vitrification may be considered more durable for the extended corrective measure performance period associated with contaminant containment. However, because of the excessive cost of vitrification, this technology was not retained for further consideration (EPA 2006, 102752, pp. 32–34).

Thermal Treatment

Only a limited set of contaminants in MDA G waste respond to thermal treatment. Organic chemical contaminants in the tuff outside the waste units are widely distributed such that large portions of the mesa tuff require treatment to mobilize or destroy the contaminants. This treatment is costly because of energy and equipment costs. Debris or other large objects buried in the media, as found at MDA G, can cause operating difficulties (EPA 1996, 102748, p. 4). This technology was not retained for further consideration.

6.1.3 Excavation/Removal Technologies

Excavating waste from MDA G requires the use of remotely operated or robotic excavators to control potential worker-safety hazards from buried containerized and noncontainerized waste. Removing waste from shafts involves rigging in tight quarters and would be impractical if waste containers have degraded. Bulk removal of waste from MDA G may require the construction of containment structures to maintain control of airborne particulate and avoid rainwater infiltration. In addition, because of the classified nature of some of the waste inventory, excavation at certain locations must be performed under a dome or tent for security purposes.

6.1.3.1 Waste Container Retrieval

Although access to the MDA G disposal shafts can be gained by removing the concrete caps from the tops of the shafts, the small diameter of the shafts provides a limited space for manipulating the shaft contents. A remotely operated backhoe cannot access and remove objects located deeper than approximately 10 ft to 12 ft. Deep removal can only be accomplished by using a crane and manual rigging equipment, which cannot be done remotely. While not impossible, this type of excavation is not desirable due to safety issues. Use of grappling devices or magnetic lifts will be possible for certain inventory items; however, because of their size or shape, many items can only be removed by means of manual rigging. Therefore, the safety hazards of working in the narrow shafts at depths greater than 12 ft eliminate vertical shaft excavation as a viable technology for MDA G. This technology was not retained for further consideration.

6.1.3.2 Trench Excavation

Removal of the waste from the MDA G shafts can be performed by excavating a large trench access area along the side of shafts, making removal by backhoe and crane more viable. This technology is routinely used at MDA G to excavate trenches to a depth of up to 65 ft in unit 2 of the Bandelier Tuff. Therefore, this technology has been retained for further consideration.

6.1.3.3 Bulk Waste Retrieval

Waste in the larger disposal areas (pits and trenches) of MDA G can be removed using large-scale soil moving and excavating equipment (remotely operated, if necessary), remote-operated grappling devices, and containerization tools. Current overburden will be removed and the waste dug, potentially sorted for characterization, and directed to new waste containers, waste treatment, and/or off-site disposal. This technology was retained for further consideration.

Because bulk waste retrieval operation needs to be large enough to permit the activity to be completed relatively quickly, a large containment structure over the operation will be necessary at MDA G. Containment permits the work to be done in multiple shifts, through most weather conditions, and without producing unacceptable levels of airborne particulate off-site. A containment structure also supports the need to shield classified waste from visual observation during excavation.

6.1.4 Ex Situ Treatment Technologies

If excavated and removed, MDA G waste materials and/or contaminated media require characterization to be recycled or to make a determination as to whether the waste material would meet the waste acceptance criteria of both on-site and off-site treatment, storage, and disposal (TSD) facilities. Additionally, some of the waste may require treatment before recycling or emplacement in an approved on- or off-site facility. General treatment technologies include neutralization, extraction, thermal treatment, stabilization, and the various debris treatments specified under RCRA.

6.1.4.1 Chemical Treatment Technologies

Extraction

Acid or solvent extraction technologies permit the separation of specific constituents from the remaining waste mass. Treatment is usually performed in batches so specific parameters can be controlled to achieve waste-treatment goals. Extractants can sometimes be recycled and reused. This technology has the potential to address a variety of MDA G waste and has been retained; however, because it is primarily applied to soil, its application may be limited (EPA 1998, 102744, p. iv; USACE 1998, 102742, pp. 51–52).

Wastewater Treatment

During the installation of selected corrective measures at MDA G, contaminated wastewaters may be generated. Wastewater treatment technologies have been retained for further consideration.

6.1.4.2 Physical Treatment Technologies

Cement Stabilization

Some materials may require stabilization in Portland cement or other cement matrices before disposal as a hazardous or mixed waste. This technology is well demonstrated throughout the waste-management industry, including customized additives to address unusual contaminants, and could be a suitable technology for a portion of the waste that might be excavated at MDA G.

Alternative Stabilization/Encapsulation Technologies

Ex situ stabilization technologies generally address the need to create a waste form that will not allow target contaminants to leach from the waste matrix to potentially impact groundwater disposal at the site. Stabilization and encapsulation technologies beyond cement-based techniques have been developed to reduce overall waste volume, address contaminants in waste that are not well stabilized by cement chemistry, or achieve greater waste-loading potentials. A number of these technologies have been used successfully at Superfund sites (EPA 2000, 102741, p. 1-5). A range of alternative stabilization/encapsulation technologies was retained on the probability that a percentage of MDA G waste will benefit from these technologies.

Debris Treatment

Much of the waste generated from the excavation of MDA G disposal units will meet the RCRA definition of debris. The alternative treatment standards for hazardous debris are specified in 20.4.1.800 NMAC, which adopts 40 CFR Part 268.45. For example, macroencapsulation is one of the immobilization technologies that may be used to reduce the potential for leaching of lead or lead-containing debris (DOE 2002, 102745, p. 1-2). A variety of debris treatment technologies may be suitable for disposing of debris at MDA G.

6.1.4.3 Thermal Treatment Technologies

Ex situ thermal treatment technologies generally include techniques to mobilize contaminants for removal from contaminated media or to destroy contaminants. A wide variety of ex situ thermal treatments exist, including thermal desorption, steam extraction, incineration, catalytic destruction, and vitrification (which is both a thermal and physical treatment). Heat is supplied using microwave, radio frequency, or thermal-radiation energy and delivered to the contaminant by various means or through direct conduction of electricity.

Thermal Desorption

Thermal desorption techniques can be used to separate VOCs and SVOCs and other volatile constituents from waste at MDA G. These techniques have been developed for application at atmospheric pressures and at vacuum conditions to optimize extraction of certain contaminants. This well-demonstrated set of technologies can achieve treatment standards with high throughput (EPA 2001, 102737, p. 1-2). Although only a limited number of organic chemicals have been identified in the surrounding environmental media at MDA G, this technology was retained for further consideration in the event that excavation of waste will be recommended as part of a remedial action alternative.

Thermal Destruction

Pyrolysis (DOE 2000, 102736, p. 1-2) and incineration (EPA 2002, 102739, p. 1-2) are the two primary technologies that provide thermal destruction of organic materials. Pyrolysis is primarily anaerobic process, whereas incineration is intended to describe the controlled combustion of materials in an aerobic environment. Pyrolysis may be performed in a refractory-lined rotary kiln, in a fluidized bed, or in a molten salt bed. Combustible gases produced during pyrolysis must generally be burned off as part of the treatment. Incineration may also be performed in a rotary kiln or a fluidized bed or in other equipment arrangements. Because of the limited quantity of organic chemicals present in the surrounding environmental media at MDA G, thermal destruction technology would affect only a small percentage of the waste. This technology was not retained for further consideration.

Vitrification

Ex situ vitrification generally includes mixing of the waste with materials that produce glass-like substances when heated sufficiently, especially if the waste matrix does not readily form a glass. Vitrification can often result in a waste volume reduction, especially compared with cement-stabilization. Vitrification is particularly suited to stabilizing small volumes of homogeneous waste streams (Evanko and Dzombak 1997, 102743, p. 35). Given the heterogeneity and volume of the waste at MDA G, this technology was not retained for further consideration.

6.2 Screening of Corrective Measures Technologies

Corrective action guidance from EPA (1994, 095975, p. 58) and DOE (1993, 073487, pp. 4-51–4-52) requires screening of potential corrective measure technologies to eliminate those that are not feasible to implement and that rely on technologies not likely to perform satisfactorily or reliably. Section VII.D.4.a of the Consent Order also requires that threshold criteria be met within a reasonable time frame. When competing technologies provide similar benefits, cost is often also used as a screening tool.

The screening of technologies included

- a review of the site and the characterization data described in the investigation report (LANL 2005, 090513, pp. 2–5, 9–16, 16–27; Appendix G, pp. G-1–G-12) to identify conditions that may limit or promote the use of certain technologies;
- identification of waste characteristics that limit the effectiveness or feasibility of technologies; and
- identification of the level of technology development, performance record and inherent construction, and operation and maintenance problems for each technology considered.

6.3 Optimized List of Technologies

Candidate corrective measure technologies were evaluated based on site conditions, waste characteristics, technology limitations, and comparative criteria among technologies, such as range of applicability and cost (Figure 6.1-1). Technologies considered potentially applicable were retained for further consideration in developing corrective action alternatives for MDA G.

7.0 IDENTIFICATION AND SCREENING OF CORRECTIVE MEASURES ALTERNATIVES

The approved CME plan identified an initial set of corrective measure alternatives for MDA G (LANL 2007, 098608, p. 17) based on site-specific conditions, the environmental setting, and the nature and extent of contamination. The formal process for alternative identification and screening employed in this CME began with identifying and screening technologies that can be used to address contaminants at MDA G, either individually or in combination (section 6). Section 7.2 identifies potential corrective measure alternatives for MDA G using the technologies retained. Section 7.3 provides a description of the alternatives. The initial screening of the alternatives, presented in section 7.4, is based on the threshold criteria defined in section VII.D.4.a of the Consent Order. The alternatives retained for further evaluation are identified in section 7.5 and described in section 7.6.

7.1 Activities Undertaken Before Implementation of Corrective Measures

Before any corrective measure is implemented, TRU waste stored on Area G CSUs will be transported and disposed of off-site at WIPP. Retrievable TRU that is stored belowground will be removed, characterized, packaged, and shipped to a permitted waste disposal facility (LANL 2006, 091691). The surface RCRA CSUs will be closed under the RCRA closure process. These activities are not part of the CME.

The Laboratory’s TRU Waste Disposition Project will retrieve, characterize, package, and ship both the above- and belowground TRU waste. Retrieval of the below ground retrievable TRU will result in the removal of approximately 121,000 Ci from the site (LANL 2006, 091691). The retrievably stored waste below ground will be characterized upon removal to determine whether it is TRU, mixed TRU, LLW, or MLLW and shipped to a permitted waste disposal facility depending upon the results of this characterization. The activity level in the tritium torpedoes is currently too high to meet WIPP waste acceptance criteria; therefore, the tritium torpedoes will be removed from Shafts 262–266 and stored elsewhere on Laboratory property until they are sufficiently decayed for disposal.

7.2 Identification of Corrective Measure Alternatives

With the exception of the no further action alternative, the potential corrective measure alternatives developed for MDA G emphasize either isolation and containment of source materials left in place or excavation and movement to a location off-site.

The approved CME plan developed and presented a total of 12 corrective measure alternatives in five general categories (LANL 2007, 098608, p. 17). These preliminary alternatives have been revised into 12 alternatives to incorporate technology options considered supportive of primary alternatives. The revised alternatives listed below incorporate the results of the technology screening described in section 6 and support the initial screening presented in this section and the evaluation presented in section 8. Based on engineering judgment, a set of combined alternatives was included in the list to ensure that potentially applicable supporting technologies were considered along with primary technologies.

Based on the results of the MDA G investigation report risk assessment (LANL 2005, 090513, Appendix G, p. G-19), the presence of tritium and organic compounds in the tuff matrix does not pose an unacceptable present-day risk to human (workers and member of the public) or ecological receptors. Both tritium and VOCs diffuse in the subsurface and the atmosphere, reducing soil and air contaminant concentrations. Tritium decays with a 12.3-yr half-life; therefore, its concentrations will be reduced over time. Lower media concentrations reduce localized risks/doses from these contaminants. Except for Alternative 1A, SVE has been included as part of all alternatives. Soil vapor extraction will be operated as long as needed to reduce VOC concentrations in pore gas. For purposes of evaluating corrective measure alternatives, a 30-yr operating period has been assumed. The effectiveness of SVE technologies in removing vapor-phase VOCs is being evaluated in a pilot study to be completed in October 2008. More information concerning the design of the SVE system can be found in Appendix F.

The SVE pilot study is evaluating the effectiveness of active and passive SVE methods for the VOC vapor plumes in the subsurface beneath MDA G and will provide data to design active- and passive-remediation systems and implementation strategies. The active-extraction test is designed to determine the relationship between applied suction and VOC-extraction rate to treat the current plume and to reduce the source term. Additionally, the test is designed to provide measurements of the radius of influence of the SVE system at MDA G. Active removal of the current VOC plume will reduce or eliminate the ability of remaining VOCs in the subsurface to diffuse toward the regional aquifer. By reducing concentrations in the middle of the Bandelier Tuff, VOCs at greater depth will diffuse back up toward the lower concentration region created by the SVE system. Passive venting will be evaluated for its capability to mitigate migration of contaminated pore gas. The SVE pilot tests will provide data to determine the amount of time required for active extraction to reduce the source to a mass that can be effectively controlled using passive venting. The data will be available in October 2008.

The viable corrective measure alternatives are listed below and are arranged from the no further action alternative to the complete removal of waste alternative.

7.2.1 No Further Action Alternatives

- Alternative 1A, Monitoring only
- Alternative 1B, Monitoring and maintenance of existing cover and SVE

7.2.2 Enhanced Source Management Alternatives

- Alternative 2A, Engineered RCRA Subtitle C final cover, monitoring and maintenance, and SVE
- Alternative 2B, Engineered alternative ET cover, monitoring and maintenance, and SVE
- Alternative 2C, Engineered alternative ET cover in combination with partial MDA G waste excavation, monitoring and maintenance, and SVE
- Alternative 2D, Optimized engineered alternative ET cover in combination with partial MDA G waste excavation, targeted waste type stabilization, biointrusion barrier, monitoring and maintenance, and SVE
- Alternative 3, Near-surface subsurface barrier, monitoring and maintenance, and SVE
- Alternative 4A, Near-surface waste stabilization, monitoring and maintenance, and SVE
- Alternative 4B, Comprehensive waste stabilization, monitoring and maintenance, and SVE
- Alternative 4C, Near-surface waste stabilization of targeted waste types, monitoring and maintenance, and SVE

7.2.3 Source-Removal Alternatives

- Alternative 5A, Partial MDA G waste-source excavation, ex situ treatment, off-site disposal, monitoring and maintenance, and SVE
- Alternative 5B, Complete MDA G waste-source excavation, waste treatment, off-site disposal, and SVE

7.3 Description of Preliminary Corrective Measure Alternatives

The alternatives listed in section 7.2 are described in greater detail in the following subsections and are summarized in Table 7.3-1.

7.3.1 Alternative 1A, Monitoring Only

The monitoring-only alternative is considered the no further action alternative for MDA G. The RCRA CSUs will be closed and the existing cover left as is. This alternative will provide the baseline for comparison for all other alternatives. This alternative includes continued monitoring of the subsurface vapor-phase VOCs, tritium, and moisture.

Continued monitoring may indicate that the existing operational covers will be sufficient to attain the corrective measures objectives. For this alternative, no effort will be made to maintain the containment systems or to control releases that occur. The control of site access and Laboratory administrative controls for the site are active institutional controls and are assumed to remain in place for 100 yr following closure.

7.3.2 Alternative 1B, Monitoring and Maintenance of Existing Cover and SVE

This alternative is similar to Alternative 1A with the addition of maintenance of existing containment features for a period of 100 yr. Maintenance activities can be expected to extend the containment effectiveness and operational life for the existing covers at MDA G. This alternative includes the monitoring described in Alternative 1A and upkeep of the existing containment systems. Any cover damage or releases identified during monitoring will be addressed through maintenance activities for the containment systems.

The control of site access, Laboratory administrative requirements, site monitoring, and site maintenance will continue for 100 yr.

Soil vapor extraction technologies will be employed to remove VOCs per the operations and maintenance plan that will be included with the CMI plan.

7.3.3 Alternative 2A, Engineered RCRA Subtitle C Final Cover, Monitoring and Maintenance, and SVE

Historical emplacement of waste in MDA G meeting the current definition of RCRA hazardous waste merits consideration of a RCRA-compliant cover or equivalent alternate for the waste, if the waste is to remain in-place. A RCRA Subtitle C cover design compliant with RCRA 264.310(a)(5) is prescribed by EPA as a base design and adopted by the State of New Mexico in 20 NMAC 4.1.500. The RCRA Subtitle C standard cover incorporates the following layers, base to surface:

- A composite barrier layer consisting of a minimum 24-in.- (60-cm-) thick layer of compacted natural or amended soil with a maximum saturated hydraulic conductivity of 4×10^{-8} in./s (1×10^{-7} cm/s) in intimate contact with a minimum 0.04-in. (40-mil) geosynthetic membrane overlying the soil layer. The function of this composite barrier layer is to limit downward moisture movement.
- A drainage layer consisting of a minimum 12-in.- (30-cm-) thick sand layer having a minimum saturated hydraulic conductivity of 4×10^{-4} in./s (1×10^{-2} cm/s), or a layer of geosynthetic material having the same hydraulic conductivity. The drainage layer allows water that infiltrates the top vegetation/soil layer to flow horizontally off of the cover through a higher permeability material.
- A top vegetation/soil layer consisting of a minimum 24-in. (60-cm) layer of soil graded at a slope between 3% and 5% with vegetation or an armored top surface. The vegetation/soil layer limits infiltration by promoting storage and ET. It also provides erosion protection for the cover and physical protection of the composite-barrier layer.

Engineered covers represent one of the primary containment alternatives for subsurface waste disposal units. The RCRA Subtitle C multilayered landfill cover is a baseline design that is recommended for use in RCRA hazardous waste landfill applications. This alternative includes postclosure monitoring and maintenance of the cover for 100 yr. A minimum of 30 yr is required under RCRA 264.310(b)(1) and RCRA 264.117 through 264.120.

Soil vapor extraction technologies will be employed to remove VOCs per the operations and maintenance plan that will be included with the CMI plan.

7.3.4 Alternative 2B, Engineered Alternative ET Cover, Monitoring and Maintenance, and SVE

In a semiarid climate, such as at MDA G, a final waste cover designed to facilitate evaporation and transpiration is a more effective design than the RCRA Subtitle C landfill cover. RCRA regulations provide for consideration of alternative requirements as long as they are protective of human health and the environment (40 CFR 264.110 for permitted facilities and for interim-status facilities). NMED provides guidance for alternative covers in "Guidance for an Alternate Cover Design," under section 502.A.2 of the New Mexico Solid Waste Management Regulations (20 NMAC 9.1), using Hydrologic Evaluation of Landfill Performance modeling (NMED 1998, 071299).

This alternative includes an ET cover placed over existing operational waste covers, taking advantage of the semiarid site conditions by evaporating and transpiring water from the cover so only very small amounts of water infiltrate beyond the cover layers. The surface of the cover is sloped to allow rainwater to run off in cases where the rate of rainfall (or snowmelt) exceeds the capacity of the soil to accept the vertical flux. The ET cover differs from the RCRA cover in that it includes only small quantities of clay and no geosynthetic membrane materials, which are considered more likely to fail because of clay desiccation and polymer degradation.

Engineered alternative landfill covers are proving to be effective in reducing infiltration in semiarid regions (Davenport et al. 1998, 069674; Dwyer et al. 2000, 069673). The benefits of this alternative include, but are not limited to, readily available construction materials, ease of construction, less complex quality assurance/quality control programs, greater cost-effectiveness, increased long-term sustainability with decreased maintenance (ITRC 2003, 091330), and better integration with the native terrain. ET covers can be adapted to enhance specific properties for a given application, such as increasing resistance to erosion with the addition of gravel surface amendments; varying depths of enriched soil to enhance or limit plant growth and types for transpiration; varying the depths of the primary ET layer to adapt the size of the reservoir layer above the waste layer; or preventing biointrusion by using barriers such as cobble, chainlink fencing, or pea-size gravel.

Soil vapor extraction technologies will be employed to remove VOCs per the operations and maintenance plan that will be included with the CMI plan.

7.3.5 Alternative 2C, Engineered Alternative ET Cover with Partial MDA G Waste Excavation, Monitoring and Maintenance, and SVE

This alternative incorporates the advantages of an ET cover for the semiarid climate at MDA G, as presented in Alternative 2B, and includes the partial excavation of select near-surface waste to minimize cover thickness. The physical differences between the Alternative 2B ET cover and the Alternative 2C ET cover include slopes of less than 4%, no internal sharp corners, more southern-facing slopes to improve ET, rock-armored side slopes, rock buttresses in steeper areas, and sediment basins at the base of existing drainages. A biointrusion barrier is also included as part of this alternative.

South-facing slopes accommodate the removal of moisture from the cover and minimize the growth of deep-rooting species. Removing the existing surface mounds in MDA G will achieve a relatively flat surface for cover placement and allow the cover to be built to only the thickness necessary to accommodate ET requirements. The use of a biointrusion barrier system will also permit the main body of the cover to be designed to a thickness necessary for ET function rather than the corollary function of biointrusion control. This alternative incorporates existing operational cover thicknesses into design of the final cover.

During design of a final remedy, engineering studies will determine whether excavation of a limited portion of the MDA G waste will be cost effective in reducing cover thickness. For the purpose of developing this alternative, it is assumed that all waste will be disposed of off-site.

Soil vapor extraction technologies will be employed to remove VOCs per the operations and maintenance plan that will be included with the CMI plan.

7.3.6 Alternative 2D, Engineered Alternative ET Cover with Partial MDA G Waste Excavation, Targeted Waste-Type Stabilization, Maintenance and Monitoring, and SVE

This alternative incorporates the Alternative 2C cover and includes partial MDA G waste excavation and targeted waste-type stabilization.

This alternative includes the deployment of in situ waste stabilization technologies and the partial excavation of select near-surface waste to support minimized cover thickness. During design of a final remedy, engineering studies will determine whether excavation of a limited portion of the MDA G waste may benefit long-term remedy performance on-site at TA-54. Excavated waste will be segregated according to its characterization as LLW or MLLW and disposed of off-site.

Stabilization will generally be used in areas where long-term erosion would be most likely to increase infiltration or the possibility of biointrusion. Although the ET cover will be designed to provide long-term protection from infiltration and biointrusion, the use of stabilization in areas with the greatest potential for future releases provides redundancy and increases long-term performance.

This alternative will be evaluated with a 100-yr active institutional control period in which access controls are maintained, monitoring is continued, and maintenance activities are performed, as required.

Soil vapor extraction technologies will be employed to remove VOCs per the operations and maintenance plan that will be included with the CMI plan.

7.3.7 Alternative 3, Near-Surface Subsurface Barriers, Monitoring and Maintenance, and SVE

Existing operational waste covers provide a degree of water-infiltration protection, as evidenced from soil moisture results in the upper tuff layers in the MDA G investigation report (LANL 2005, 090513, p. 22) and the results of a vadose zone study (LANL 2005, 090513, Appendix I). This alternative maintains operational waste covers and provides additional protection through deployment of near-surface subsurface barriers to enhance the biotic isolation of shallow waste. Near-surface subsurface barriers will employ soil-grout mixing technology within the operational cover materials of select waste pits and trenches, based on waste contaminant contents and migration potential. Existing covers will also be graded and extended as necessary to direct surface runoff to drainage channels away from waste disposal units.

This alternative will be evaluated with a 100-yr active institutional control period in which maintenance of access controls, continued monitoring, and maintenance activities are performed, as required.

Soil vapor extraction technologies will be employed to remove VOCs per the operations and maintenance plan that will be included with the CMI plan.

7.3.8 Alternative 4A, Near-Surface Waste Stabilization, Monitoring and Maintenance, and SVE

As with Alternative 3, the operational covers installed over the waste provide protection from infiltration by surface water. To further protect the waste from water infiltration and/or biotic intrusion, vertical planar in situ vitrification technology will be deployed for the near-surface waste.

This alternative will vitrify the upper 3 ft (0.9 m) of each waste unit (beneath operational cover soil) to provide an impermeable monolithic barrier. The near-surface waste will become part of the resulting glassy matrix, and contaminants will be fixed within the matrix. The barrier will also protect deeper waste, since surface water and biota will not penetrate the mass. This alternative includes grading and extending cover materials to direct surface runoff away from the waste disposal units.

Soil vapor extraction technologies will be employed to remove VOCs per the operations and maintenance plan that will be included with the CMI plan.

7.3.9 Alternative 4B, Comprehensive Waste Stabilization, Monitoring and Maintenance, and SVE

Complete stabilization of MDA G waste, to the extent practical, is an alternative to placing additional cover materials at MDA G. In situ vitrification or jet-grouting technologies produce waste forms that limit contaminant migration and restrict the flow of infiltrating water through the waste mass, while shielding the waste contaminants from burrowing animals or plants.

Deeper waste disposal units at MDA G, such as disposal shafts and pits, may not be fully stabilized using existing technology. Stabilization of the upper layers of the waste can be achieved using vertical planar in situ vitrification technology. This technology has a practical depth limit, which is less than the 60-ft (18-m) depth of some of the shafts and pits. Jet grouting can achieve the additional depth necessary. Therefore, shafts will be jet grouted at depth and upper portions vitrified.

This alternative includes grading and extending operational cover materials as necessary to direct surface runoff to drainage channels away from waste disposal units.

This alternative will be evaluated with a 100-yr active institutional control period in which access controls are maintained, monitoring is continued, and maintenance activities are performed, as required.

Soil vapor extraction technologies will be employed to remove VOCs per the operations and maintenance plan that will be included with the CMI plan.

7.3.10 Alternative 4C, Near-Surface Stabilization of Target Waste Types, Monitoring and Maintenance, and SVE

As with Alternative 4A, vertical planar in situ vitrification technology will be used for the near-surface waste, based on waste type and potential for long-term contaminant release. Alternative 4C will vitrify the upper 3 ft (0.9 m) of each selected waste unit beneath a soil cover to provide an impermeable monolithic barrier. The near-surface waste will become part of the resulting glass matrix and contaminants will be fixed within the matrix. The barrier will also protect deeper waste because surface water and biota will not be able to penetrate the mass. This alternative includes grading and extending operational cover materials, as necessary, to direct surface runoff to drainage channels away from waste disposal units.

This alternative will be evaluated with a 100-yr active institutional control period in which access controls are maintained, monitoring is continued, and maintenance activities are performed, as required.

Soil vapor extraction technologies will be employed to remove VOCs per the operations and maintenance plan that will be included with the CMI plan.

7.3.11 Alternative 5A, Partial MDA G Waste-Source Excavation, Ex Situ Treatment, Off-Site Disposal, Monitoring and Maintenance, and SVE

This alternative includes identifying waste that presents the greatest potential for risk to the public. The risk is based on surface dispersion, loss of active institutional controls, and contaminant inventory and concentrations in the dispersible materials. Waste buried in areas subject to higher erosion by wind and water and waste buried in large shallow configurations will be the primary focus of the effort, along with areas where chemical releases with high potential for migration is known to have occurred. Under this alternative, the targeted waste will be excavated and removed from MDA G, treated as necessary to meet disposal waste acceptance requirements, and disposed of off-site

This alternative will be evaluated with a 100-yr active institutional control period in which access controls are maintained, monitoring is continued, and maintenance activities are performed, as required.

Soil vapor extraction technologies will be employed to remove VOCs per the operations and maintenance plan that will be included with the CMI plan.

7.3.12 Alternative 5B, Complete MDA G Waste-Source Excavation, Waste Treatment, Off-Site Disposal, and SVE

Source removal is the most reliable method for reducing or eliminating long-term on-site risks from MDA G, although short-term risks may increase during the implementation of the remedy. This alternative entails completely excavating waste from the 32 pits, 193 shafts, and 4 trenches at MDA G, followed by treating the waste to meet the receiving facility’s waste acceptance criteria and disposal off-site. This poses risk for workers involved in the excavation activities and transportation of the waste off-site.

This alternative does not include excavation of LLW from the pits and shafts that are not part of Consolidated Unit 54-013(b)-99. These pits and shafts are regulated by DOE as LLW disposal units. Wastes were not disposed of in these units before the effective dates of DOE’s radioactive waste management orders, and they have always been managed as LLW disposal units that will be subject to requirements for closure in place.

Waste treatment, characterization, and packaging requirements for waste acceptance at these off-site locations are included in this alternative.

This alternative eliminates the need for long-term institutional controls for MDA G waste. The requirement for long-term monitoring is transferred to the disposal facility accepting the waste.

Soil vapor extraction technologies will be employed to treat VOCs per the operations and maintenance plan that will be included with the CMI plan.

7.4 Screening and Retention of Corrective Measure Alternatives

The corrective measure alternatives developed and above represent the culmination of an effort to integrate knowledge of the MDA G—including waste locations, types, and contaminants, environmental setting, and human and ecological receptor exposure pathways—with methods and technologies to reduce future potential impacts to human and ecological receptors. Although alternatives have been developed to minimize or eliminate future site risks, not all alternatives will perform equally well. The alternatives also vary greatly in cost effectiveness and environmental impact.

A screening process was used to reduce the number of alternatives by eliminating those not likely to be as effective as others. Screening was based on whether the alternative can meet the regulatory threshold criteria. Threshold criteria for the MDA G corrective action are

- protect human health and the environment,
- attain media cleanup levels,
- achieve source control, and
- meet waste management standards.

Additional qualitative screening criteria used to evaluate alternatives were whether

- alternatives are feasible to implement,
- the technologies selected will perform satisfactorily or reliably, or
- alternatives achieve the target corrective measure objectives within a reasonable period.

This screening process eliminated alternatives with limitations relative to other identified alternatives, based on the waste and site-specific conditions surrounding MDA G. The screening criteria and screening process is explained below; the results of screening are presented in Table 7.4-1. The alternatives represent the best elements of the 11 preliminary alternatives presented in the CME plan (LANL 2007, 098608, p. 17) as well as the best technological options available for the site, based on the screening process performed in section 6.2. The alternatives retained for evaluation meet the screening criteria presented in section 5.2 and are also expected to meet the objectives of DOE Orders 435.1 and 5400.5, applicable to the radionuclide portion of the MDA G wastes, which is regulated by DOE.

7.4.1 Corrective Measure Alternative 1B, Monitoring and Maintenance of Existing Covers, and SVE

Alternative 1B includes maintenance of the existing covers and was retained for evaluation because it represents a minimum action alternative for comparison with other more robust alternatives.

This alternative includes closure of RCRA CSUs, retrieval of TRU waste, monitoring, and it provides for upkeep of the existing containment systems, specifically the operational covers placed over waste at MDA G. Any cover damage or releases identified during monitoring will be detected and corrected through maintenance of the containment systems.

Active institutional controls (the control of site access, Laboratory administrative requirements, site monitoring, and site maintenance) are assumed to continue for 100 yr. This alternative includes employing SVE technologies to address VOC contamination in the vadose zone.

7.4.2 Corrective Measure Alternative 2B, Engineered Alternative ET Cover, Monitoring and Maintenance, and SVE

This alternative was retained because it provides all of the waste containment benefits, including minimizing erosion, reducing infiltration and biointrusion, and performing SVE of VOCs within the vadose zone. The alternative is expected to meet all screening criteria, is based on proven technologies and engineering principles, and can be readily implemented using materials widely available, many in the vicinity of the Laboratory.

Active institutional controls (the control of site access, Laboratory administrative requirements, site monitoring, and site maintenance) are assumed to continue for 100 yr.

7.4.3 Corrective Measure Alternative 2C, Engineered Alternative ET Cover with Partial MDA G Waste Excavation, Monitoring and Maintenance, and SVE

This alternative was retained because it provides all of the waste containment benefits (including reduced infiltration and biointrusion) provided by Alternative 2B but with additional enhancements, including excavation of waste that has potential for exposure if eroded, incorporation of a biointrusion barrier layer into the cover, and SVE of the vadose zone. The alternative is expected to meet all screening criteria in an efficient manner, is based on proven technologies and engineering principles, and can be readily implemented using materials widely available, many in the vicinity of the Laboratory.

Active institutional controls (the control of site access, Laboratory administrative requirements, site monitoring, and site maintenance) are assumed to continue for 100 yr.

7.4.4 Corrective Measure Alternative 5B, Complete MDA G Waste-Source Excavation, Waste Treatment, Off-Site Disposal, and SVE

This alternative was retained because it provides an option to remove all waste from 32 pits, 193 shafts, and 4 trenches from the MDA G. It is expected to meet all screening criteria, is based on proven technologies and engineering principles, and can be readily implemented using materials widely available, many in the vicinity of the Laboratory. This alternative can be compared to in-place management of waste at MDA G. SVE will treat unexcavated contaminated areas in the vadose zone.

7.5 Formal Description of Retained Alternatives

As a precursor to the formal evaluation performed in section 8, each of the retained alternatives has been further defined in the following subsections to support impact/risk analysis, and cost analysis.

7.5.1 Corrective Measure Alternative 1B, Monitoring and Maintenance of Existing Cover and SVE

Alternative 1B uses the cover remaining after the surface is regraded and revegetated at the time of D&D and closure of all surface structures. Maintenance of the cover will occur for a period of 100 yr. Maintenance activities can be expected to extend the effectiveness and operational life for the existing intermediate cover for MDA G's disposal pits and shafts. Major elements of the alternative include

- installing cover consisting of natural materials that allow locally adapted vegetation to grow over time, with slopes expected to be between 2% and 10% for most of the surface;
- monitoring soil and air pathways to identify contaminant migration and ensure that radioactive gas flux from the unit is maintained;
- implementing SVE technologies to remove VOCs from the vadose zone;
- repairing the cover, as necessary, to address erosion and animal burrowing, patch holes, and manage vegetation (remove trees and invasive species) to limit the potential for biotic intrusion into buried waste;

- maintaining fenced boundary to restrict public and large-animal access to the site; and
- inspecting the site and cover regularly, monitoring contaminant and moisture levels, maintaining site and cover, managing cover vegetation, and restricting site access for the 100-yr active institutional control period.

7.5.2 Corrective Measure Alternative 2B, Engineered Alternative ET Cover, Monitoring and Maintenance, and SVE

Alternative 2B is intended to contain MDA G waste potentially exposed by erosion, minimize infiltration of moisture into waste, and treat subsurface vapor-phase VOCs with SVE. Major elements of the alternative include

- installing an ET cover consisting of natural materials and locally adapted vegetation to reduce water infiltration by encouraging evaporation and transpiration from the bulk cover materials with the cover having a sloped surface between 2% and 10% to encourage precipitation runoff but limit erosion potential;
- limiting settlement potential with cover materials and construction techniques, selecting materials resistant to weathering, and designing for potential seismic events;
- designing cover thickness and properties (e.g., gas permeability and saturated/unsaturated hydraulic properties) to achieve radioactive gas flux limits from the unit and limit water infiltration to maintain pathway-specific exposures;
- incorporating stormwater and snowmelt water management designs to limit cover and mesa erosion potential;
- terminating cover in clean-fill rock armor and soil dikes to maximize use of available space;
- fencing the boundary to restrict public and large-animal access to the site;
- installing perimeter roadway to facilitate inspection and maintenance activities;
- implementing SVE technologies to remove VOCs from the vadose zone; and
- inspecting site and cover regularly, monitoring contaminant and moisture levels, maintaining site and cover, managing cover vegetation, and restricting site access for 100-yr active institutional control period.

7.5.3 Corrective Measure Alternative 2C, Engineered Alternative ET Cover with Partial MDA G Waste Excavation, Monitoring and Maintenance, and SVE

Alternative 2C is intended to contain MDA G waste, realize the benefits from excavation of waste potentially exposed by erosion, incorporate a biointrusion barrier in the ET cover profile, treat subsurface vapors with SVE, and maintain the site for 100 yr. Major elements of the alternative include

- excavating the uppermost 6 ft of Pit 28 to flatten the topography under the cover (both to reduce the amount of fill needed for the cover and to reduce the likelihood of erosion);
- characterizing the excavated waste and disposing of this waste;
- installing an ET cover consisting of natural materials and locally adapted vegetation to reduce water infiltration by encouraging evaporation and transpiration from the bulk cover materials and with a sloped surface between 2% and 10% to encourage precipitation runoff but limit erosion potential;

- incorporating a biointrusion barrier to limit burrowing animals and plant roots;
- limiting settlement potential with cover materials and construction techniques, selecting materials resistant to weathering, and designing for potential seismic events;
- designing cover thickness and properties (e.g., gas permeability and saturated/unsaturated hydraulic properties) to achieve radioactive gas flux limits from the unit and limit water infiltration to maintain pathway-specific exposures;
- incorporating stormwater and snowmelt management designs to limit cover and mesa erosion potential;
- terminating cover in clean-fill rock armor and soil dikes to maximize use of available space;
- fencing the boundary to restrict public and large-animal access to the site;
- installing a perimeter roadway to facilitate inspection and maintenance activities;
- implementing SVE technologies to remove VOCs from the vadose zone; and
- inspecting the site and cover regularly, monitoring contaminant and moisture levels, maintaining site and cover, managing cover vegetation, and restricting site access for 100 yr.

7.5.4 Corrective Measure Alternative 5B, Complete MDA G Waste-Source Excavation, Waste Treatment, Off-Site Disposal, and SVE

This alternative was retained because it removes all the waste from 32 pits, 193 shafts, and 4 trenches at MDA G. This alternative is expected to meet all screening criteria, is based on sound technologies and engineering principles; however, the technical aspects of excavating certain burial configurations are unproven. This alternative can be implemented using widely available backfill materials, many in the vicinity of the Laboratory. Alternative 5B contrasts with in-place management of legacy waste at MDA G.

Major elements of the alternative include

- removing, characterizing, repackaging, and shipping all MDA G waste to an approved off-site disposal facility;
- backfilling all excavations with clean soil and compacting, regrading, and vegetating;
- monitoring migration of contaminants already released to environmental;
- implementing SVE technologies to remove VOCs from the vadose zone; and
- installing a roadway to facilitate inspection and maintenance activities for a defined time period.

8.0 EVALUATION OF CORRECTIVE MEASURE ALTERNATIVES

All corrective measure alternatives found to meet the Consent Order threshold criteria and additional screening criteria in section 7.4 were further evaluated based on the criteria specified in Section XI.F.10 of the Consent Order and the approved MDA G CME plan (LANL 2007, 098608, pp. 22–23). The evaluation was based on the applicability, technical practicability, effectiveness, implementability, protection of human health and the environment, and cost of each alternative. The corrective measure alternatives evaluated are listed below.

- Alternative 1B: Monitoring and Maintenance of Existing Cover and SVE
- Alternative 2B: Engineered Alternative ET Cover, Monitoring and Maintenance, and SVE

- Alternative 2C: Engineered Alternative ET Cover with Partial MDA G Waste Excavation and Off-site Disposal, Monitoring and Maintenance, and SVE
- Alternative 5B: Complete MDA G Waste Source Excavation, Waste Treatment, Off-Site Disposal, and SVE

These alternatives assume that retrievably stored TRU waste has been removed from the site. In addition, SVE will be implemented for all alternatives for VOC releases (LANL 2007, 096110, p. E-4). Groundwater monitoring will be part of all alternatives and will be conducted in accordance with the IFWGMP (LANL 2008, 101897) or subsequent watershed-specific groundwater monitoring plans. Alternatives 1B, 2B, and 2C include monitoring unsaturated zone moisture to evaluate cover performance.

The evaluation of long-term impacts on human health and ecological risk/dose for the containment alternatives references mathematical models that simulate the performance of the corrective measure alternative. The models used to analyze potential long-term impacts are described in several documents (Day et al. 2005, 090536; LANL 2005, 090513; LANL 2005, 092068; LANL 2005, 094156; Wilson et al. 2005, 092034).

8.1 Alternative 1B, Monitoring and Maintenance of Existing Covers and SVE

Alternative 1B proposes implementing inspection and maintenance of a vegetative cover that will be in place upon closure of Area G. At the time of closure, the surface structures and concrete and asphalt pads will have been removed and the surface regraded and revegetated. An isopach map of soil and crushed tuff above the top of waste identifies the soil thickness that will be present at closure (Figure 8.1-1).

The Nuclear Regulatory Commission (NRC) regulations require a minimum of 3 ft (1 m) of cover soil above LLW pits. Although NRC regulations do not apply to DOE sites such as MDA G, it is used as a reference cover depth. The final topography of the cover at closure has steep slopes between pits (the south side of Pit 28) and in the vicinity of mounds (Pit 39). In some cases, slopes approach a 20% grade in the vicinity of Pits 25 and 31.

This alternative involves no additional corrective actions for the following reasons.

- Regrading and revegetation on the surface will provide ET of soil moisture to limit infiltration except in extreme climate conditions (gravimetric moisture content in the 107-ft- [33-m-] bgs depth is 5.7% [LANL 2005, 090513, p. 105]).
- The fence surrounding the site and the access gate at the TA-54 entrance and Pajarito Road access restrictions provide sufficient control against public access.
- The inspection and maintenance program includes measures to protect against severe erosion and to detect areas of focused recharge.
- Based on the conceptual site model and the results of investigations, groundwater contamination is not expected. The groundwater monitoring program described in “Technical Area 54 Well Evaluation and Network Recommendations, Revision 1” (LANL 2007, 098548) should provide data to confirm that there is no groundwater contamination.

8.1.1 Applicability

Regular inspection of the facility during the institutional control period will provide evidence of human intruders and allow early detection of damage to access barriers or damage from biota and erosion. These damages will be repaired, as needed, to meet existing performance criteria for the 100-yr active institutional control period.

Downward migration of contaminants is limited in the semiarid environment of northern New Mexico because low precipitation and high ET create a moisture deficit. Modeling results from Appendix D demonstrate that deep percolation through and below the cover is limited. However, a cover thickness of 6.6 ft (2 m) will be required to minimize flux because of the poor water storage capacity of the crushed tuff used as backfill in the pits. Infiltration exceeds the value specified by NMED for an equivalent Subtitle C RCRA cover. As discussed in section 4.2.1, modeling has shown that VOCs are not likely to impact the regional aquifer. Periodic site inspections will be performed to evaluate erosion and assess the need for maintenance.

The use of SVE provides suitable removal and treatment of gaseous VOCs. The technology is typically applicable only to volatile compounds with a vapor pressure greater than 0.02 in. Hg (0.5 mm Hg) or a Henry's law constant greater than 0.01. Its effectiveness is also influenced by factors such as the moisture content, organic content, and air permeability of the soil. SVE is not effective for heavy oils, metals, PCBs, or dioxins, but it often promotes in situ biodegradation of low-volatility organic compounds because of the continuous flow of air through the soil. A pilot test at MDA L showed that SVE can remove large quantities of VOCs from the unsaturated zone in a similar geologic setting (LANL 2006, 094152). A SVE pilot test is being conducted at MDA G to evaluate the effectiveness of SVE technologies on VOCs at MDA G. Preliminary results indicate this technology is viable for use at MDA G. The final report is due to NMED October 31, 2008, and a final evaluation of its use for corrective measures at MDA G will be determined at that time.

8.1.2 Technical Practicability

Inspection and maintenance of MDA G is technically practical and is the method currently used to ensure the integrity of the disposal units. Native vegetated soil cover has been used at MDA G and numerous other locations at the Laboratory's belowgrade waste disposal areas for nearly 50 yr with minimal maintenance (LANL 2005, 090513, p. vi). Inspection will include a site walkthrough every 5 yr to find areas where gullies are forming, where subsidence has occurred, and where focused recharge may be present. Maintenance will include repairing gullies and subsidence areas with rock armor or additional fill. An inspection will occur after every 25-yr, 0.25-h, or greater storm.

The practicability of inspection and maintenance procedures has been demonstrated at the site by using existing procedures for the past 20 yr to ensure that access barriers, such as fences, are inspected and maintained as part of the Area G nuclear facility authorization basis. These existing procedures provide more frequent inspections than are proposed for implementation of this alternative.

8.1.3 Effectiveness

The erosion modeling presented in Appendix E indicates that vegetated soil covers are effective at controlling erosion. However, bare soil with high erosion potential (i.e., steep slope and soil with low cohesion) does not control erosion. The results of the investigation reports show that the MDA G native vegetative cover, with minimal maintenance, has been effective in containing surface and subsurface contaminants at levels that do not pose a potential unacceptable risk to human health or the environment

(LANL 2005, 090513, p. vi). Upgrading the cover and its maintenance will provide additional protection and reduce infiltration. Over the 100-yr period of active institutional control, a vegetative cover will be established that provides additional control of erosion and decreases infiltration of moisture beyond surface soil.

Current inspection and maintenance procedures at MDA G enable early detection of damage to access barriers and erosion controls, evidence of human intruders, or damage from biota. These inspections are necessary because the cover lacks gravel mulch for erosion protection against significant precipitation events and has steep slopes that are easily eroded in some areas. Inspections are also conducted after potentially severe events and repairs are made accordingly. Although the proposed inspection and maintenance schedule presented in Appendix G is less frequent than the current schedule, it will be adequate because it has provisions for inspecting and repairing the cover after extreme erosion and infiltration events that have the most deleterious effect on cover performance.

Inspection of subsidence areas will prevent areas of focused recharge. However, the existing cover is not optimized to reduce subsidence.

Pore gas will be monitored in accordance with the long-term subsurface vapor-monitoring plan for MDA G (Appendix H).

The erosion modeling discussed in Appendix E indicates an average annual soil loss in excess of the design goal under bare soil conditions of 2 tons/acre/yr (4.5 tonne/ha/yr). Approximately 15 in. (39 cm) of cover will need to be added every 100 yr to maintain the cover at its minimum thickness for bare soil conditions. Under bare soil conditions and without maintenance, the Alternative 1B cover will erode, and waste may be exposed. In general, the cover meets the design goal under vegetated conditions, except under high-intensity storms.

After the 100-yr active institutional control period expires, uprooting of climax vegetation may expose waste. Biointrusion and thinning of the cover by erosion will limit the effectiveness of the cover in preventing infiltration and limiting further biointrusion.

8.1.4 Implementability

Implementation of Alternative 1B poses no administrative or technical implementation challenges. The equipment and materials required are readily available. Minimal construction is required; therefore, this alternative can be implemented immediately upon closure of MDA G.

8.1.5 Human Health and Ecological Protectiveness

Impacts to human and ecological receptors from implementation of the remedy will be assessed separately as the remedy implementation/installation period (short-term) and the remedy operation period (long-term). This separation differentiates between hazards associated with construction of the remedy versus hazards associated with cover maintenance and SVE operation. The monitoring and maintenance period following completion of the cover installation is assessed under long-term effects.

8.1.5.1 Injuries and Accidents

Alternative 1B is currently protective of human heath, and the environmental monitoring data have shown that potential exposures at the MDA G fence line are within applicable standards for protecting human health. Human intrusion to MDA G is prevented by institutional controls.

Upon closure of the Area G CSUs and removal of retrievable TRU waste, the surface will be cleared of buildings, structures, asphalt, and concrete, regraded, and revegetated. Impacts to human health from accidents and injuries is associated with the physical hazards of routine erosion control and surface maintenance activities and traffic risks associated with the transportation of raw materials necessary for this maintenance. Exposure to buried waste contaminants is not anticipated during these activities, except for surface flux concentrations of tritium and organic chemical vapors.

Worker risks associated with the implementation of the remedy are primarily a function of accident incidence rates for each work type and the number of hours of work required by type. Assuming that all of the project work hours are categorized as construction work, an incident rate of 6.3 nonfatal injuries per 100 full-time workers (or per 200,000 work hours) (3.1×10^{-5} nonfatal injuries per work hours) applies (DOL 2006, 097080, p. 6). The total of 72,000 work hours estimated for maintaining the surface results in an estimated 3 nonfatal injuries for the 100-yr active institutional control period.

Fatality incidence rates for the same work, based on 2005 statistics for the construction industry (DOL 2006, 097080, p. 4) at 5.4×10^{-8} per work hour would result in less than 1 fatality predicted.

The risk of traffic accidents associated with the remedy is generally considered a function of total miles of travel for the project vehicles. Based on an average accident rate for large trucks of 2.3 fatal accidents per 100 million miles (DOT 2002, 097082, p. 2) or 2.3×10^{-8} fatal accidents per mile and an estimated maximum of 133,000 truck transport miles on public roads for delivery of project resources, the overall incident rate for fatal traffic accidents for the project is less than 1.

The cover maintenance program will be performed under the rigorous workforce safety awareness program in place for all Laboratory workers and subcontractors, including detailed job planning, job-specific training, and safety monitoring by the Laboratory's Health and Safety disciplines. Government project injury incidents rates have typically been lower in relation to the general construction industry. As a result, injury and accident incidence on the project can be expected to achieve the much lower incidence rates historically applicable to the federal government workforce.

8.1.5.2 Short-Term Ecological Effects

Biological resource field surveys have been conducted at TA-54 (including MDAs G, H, and L) for compliance with the Federal Endangered Species Act of 1973; Public Law (PL) 93-205; the New Mexico Wildlife Conservation Act; Executive Order (EO) 11990, May 24, 1977, "Protection of Wetlands"; EO 11988, May 24, 1977, "Floodplain Management"; 10 CFR 1022, "Compliance with Floodplain/Wetlands Environmental Review Requirements"; and DOE Order 5400.5, "Radiation Protection for the Public and the Environment."

No wetlands exist in the immediate vicinity of MDA G, but wetlands and floodplains exist in the lower portion of Pajarito Canyon. Possible threatened and endangered (T&E) species for the area were identified, but no species or habitats are located in TA-54. Further information is contained in "Biological Assessment of Environmental Restoration Program, Operable Unit 1148, TA-54" (Banar 1996, 058192).

As required by the National Historic Preservation Act of 1966, a cultural resources survey was conducted during the summer of 1991 at TA-54 (LANL 1992, 007669). A total of 68 archaeological sites were located within the boundary of TA-54. Of this number, 56 are eligible to be included in the National Register of Historic Places. MDA G was evaluated for archeological sites with no further assessment or action required. Alternative 1B activities will not impact cultural resources.

Environmental damage to biological resources resulting from regrading and installation of the Alternative 1B cover will be localized over the already-disturbed MDA G. Once vegetation has been established, there will be a beneficial effect to ecological receptors.

8.1.5.3 Long-Term Human Health Effects

Exposure to Contaminants

During the monitoring and maintenance period, industrial workers will perform site surveillance, maintenance, and monitoring activities designed to prevent deep-rooting plants and burrowing animals from transporting buried waste to the surface, maintain erosion controls, and repair erosion damage. The measured and modeled VOC flux to the surface indicates no added risk to workers from this source. The industrial worker exposure scenario from the MDA G investigation report derives from the potential exposures from performing monitoring and site maintenance activities (LANL 2005, 090513, Appendix G, p. G-1).The frequency of monitoring and maintenance was assumed to require workers on-site 4 h/wk over a 50-wk work year for an individual worker or about one-tenth of the time basis used for the site worker scenario.

Worker health impacts are modeled using the industrial scenario identified in the MDA G investigation report, including exposure point concentrations for the 16 COPCs identified for workers (LANL 2005, 090513). Based on the greatly reduced time workers will spend at the site to conduct cover inspections and maintenance activities (4 h/wk versus 40 h/wk) and the greatly reduced potential for exposure to contaminants that results from the presence of cover materials over the waste units, the risks and doses to the site worker are considered bounded by one-tenth the site worker scenario values. The presence of a cover would further reduce these values, but at one-tenth the site worker exposures, the values are well below target levels for risk.

8.1.5.4 Long-Term Ecological Effects

The depth to waste will not be increased because no additional cover soil will be added to the surface at MDA G. The existing cover depth (minimum of 3 ft above the waste units) provides some protection against ecological receptors. Animals such as pocket gophers, mice, and harvester ants that burrow below 3.5 ft have the potential to bring waste to the surface of the cover. Roots of grasses, forbs, shrubs and trees can penetrate to the waste horizon. Plants with high uptake factors increase radionuclide concentrations at the surface. Plant uptake factors are 30 times higher for climax vegetation than for early succession plants because deeper tree roots penetrate into waste and more of a plant’s root mass comes into contact with contaminated soil. Contaminant concentrations in surface soil are higher with climax vegetation because trees generate surface litter. Placing new soil on the cover during active erosion maintenance entombs contaminated material on the cover surface. Therefore, airborne contamination during active maintenance will produce exposures that are less than or equal to the base case with no maintenance. Maximum animal burrow depths for pocket gophers, mice, and harvester ants are 4.9 ft, 6.6 ft, and 8.2 ft, respectively. Plants contribute the greatest radionuclide transport to the surface in the early part of the 100-yr active institutional control period because of the predominance of high-uptake plants in the early stages of succession. Placing new soil during active erosion maintenance stabilizes radioactive material on the cover surface.

During the monitoring and maintenance period, surface maintenance activities performed to ensure cover integrity and to limit potential for biota to reach buried waste may result in the removal of some vegetation and burrowing animals, or the filling of extensive animal burrow networks. Disturbances to local fauna will be limited through the use of access-restriction fencing around the area (affecting primarily larger animals).

8.1.6 Cost

Costs associated with Alternative 1B have been estimated for all phases of the project, including support activities, site preparation, construction, materials, and continuation of active site institutional controls for the 100-yr active institutional control period following construction of the cover. Significant detailed assumptions about the remedy, the approach for the construction, and sources for materials of construction were made in developing a cost estimate. The actual project costs will depend on specific design details and project decisions generated during formal design activities to be implemented if this cover alternative is selected.

Alternative 1B includes construction costs (e.g., capital costs) and annual costs required to maintain the cover after the initial construction period. To compare Alternative 1B costs with other alternatives that spend money over different time periods, the costs were discounted to a 2008 net present value, as recommended in “A Guide to Developing and Documenting Cost Estimates during the Feasibility Study” (EPA 2000, 071540).

Present value costs for the alternative are presented in the following sections as the sum of all capital costs and continuing costs. Presentation of capital and operating and maintenance costs as present value is consistent with the CME requirements contained in section VII.D.4.b.v of the Consent Order. The principle is also embraced for federal programs. The Office of Management and Budget (OMB) Circular A-94 states, “The standard criterion for deciding whether a government program can be justified on economic principles is net present value” (Office of Management and Budget 1992, 094804, p. 3). The OMB circular recommends a base-case analysis using a discount rate of 7.0% for projects that fit the category of public investments. Although it is unclear if the closure of MDA G should be considered a benefit-cost analysis or a cost-effectiveness analysis, analysis including alternative discount rates is encouraged by the circular.

Net present value was calculated according to the following formula:

$$PV_{total} = \sum_{t=1}^{t=n} \frac{1}{(1+i)^t} \cdot C_t$$

Where PV_{total} = present single sum of money

t = specific year

n = final project year

i = the discounted interest rate

C_t = cost in year t in base year dollars

The discount factor, the $1/(1 + i)^2$ term from the present value equation, has been calculated for interest rates of 3.0% and 7.0% to provide a range of values for discount factors. The multiyear discount factor for a discounted interest rate of 3.0% over a 30-yr period is 19.60, for a 100-yr period it is 31.60. For a rate of 7.0% over a 30-yr period, the factor is 12.41, for a 100-yr active institutional control period it is 14.27. The present value analyses are presented in Tables 8.1-1 to 8.4-1.

8.1.6.1 Estimate of Capital Costs

Capital costs consist of direct costs (construction), indirect costs (nonconstruction and overhead), and uncertainty estimates (contingency allowances). Table 8.1-1 summarizes the capital cost for Alternative 1B. Detailed estimates of capital cost in calendar year (CY) 2008 dollars are provided for this alternative in Appendix G. Cost estimates are expected to be within the accepted standard accuracy range of +50% to –30% established by EPA for remedial alternative estimates at the alternatives screening stage (EPA 2000, 071540, p. 2-4).

Contingency cost estimates (from the preliminary status of the design) were developed based on past on-site removal actions (MDA P), other DOE site experience (Sandia, Hanford, Rocky Flats), and factors such as the location of MDA G near existing operating facilities.

The cost of safety and security activities have been estimated, but a high degree of cost uncertainty exists until site-specific health, safety, and security plans are established.

8.1.6.2 Estimate of Recurring Costs

Inspection, maintenance, and monitoring costs following completion of remedy construction include associated material and energy costs, cost for managing waste produced after completion of initial construction, management and administrative costs, other indirect costs, and contingency.

Following the implementation of the base cover alternative, the operating and maintenance costs for the alternative are limited to the 100-yr active institutional control period.

The following major assumptions were made in developing the estimate of operating and maintenance costs for the cover:

- Inspection and maintenance activities for MDA G will require two personnel working an average of 4 h/wk.
- No major reconstruction or repairs of the cover will be required during the 100-yr active institutional control period with repairs limited to replacing materials removed by erosion, associated revegetation, and fence repairs.

Monitoring, inspection, and maintenance costs are described in Appendix G. Costs for monitoring pore gas, dust, weather, and runoff/sediment are included in this estimate. Monitoring procedures will be evaluated every 5 yr. A report will be prepared each year for monitoring activities. Maintenance includes replacement of parts, as required, and cleaning and/or replacing miscellaneous items. Neutron moisture meter monitoring will be conducted annually in existing boreholes, and TDR arrays in the cover will be monitored continuously with data loggers. Analytical services will be provided by an off-site laboratory.

The capital and recurring cost estimate as well as PV analysis is provided in Table 8.1-1.

8.2 Alternative 2B, Engineered Alternative ET Cover, Monitoring and Maintenance, and SVE

Alternative 2B consists of design and construction of an engineered ET cover, including stormwater and erosion controls, unsaturated zone monitoring, and monitoring and maintenance for the 100-yr active institutional control period. The alternative incorporates the existing shaft caps and operational waste covers under a new engineered ET cover. Exclusion fencing is maintained to protect against the disturbance of the engineered ET cover. The alternative includes regular inspection of the engineered ET cover for excessive erosion or water accumulation and cover maintenance when necessary to prevent erosion. Monitoring is the same as for Alternative 1B, except it will include moisture monitoring of the unsaturated zone under the cover, as described in section 8.2.6.1. This alternative includes installation and intermittent operation of an SVE system.

A preliminary concept for such a cover was prepared to meet the Laboratory's DOE Order 435.1 compliance program (Day et al. 2005, 090536). Because this cover design would meet the performance objectives of DOE Order 435.1, it is also expected to meet the corrective measures objectives of the Consent Order and is included as the baseline cover design for Alternative 2B. The preliminary design concept includes an approximately 8-ft-thick cover composed of the following layers, from base to surface.

- A 7.5-ft layer of crushed tuff intermixed with rock and amendments will provide the necessary thickness and low permeability to maintain effective ET and to prevent erosion from the end of the 100-yr active institutional control period. The thickness of the cover is also considered suitable to minimize the impact of biotic intrusion from the burrows and tunnels of burrowing animals and the typical root masses of plants, thus minimizing the chance that the buried waste in MDA G or associated contaminants could be exposed or brought to the surface.
- A 3-in. layer of topsoil will help establish rooting plants.
- A 3-in. layer of gravel mulch will help protect the topsoil from erosion as plants become established.

This alternative includes active institutional including maintenance of access controls, continued monitoring, and maintenance activities.

Incorporation of a biointrusion barrier to reduce cover thickness was not included in evaluation of this alternative, but will be evaluated in the final design if an ET cover is chosen as the selected alternative.

The objectives of the Alternative 2B engineered ET cover are to (1) reduce the amount of precipitation that percolates into and through buried waste (minimizing the potential for subsurface contaminant transport); (2) reduce erosion to prevent direct exposure of the waste and minimize surface transport of contaminants; and (3) minimize the intrusion of deep-rooting plants and burrowing animals to prevent contaminant transport to the surface.

The exposed layer of the Alternative 2B ET cover is composed of gravel mulch underlain by topsoil of equal thickness. The second layer is composed of crushed tuff, a small admixture of bentonite and occasional angular rock. Because the second layer of the cover consists of a thick layer of crushed tuff, the functionality of the cover will not be compromised by differential settlement or localized erosion. Adding more soil to areas that have settled or eroded will easily maintain the cover. A third layer of the base cover consists of 12 in. of clean gravel that will serve as a capillary break. A profile of the Alternative 2B cover is shown in Figure 8.2-1.

Modeling conducted for MDA G concluded that 8 ft (2.5 m) of cover will provide an infiltration barrier (LANL 1997, 063131, p. 2-71). Additional cover may be necessary if the rates of erosion at the site are significantly greater than originally estimated. The base cover was developed to provide a cover to isolate the waste disposed of at MDA G, minimize biotic intrusion, and prevent erosion to satisfy the performance objectives.

Alternative 2B includes a vegetated soil cover of sufficient thickness to store infiltrating precipitation and support a healthy vegetative community. The material layers of the base cover are illustrated in Figure 8.2-1. The vegetative layer will consist of a gravel mulch and topsoil layer. The specification is based on research on engineered ET covers conducted at the Laboratory and Sandia National Laboratory, New Mexico (Nyhan et al. 1998, 071345, p. 21; Dwyer 2001, 071298, p. 63; Dwyer 2002, 071347). The vegetative gravel/soil layers serve two functions: (1) to control erosion without compromising the ET features of the cover, and (2) to promote initial plant growth on the cover, further reducing runoff and erosion. The vegetative layer consists of approximately 3 in. each of gravel mulch and topsoil. Pea-gravel in the gravel mulch will trap nutrients and provide a stable growth surface for vegetation. The topsoil beneath the gravel mulch will help promote the vegetative growth over the surface cover. The vegetative layer will be underlain by 7.7 ft of crushed tuff mixed with bentonite clay (6% admixture) and angular rock (12% by volume).

Because much of the native tuff is friable, bentonite clay will be added to the crushed tuff to increase the compactability and stability and improve the hydrologic properties for ET. Beneath the crushed tuff layer, a filter layer will consist of 12 in. (30 cm) of clean gravel, overlying the operational crushed tuff cover of varying thickness on top of the waste. This layer will enhance the water-carrying capacity of the soil above and, therefore, promote and sustain vegetation growth. This cover alternative will have a slope between 2% and 10% to promote moderate sheet flow and minimize flow concentration across the surface. Also, placement of rock armor along the slope edges will limit erosion at the mesa edge. A plan view of the Alternative 2B cover is shown on Figure 8.2-2.

To reduce the VOC plume identified at the site, Alternative 2B proposes using active and passive SVE technologies if future VOC concentrations exceed threshold values.

This alternative meets all screening criteria as long as active institutional controls are maintained. The applicability, practicability, effectiveness, implementability, impacts to human health and the environment, and cost of this alternative are addressed below.

8.2.1 Applicability

Waste disposed of at MDA G is stable and not prone to migration in the absence of focused recharge. (Note: focused recharge may occur where surface water runoff is channeled to depressed areas that retain water for a sufficient time to allow infiltration that exceeds the storage capacity of the underlying soil.) Although infiltration is low in the arid environment of northern New Mexico, the construction of an ET cover restricts surface water infiltration to that of natural soil profiles without focused recharge. The ET cover thickness also provides additional barriers to human and biotic intrusion into the waste, thereby reducing the potential for exposures, and inadvertent dispersion of waste and contaminants.

SVE provides suitable extraction and treatment for VOCs. The technology is applicable only to volatile compounds with a vapor pressure greater than 0.02 in. Hg (0.5 mm Hg) or a Henry's Law constant greater than 0.01. Effectiveness is also influenced by factors such as the moisture content, organic content, and air permeability of the soil. It is not effective for heavy oils, metals, PCBs, or dioxins, but it often promotes in situ biodegradation of low-volatility organic compounds because of the continuous flow of air through the soil. A pilot test at MDA L showed that SVE can successfully remove large quantities of VOCs from the unsaturated zone in a similar geologic setting (LANL 2006, 094152). A pilot test of SVE is currently being conducted at MDA G. This pilot test will evaluate the effectiveness of SVE technologies on MDA G VOCs. This pilot project is underway, and preliminary results indicate this technology is viable for use at MDA G. The final report is due to NMED on October 31, 2008, and a final evaluation of its use for corrective measures at MDA G will be determined at that time.

8.2.2 Technical Practicability

Engineered covers with a vegetative component, like the Alternative 2B cover, have been proven effective in the arid and semiarid environments of the southwestern United States as referenced in the corrective measures study report for MDA H (Dwyer et al. 2000, 069673, p. 24; LANL 2005, 089332, p. 25). Dwyer et al. monitored soil moisture flux rates over a 4-yr period in a cover comparison demonstration program at Sandia National Laboratories. The performance of an anisotropic barrier and ET cover exceeded the performance of RCRA Subtitle C and D covers, as well as a geosynthetic clay liner cover, as measured by flux rates.

Engineered ET covers are effective because they rely on “natural” conditions at the site to protect the soil surface from erosion while storing infiltration water for vegetative growth. The result minimizes downward water movement. Engineered ET covers have been installed at several locations in the southwest where they perform well when properly maintained (Dwyer 2002, 071347, pp. 3–4).

Alternative 2B cover is easy to construct and maintain, may use readily available native tuff in combination with other construction materials, and is an appropriate selection for a semiarid climate. Using local materials in the design not only ensures availability of materials but provides the benefit that the properties of the materials are thoroughly understood in the mesa setting relative to hydrologic properties, material handling, weathering, and compatibility with native species.

Alternative 2B cover promotes vegetation that will work in conjunction with evaporation to minimize moisture and maximize available storage for subsequent precipitation events. Initial plant coverage limits soil erosion and fosters the growth of native plant species to produce cover stability.

Cover performance may be affected by normal and extreme weather, site geology and hydrology, local wildlife, construction materials, and configuration of waste disposal units. Design and construction risks are minimal for Alternative 2B.

The technical practicability of the Alternative 2B cover is limited by the excessive use of rock armor on side slopes. The transportation of high-quality rock to this site is cost-prohibitive. In addition, no local source of bentonite is available to add to the cover soil.

8.2.3 Effectiveness

The Alternative 2B cover will minimize future migration of contamination from the MDA G waste units. Once installed and vegetation is established, the cover will provide a uniform low-infiltration rate across the waste disposal area. The cover thickness will limit biointrusion and discourage plants and animals on the mesa from contacting buried waste and dispersing waste contaminants from the burial zone.

This alternative poses minimal exposure risk to site workers, the public, or ecological receptors. A vegetated soil cover of sufficient thickness to store precipitation and support healthy vegetation will effectively extend the life and performance characteristics of the existing operational cover, reduce water and wind erosion, and reduce the potential for bio- and human intrusion into the waste disposal cells, thereby reducing exposure to site workers, the public, and ecological receptors.

Passive erosion protection is included in the cover design using techniques such as rock armor in susceptible locations, but regular inspection during the 100-yr active institutional control period will ensure that excessive erosion is addressed. Fully established vegetative covers may require maintenance to limit deep-rooting plants and trees while maintaining resistance to erosion.

Procedures in place during the institutional control period will ensure that access barriers, such as fences, are inspected and maintained in addition to the primary waste containment feature, the ET cover. Regular inspection of the facility during the institutional control period will also allow early detection of damage to access barriers, evidence of human intruders, or damage from biota.

During the initial monitoring period, moisture-monitoring equipment will be installed within and below the cover, and a neutron probe will be used to monitor moisture in existing boreholes to verify the cover is performing as designed.

Even without active maintenance beyond the 100-yr active institutional control period, landform erosion modeling indicates that the Alternative 2B cover will perform better than the existing cover materials (Wilson et al. 2005, 092034). The Alternative 2B cover will not expose the original operational cover surfaces at the site during the DOE stability period.

This alternative is protective of human heath because current monitoring data demonstrate acceptable exposure at the MDA G fence line, and human intrusion is minimized by institutional control. This alternative omits waste treatment and is, therefore, not effective in reducing waste volume or toxicity, although chemical degradation may result in decreased toxicity over time.

8.2.4 Implementability

Alternative 2B is readily implementable since it requires no advanced or complex construction or engineering techniques. Standard surveying and earth-moving technologies and equipment are adequate to prepare, mix, and place the component layers of the cover in minimum thicknesses and with designed slopes. Materials of construction are readily available but not locally and are expensive to transport to the site. Standard construction techniques are adequate for installing electrical, instrumentation, and piping systems and placing ditches/swales, rock armor, and fences.

The performance properties of the cover (compaction, required slopes, and thickness) depend on the earthen materials chosen. The cover is intended to achieve and maintain specified performance characteristics throughout the performance period without human intervention after installation. Monitoring, inspection, and repairs conducted during the 100-yr period of institutional controls period will ensure that the cover works as intended and will allow damage identified to be repaired, potentially extending the overall life of the remedy. Inspection will include a site walk every 5 yr and after every 25-yr, 0.25-h, or greater storm to find areas where gullies are forming, areas where subsidence has occurred, and focused recharge may be present. Maintenance will include repairing gullies and subsidence areas with rock armor or additional fill. Erosion modeling shows the cover has minimal erosion potential from 5-yr storms under high and moderate erosion conditions.

Some impediments to implementability include the following:

- Top gravel mulch is not sized for the steep slopes and will erode under the 100-yr storm. (Approximately 0.89 cm of cover will need to be replaced after 100 yr to maintain the minimum thickness of cover under bare soil conditions.)
- The design includes a roofline that requires an excessive amount of fill.

8.2.5 Human Health and Ecological Protectiveness

Impacts to human health and the health of ecological receptors from implementation of the remedy are assessed separately. The remedy implementation/installation period is considered for short-term impacts, and the remedy operation period is considered for long-term impacts. Short-term and long-term differentiate between hazards associated with construction of the remedy versus hazards associated with its operation. The 100-yr active institutional control period following completion of the cover installation is assessed under long-term effects.

8.2.5.1 Short-Term Human Health Effects

Injuries and Accidents

The greatest impacts to human health from installing the cover are associated with the physical hazards of construction activities and traffic risks associated with the transportation of raw materials to the site for the cover construction. Workers will not be exposed to buried waste during cover construction activities because excavation into the waste disposal sites is not required for installing the cover and at least 2 ft of working cover will remain over the waste.

Worker risks associated with the implementation of the remedy are primarily a function of accident incidence rates for each work type and the number of hours of work required by type. If all of the project work hours are categorized as construction work, an incident rate of 6.3 nonfatal injuries per 100 full-time workers (or per 200,000 work h) (3.1×10^{-5} nonfatal injuries per work hour) applies (DOL 2006, 097080, p. 6). The total of 139,000 work hours estimated for installation of the cover will result in an estimated 5 nonfatal injuries.

Fatality incidence rates for the same work, based on 2005 statistics for the construction industry (DOL 2006, 097080, p. 4) at 5.4×10^{-8} per work hour would result in less than 1 fatality predicted for the cover installation project.

The risk of vehicle traffic accidents associated with implementation of the remedy is generally considered a function of total miles of travel for the project vehicles. Based on an average fatal accident rate per vehicle miles for large trucks of 2.3 fatal accidents per 100 million miles (DOT 2002, 097082, p. 2) or 2.3×10^{-8} fatal accidents per mile and an estimated maximum of 3,603,000 truck transport miles on public roads for delivery of project resources, an overall incident rate for fatal traffic accidents for the project would be less than 1.

8.2.5.2 Short-Term Ecological Effects

Environmental damage to biological resources resulting from installation of the Alternative 2B cover will be localized over the already-disturbed MDA G along with a new project lay-down/staging area and a project management area totaling approximately 85 acres. Once work is completed, the surface of the site will be revegetated. Noise associated with this alternative will be managed within applicable limits based on workday duration. Disturbances to local fauna will be limited, partly through the continued use of access restriction fencing around the area (affecting primarily larger animals) and because work activities will focus on the already-disturbed waste disposal area and have minimal impacts outside this area. Disturbances will be limited to the estimated 24-mo period necessary to install the cover.

8.2.5.3 Long-Term Human Health Effects

Exposure to Contaminants

During the 100-yr period of active institutional control following construction of the cover, workers will perform site surveillance, maintenance, and monitoring activities designed to prevent deep-rooting plants and burrowing animals from transporting buried waste to the surface. The industrial exposure scenario derives from the potential exposures to contaminants that come from performing these monitoring and site maintenance activities. The frequency of monitoring and maintenance activities was assumed to require workers on-site 4 h/wk over a 50-wk work year for an individual worker or about one-tenth of the time basis used for the industrial scenario in the MDA G investigation report (LANL 2005, 090513, Appendix G, p. G-1).

Installing the cover will significantly reduce exposure potentials at MDA G as well as the release of contaminants from MDA G to channel sediments and airborne exposure pathways, thereby further reducing the potential of contaminant migration to groundwater.

8.2.5.4 Long-Term Ecological Effects

The depth to waste will be increased through the addition of cover soil to the surface at MDA G, so animal burrows are not likely to be able to reach buried waste. These layers, and associated depth of cover, will also limit the likelihood that deep-rooting plant species can reach the buried waste. A 3.3-ft- to 6.7-ft- (1-m- to 2-m-) thick cover and the existing operational cover thicknesses will limit animal and plant intrusion into waste. In addition, the provision for 100-yr active institutional control period that involves tree removal will delay the succession to climax vegetation. It is necessary to keep the cover in grass as 100% of roots are less than 14.7 ft (4.4 m) deep and prevent invasive species, such as clover or Russian thistle from establishment on the cover. Placing new soil during active erosion maintenance entombs material on the cover surface. Some animal biointrusion into a thicker cover may actually tend to dilute surface radioactivity produced from the decay of contaminated plant debris with cleaner soil from within the cover.

8.2.6 Cost

Costs associated with the Alternative 2B cover have been estimated for all phases of the project activities, including support activities, site preparation, construction, materials, and continuation of 100-yr active institutional control period following completion of construction of the cover. Significant detailed assumptions about the remedy and the approach for the construction and sources for materials of construction were made in developing a cost estimate for the cover alternative. The actual project costs will depend on specific design details and project decisions that will only be available from formal design activities that will occur only if the cover alternative is selected.

The Alternative 2B cover includes construction costs expended at the beginning of a project (e.g., capital costs) and annual operation and maintenance and monitoring costs required to maintain the cover after the initial construction period. To compare costs of other alternatives that have expenditures over differing time periods, the costs were discounted to a 2008 net present value, as described in section 8.1.6.

8.2.6.1 Estimate of Capital Costs

Capital costs consist of direct costs (construction and materials), indirect costs (nonconstruction and overhead), and uncertainty estimates (contingency allowances) for the base cover alternative. Table 8.2-1 summarizes the capital cost for the cover alternative by major project activity.

Contingency cost estimates were developed based on past on-site removal actions (MDA P), other DOE site experience (Sandia, Hanford, Rocky Flats), and factors such as the site location of MDA G near existing operating facilities.

The following major assumptions were made in developing the estimate of capital costs for the Alternative 2B cover.

- D&D and RCRA closure costs of the Area G CSUs are not included in the cost estimates.
- Bandelier Tuff required for components of the cover will be quarried on-site at the Laboratory from within TA-61 and trucked to TA-54, where materials will be stockpiled.
- Angular rock, rock armor, and bentonite will be imported.
- Installation activities will require 24 mo.
- Removal of retrievable TRU waste is not included in the capital cost.

The capital cost estimate for the unsaturated monitoring TDR equipment is included in Table 8.2-1 (see “Monitoring System Installation”).

8.2.6.2 Estimate of Recurring Costs

Inspection, maintenance, and monitoring costs following completion of remedy construction include associated material and energy costs, cost for managing waste produced after completion of initial construction, management and administrative costs, other indirect costs, and contingency.

The operating, maintenance, and monitoring costs for the alternative are limited to the 100-yr active institutional control period following the implementation of the base cover alternative.

The following major assumptions were made in development of the estimate of operating, maintenance, and monitoring costs for the cover.

- Inspection and maintenance activities for MDA G will require two personnel working an average of 4 h/wk.
- No major reconstructions or repairs of the cover will be required during the 100-yr active institutional control period; repairs will be limited to replacing materials removed by erosion, associated revegetation, and fence repairs.

Monitoring, inspection, and maintenance costs are described in Appendix G. Costs for monitoring pore gas, dust, weather and runoff/sediment are included in this estimate. Monitoring procedures will be evaluated every 5 yr. A report on monitoring activities will be prepared each year. Maintenance includes replacing parts as required, and cleaning and/or replacing miscellaneous items. Neutron moisture meter monitoring will be conducted annually in existing boreholes, and TDR arrays in the cover will be monitored continuously with data loggers. Analytical services were assumed to be provided by an off-site laboratory.

The capital and recurring cost estimate as well as PV analysis is provided in Table 8.2-1.

8.3 Alternative 2C, Engineered Alternative ET Cover with Partial MDA G Waste Excavation, Monitoring and Maintenance, and SVE

The design of the Alternative 2C cover is similar to that of the Alternative 2B cover, except the design of the latter is optimized to minimize erosion. The design includes a biobarrier and partial excavation of waste in one pit. Alternative 2C was optimized by value assessment (VA) engineering presented in Appendix C. A plan view of the Alternative 2C ET cover and a section view of the cover are shown on

Figures 8.3-1 and 8.3-2, respectively. Salient features of Alternative 2C developed from the VA to optimize the Alternative 2B cover design include the following.

- The uppermost 6 ft of waste will be removed from Pit 28 to reduce the amount of fill needed for the cover and to decrease the overall cover slope.
- The cover slopes will be reduced to less than 4% and the slope length minimized to prevent erosion by infiltrating most of the runoff. The resulting plant growth stabilizes the surface and provides ET to remove the water. The 4% slope will withstand the 1000-yr storm.
- The layers of the cover will include the following, in descending order.
    1. A surface layer of 1.5-ft-thick vegetated soil gravel admixture. Conceptual design of the 1.5 ft layer of rock mulch is based on the 1000-yr storm conditions and actual slope segments.
    2. A 3.5-ft-thick water-storage medium composed of crushed tuff mixed with soil to improve water storage and ET and thereby minimize infiltration.
    3. A 1.0-ft-thick filter medium (natural materials such as gravel to provide a filter between the cover soil and biointrusion barrier).
    4. A 1-ft-thick biointrusion barrier of cobbles.
- The top surface is featureless with no internal sharp corners to minimize erosion.
- The cover thickness is designed to minimum thickness necessary to reach RCRA Subtitle C equivalent infiltration (5 ft). The additional 1.5 ft of soil/mulch cover contributes to the total water-storage capacity.
- Most runoff is directed to existing drainages that will have sediment basins. These basins will capture suspended contaminants before they are dispersed into the watershed and can also be sampled to monitor cover performance.
- Rock-armored-soil side slopes will blend into existing grade and minimize the amount of riprap required. Rock buttresses are used in some areas to eliminate excessively steep side slopes.
- A biointrusion barrier will minimize intrusion by plants and animals.

In addition, Alternative 2C proposes using SVE technologies to reduce the VOC plume present in the vadose zone.

As with Alternative 2B, the objectives of the Alternative 2C optimized ET cover are to (1) reduce or limit the amount of water that percolates into and through buried waste (minimizing the potential for subsurface contaminant transport); (2) reduce or limit erosion to prevent direct exposure of the waste and minimizing surface transport of contaminants; and (3) prevent the intrusion of deep-rooting plants and burrowing animals.

Figure 8.3-3 presents a schematic of the layers that compose the Alternative 2C cover. The cover consists of a surface treatment of gravel/topsoil admixture (18 in.) on top of cover soil (3.5 ft minimum) on top of a biobarrier cobble layer (1 ft minimum).

8.3.1 Applicability

The Alternative 2C ET cover contains the waste disposed of in the units at MDA G based on the same principals outlined in section 8.2.1 for the Alternative 2B cover (i.e., erosion stability and limited migration of waste, low infiltration). The applicability of Alternative 2C was optimized through the VA engineering process.

The use of SVE provides suitable treatment for VOCs. The technology is typically applicable only to volatile compounds with a vapor pressure greater than 0.02 in. Hg (0.5 mm Hg) or a Henry's law constant greater than 0.01. Effectiveness is also influenced by factors such as the moisture content, organic content, and air permeability of the soil. It is not applicable for heavy oils, metals, PCBs, or dioxins, but it often promotes in situ biodegradation of low-volatility organic compounds because of the continuous flow of air through the soil. A pilot test at MDA L showed that SVE can successfully remove large quantities of VOCs from the unsaturated zone in a similar geologic setting (LANL 2006, 094152). A pilot test of SVE is currently being conducted at MDA G. This pilot test will evaluate the effectiveness of SVE technologies on MDA G VOCs. This pilot project is underway, and preliminary results indicate this technology is viable for use at MDA G. The final report is due to NMED on October 31, 2008, and a final evaluation of its use for corrective measures at MDA G will be determined at that time.

8.3.2 Technical Practicability

Alternative 2C is an improvement over Alternative 2B because modeling modifications optimize ET, reduce infiltration, and minimize long-term erosion and biointrusion. These modifications are detailed in Appendixes D and E.

Like Alternative 2B, the Alternative 2C design is relatively simple, easy to construct and maintain, uses readily available native tuff in combination with soil and other readily available construction materials, and is an appropriate selection for a semiarid climate. Using local materials in the design not only ensures availability of materials but provides the benefit that the material properties are thoroughly understood in the mesa setting relative to hydrologic properties, material handling, weathering, and compatibility with native species.

Alternative 2C proposes limited excavation of waste in Pit 28 to reduce steep slopes on the southeast side. If the waste is not excavated, then a large amount of fill will be needed to smooth the cover to a 4% grade or less. Considering erosion, covers with less than 4% grade and shallow slopes perform well even without maintenance under bare soil conditions. Partial excavation of waste in this case is an option that stabilizes the cover from long-term erosion. However, the excavation of waste entails all of the risks and costs associated with excavation, packaging, transportation, and final disposition.

The practicability of Alternative 2C is improved over Alternative 2B because less fill as a base for the cover and less rock armor on sides slope are used to tie into existing grades. Alternative 2C also eliminates the use of the bentonite amendment and the angular rock in the cover described in Alternative 2B, thus increasing its practicability because no local source of bentonite or angular rock is available in the area of the Laboratory.

8.3.3 Effectiveness

The optimized ET cover reduces erosion potential, minimizes the amount of fill required, has cover materials that are protective under 1000-yr storm conditions, and is gradually sloped. Alternative 2C has the best aesthetics of the engineered covers because it is the most similar to the natural landscape, requires less rock armor, and is constructed from materials that are readily available. In addition, the cover thickness is designed to minimum thickness to reach RCRA Subtitle C equivalent infiltration. Most water is directed to existing drainages that will have sediment basins. These basins will capture suspended contaminants before they are dispersed into the watershed and can also be sampled to monitor cover performance.

Except for the removal of 6 ft of waste from Pit 28, Alternative 2C does not include treatment for MDA G waste and is therefore not effective in reducing waste volume or toxicity, although chemical degradation may result in decreased toxicity over time.

Erosion modeling discussed in Appendix E indicates an average soil loss of less than 1.86 tonnes/ha/yr across the site under bare soil conditions. This loss is less than the design goal of 4.5 tonnes/ha/yr. Approximately 0.28 in (0.71 cm) of cover would be eroded every 100 yr under bare soil conditions, indicating the cover thickness will have to be increased by 3 in. to maintain the cover at its minimum thickness for a 100-yr active institutional control period.

8.3.4 Implementability

Inspection will include a monthly site walk to find areas where gullies are establishing, areas where subsidence has occurred, and where focused recharge may be present. Maintenance will include repairing gullies and subsidence areas with rock armor or additional fill. An inspection will occur after every 25-yr, 0.25-h, or greater storm.

8.3.5 Human Health and Ecological Protectiveness

Impacts to human health and the health of ecological receptors from implementation of the remedy are assessed separately. The remedy implementation/installation period is considered for short-term impacts and the remedy operation period is considered for long-term impacts. Short- and long-term impacts differentiate between hazards associated with construction of the remedy versus hazards associated with its operation.

8.3.5.1 Short-Term Human Health Effects

Injuries and Accidents

Short-term injury and accidents are predicted to be associated with the physical hazards of construction activities and traffic risks associated with the transportation of raw materials to the site for the cover construction. Exposures to buried waste contaminants are not anticipated during cover construction activities, except for surface flux concentrations of organic chemical vapors from the limited subsurface organic vapor areas beneath MDA G, because excavation into the waste disposal units is not required for installing the cover.

Following the method described in section 8.2.5, the total of 119,000 work hours estimated for installing the cover and excavating the top 6 ft of Pit 28 will result in an estimated 4 nonfatal injuries. The potential for worker exposures to hazardous chemicals and radionuclides during the excavation of the top 6 ft of Pit 28 will be evaluated and mitigated through the combination of in-depth job planning, worker training, appropriate engineered controls and PPE, and the continued monitoring of the area and the workers. A site-specific health and safety plan fully documenting the hazards present and the actions to be taken in the event that threshold values are exceeded will be prepared for the project.

Fatality incidence rates for the same work, based on 2005 statistics for the construction industry (DOL 2006, 097080, p. 4) at 5.4×10^{-8} per work hour would result in less than 1 fatality predicted for the cover installation project.

The risk of vehicle traffic accidents associated with implementation of the remedy is generally considered a function of total miles of travel for the project vehicles. Based on an average fatal accident rate per vehicle miles for large trucks of 2.3 fatal accidents per 100 million miles (DOT 2002, 097082, p. 2) or 2.3×10^{-8} fatal accidents per mile and an estimated maximum of 2,741,000 truck transport miles on public roads for delivery of project resources, an overall incident rate for fatal traffic accidents for the project would be less than 1.

Exposures to Contaminants

Following implementation of SVE, risk values are expected to be substantially below those estimated in the MDA G investigation report (LANL 2005, 090513, Appendix G). The investigation report calculated an HI of 0.07 (well below the 1.0 risk target value), a total excess cancer risk of 1×10^{-8} (well below the 1×10^{-5} value). As a result of exposure to contaminants in MDA G drainages as described in section 8.2.5 and because of the reduced levels of VOCs following SVE, these limits are considered bounding.

Access restrictions will remain in place during the construction and throughout the following 100-yr active institutional control period.

8.3.5.2 Short-Term Ecological Effects

The short-term ecological effects of Alternative 2C are equivalent to those described in section 8.2.5.2 for Alternative 2B.

8.3.5.3 Long-Term Human Health Effects

Exposure to Contaminants

The similarities between Alternatives 2B and 2C result in equivalent exposure to that predicted for Alternative 2B or lower because of the lower erosion potential of the Alternative 2C cover. Any potential future exposures will be a function of overall cover thickness.

8.3.5.4 Long-Term Ecological Effects

The short-term ecological effects of Alternative 2C are equivalent to those described in section 8.2.5.2 for Alternative 2B. Significantly fewer natural resources are required to construct this alternative.

8.3.6 Cost

Costs associated with Alternative 2C have been estimated for all phases of the project activities, including support activities, site preparation, SVE operations, construction, materials, and continuation of 100-yr active institutional control period following completion of construction of the cover. Detailed assumptions about the remedy and the approach for the construction and sources for materials of construction were made in developing a cost estimate for the cover alternative. The actual project costs will depend on specific design details and project decisions that will be determined only if this cover alternative is selected.

The Alternative 2C cover includes construction costs expended at the beginning of a project (e.g., capital costs) and annual operation and maintenance and monitoring costs required to maintain the cover after the initial construction period and were calculated as detailed in Appendix G.

8.3.6.1 Estimate of Capital Costs

Capital costs consist of direct costs (construction and materials), indirect costs (nonconstruction and overhead), and uncertainty estimates (contingency allowances) for Alternative 2C. Table 8.3-1 summarizes the capital cost for this alternative, by major project activity.

The following major assumptions were made in developing the estimate of capital costs for the Alternative 2C cover.

- D&D and RCRA closure costs of the Area G CSUs are not included in the cost estimates.
- Bandelier Tuff required for components of the cover will be quarried on-site at the Laboratory from within TA-61 and trucked to TA-54 where the materials will be stockpiled.
- Angular rock and rock armor will be imported.
- ET cover and biointrusion barrier installation activities will require 24 mo.
- Removal of retrievable TRU waste is not included in the capital cost.
- Waste will be partially removed from Pit 28.

Contingency cost estimates were developed based on past on-site removal actions (MDA P), estimates made at Idaho National Laboratory (INL) and other DOE sites (Sandia, Hanford, and Rocky Flats), and factors such as the site location of MDA G near existing operating facilities. As a check on the cost estimate, projected costs for Alternative 2C were compared to projected costs for a similar alternative at INL (Appendix G). The approach to waste excavation at INL was used as a paradigm for the limited waste excavation for Alternative 2C, and costs were relatively equivalent for similar waste types, volumes, and site conditions. A 55% contingency was costed at INL.

Alternative 2C has additional contingency added because of the uncertainty of Pit 28 contents. Safety and security activities have been estimated, but a high degree of cost uncertainty exists until site-specific health, safety, and security plans are established.

8.3.6.2 Estimate of Recurring Costs

Inspection, maintenance, and monitoring costs following completion of remedy construction include associated material and energy costs, the cost for managing waste produced after initial construction is completed, management and administrative costs, other indirect costs, and contingency.

The operating, maintenance, and monitoring costs for the alternative are limited to the 100-yr active institutional control period following the implementation of the base cover alternative.

The following major assumptions were made in developing the estimate of operating, maintenance, and monitoring costs for the cover:

- Inspection and maintenance activities for MDA G will require two personnel working an average of 4 h/wk.
- No major reconstructions or repairs of the cover will be required during the 100-yr active institutional control period; repairs will be limited to replacing materials removed by erosion, associated revegetation, and fence repairs.

Monitoring, inspection, and maintenance costs are described in Appendix G. Costs for monitoring pore gas, dust, weather, and runoff/sediment are included in this estimate. Monitoring procedures will be evaluated every 5 yr. A report will be prepared for each area for monitoring activities. Maintenance includes replacing parts as required and cleaning and/or replacing miscellaneous items. Neutron moisture meter monitoring will be conducted annually in existing boreholes, and TDR arrays in the cover will be monitored continuously with data loggers. Analytical services were assumed to be provided by an off-site laboratory.

The capital and recurring cost estimate as well as PV analysis is provided in Table 8.3-1.

8.4 Alternative 5B, Complete MDA G Waste-Source Excavation, Waste Treatment, Off-Site Disposal, and SVE

Under this alternative, the 32 pits, 193 shafts, and 4 trenches at MDA G will be excavated and the waste shipped to an off-site, licensed, permitted facility for disposal. Secure high-bay warehouses for processing and temporarily storing classified and unclassified waste will be built on-site to minimize handling and transportation logistics and cost. SVE will be implemented outside and below the excavated area to remove VOCs from the vadose zone, and monitoring will be conducted for up to 30 yr.

For this alternative, existing retrievable TRU waste will have been removed before implementation. The pits will be excavated using a tiered approach based on hazard level and assessment of specific inventory. Excavation of pits will be accomplished using standard excavation methods unless potential or real hazards dictate remote handling. Excavation of shafts will be performed using a parallel trench approach.

All 193 shafts at MDA G are in close proximity to the pits and trenches and will therefore have to be excavated concurrently. Except for Shafts 200–233, the shafts are considerably deeper than the pits. In most cases, they are twice as deep.

The top of the shafts and the entire pit will be excavated at the same time. The excavation will then continue in a trenching fashion parallel to the shafts in 6-ft increments to expose and remove all waste and remaining contaminated overburden. The waste in Pits 1–5 will have to be segregated and characterized to separate newly generated TRU waste from LLW and MLLW.

For optimal worker safety, waste removal of some shafts and pits will likely be conducted using remote methods in the area immediately surrounding the existing units because of the reported presence of unknown chemical waste. Pits 27, 29, 30, 33, 35, and 37 contain the unknown chemical waste and are located on the northwest part of the site in an irregular configuration. These pits range in depth from 35 ft to 61 ft.

Waste will be removed and transported to temporary structures for sorting, declassification, characterization, and packaging. Wherever practical, waste minimization techniques will be applied to the removed waste (e.g., decontamination and recycling of metals). Excavated waste determined to be hazardous or MLLW may require treatment to satisfy land disposal restriction requirements under 40 CFR 268 and 20.4.1.800 NMAC. Specific treatment facilities are presently not identified. Because of security considerations, all excavation and declassification activities will be conducted under the cover of temporary surface structures. These structures might be considered nuclear facilities, which will impose additional requirements on design and operation.

Waste shipped off-site must meet U.S. Department of Transportation shipping requirements and TSD-specific waste acceptance criteria and permit conditions before shipment and disposal occurs. The radioactive nonhazardous waste can be disposed of at a number of permitted radioactive waste disposal facilities.

Radioactive waste at MDA G has the potential to be contaminated with hazardous materials (i.e., mixed waste) and, therefore, may be disposed of only at facilities licensed to manage mixed radioactive/hazardous waste up to an authorized limit. Several TSD facilities may be appropriate for one or more categories of waste that may be anticipated in the MDA G inventory. These include

- Nevada Test Site,
- Duratek in Tennessee,
- Perma-Fix in Florida,
- Waste Control Specialists in Texas,
- Allied Technology Group in Washington, and
- Envirocare in Utah.

Buried pre-1970 waste with TRU elements does not have an identified long-term repository because it is not included in the allocation for WIPP; thus, the fate of this waste steam has not been decided. However, for purposes of costing, it is assumed it will be shipped in drums with LLW to Envirocare in Utah.

All waste requiring off-site disposal will be transported on Pajarito Road and then on NM 4. An estimate of 3,570,000 yd^3 of disposal-unit waste, including residual waste, will be transported on public roads. An estimate of 2,074,000 yd^3 of fill material will be imported from a local location estimated at approximately 12 miles away. Any of the removed overburden materials characterized as solid, hazardous, mixed waste, or LLW will be managed according to applicable waste management and disposal requirements.

The facilities required for the excavation alternative include a facility for waste sorting, a tent over the excavation for security purposes and protection from the elements, a waste declassification facility, a storage vault, and a storage area for removed materials. Appropriate PPE would be used in areas of material sorting, declassification, characterization, and packaging.

To reduce or eliminate the organic vapor plume identified at the site, Alternative 5B proposes using SVE if future VOC concentrations exceed threshold values.

8.4.1 Applicability

Excavation and off-site disposal is applicable to the complete range of contaminant groups with no particular target group.

The use of SVE provides suitable removal and treatment of gaseous VOCs. The technology is typically applicable only to volatile compounds with a vapor pressure greater than 0.02 in. Hg (0.5 mm Hg) or a Henry's law constant greater than 0.01. Its effectiveness is also influenced by factors such as the moisture content, organic content, and air permeability of the soil. Soil vapor extraction is not effective for heavy oils, metals, PCBs, or dioxins, but it often promotes in situ biodegradation of low-volatility organic compounds because of the continuous flow of air through the soil. A pilot test at MDA L showed SVE can remove large quantities of VOCs from the unsaturated zone in a similar geologic setting (LANL 2006, 094152). An SVE pilot test is being conducted at MDA G. This pilot test will evaluate the effectiveness of SVE technologies on MDA G VOCs. This pilot project is underway, and preliminary results indicate this technology is viable for use at MDA G. The final report is due to NMED on October 31, 2008, and a final evaluation of its use for corrective measures at MDA G will be determined at that time.

8.4.2 Technical Practicability

This alternative is expected to meet all screening criteria and is based on sound technologies and engineering principles; however, the technical aspects of excavating certain burial configurations are unproven. Until the mid-1980s, excavation and off-site disposal were the most common methods for cleaning up hazardous waste sites.

In the long-term, the performance, reliability, and minimization of hazards at the site are optimal because no hazardous constituents remain at MDA G. This alternative does, however, present significant short-term and long-term considerations. The unknown composition and the presence of potentially hazardous materials may require the use of remote excavation of many of the units.

The large volume of material to be transported for off-site disposal may impact the technical practicability as well. Waste removal will reduce the source material and will affect the time of operation for SVE; it is estimated that total excavation could take up to 30 yr to complete.

8.4.3 Effectiveness

The excavation of waste from the 32 pits, 193 shafts, and 4 trenches and surrounding contaminated tuff is effective in eliminating the potential long-term impacts to the areas surrounding MDA G. Complete excavation of waste at MDA G eliminates the need for long-term maintenance and/or monitoring at the location but will take approximately 30 yr to implement. This alternative, however, transfers the potential impact of the waste to the off-site disposal facility that accepts the waste and will result in transporting thousands of truckloads of hazardous and radioactive waste through local communities over a 30-yr period. Separate containers are necessary for materials shipped to WIPP as TRU and those sent to Nevada Test Site as MLLW. The reliability of off-site permitted facilities is under the purview of the regulatory agency that issues the permit and oversees compliance at the site.

The sorting and segregation of the excavated materials potentially increases the quantity of waste to be disposed of by increasing the amount of packaging materials necessary for transport and disposal at various locations depending on the waste type.

The Federal Remediations Technology Roundtable estimates typical excavation times of about 2 mo for excavating 20,000 tons of contaminated soil (FRTR 2004, 102751). However, waste at MDA G is not comparable to Roundtable estimates because of the nature of the waste and the need to segregate the waste. The estimate is based on the experience of retrieving and segregating similar waste and estimates performed at INL, which is evaluating similar alternatives (Holdren et al. 2007, 098642). The presence of unknown waste within numerous units, necessitating the use of remote-handling and/or robotic equipment during excavation, sorting, segregation, and stockpiling of waste, indicates an estimate of at least 23 yr to complete the project, based on INL’s experience.

In the short-term, this alternative is the least effective of the four at mitigating the impact of contamination. Disturbance and excavation of the units increase the possibility of accidental release of hazardous and/or radioactive materials. The possibility of release upon disturbance of the units containing unknown chemical waste materials increases the short-term risk of contamination dispersal.

Intermittent operation of SVE in areas outside the excavation will prevent migration of VOCs.

8.4.4 Implementability

Implementation of this alternative requires

- conducting a hazard categorization and hazard analysis to identify operating procedures associated with unknown waste materials;
- using remote handling, engineering controls, and/or PPE up to Level A to reduce exposures associated with unknown chemical materials;
- constructing temporary security enclosures over the removal area and in any area designed for sorting, declassifying, and reshaping operations;
- sorting and declassifying shapes and related materials before disposal because classified waste removed from MDA G must undergo a declassification review and potential reshaping by milling, crushing, shredding, or other methods before it can be recycled or disposed of off-site;
- removing materials from the units inside a movable temporary structure; and
- conveying excavated waste materials to an enclosed storage and sorting area where they will be evaluated.

The waste will be sorted for classification, decontamination, disposal of at a permitted off-site location, or recycled. A separate packaging facility is also required.

Most of the overburden material will be removed as waste and new fill will be brought in to replace it. Much of the overburden would be characterized as LLW, hazardous waste, and/or MLLW. Once the excavated area has been backfilled, the site will be regraded and revegetated.

Alternative 5B is estimated to take 12 mo to design, and it could take up to 30 yr to remove the waste, depending on federal funding levels.

8.4.5 Human Health and Ecological Protectiveness

8.4.5.1 Short-Term Human Health Effects

Injuries and Accidents

Worker risk associated with the implementation of Alternative 5B is based on the requirement that all workers adhere to rigorous DOE, state, and federal worker-safety regulations and that engineered barriers are designed to protect workers. During planning and implementation, engineering controls designed to ensure that no worker will be exposed to risks/doses above the levels specified by DOE, state, and federal worker-safety regulations will be emplaced. This alternative involves workers spending 29,267,000 work hours on-site. Following the methodology described in section 8.2.5.1, the total worker hours on-site will result in an estimated 907 nonfatal injuries during excavation, backfilling, and regrading, and revegetating over the 30-yr execution.

Potential accidents resulting from extensive excavation and associated waste handling include industrial hazards/accidents, fires with release of radioactive/hazardous materials, explosions and associated releases of radioactive materials, spills of hazardous and radioactive materials, inadvertent exposures to penetrating radiation, and transport accidents. In addition, workers at off-site disposal locations will be exposed to hazards associated with the handling and disposal of this waste.

Both unmitigated and mitigated worker and transportation risks associated with Alternative 5B are assessed. Unmitigated risk refers to the risk from postulated accident scenarios for which no controls are credited in reducing either the likelihood or consequences of an accident, while mitigated risk is based on crediting the reduction of the likelihood or consequences of an accident to the implementation of controls preestablished for all remediation activities.

A risk assessment of all remediation activities was performed according to various accident categories (Omicron 2001, 070229). These remediation activities include the following:

1. site preparation
2. site excavation
3. sorting/segregation
4. declassification
5. packing/loading
6. transportation
7. site restoration

Accident categories include industrial hazards/accidents, potential fires with release of radioactive/hazardous materials, potential explosions and associated releases of radioactive materials, spills of radioactive materials, and inadvertent exposures to penetrating radiation. The evaluation goals were to determine (1) the overall dominant worker risk remediation activity, (2) the dominant worker risk accident category for each of the remediation activities, (3) the risk to the public from remedial activities, and (4) major controls that could be instituted to prevent or mitigate the dominant risk.

Of the more than 150 accidents postulated from remedial activities, the total potential risk is dominated by standard or industrial types of accidents (58%). For most remedial activities, the second-most dominant risk is from explosions (27%), followed by excavation (26%) and transportation (7%).

Implementing a variety of administrative and engineered controls (i.e., mitigating risks) reduces the risk for nonstandard industrial accidents by nearly 43%. Proposed controls include shaft/pit stabilization, blast shields/berms, remote excavation, remote waste removal techniques, remote video surveillance, explosives inerting, and radiation monitors.

The risk to the public from all activities, except potential fire and explosions and on-site/off-site transportation, is negligible. If Alternative 5B is selected, a safety analysis is required to detail the risks from potential hazards before administrative and engineering controls are designed.

Some removal activities will be performed as a remote operation because of the combination and configuration of the material in the pits, shafts, and trenches.

Modeling the risk to the public from a transportation accident was dominated by standard industrial accidents types such as vehicle crashes and accidents associated with transportation activities in which serious or fatal consequences could occur to members of the public as a result of the vehicle accident alone. Drivers responsible for transporting the waste to off-site disposal locations may be at risk of having traffic accidents. It is assumed that large trucks will be used with a capacity of 12 yd^3 for fill and 20 yd^3 for waste removal. The probability of a fatal crash involving a large truck would be 2.3×10^{-8}/mi. Assuming 163,765,000 truck miles, or a probability of approximately 4 fatalities. Under Alternative 5B, other members of the public (i.e., not nearby residents) may be exposed to the risk of transporting the waste across the nation's highways.

For all nontransportation accident scenarios of concern, the total average (between the unmitigated and mitigated) risk to workers from all remediation activities is 22 times greater than risk to the public; in other words, the risk to the public is less than 5% of the risk to the worker.

Because of the extensive excavation and waste handling required at the site, Alternative 5B poses the highest exposure to workers, and only Alternative 5B poses exposure to the public from transportation of waste on public roads.

8.4.5.2 Short-Term Ecological Effects

The environmental impacts of Alternative 5B are evaluated in terms of the potential biological and cultural resource damage that may be incurred during implementation.

Biological resource field surveys have been conducted for the TA-54 area (MDAs G, H, and L) for compliance with the Federal Endangered Species Act of 1973; the New Mexico Wildlife Conservation Act; PL 93-205; EO 11990, May 24, 1977, “Protection of Wetlands”; EO 11988, May 24, 1977, “Floodplain Management”; 10 CFR 1022, “Compliance with Floodplain/Wetlands Environmental Review Requirements”; and DOE Order 5400.5, “Radiation Protection for the Public and the Environment.”

No wetlands exist in the immediate vicinity of MDA G, but wetlands and floodplains exist in the lower portion of Pajarito Canyon. Possible T&E species for the area were identified, but no species or habitats were located. Further information is contained in “Biological Assessment of Environmental Restoration Program, Operable Unit 1148, TA-54” (Banar 1996, 058192).

A cultural resource survey was conducted during the summer of 1991 at TA-54, as required by the National Historic Preservation Act of 1966 (LANL 1992, 007669). A total of 68 archaeological sites were located within the boundary of TA-54. Of this number, 56 are eligible for inclusion on the National Register of Historic Places, and 12 have been declared ineligible. Alternative 5B will have limited impact on cultural resources. A mitigation plan will be developed for impacted sites.

8.4.5.3 Long-Term Human Health Effects

No local or regional long-term potential human health impacts are associated with excavation because the material in the MDA G pits, shafts, and trenches will be removed, decontaminated or treated as necessary, and disposed of in either off-site facilities or recycled, where appropriate.

8.4.5.4 Long-Term Ecological Effects

No long-term ecological risks are associated with excavation at MDA G because the material in the MDA G pits, shafts, and trenches will be removed and disposed of in permitted units or recycled, as appropriate, and the area will be regraded and revegetated.

8.4.6 Cost

8.4.6.1 Estimate of Capital Costs

Capital costs consist of direct costs (construction), indirect costs (nonconstruction and overhead), and uncertainty estimates (contingency allowances). Table 8.4-1 summarizes the capital cost for Alternative 5B. Detailed estimates of capital cost in CY2008 dollars are provided for this alternative in Appendix G. Cost estimates may not be within the accepted standard accuracy range of +50% to –30%

established by EPA for remedial alternative estimates at the alternatives screening stage (EPA 2000, 071540, p. 2-4).

Contingency cost estimates were developed based on past on-site removal actions (MDA P), estimates made at INL and other DOE site experience (Sandia, Hanford, and Rocky Flats), and factors such as the site location of MDA G near existing operating facilities. As a check on the cost estimate, projected costs for Alternative 5B were compared to projected costs for a similar alternative at INL (Appendix G). The approach to waste excavation at INL was used as a paradigm for waste excavation for Alternative 5B and costs were relatively equivalent for similar waste types, volumes, and site conditions. A 55% contingency was costed at INL.

Alternative 5B has additional contingency added because of the uncertainty of shaft contents and degradation of containers in the shafts. Safety and security activities have been estimated, but a high degree of cost uncertainty exists until site-specific health, safety, and security plans are established. Appendix G analyzes the contingency considerations.

As noted in section 7.3.12, Alternative 5B does not include removal of wastes from the LLW disposal pits and shafts that are regulated only by DOE. Although design requirements for closure of these units under DOE Order 435.1 have not been determined, costs are included in the estimate for Alternative 5B based on an ET cover design.

Capital Costs for Monitoring

Costs for monitoring soil moisture, pore gas, dust, weather, runoff/sediment, and groundwater are included in this estimate because they will be required until excavation is complete. Pore-gas monitoring will use existing boreholes that extend beyond the base of the waste disposal units. The existing TA-54 weather station will be used to monitor weather. Dust and control of runoff/sediment will require new installations.

8.4.6.2 Estimate of Recurring Costs

Inspection, maintenance, and monitoring costs following completion of remedy construction include associated material and energy costs, cost for management of waste produced after completion of initial construction, management and administrative costs, other indirect costs, and contingency.

The operating, maintenance, and monitoring costs for the alternative are limited to a 100-yr period following the implementation of the Alternative 5B action.

The capital and recurring cost estimate as well as PV analysis is provided in Table 8.4-1.

9.0 SELECTION OF THE RECOMMENDED CORRECTIVE MEASURE ALTERNATIVE

The purpose of this CME is to identify, develop, and evaluate corrective measures alternatives and recommend the corrective measure(s) to be taken at the MDA G. As part of this CME process, 12 corrective measure alternatives were screened against CME corrective action objectives and criteria specified by the Consent Order. Screening of these technologies resulted in the selection of four general types of technologies for developing corrective measures alternatives. Development of corrective measures alternatives using individual technologies or various combinations of these technologies resulted in the selection of the four candidate corrective measures alternatives listed below that are suitable for the site.

- Alternative 1B, Monitoring and Maintenance of Existing Covers and SVE
- Alternative 2B, Engineered Alternative ET Cover , Monitoring and Maintenance, and SVE
- Alternative 2C, Engineered Alternative ET Cover with Partial MDA G Waste Excavation, Monitoring and Maintenance, and SVE
- Alternative 5B, Complete MDA G Waste-Source Excavation, Waste Treatment, Off-Site Disposal, and SVE

Following a detailed evaluation, one candidate corrective measures alternative presented the lowest overall risk to human health and the environment, while minimizing cost and meeting CME corrective action objectives. This alternative is Alternative 2C, Engineered Alternative ET Cover with Partial MDA G Waste Excavation, Monitoring and Maintenance, and SVE.

Selection of the recommended Alternative 2C is based on the criteria listed in Table 9.0-1. The numeric ranking ranges from 1 (poorest ability to meet the selected criteria) to 5 (most readily meeting the criteria). This table summarizes the corrective measure alternatives based on the six evaluation criteria defined in Section XI.F.10 of the Consent Order and discussed in section 8. It also includes five selection criteria presented in sections 9.1 to 9.5, which are defined in Section XI.F.11 of the Consent Order. Table 9.0-2 compares the estimated costs associated with each alternative.

Although both Alternatives 2B and 2C satisfy selection requirements of the Consent Order, Alternative 2C has been selected as the recommended corrective measure because Alternative 2C has benefits over Alternative 2B. These benefits include less cover material and a decrease in surface erosion as a result of the flattening of the site topography. The reduction in the cover slopes in Alternative 2C stems from the removal of some waste out of Pit 28.

Alternative 2C also offers additional protection against direct contact with the majority of waste in MDA G. Components of the cover design will minimize infiltration of water and mitigate biointrusion and human intrusion through the use of biobarriers and capillary breaks. In this alternative, the engineered ET cover would be constructed on the existing operational cover after removing some waste from Pit 28.

The engineered ET cover would be constructed of natural materials, many of which are locally available, that would perform with minimal maintenance by emulating the natural ecosystem. This alternative also poses minimal risk to site workers implementing institutional controls associated with environmental and groundwater monitoring and routine maintenance and surveillance of the site. The risk to human health and the environment following implementation of this alternative is acceptable.

Although not an evaluation criterion specified in the Consent Order, the lower cover profile with Alternative 2C also results in less visual impact

9.1 Achieving Cleanup Objectives in a Timely Manner

Because risk-based cleanup objectives are not currently exceeded, this criterion is not applicable.

9.2 Protecting Human Health and the Environment

The results of the evaluation in section 8 indicate that the lower slopes for Alternative 2C greatly enhance performance of the cover. This added enhancement reduces the overall risk to human health and the environment over Alternatives 1B and 2B. Waste removal also provides this level of assurance without long-term monitoring and maintenance (Alternative 5B). However, it is recognized that very high costs and hazards, such as worker fatalities and potential exposure of radioactive and hazardous waste to the public, are associated with excavation of waste and transportation off-site required in Alternative 5B. Thus, it was determined that Alternative 2C was the best option for the protection of human health and the environment.

9.3 Controlling or Eliminating Sources of Contamination

Alternatives 2B, 2C, and 5B are the best suited for controlling or eliminating sources of contamination at MDA G because they address all of the contamination control/elimination issues associated with both the hazardous and radioactive waste. Alternative 5B eliminates the source of MDA G contamination, whereas Alternative 2C only partially eliminates sources of contamination. Both Alternatives 2B and 2C control the sources of contamination, and an analysis of different variables concludes that Alternative 2C provides the best compromise between control and elimination of sources of contamination at MDA G.

9.4 Controlling Migration of Released Contaminants

By directing runoff into one watershed and capturing sediment eroded from the cover in sediment basins, the potential for release of contaminated sediments into the Pajarito and Mortandad Canyon watersheds is minimized. Maintenance will repair covers to minimize erosion of waste as sediment or airborne transport. In addition, the SVE technologies will control migration of the VOCs.

9.5 Managing Remediation of Waste in Accordance with State and Federal Regulations

Alternative 1B produces the least remediation waste and is ranked the highest. Alternatives 2B and 2C will produce more waste, and both are ranked accordingly. Alternative 5B will produce large volumes of remediation waste and is ranked the lowest because of the complexities and risks involved in excavating the material and ensuring that the waste is managed and disposed of in a compliant manner.

10.0 DESIGN CRITERIA TO MEET CLEANUP OBJECTIVES

As required in section XIF.12 of the Consent Order, this section presents a preliminary plan and key specifications to illustrate the ET cover technology and its anticipated implementation. The preliminary design information includes a discussion of the design life of the alternative and provides reference to engineering calculations for any proposed remediation system.

10.1 Design Approach

The design process to be performed during the CMI phase includes the following activities.

1. Identify critical infiltration events, including identification of the design precipitation event (maximum precipitation event that the design is based upon) or series of events.
2. Determine the minimum required water-storage capacity of MDA G soil based on design infiltration events identified in Step 1.
3. Determine the minimum soil thickness required.
4. Identify the seed mixture to be used, the surface treatment to be employed before seeding, and the frequency of watering required to establish the vegetative cover, with agreement by

San Ildefonso Pueblo on the seed mixture to ensure invasive species do not migrate to Pueblo lands.

5. Design a biointrusion barrier.
6. Verify this design will have a performance equivalency with the requirements of 20 NMAC 9.1 for alternative cover design.
7. Design a moisture-monitoring system using TDR arrays and a neutron logging program in existing boreholes.
8. Design an SVE system that uses active and/or passive technologies for extracting VOC vapors from the vadose zone.
9. Develop a plan for monitoring the performance of the remedy.
10. Develop an operations and maintenance manual based on design and monitoring requirements that will be reviewed during final design meetings and submitted to NMED and DOE for approval.

10.2 Preliminary Design Criteria and Rationale

Preparation of the CMI plan includes a schedule for design, including development of design calculations and documentation, which will be submitted to NMED according to the CMI schedule. Design calculations will include, but will not be limited to, the following:

- The cover will have sufficient capacity to store the “maximum” infiltration quantity resulting from the worst-case precipitation event (generally spring snowmelt) until it can be removed through ET.
- The cover design will have performance equivalency with the requirements of 20 NMAC 9.1 for alternative cover design.
- The proposed seed mixture used to stabilize the cover with vegetation comprising plant communities will closely emulate the local plant community and ensure the vegetative cover remains viable. The proposed seed mixture will be reviewed with San Ildefonso Pueblo to ensure the mixture does not contain invasive species that may affect Pueblo lands.
- The proposed surface treatment method will encourage establishing native vegetation, foster plant growth, and reduce erosion.
- The evaluation of SVE technologies will effectively limit VOC migration that might impact groundwater if SLs are exceeded.

The proposed moisture-monitoring system will verify that volumetric water content levels below the pits, shafts, and trenches do not exceed a value negotiated with NMED or 12%, the amount at which transport velocities in the vadose zone may increase over time (LANL 2005, 089332, pp. J-12–J-13). This monitoring criterion is applicable to all boreholes in unit Qbt 1v(u) from depths of 60 ft to 100 ft and will ensure that downward aqueous-phase transport through the vadose zone is sufficiently slow to prevent exceedances of groundwater screening criteria in the regional aquifer and prevent MCLs from being exceeded.

Figure 8.3-1 presents a plan view, and Figure 8.3.2 presents a section view of the final cover upper surface of Alternative 2C.

Preliminary specifications sufficient for evaluating the approximate cost of the alternative are included for

1. cover vegetation;
2. surface treatment (gravel admixture—typical gravel-topsoil mixture, gravel size);
3. cover soil (water storage medium—thickness, texture);
4. filter medium (natural materials such as gravel to provide a filter between the cover soil and biointrusion barrier); and
5. biointrusion barrier (cobble size and uniformity).

Table 10.2-1 presents key elements of material specifications for layers based on imported soil and rock.

10.2.1 Surface Treatments

Surface treatments, such as the addition of soil nutrients and a soil/gravel admixture and initial watering are required in the semiarid climate at the Laboratory to assist in establishing native vegetation and reducing erosion. During the CMI design phase, a seed mix will be specified to stabilize the cover with vegetation consisting of plant communities that closely resemble the undisturbed and well-established plant communities in the MDA G area. Specifications of the surface treatment are provided in Appendix D. The seed mix will be reviewed with San Ildefonso Pueblo to ensure that invasive grasses are not included.

The addition of a 1.5-ft- (0.46-m-) thick layer of gravel on the surface of the cover offers the following advantages for the MDA G cover:

- A gravel layer will reduce surface erosion from stormwater runoff and wind and will hold seeds in place until germination can occur.
- Moisture will be retained in the uppermost layer of soil, allowing native grasses to be established. These native grasses will increase the water-storage capacity of the cover by transpiring moisture and preventing drainage after significant rainfall events. A gravel layer retains moisture near the soil surface, distant from the waste, where water-seeking roots will not intrude into the shafts or pits. Rock armor or riprap, in contrast to a gravel layer, will not support significant vegetation growth.

The disadvantages of a gravel layer may include a reduced soil evaporation rate. Fine-grained soil generally has a higher evaporation rate than coarse-grained soil. As gravel acts as very coarse-grained soil, the cover surface will have reduced evaporation. This reduced evaporation will not become substantial enough to reject using a surface gravel layer on the MDA G cover because transpiration from plants more than compensates for the reduced soil evaporation.

An alternative to a gravel layer is a soil/gravel admixture. Erosion and water balance studies at the Laboratory indicate that moderate amounts of gravel mixed into the cover topsoil will control both water and wind erosion with little effect on the vegetation or the soil-water balance (Wilson et al. 2005, 092034). As wind and water flow over the cover surface, some winnowing of fines from the admixture is expected, creating a vegetated, erosion-resistant surface sometimes referred to as a "desert pavement."

The design of a soil-gravel admixture layer is based primarily on the need to protect the soil cover from erosion. A soil-gravel admixture protects a cover from long-term wind erosion. The protection from water erosion depends on the depth, velocity, and duration of stormwater flowing across the MDA G cover. Flow values can be established from the physical properties of the cover (slope, convex or concave grading, slope uniformity, and length of flow paths) and the intensity of the precipitation (precipitation rates, infiltration versus runoff relationships, snowmelt, and off-site flows).

The decision on surface treatment will be based on review of site-specific conditions at MDA G and Laboratory data from cover experiments at TA-51 (Nyhan et al. 1996, 063111). The best surface layer will be chosen during the CMI design phase and discussions with NMED.

Evapotranspiration covers are intended to function under unsaturated conditions; consequently, obtaining very low saturated hydraulic conductivity is not essential to a successful cover. The cover-soil moisture characteristics and cover-compaction density are crucial parameters. Compaction-density requirements will be based on the design criteria used but generally will achieve the density in the upper soil layer that approximates that of the surrounding undisturbed soil. Uniformity of compaction is critical to avoid creating preferential infiltration pathways.

10.2.2 Cover Soil

The performance of the engineered ET cover relies on its thickness. The engineered ET cover for MDA G will be thick enough to ensure that the water-storage capacity of the cover is sufficient to store the maximum infiltration quantity resulting from the design precipitation event until it may be removed through ET. Specifications for the cover soil are provided in Appendix D.

10.2.3 Filter Media

Inclusion of a filter media layer with a particle size between the cover soil and the biointrusion barrier cobbles will enhance the effectiveness of the biobarrier. It will also improve the waste storage of the cover by providing a capillary break. Specifications for filter media are provided in Appendix D.

10.2.4 Biointrusion Barrier

When the cover depth is established, biointrusion-barrier requirements will be evaluated to optimize its performance. The biointrusion barrier must prevent plant roots and animals from intruding into the waste where they may create conduits for water to move downward into the waste units or transport waste to the surface. The specifications for the biointrusion barrier are provided in Appendix D.

10.3 General Operation and Maintenance Requirements

Subject matter experts will establish appropriate requirements for irrigating the cover. Irrigation is needed during the 2 yr following construction to aid in germinating and establishing the vegetative cover. Establishing the vegetation will be offset by keeping infiltration below the storage capacity of the cover. The Laboratory will implement the irrigation plan.

During the first 2 yr after construction, the Laboratory will inspect the cover quarterly and after significant precipitation events to identify erosion of the cover. Any eroded areas will be repaired. After the cover is established, it will be inspected annually in the fall (after the monsoon season has ended), and any cover erosion will be repaired.

During the CMI design phase, an area will be designated within the Area G fence to store the soil/gravel admixture used for cover maintenance. A small shed will be placed in this area to store tools and grass seed.

Moisture-monitoring equipment for the cover will be inspected regularly according to the time frame recommended by the manufacturer and repaired, as necessary.

Until the results of the SVE pilot tests are available, it is assumed that SVE extraction will be operated for 2 mo on and 22 mo off over a 24-mo period.

10.3.1 Long-Term Monitoring Requirements

Groundwater monitoring of the regional aquifer beneath MDA G will be based on the TA-54 well evaluation and network report (LANL 2007, 098548).

Installation of a moisture monitoring system is proposed for Alternatives 1B, 2B, and 2C to measure performance of the vegetative cover. The proposed system to monitor cover performance will consist of (1) TDR probes installed in arrays and an associated data collection system and (2) neutron logging of the four existing boreholes at MDA G.

Two TDR arrays consisting of three probes each are proposed. One array will be placed in the cover directly above disposal shafts, and one will be installed in the cover in an off-shaft location within the MDA G fence line. In each array, the TDR probes will be placed horizontally at appropriate depths at and just below the gravel/topsoil interface. The three arrays will be tied to one data collection center consisting of a data logger, remote data access, associated solar equipment to operate the data center, and a tipping bucket rain gauge to monitor precipitation events. The remote access instrumentation will allow for collecting data remotely with a modem connection. Moisture levels will be recorded twice daily on a data logger. The data will be analyzed and reported quarterly for the first 5 yr to verify the cover is performing at the preestablished rate of moisture loss or better. Thereafter, the data will be analyzed and reported annually.

Four existing boreholes will be neutron logged monthly at 1-ft intervals for 2 yr to establish time series trends for developing a depth profile of moisture to confirm the conceptual model. After the first 2 yr, neutron logging will be conducted annually. Review of the depth profile of moisture will be included in a 5-yr review with NMED.

Volatile organic compounds will be monitored with field instrumentation in the subsurface in existing boreholes until NMED determines this monitoring is not necessary (Appendix H). Tritium vapor will be monitored in the subsurface until DOE determines this monitoring is not necessary.

Radon and dust will be monitored at the MDA site boundary according to existing monitoring plans.

Sediment will be sampled quarterly and analyzed for RCRA contaminants and selected radiological isotopes in four sediment basins.

10.4 Additional Engineering Data Required

Before the CMI design is completed, additional data is required to aid in design, including

- verifying the existing depths to the top of waste to properly determine the operational cover thickness and fill (if any) required to establish a graded base for the biointrusion barrier;
- testing the geotechnical properties of all materials used for the biointrusion barrier, filter media, surface treatment, and rock armor;
- updating the DOE model;

- evaluating the results of the SVE pilot study; and
- obtaining waste characterization and waste profile sampling results for the material in the upper 6 ft of Pit 28.

10.5 Additional Requirements

10.5.1 Permits and Regulatory Requirements

NMED will select a final remedy, issue a Statement of Basis for the selected remedy, and designate a period of time for public comment (section 11.1).

10.5.2 Access, Easements, Right-of-Way

An agreement may be required between the Laboratory Environmental Program and Facility Operations staff that will delineate the specific roles and responsibilities of the facility owner and the project constructing the cover.

10.5.3 Health and Safety Requirements

A site-specific health and safety plan will be prepared to determine the health and safety requirements to be followed during construction of the MDA G cover, during construction of the monitoring system, during operation and maintenance activities, and during monitoring activities.

10.5.4 Community Relations Activities

A community relations program has been implemented to keep stakeholders, including the Los Alamos and White Rock communities, San Ildefonso Pueblo, Northern New Mexico Citizen Advisory Board, and interested parties aware of project activities and progress.

11.0 SCHEDULE FOR COMPLETION OF ACTIVITIES

A schedule presenting activities for completing the recommended corrective measure alternative is presented in Figure 11.0-1.

11.1 Specific Consent Order Milestones

Specific Consent Order milestones:

- The Laboratory will submit the MDA G CME report no later than September 12, 2008, and NMED will approve the CME report by January 31, 2009.
- NMED will prepare a Statement of Basis for selecting the remedy and issue the Statement of Basis for public comment.
- NMED will receive public comments on the Statement of Basis for at least 60 d following public notice, select a final remedy, and issue a response to comments within 90 d of the end of the comment period, or other appropriate time. NMED will provide an opportunity for a public hearing, which may extend the public comment period.
- The Laboratory will submit a CMI plan within 9 mo after NMED selects a final remedy. The CMI plan will contain a schedule for implementation of the corrective action.

- The corrective measure alternative will be implemented according to the schedule in the CMI plan.
- The Laboratory will complete the remedy and submit a remedy completion report no later than December 31, 2015.
- NMED will approve the remedy completion report by April 4, 2016.

11.2 Intermediate Milestones

In addition to the milestones specified in the Consent Order, other intermediate milestones may be established. Consent Order requirements for the CMI plan identify documents and an associated schedule for deliverables. The schedule for CMI-identified documents, which are beyond the scope of the CME report schedule, include the following:

- construction work plan
- operation and maintenance plan
- waste management plan
- health and safety plan
- community relations plan
- progress reports

Other activities identified in the Consent Order include an SVE pilot test which will completed by October 31, 2008. No bench scale tests are planned to implement the remedy.

The schedule for monitoring and data submittal to NMED includes

- monitoring and sampling to be conducted according the pore-gas and groundwater monitoring plans for the Laboratory and
- preparing and submitting preliminary data and status reports quarterly.

12.0 REFERENCES AND MAP DATA SOURCES

12.1 References

The following list includes all documents cited in this report. Parenthetical information following each reference provides the author(s), publication date, and ER ID number. This information is also included in text citations. ER ID numbers are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau; the U.S. Department of Energy–Los Alamos Site Office; the U.S. Environmental Protection Agency, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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12.2 Map Data Sources

Hypsography, 20- and 100-ft Contour Intervals; Los Alamos National Laboratory, ENV-Environmental Remediation and Surveillance Program; 1991

LANL DOE Boundary; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; Development Edition of 05 January 2005

LANL Technical Areas; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; Development Edition of 05 January 2005

Materials Disposal Areas; Los Alamos National Laboratory, ENV-Environmental Remediation and Surveillance Program; ER2004-0221; 1:2,500 Scale Data; 23 April 2004

Paved Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; Development Edition of 17 January 2006

Waste Storage Features; Los Alamos National Laboratory, ENV-Environmental Remediation and Surveillance Program, ER2005-0748; 1:2,500 Scale Data; 06 October 2005

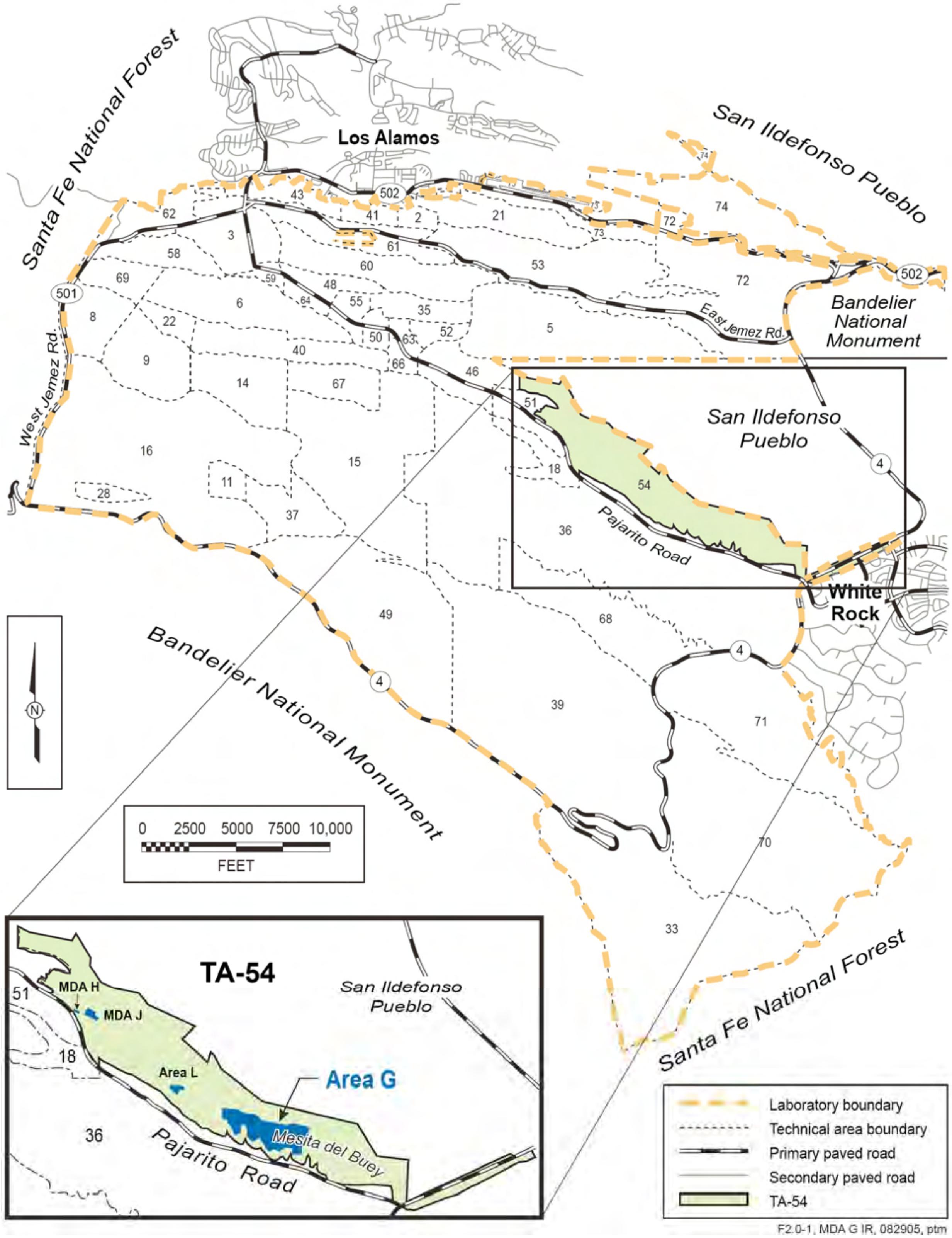
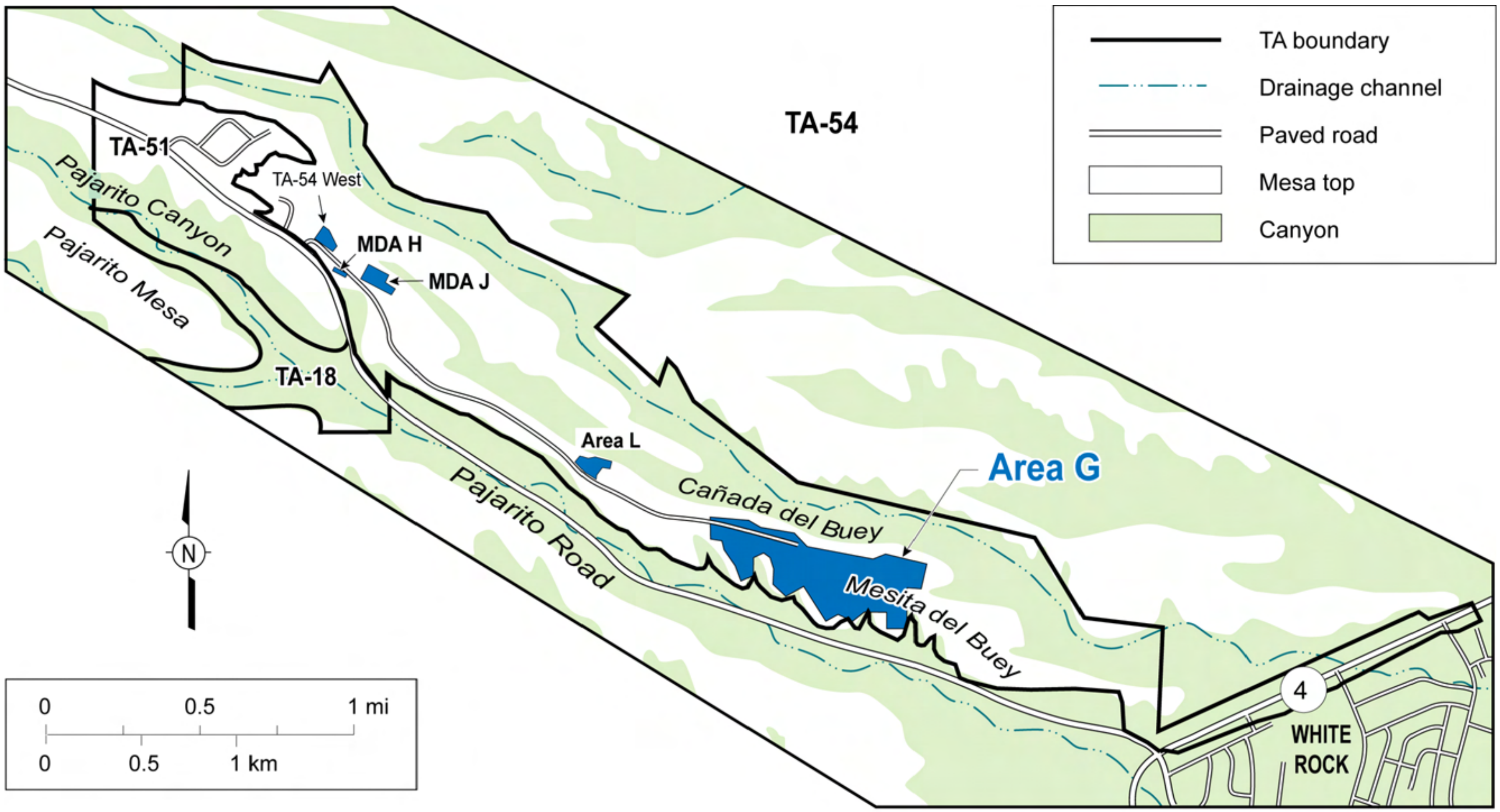


Figure 1.0-1 Location of Area G in TA-54 with respect to Laboratory TAs and surrounding land holdings



Source: A. Kron_MDA L RFI Rpt., 120302, modified for F2.1-1, MDAG IR, 082605, ptm

Figure 1.0-2 Location of Area G in TA-54

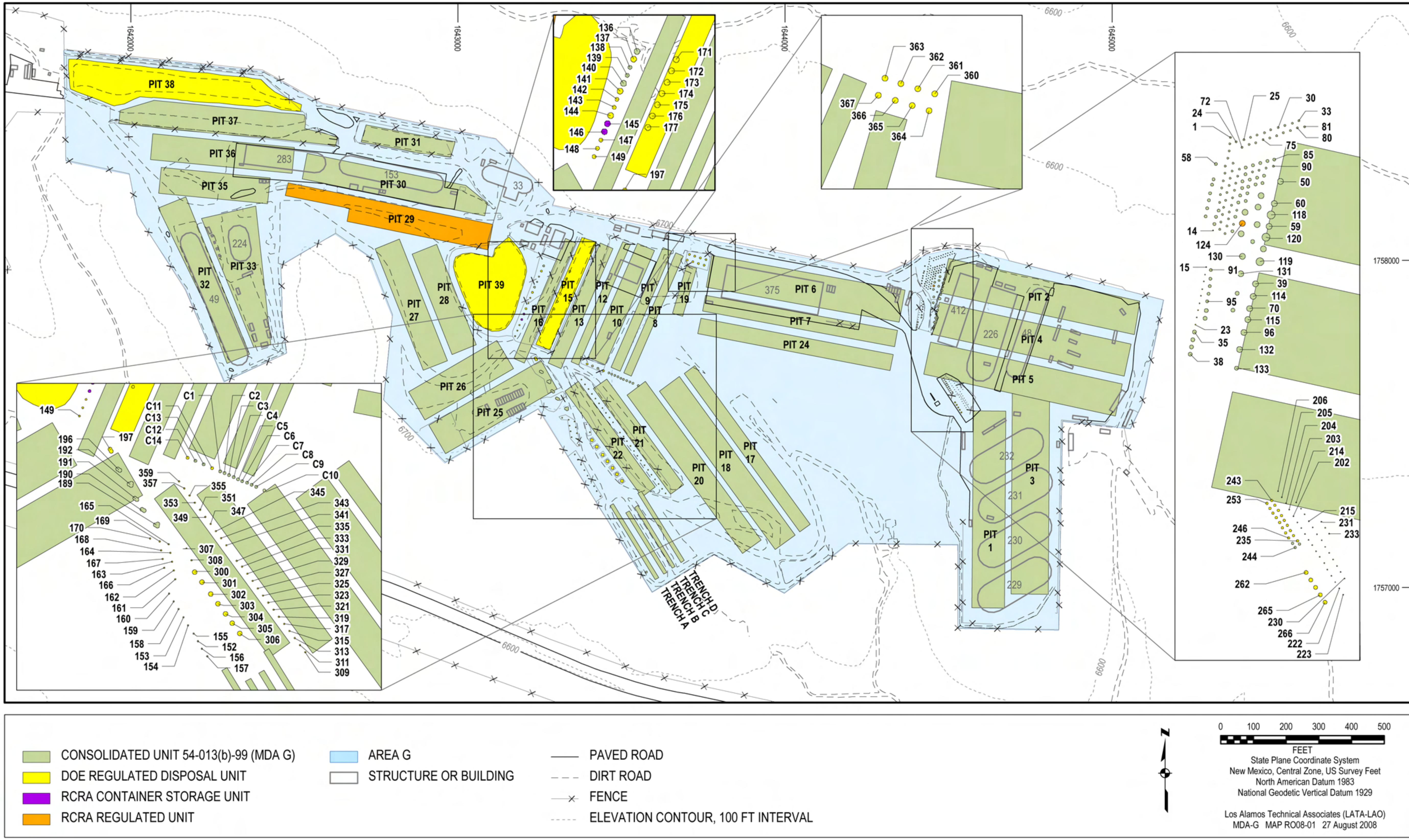


Figure 1.0-3 Area G waste disposal units

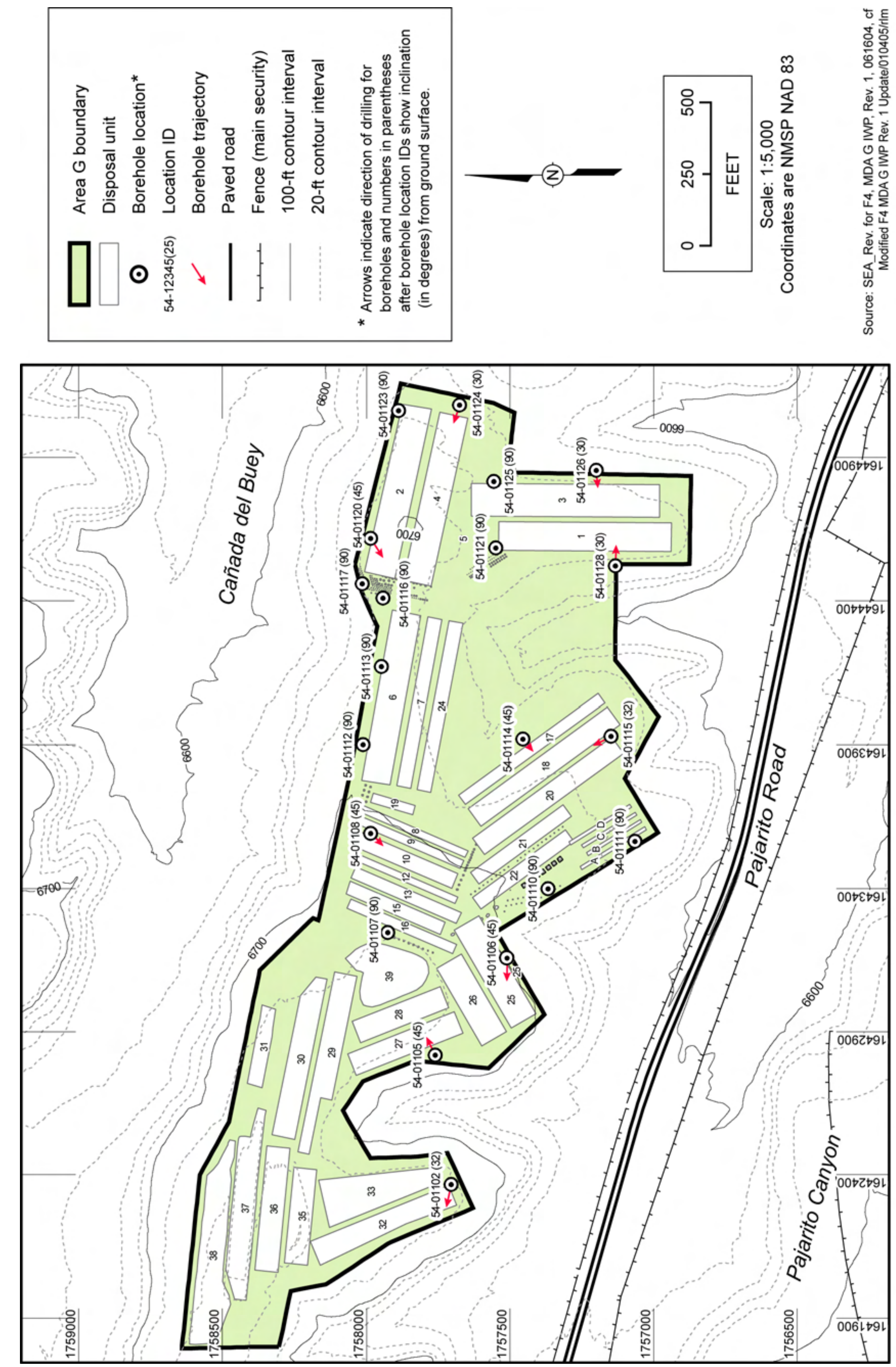


Figure 2.3-1 Locations of MDA G Phase I RFI boreholes

Figure 2.3-2 Radionuclides detected above BVs in Area G channel sediments

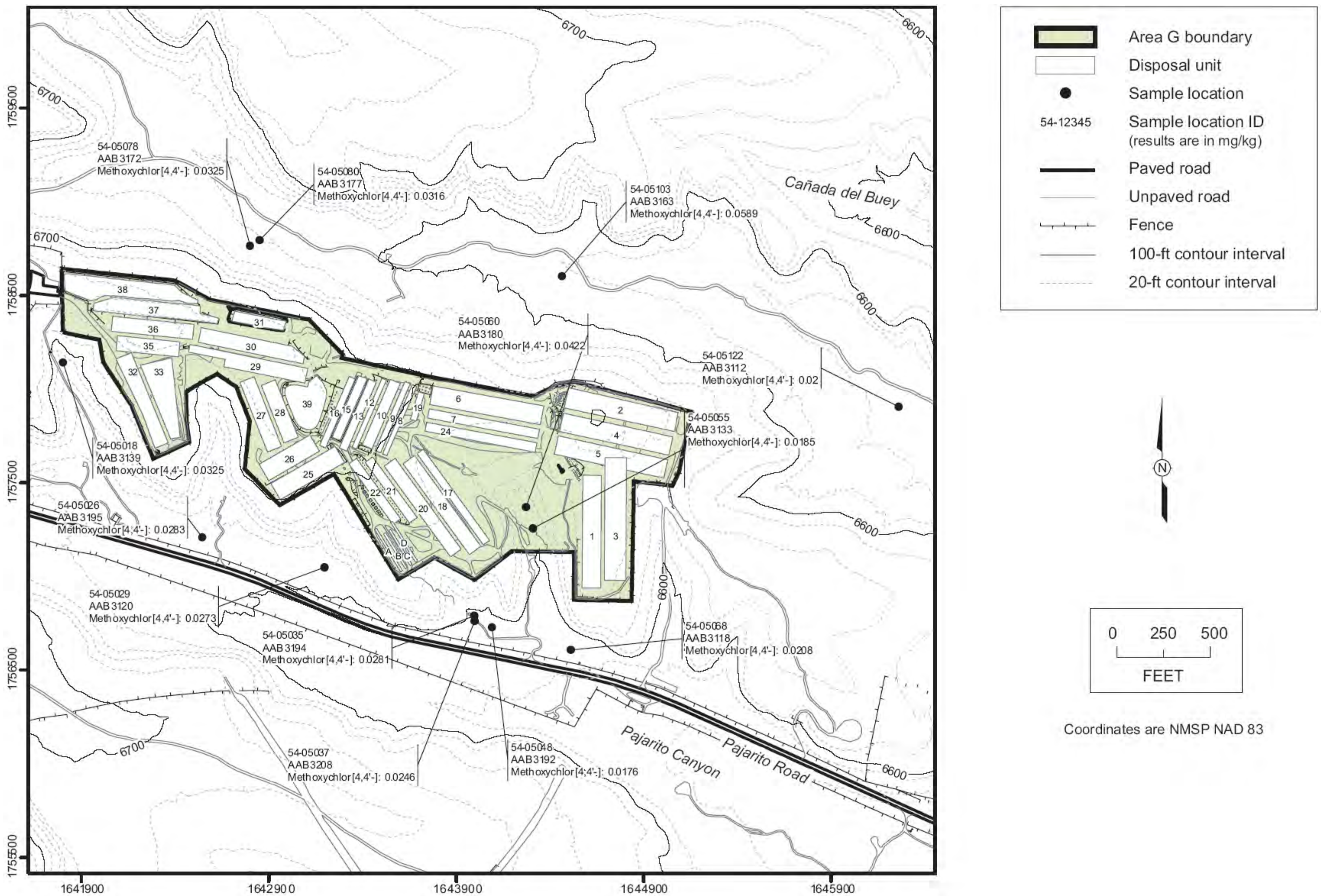


Figure 2.3-3 Organic chemicals detected in channel sediments at Area G

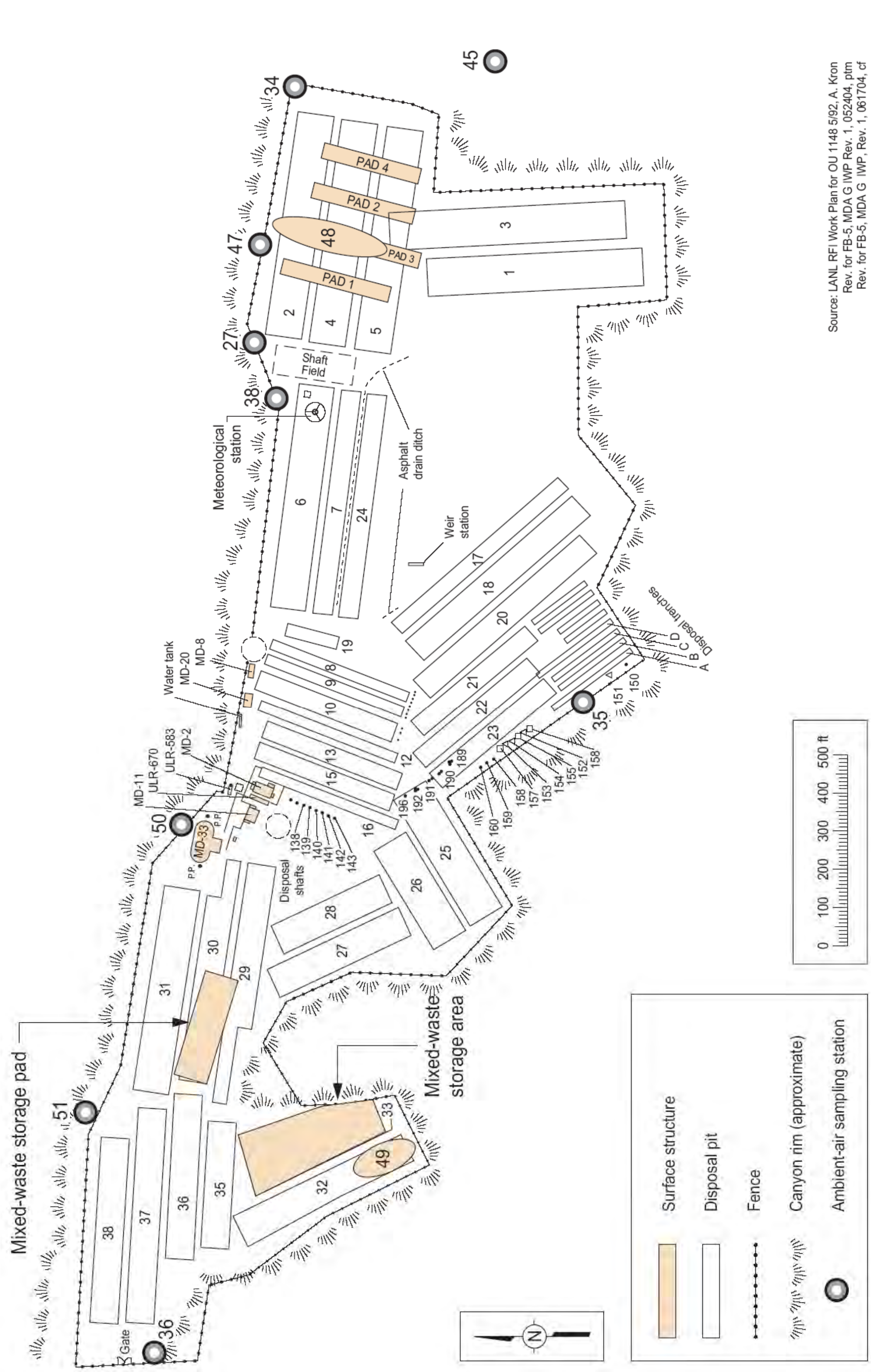


Figure 2.3-4 Locations of ambient-air sampling stations at Area G

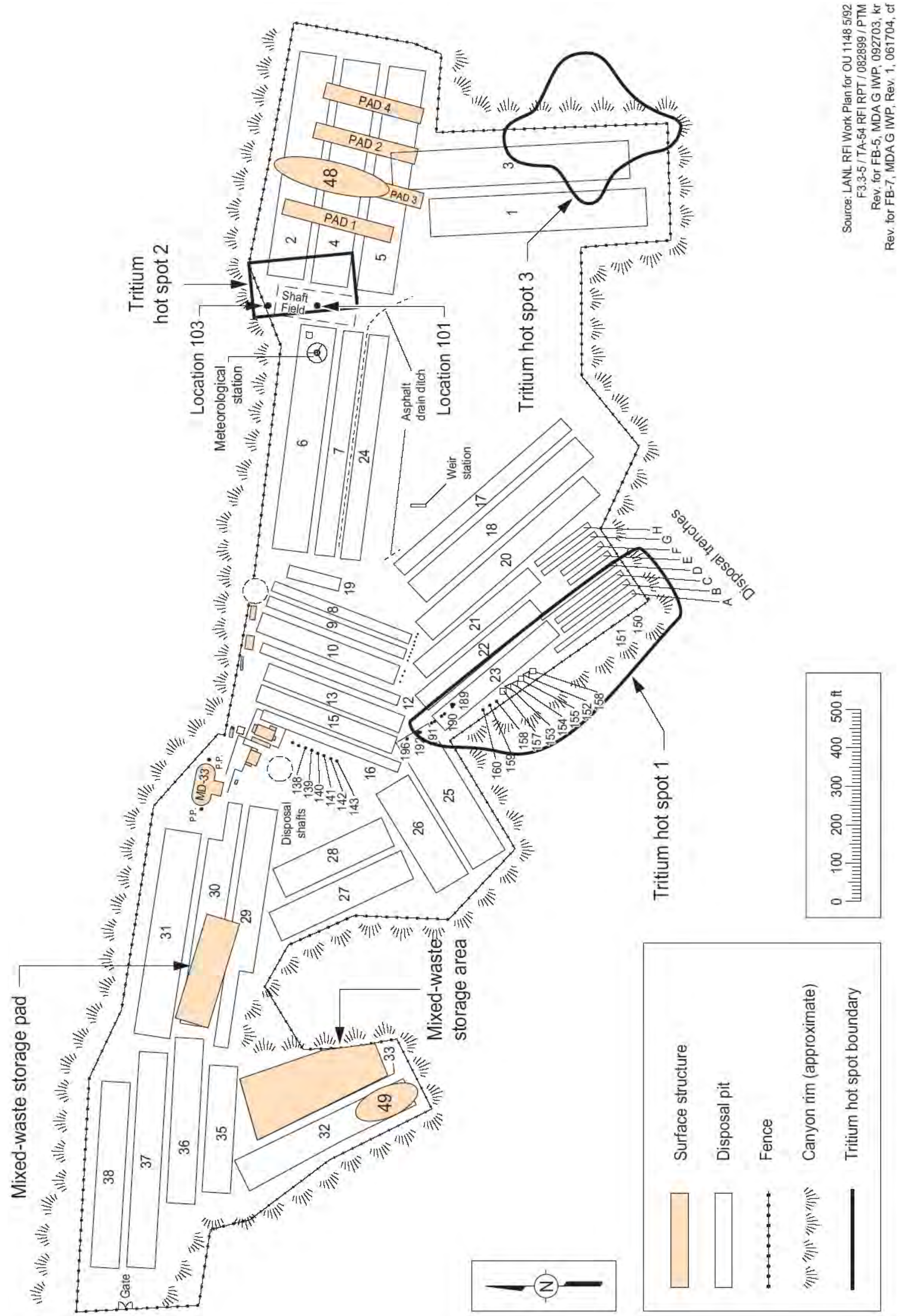
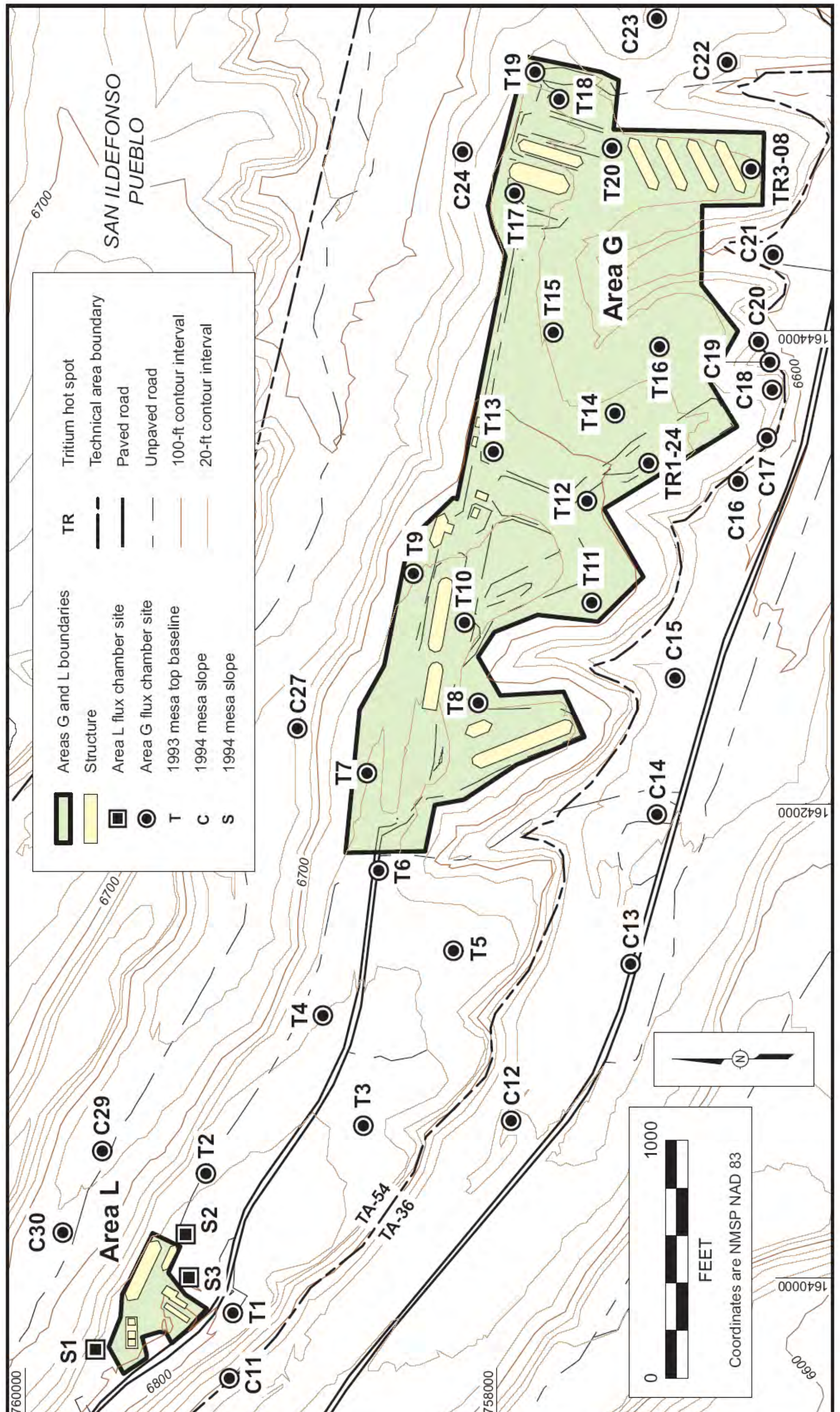


Figure 2.3-5 Locations of tritium high-flux areas at Area G



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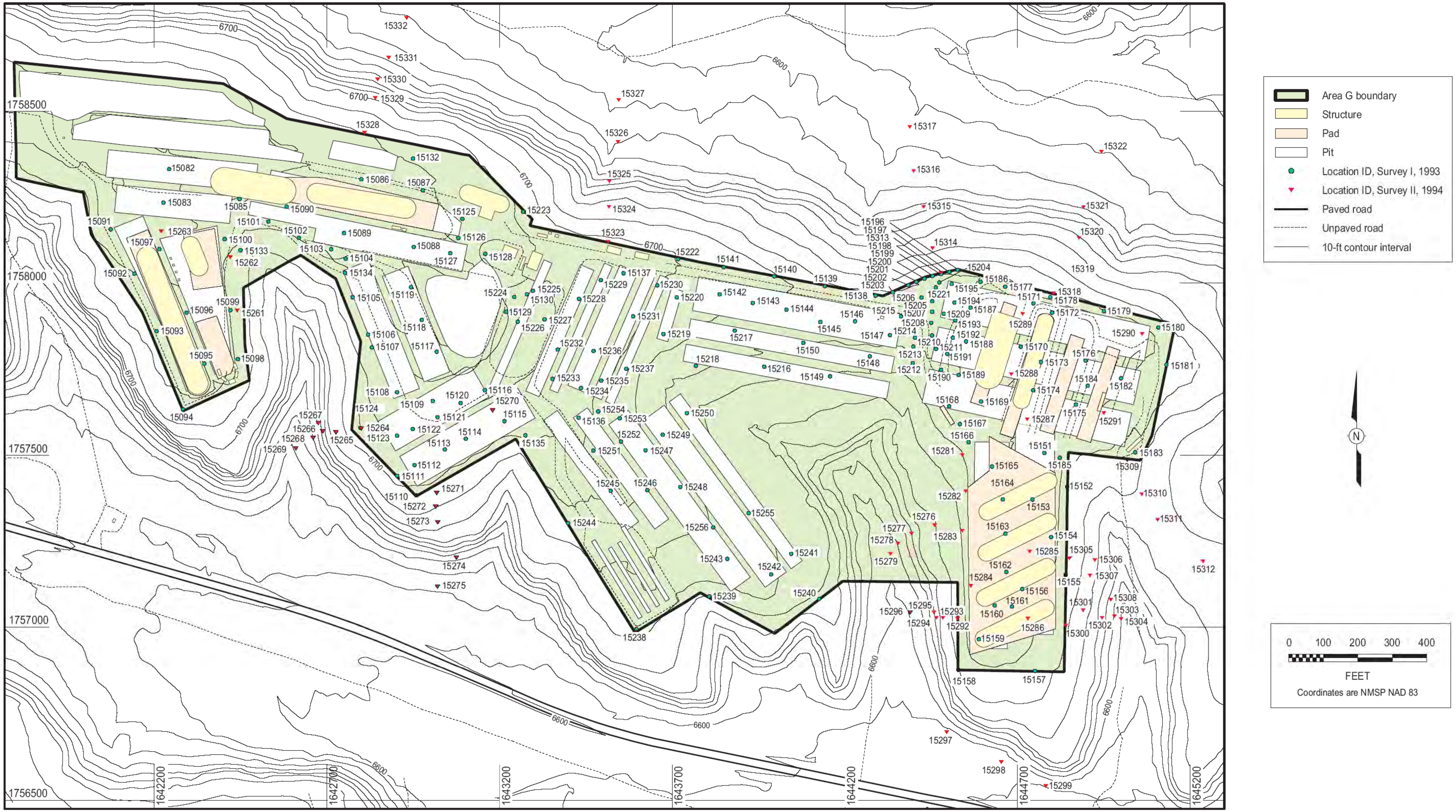
Rev. for FB-8, MDA G IWP, Rev. 1, 061704, cf

Figure 2.3-6 Tritium and VOC surface flux chamber sampling locations at Areas G and L



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Rev. for FB-9, MDA G IWP, Rev.1, 061704, cf

Figure 2.3-7 VOC EMFLUX surface flux sampling locations at Area G

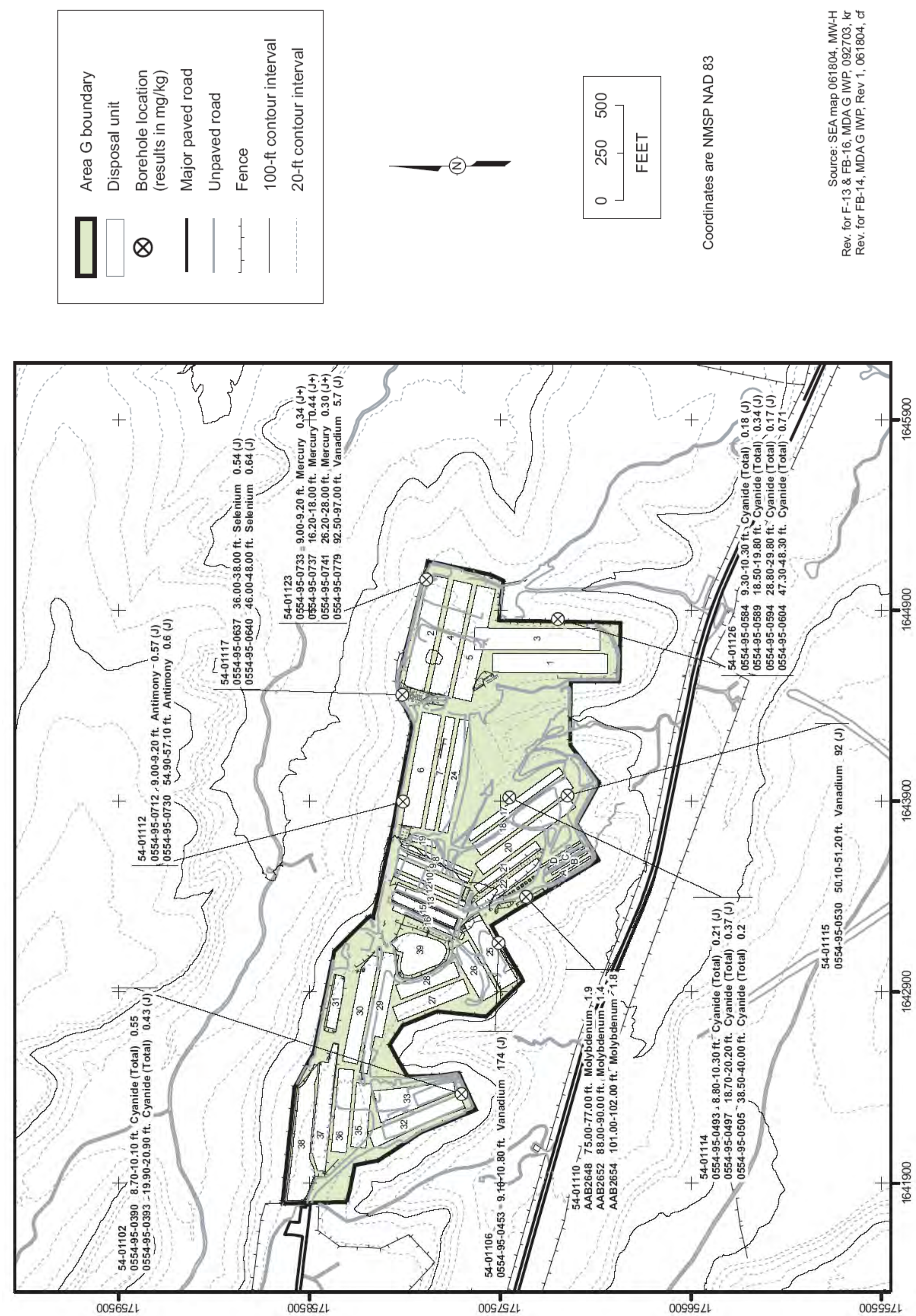


Figure 2.3-8 Inorganic chemicals detected above BVs in subsurface tuff at MDA G

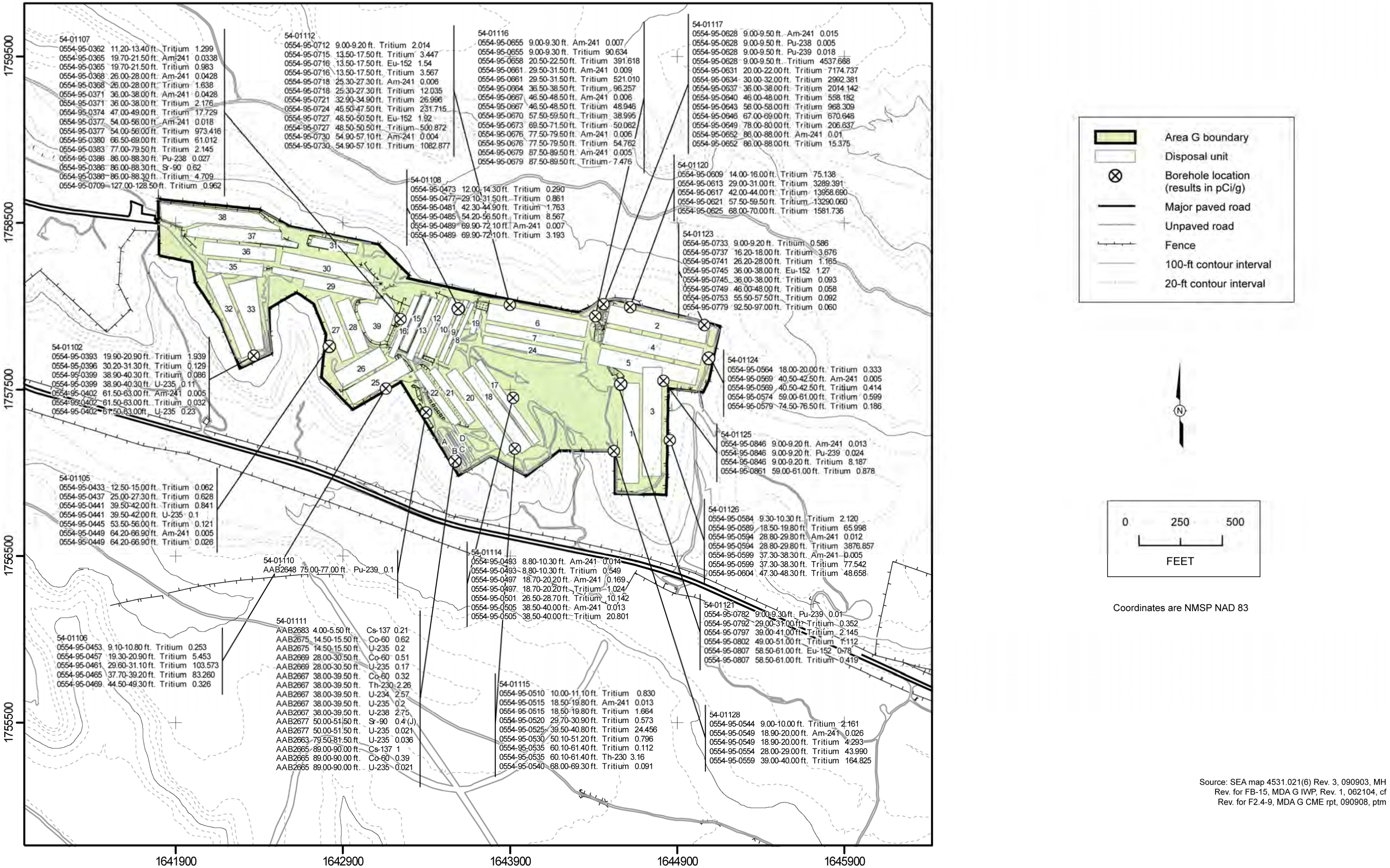


Figure 2.3-9 Radionuclides detected above BVs in subsurface tuff at MDA G

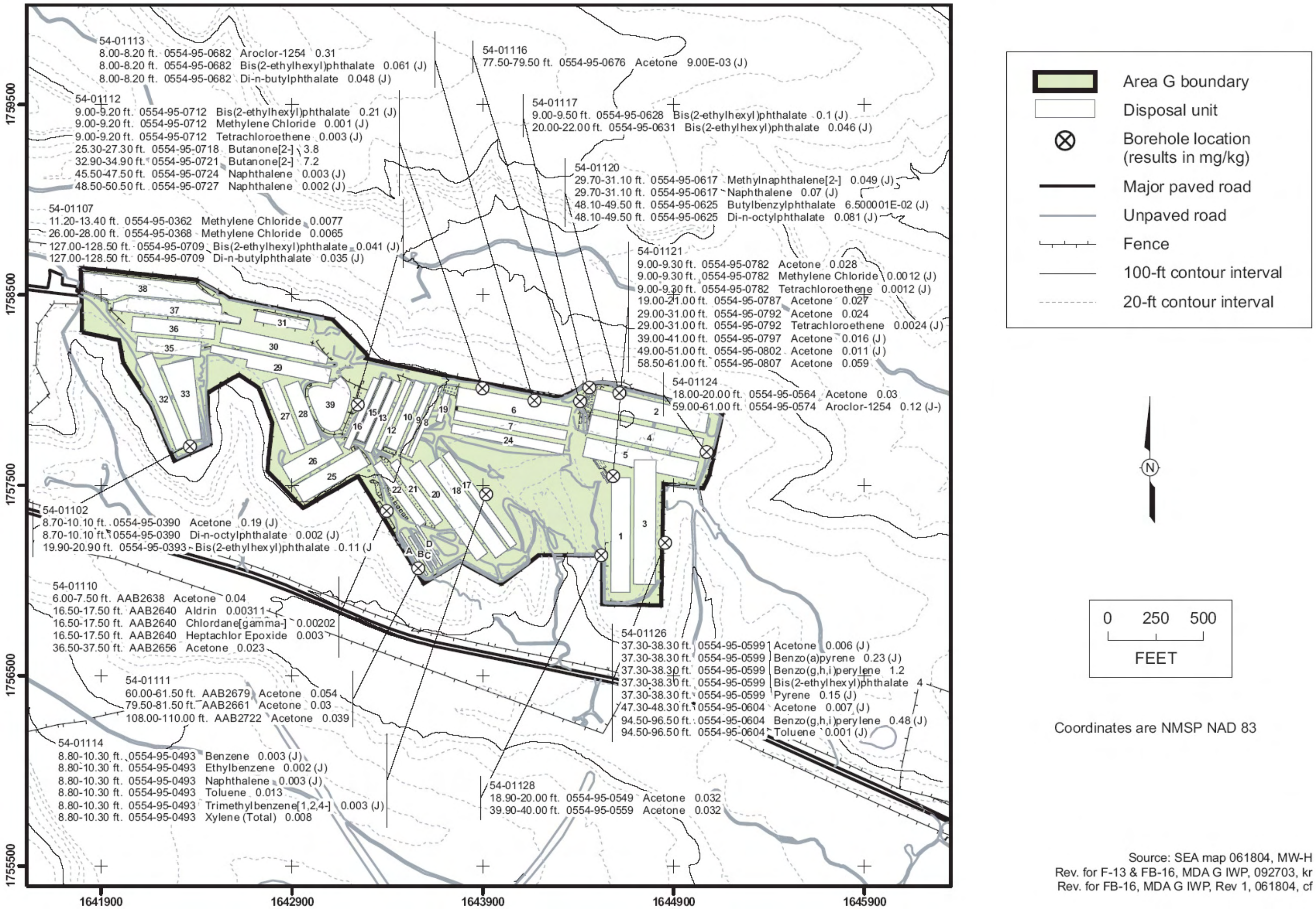


Figure 2.3-10 Organic chemical detected in subsurface tuff at MDA G

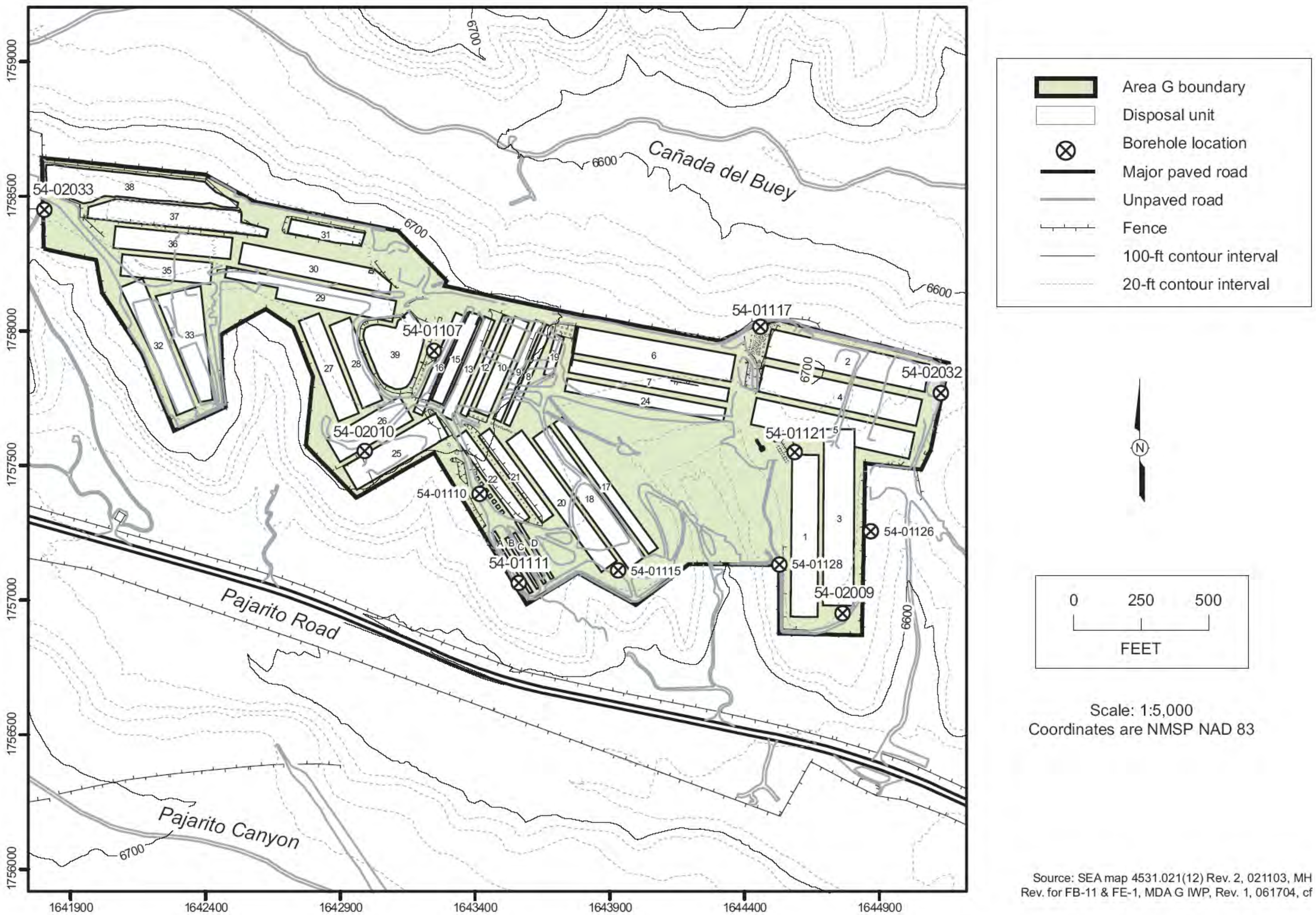


Figure 2.3-11 MDA G pore-gas monitoring borehole locations (through 2002)

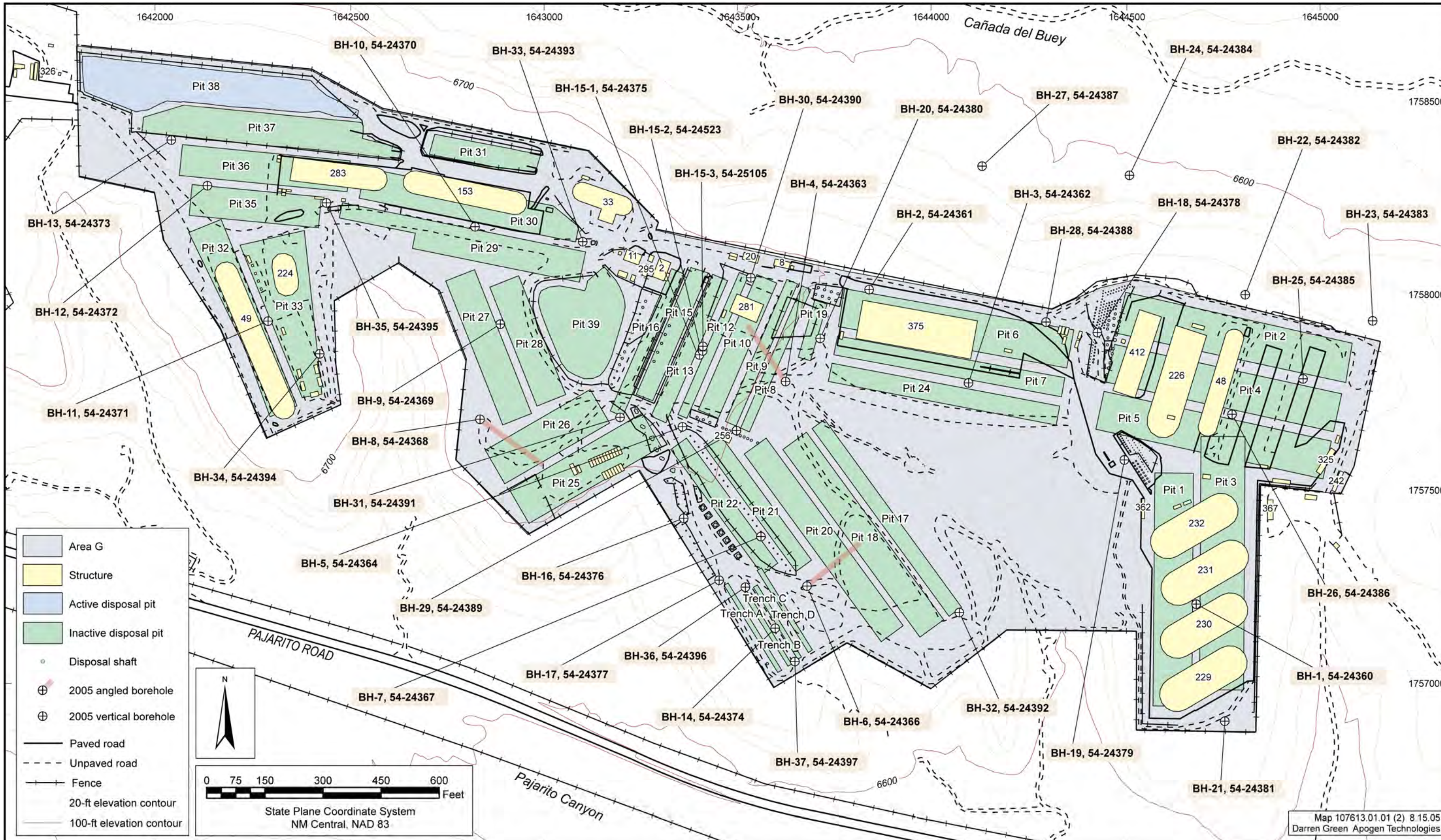


Figure 2.3-12 Boreholes drilled during the 2005 MDA G investigation

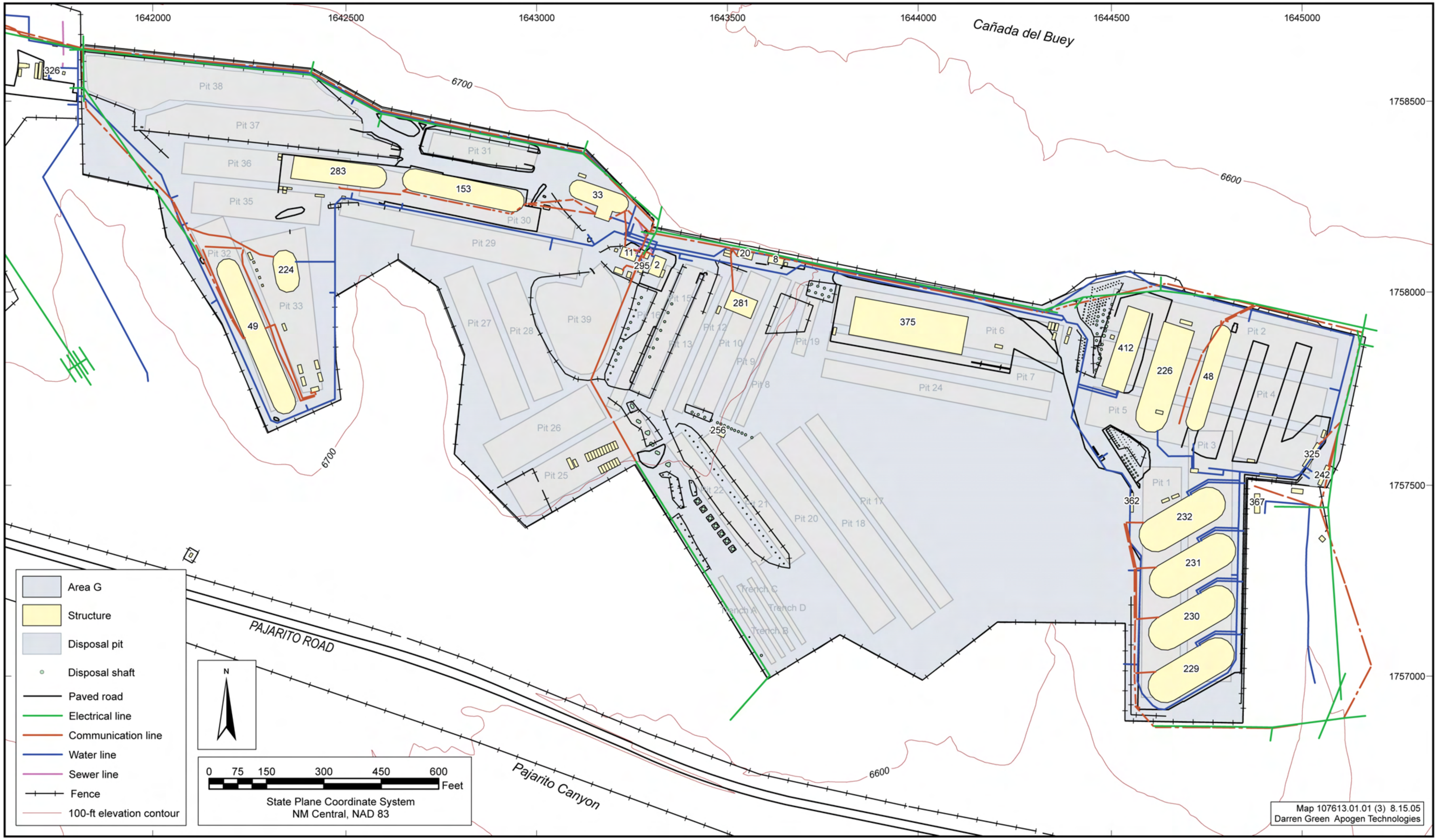


Figure 3.2-1 Utilities and subsurface structures at Area G

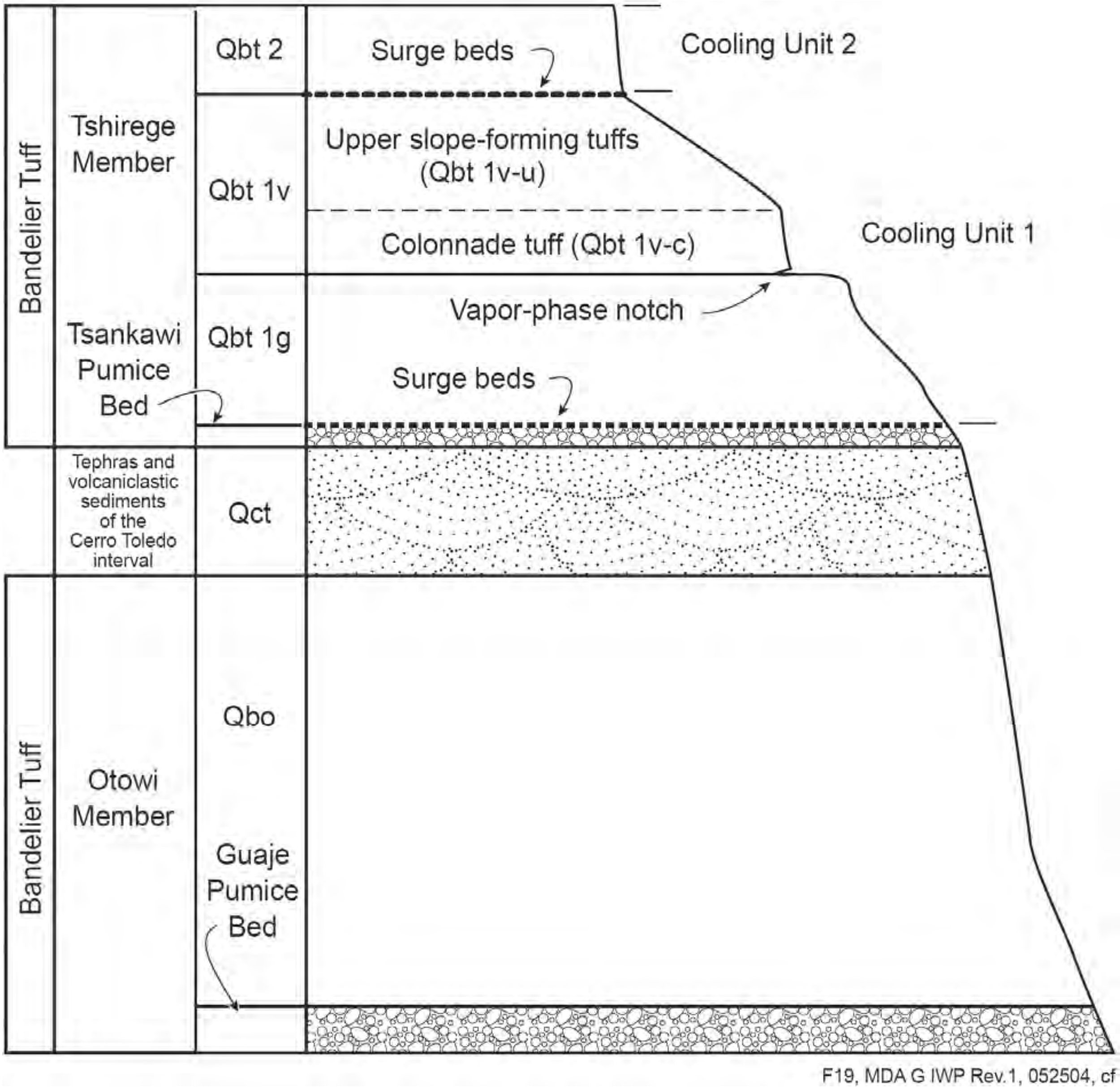


Figure 3.2-2 Generalized stratigraphy of Bandelier Tuff at TA-54

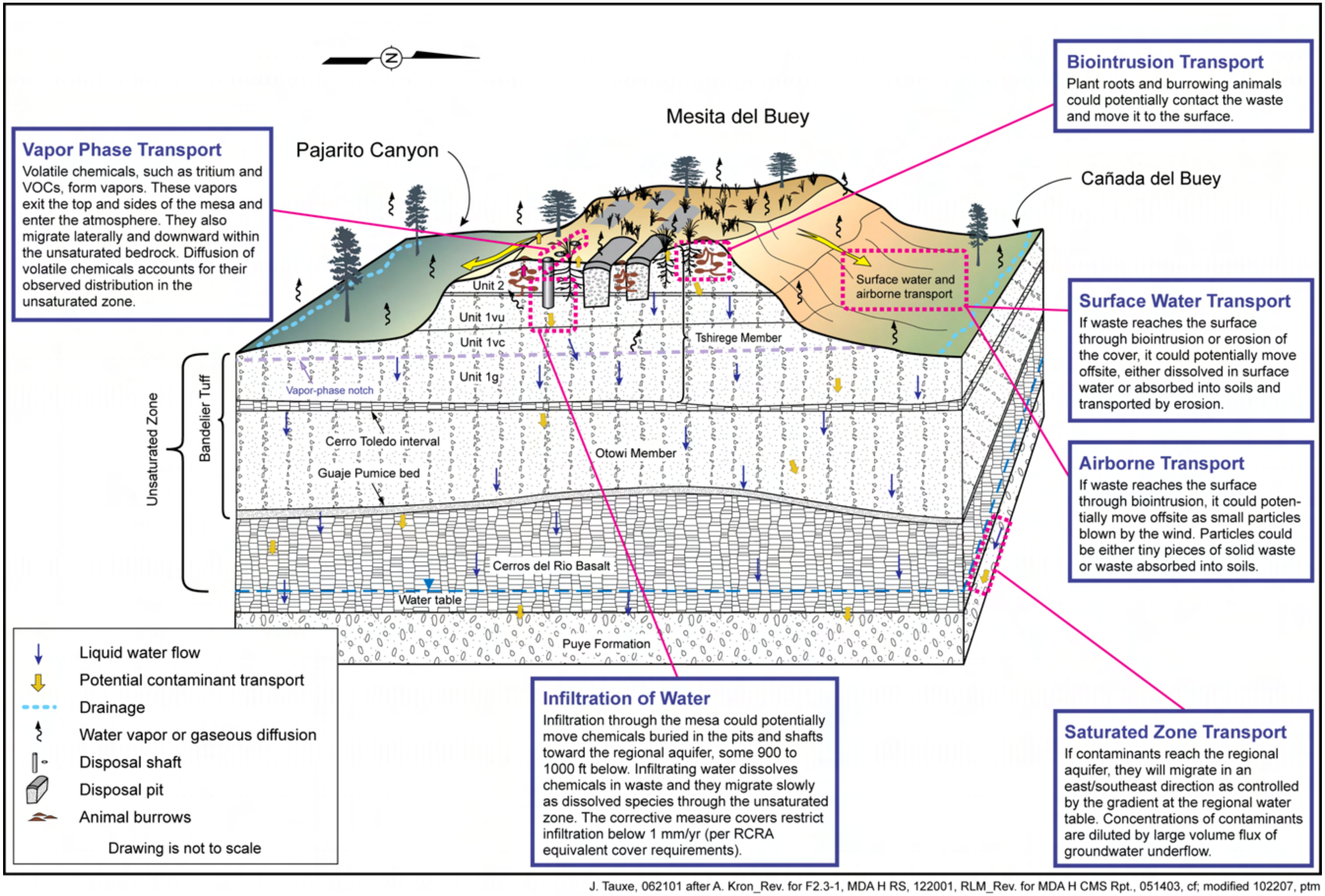


Figure 3.2-3 Hydrogeologic conceptual site model for Area G

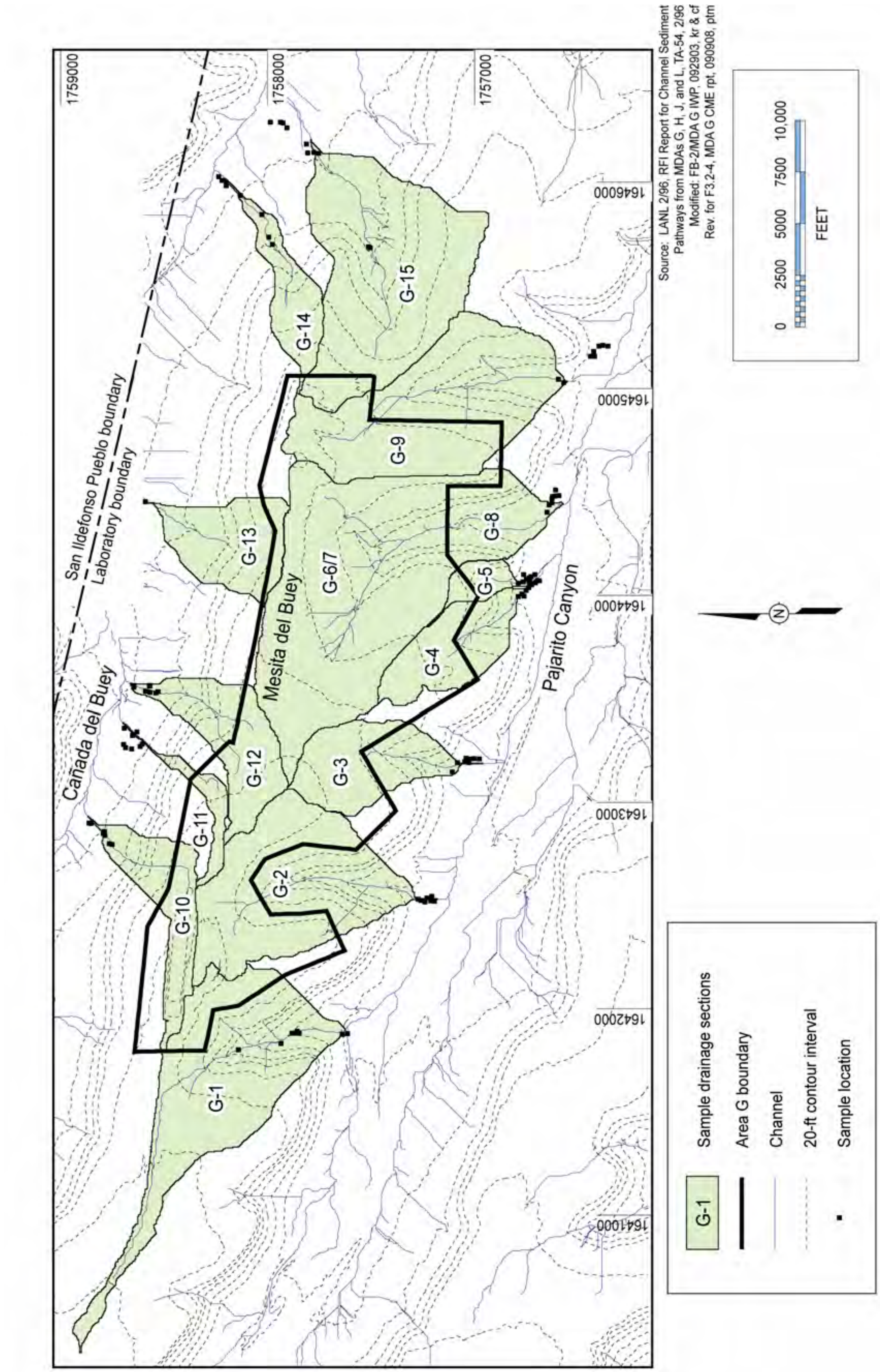
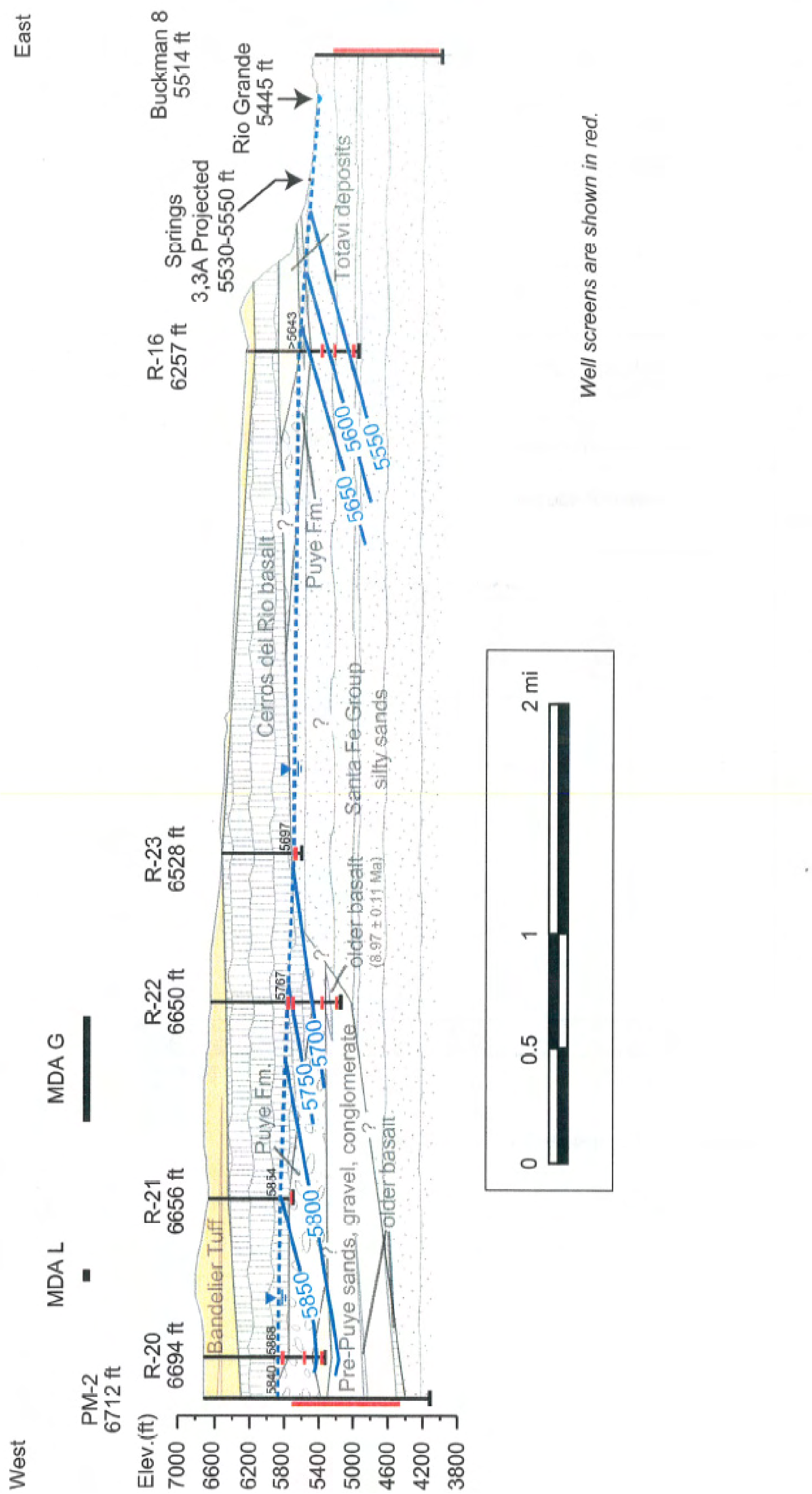
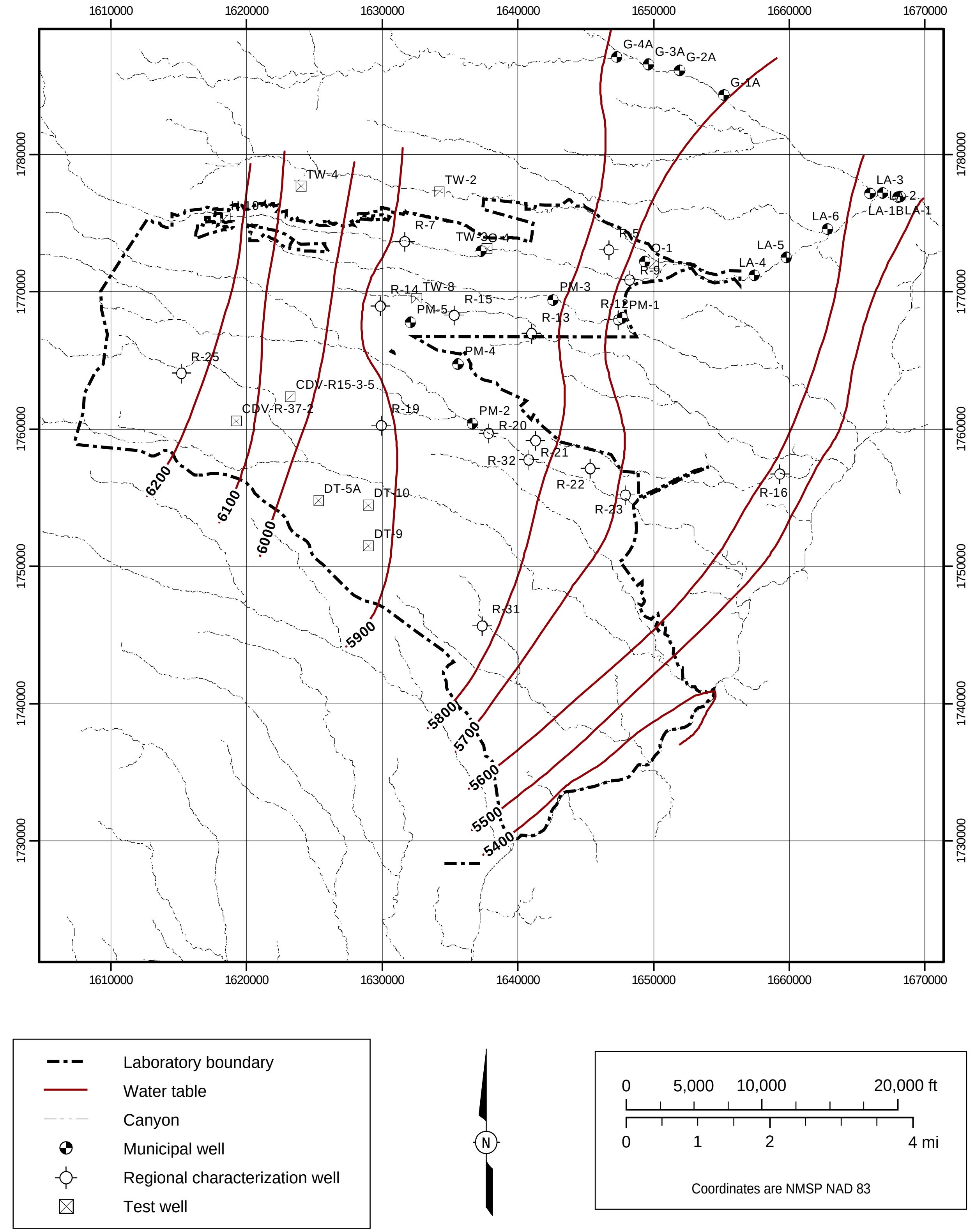


Figure 3.2-4 Locations and designations of Mesita del Buey drainage sections



Source: Dave Broxton, 2003_Rev. for F20, MDA L IWP Rev.1, 122203, cf

Figure 3.2-5 Hydrogeologic cross-section through the Pajarito Plateau near TA-54



Source: GIS Lab m200714, REK, 061703_Rev. for F23, MDA L IWP Rev.1, 121803, cf

Figure 3.2-6 Regional groundwater surface elevations at the Laboratory

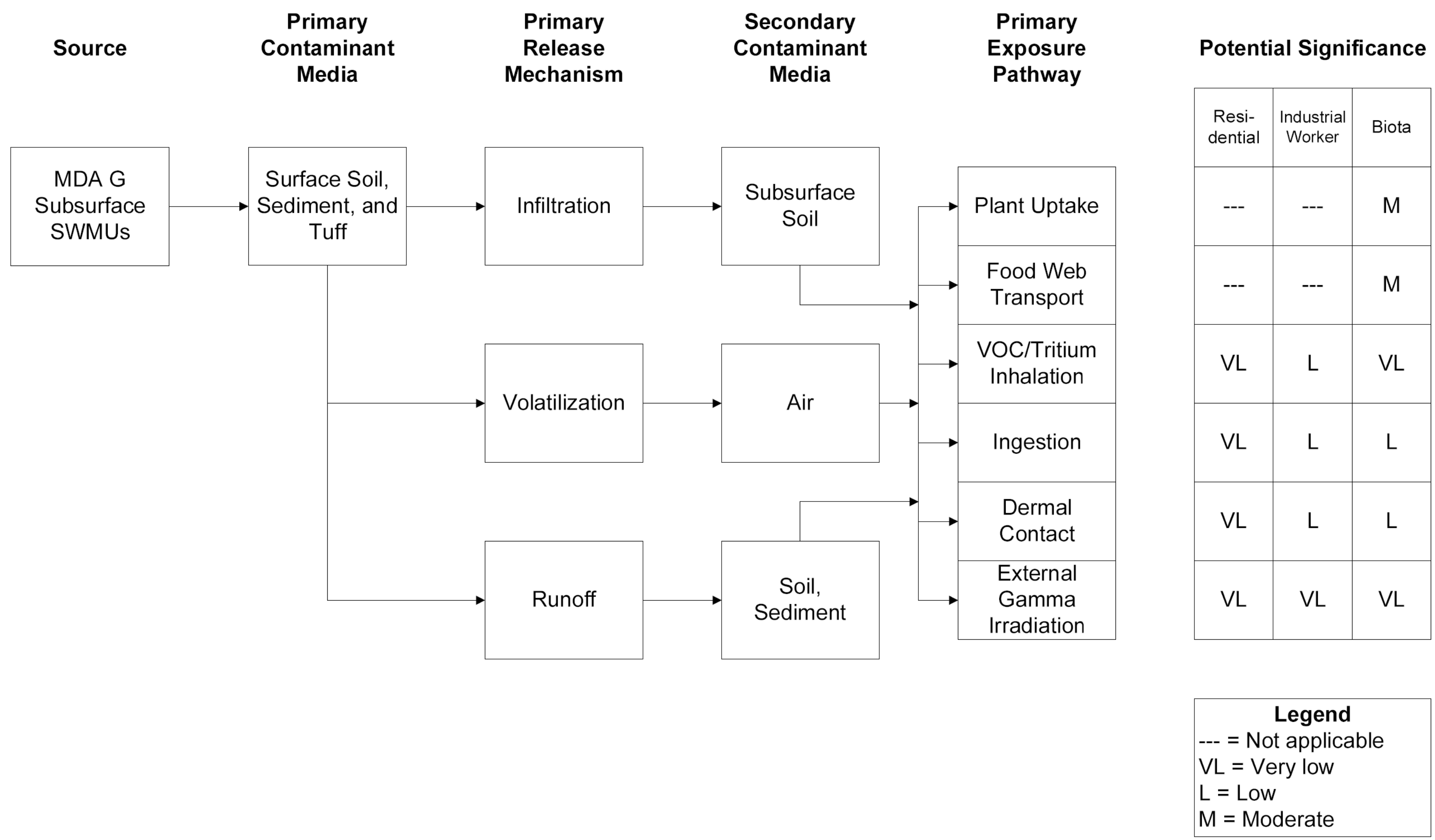


Figure 4.0-1 Conceptual site model of contaminant transport and exposure at MDA G

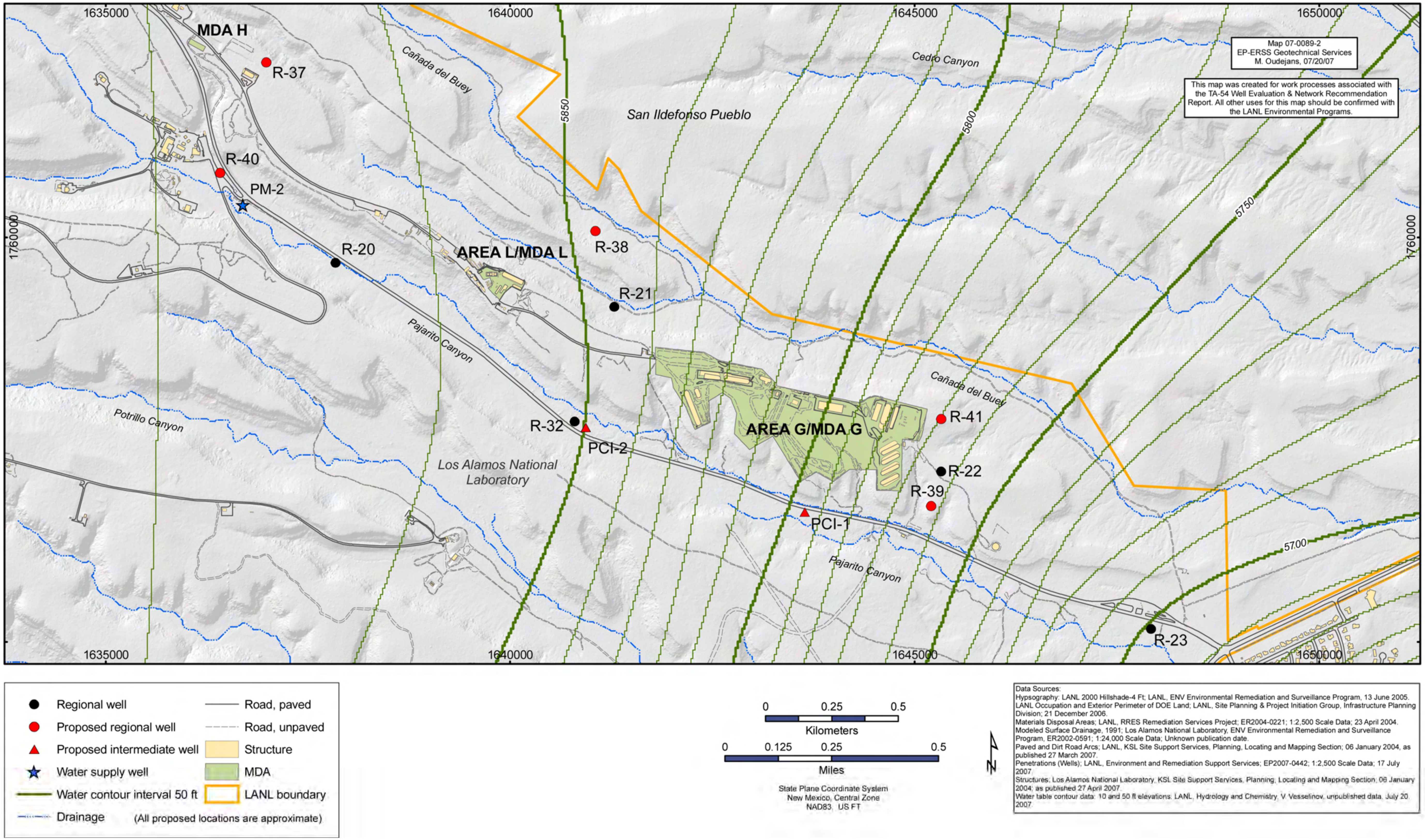


Figure 4.2-1 Existing water-supply wells and regional wells and proposed locations for new wells

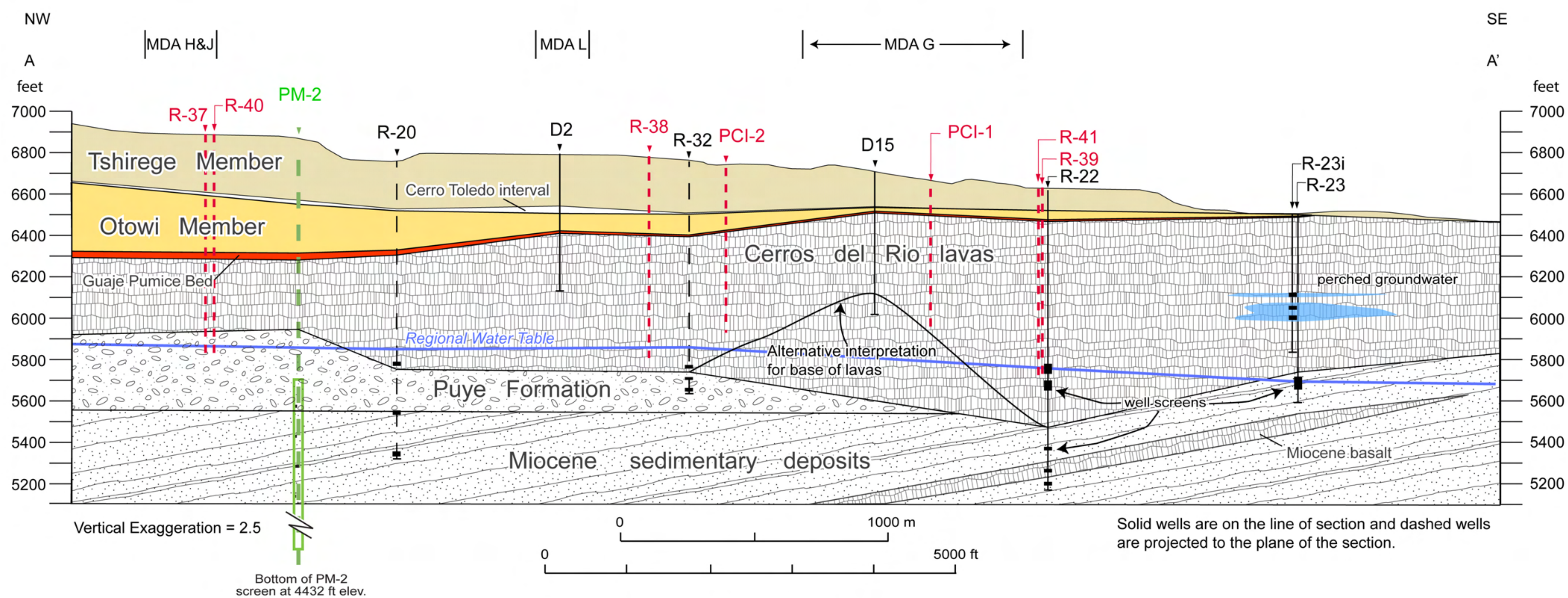


Figure 4.2-2 Cross-section showing the TA-54 monitoring well network with five proposed regional and two proposed intermediate-zone monitoring wells

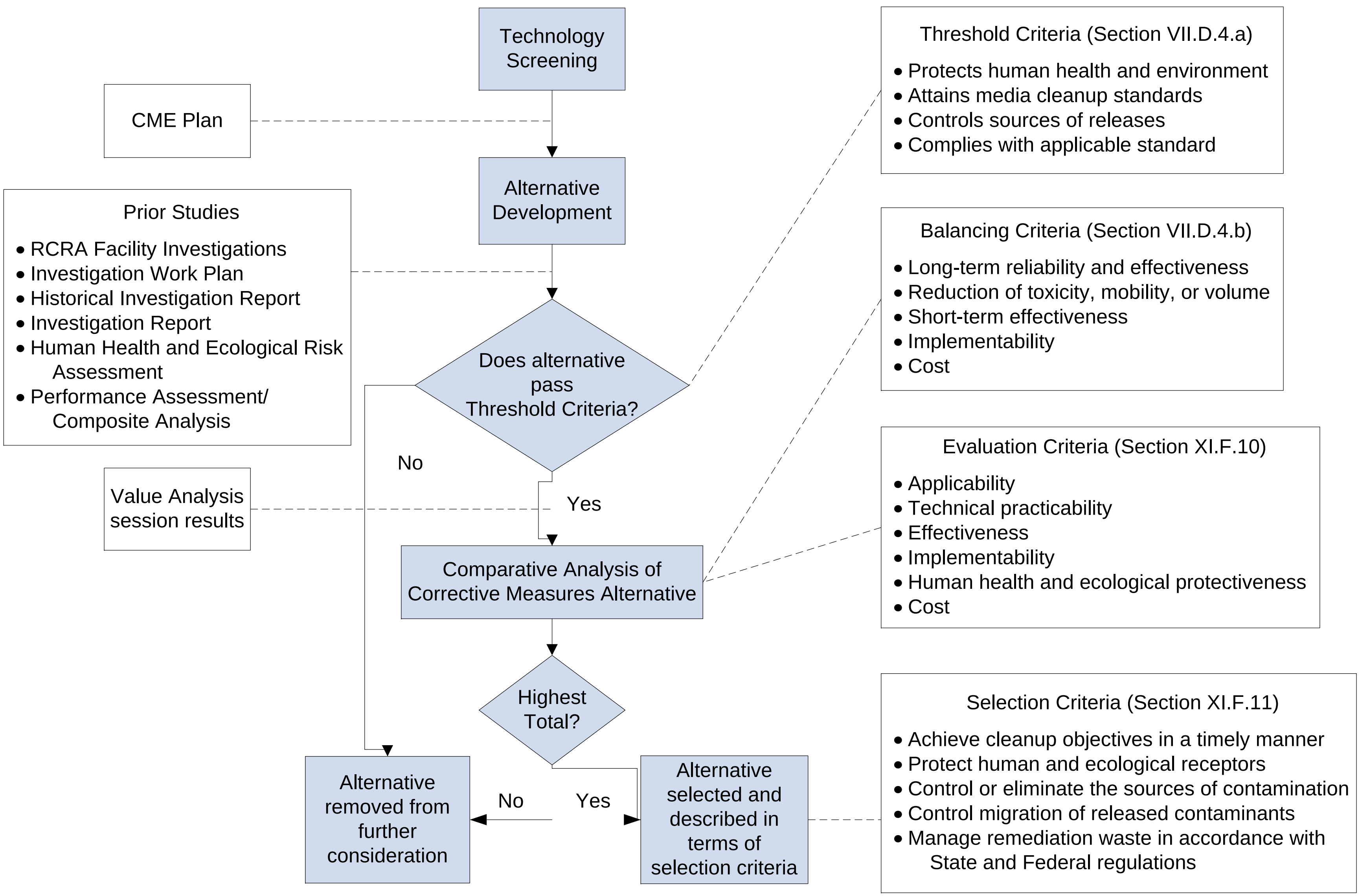


Figure 5.2-1 The selection process for the preferred corrective measure alternative

Corrective Measure Technology Category	Sub-Category Technology	Candidate Technology	Description	Screening Comments	Status
Containment	Vertical Barriers	Slurry Walls	A trench around a disposal unit filled with bentonite slurry, cement-grout, or other barrier material to impede lateral migration of contaminants.	Limited lateral migration at MDA G	Not Retained
		Rock-Grout Mixing	Formed by drilling adjacent deep shafts around a disposal site, mixing cut rock with injected grout as shaft is drilled to impeded lateral migration of contaminants.	Limited lateral migration at MDA G	Not Retained
		Synthetic Membrane	A membrane or liner placed in a vertical trench to form a wall to impede lateral movement of contaminants.	Short design life	Not Retained
		Reactive Barrier	A chemically active material designed to adsorb or degrade contaminant(s), used either alone or in conjunction with another cotainment barrier.	Limited lateral migration at MDA G	Not Retained
	Deep Subsurface Horrizontal Barriers	Deep Subsurface Horrizontal Barriers	A horizontal layer placed beneath a disposal unit to contain downward migration of contaminants.	Downward migration limited if site covered	Not Retained
	Near-Surface Horizontal Barriers	Soil-Grout Mix	A layer of grout-stabilized soil placed over existing waste disposal units to further reduce permeability to water infiltration and pemetration from biota.	Potentially Applicable	Retained
		In Situ Vitrification	Formation of an essentially impermeable layer of glass-like material by using heat to melt soil or rock.	Cost prohibitive	Not Retained
	Surface Barriers	Asphalt Cover	An asphalt layer placed to impede surface erosion	Limited service life vs. geologic materials, traps moisture	Not Retained
		Compacted Clay Cover	A simple cover formed from compacted clay to limit excess infiltration of water from the surface.	Incompatible with arid sites	Not Retained
		Multi-Layer Cover	A cover constructed from layers of geologic and synthetic materials placed to inhibit infiltration, erosion, and biotic intrusion.	Clay dessication limits performance	Not Retained
		Evapotranspiration Cover	A cover designed for arid climates constructed of geologic materials (often designed to support specific vegetation) that minimizes water infiltration by supporting evapotranspiration of near-surface water.	Potentially Applicable	Retained
		Biotic Barrier	A horizontal barrier of geologic and/or man-made materials placed to limit intrusion of plants and animals.	Potentially Applicable	Retained

(Shaded box) Technology eliminated from further evaluation

Figure 6.1-1 Screening of corrective measure technologies (page 1 of 4)

Corrective Measure Technology Category	Sub-Category Technology	Candidate Technology	Description	Screening Comments	Status
In Situ Treatment	Biological Treatment Methods	Microorganisms	Microorganisms that feed on organic material have been effective in treating low-level concentrations of radioactive waste in wastewater treatment processes.	Not applicable to waste forms	Not Retained
In Situ Treatment	Physical Treatment Methods	Soil-Gas Venting	Boreholes are placed in the area of focus and allowed to vent to atmosphere or to an offgas treatment system.	Applicable for VOCs	Retained
		Soil Vapor Extraction	Uses air pressure, vacuum, or diffusion force to remove subsurface vapors to a treatment system.	Applicable for VOCs	Retained
		Pneumatic Fracturing	Injects pressurized fluid into soil/rock matrix to cause fracturing to improve permeability to locally increase mobility of contaminants for recovery or treatment.	Involves large quantities of fluids	Not Retained
		Electrokinetic Soil Treatment	An anode and cathode array support conduction of electricity through the subsurface media, usually in conjunction with low permeability soils. Ionically charged species migrate in the induced electric field.	Ineffective in low-moisture soils	Not Retained
		Electroacoustic Treatment	Acoustic method for mobilizing organic contaminants in soils.	Demonstrated for organics only	Not Retained
		Dynamic Compaction	Surface technique applied to buried wastes to consolidate wastes and reduce potential for future subsidence.	Potentially applicable with cover designs	Retained
		Waste Stabilization	Uses cementitious grout or other binding material to stabilize wastes in-place. Applied by injection into waste units.	Potentially applicable	Retained
In Situ Treatment	Thermal Treatment Methods	Vitrification	Vitrification of waste materials from the surface down or using consecutive vertical planar joule heated melts.	Limited depths; may volatilize wastes; more durable waste form	Not Retained
		Thermal Treatment	Soil heating technologies to either enhance mobility of contaminants for extraction (hot-air injection or steam injection) or degrade contaminants to less hazardous materials (electric resistance heating, induction heating, or conductive heating).	Acts only on organic contaminants	Not Retained

(Shaded box) Technology eliminated from further evaluation

Figure 6.1-1 Screening of corrective measure technologies (page 2 of 4)

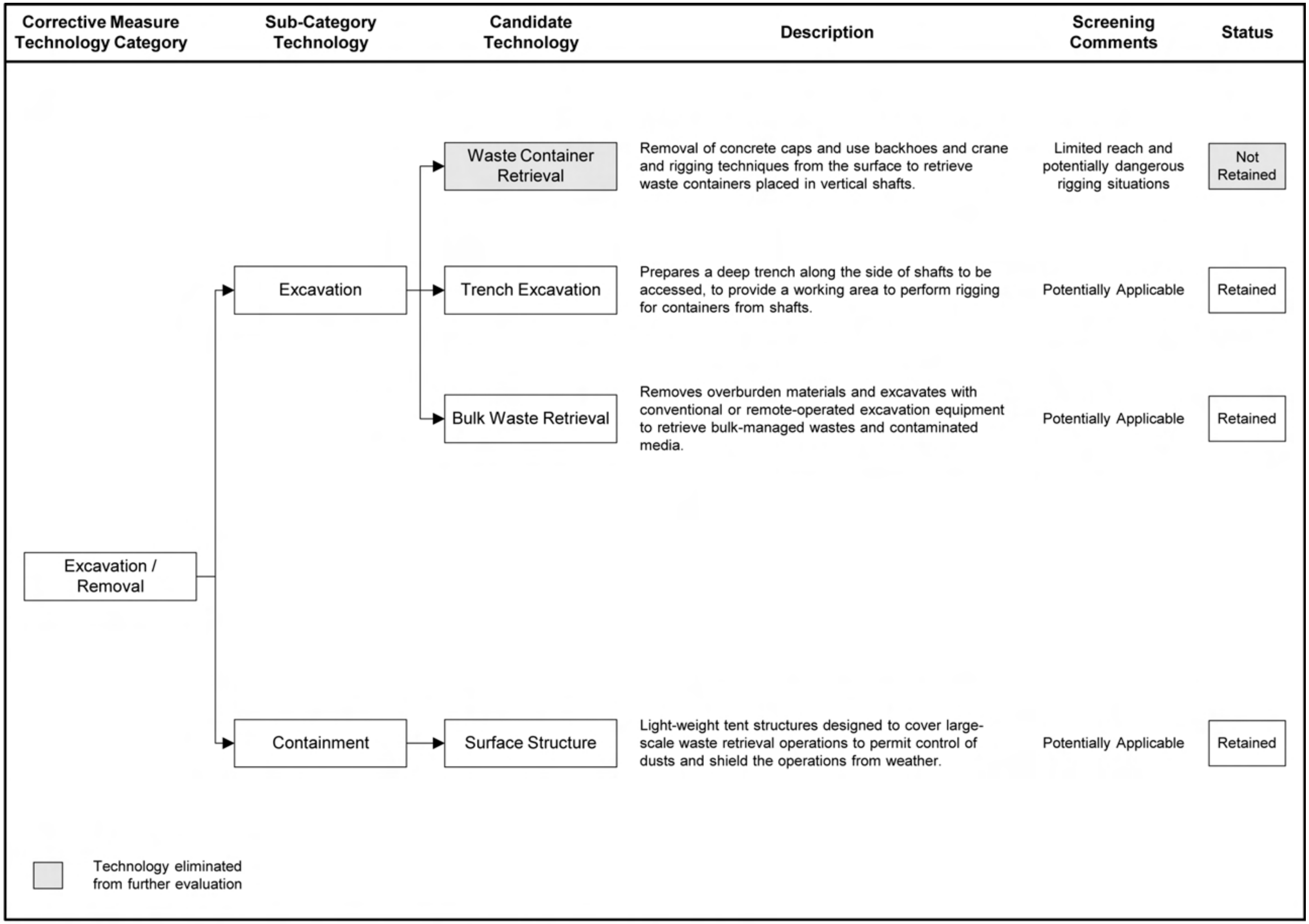


Figure 6.1-1 Screening of corrective measure technologies (page 3 of 4)

Corrective Measure Technology Category	Sub-Category Technology	Candidate Technology	Description	Screening Comments	Status
Ex Situ Treatment	Chemical Treatment	Extraction	Uses acids or solvents to leach contaminants from contaminated media.	Potentially Applicable	Retained
		Wastewater Treatment	Wastewater treatment can range from simple pH adjustment to complex multi-stage processes to address a range of contaminants.	Potentially Applicable	Retained
	Physical Treatment	Cement Stabilization	Cementitious materials, Portland cement or other pozzolans, are employed to bind waste into a solid semi-permeable mass, generally to meet target leaching criteria, such as TCLP.	Potentially required for some wastes	Retained
		Alternative Stabilization / Encapsulation	A variety of non-cementitious stabilization methods have been developed around polymers and chemical additives.	Less adaptive than Cement Stabilization; Potentially required for some wastes	Retained
		Debris Treatment	Debris treatments considered Best Demonstrated Available Technologies (BDAT) under RCRA are contained in 40 CFR 268.45.	Potentially required for some wastes	Retained
	Thermal Treatment	Thermal Desorption	Applies heat to bulk materials, typically in a rotary kiln, to mobilize organics to the off-gas for treatment.	Potentially Applicable	Retained
		Thermal Destruction	Pyrolytic (anaerobic) of incinerator-based (aerobic) destruction of organic compounds.	Thermal desorption more applicable	Not Retained
		Vitrification	Produces a glass-like substance out of waste materials, typically using additives that produce glass at sufficient heat. Waste loading depends on waste and desired glass characteristics.	Cement stabilization less costly	Not Retained

(Shaded box) Technology eliminated from further evaluation

Figure 6.1-1 Screening of corrective measure technologies (page 4 of 4)

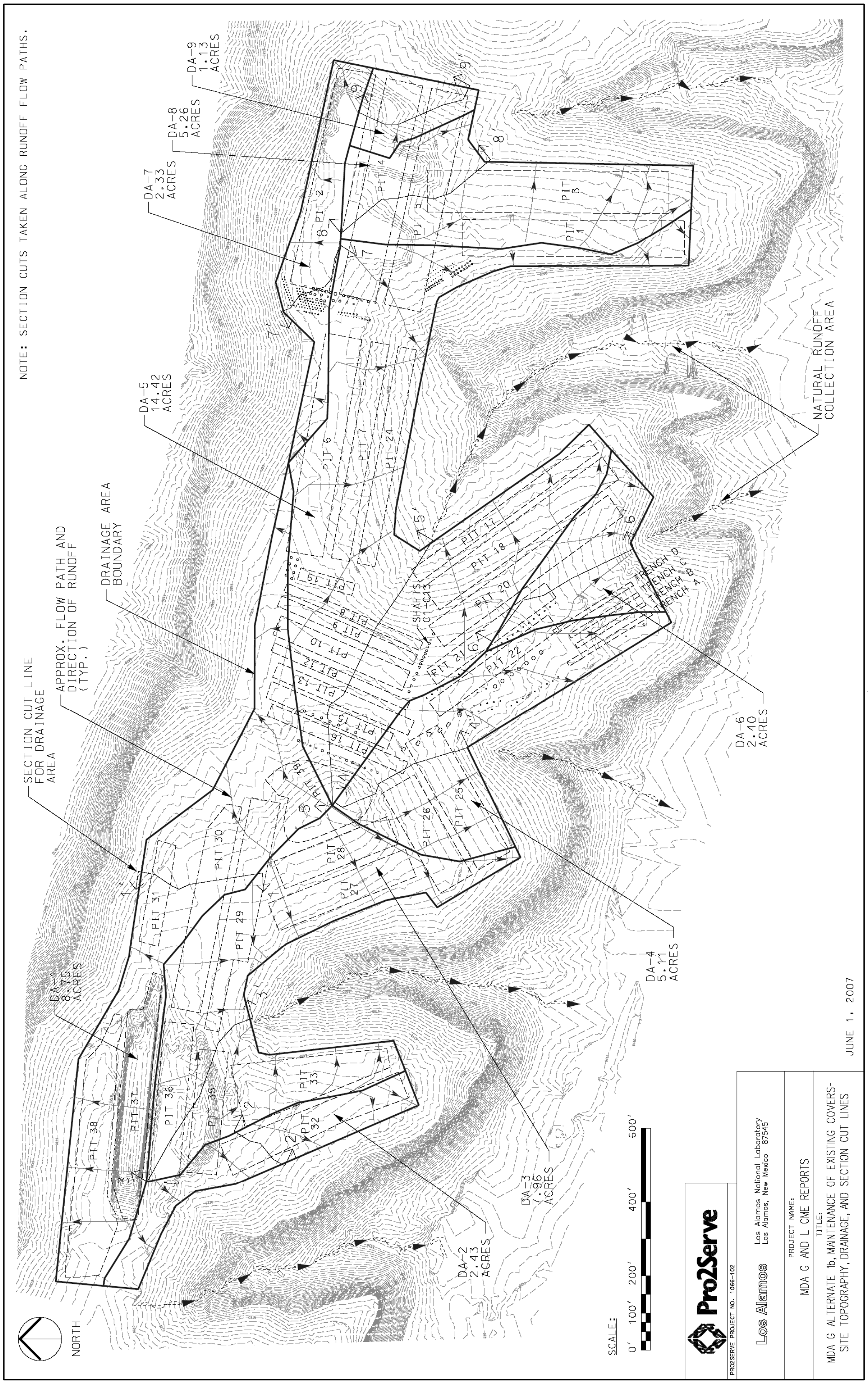
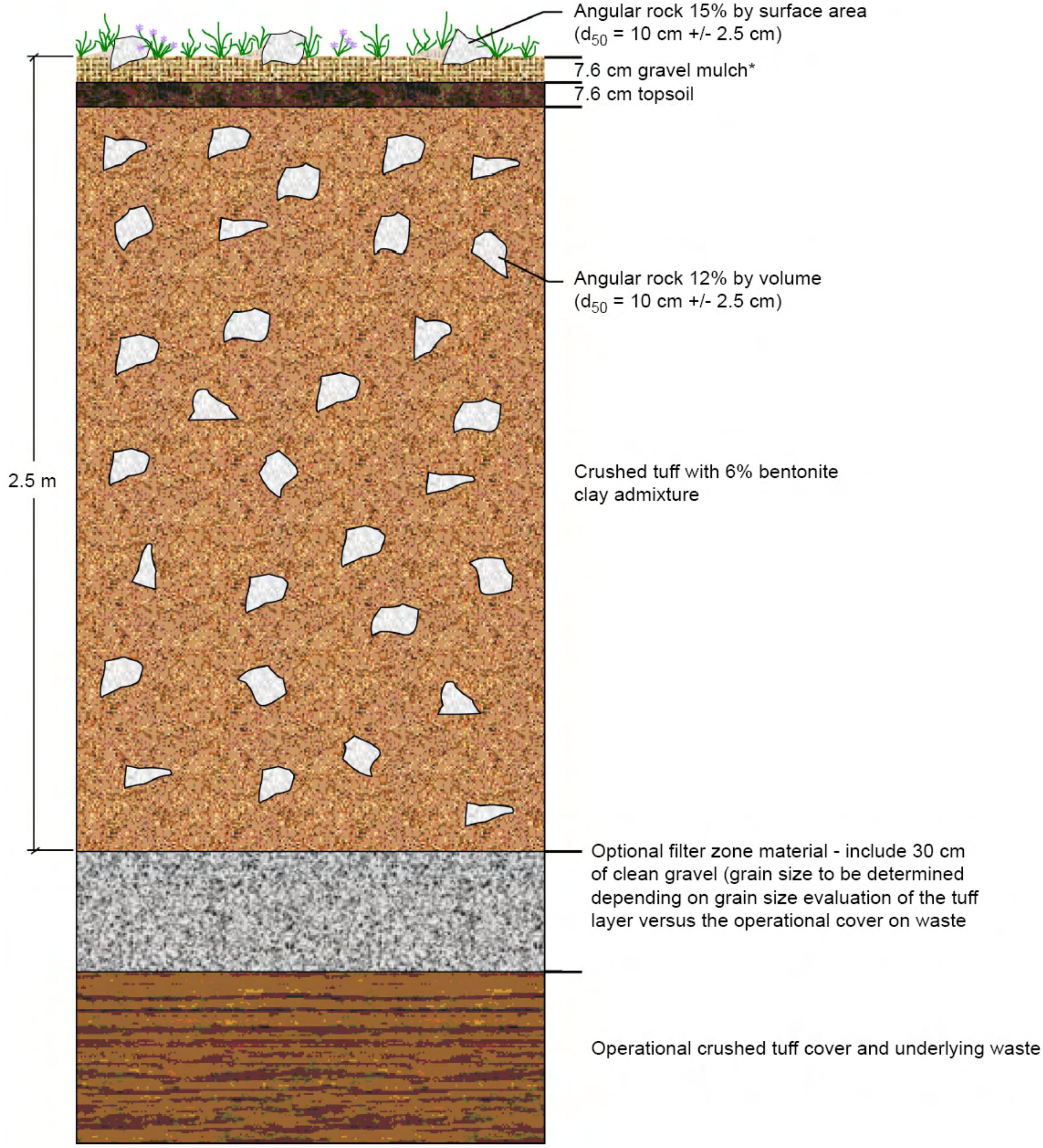


Figure 8.1-1 Isopach map of proposed Alternative 1B



*Gravel mulch is 1/2" minus pea gravel intermixed with topsoil

Figure 8.2-1 The material layers of the base cover for Alternative 2B

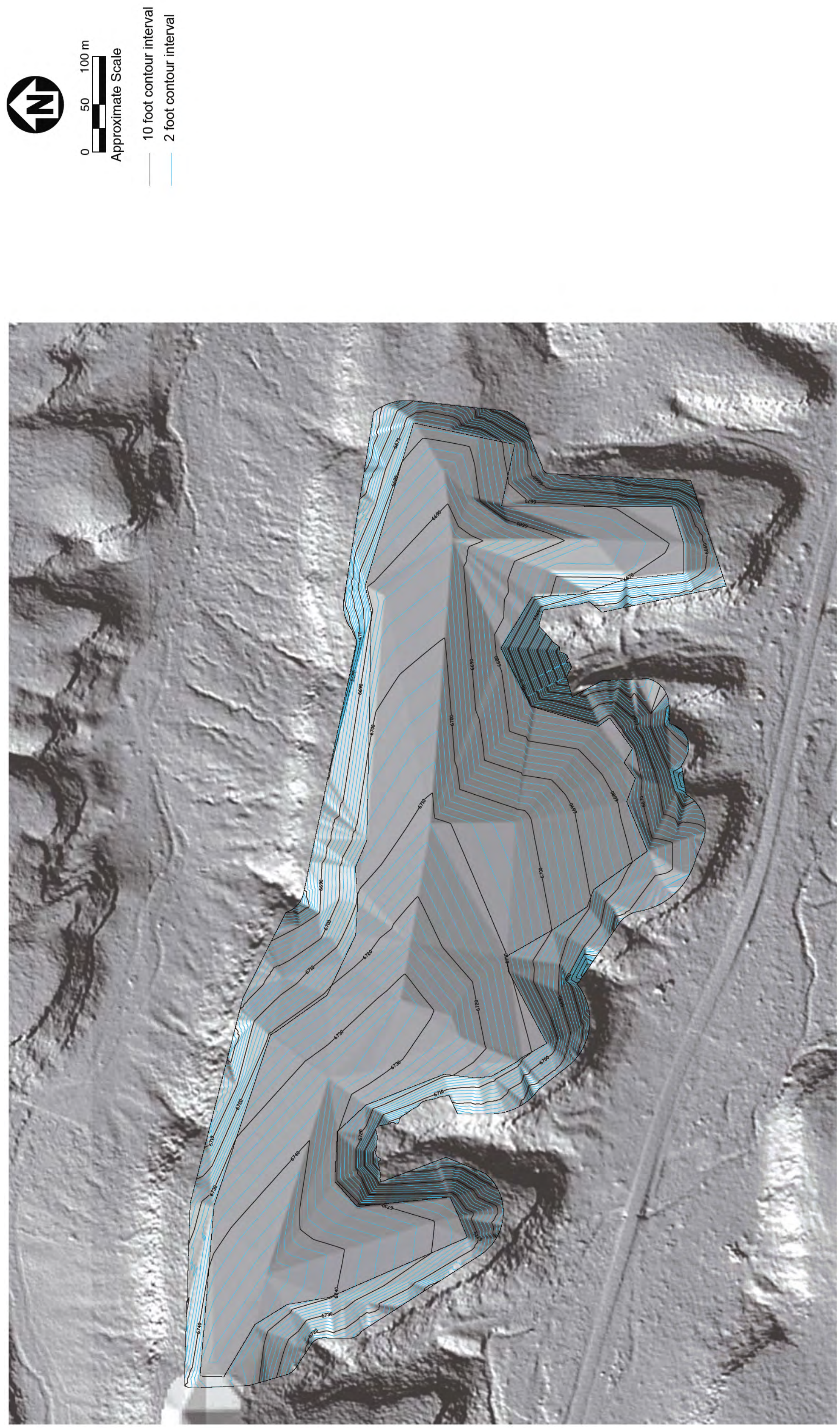


Figure 8.2-2 Plan view of the base cover for Alternative 2B

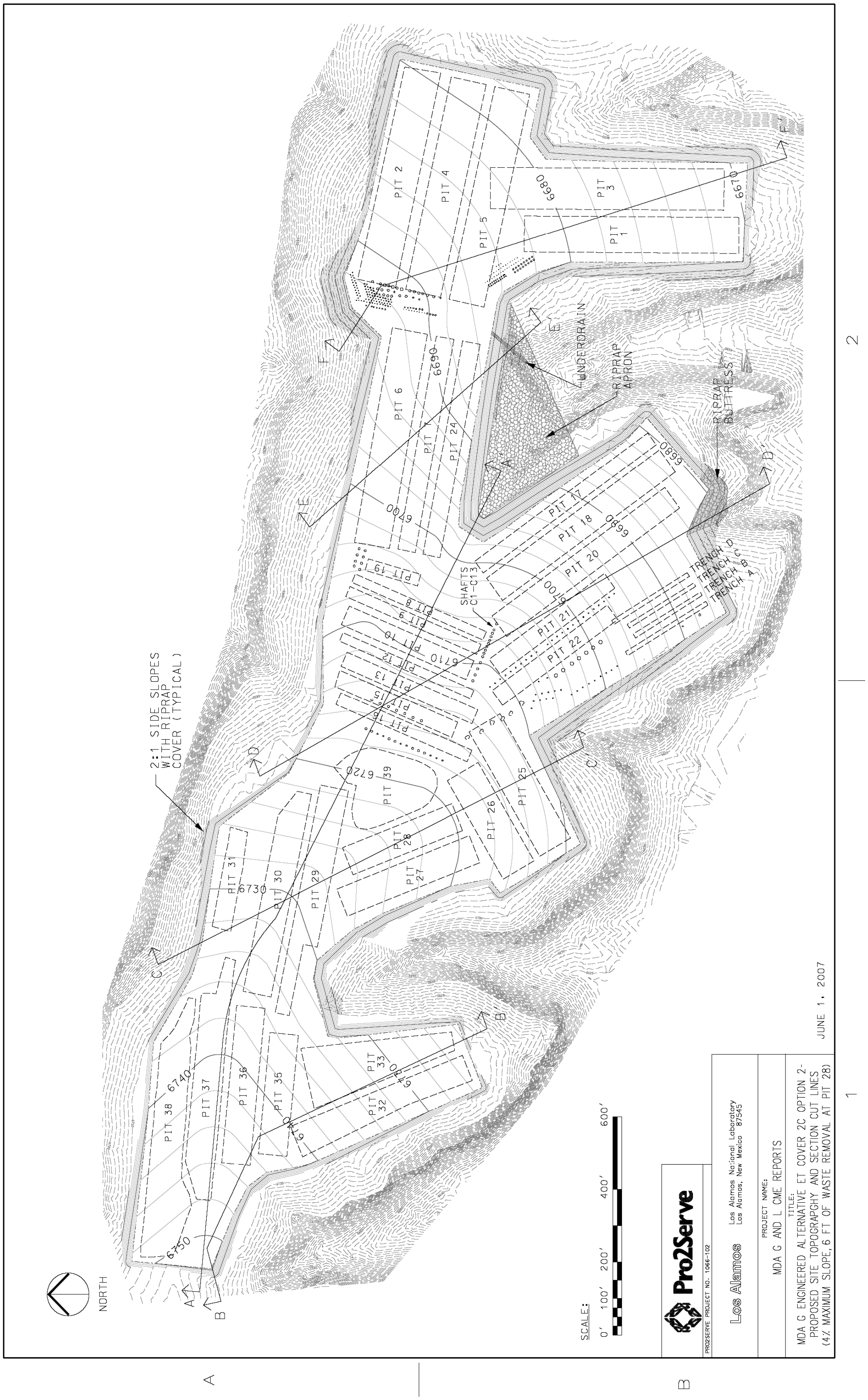


Figure 8.3-1 Plan view of Alternative 2C

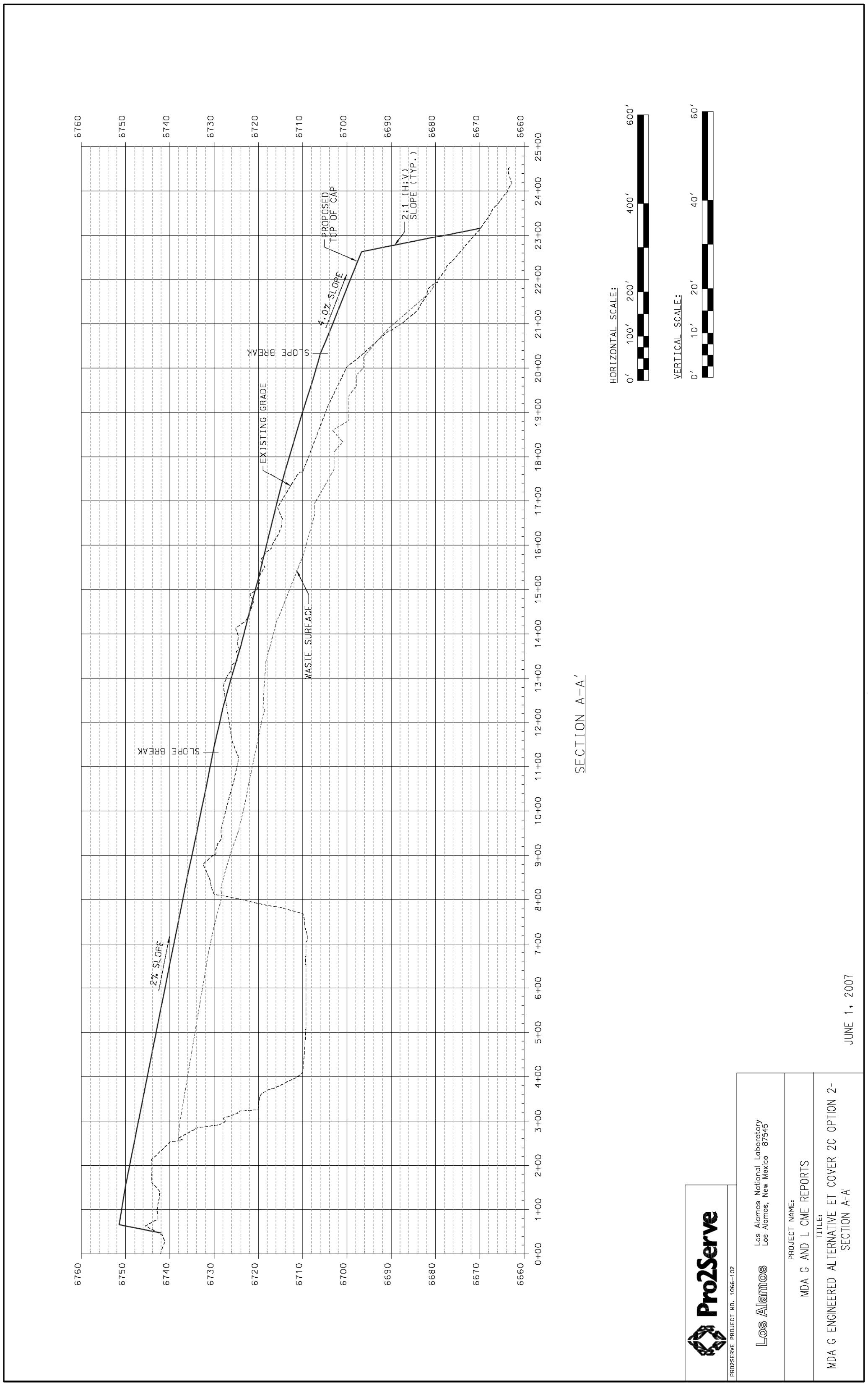


Figure 8.3-2 Section view of Alternative 2C

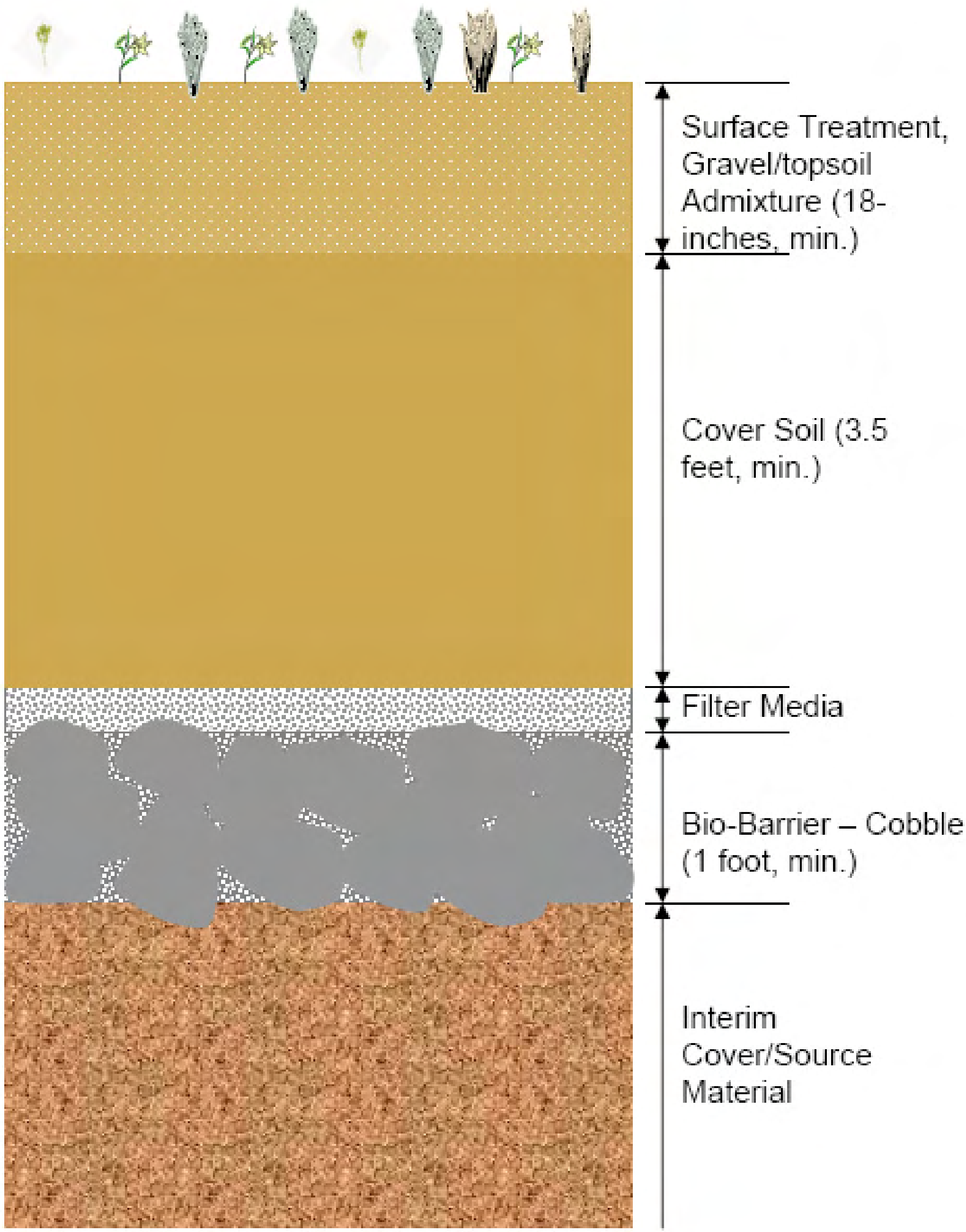


Figure 8.3-3 The material layers of the cover for Alternative 2C

10-Sep-08 15:42

Activity ID	Activity Name	Original Duration	Start	Finish
TA-54 MDA G CME REPORT		1786	12-Sep-08	31-Dec-15
B45D8M0800C	TA-54 MDA G: Submit Report	0	12-Sep-08*	
B45D8M0810C	TA-54 MDA G: Review Report	142	12-Sep-08	31-Jan-09
B45D8M0820C	TA-54 MDA G: Public Comment Period	60	01-Feb-09	01-Apr-09
B45D8M0830C	TA-54 MDA G: Final Remedy Decision	90	02-Apr-09	30-Jun-09
B45D8M0840C	TA-54 MDA G: Design Cover and Prepare ...	365	01-Jul-09	30-Jun-10
B45D8M0850C	TA-54 MDA G: Review and Approval	90	01-Jul-10	28-Sep-10
B45D8M0860C	TA-54 MDA G: Remedy Implementation	1889	29-Sep-10	30-Nov-15
B45D8M0870C	TA-54 MDA G: Prepare RCR	511	08-Aug-14*	31-Dec-15
B45D8M0880C	TA-54 MDA G:Submit RCR	0		31-Dec-15

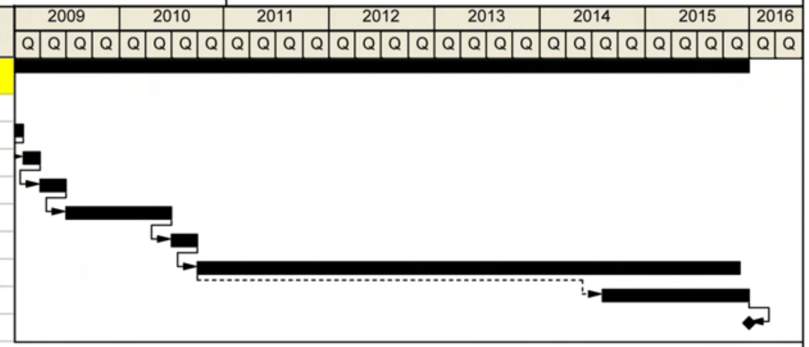


Figure 11.0-1 Schedule for recommended Alternative 2c

Table 1.0-1
Area G Waste Unit Categories

	Corrective Action Disposal Units	TRU Waste Storage Units	LLW Disposal Units	LLW/Retrievable TRU Waste Storage Units	RCRA Disposal Units	Container Storage Units
Closure Approach	**Area G Waste Disposal Units** – Closure Requirements Defined by DOE Order 435.1					Closure Requirements Defined by Operating Permit[a]
	MDA G, Consolidated Unit 54-013(b)-99, Closure Requirements Defined under Corrective Action				Closure Requirements Defined by Operating Permit	
Unit	Pits 1–8, 10, 12, 13, 16–22, 24–28, 30–33, and 35–37 Shafts C1–C10, C12, C13, 1–20, 22, 24–96, 99–112, 114, 115, 118–123, 125–136, 138–140, 150–160, 189–192, and 196	TRU waste in corrugated metal pipes stored atop Pit 29 Pit 9 Trenches A–D Shafts 200–233	Pit 15 Pits 38 and 39 Shafts 21, 23, 97, 137, 141–144, 147–149, 161–177, 197, 300, 301, 307, 308, 360–367, 369, and 370 Shafts C11, C14, 321, 323, 325, 327, 329, 331, 333, 335, 339, 341, 343, 345, 347, 349, 351, 355, and 357 Shafts 309, 311, 313, 315, 317, 319, 337, 353, and 359	Shafts 235–243, 246–253, 262–266, and 302–306	Pit 29 (below TRU corrugated metal pipes storage layer) Shaft 124	Pad 1 (54-226 and 54-412) Pad 3 (54-48) Pads 5, 7, and 8 (54-49, 54-224, 54-144, 54-145, 54-146, 54-177, 54-1027, 54-1028, 54-1030, and 54-1041) Pad 6 (54-153 and 54-283) Pad 9 (54-229, 54-230, 54-231, and 54-232) Pad 10 (formerly Pads 2 and 4) Pad 11 (54-375)[b] 54-8 54-33 Shafts 145 and 146

Note: Shaded area indicates units addressed in this CME report.

[a] Associated buildings in parentheses with exception of Pad 10.

[b] Included in RCRA permit application renewal.

Table 1.0-2
Consolidated Unit 54-013(b)-99 SWMUs

SWMU	Description
SWMU 54-013(b)	SWMU 54-013(b) was a vehicle monitoring/decontamination area located in the central portion of Area G on the surface of Pit 19. The area was used to decontaminate trucks and TRU waste drums but is no longer in use.
SWMU 54-014(b)	SWMU 54-014(b) consists of Pit 9, an inactive disposal pit measuring 30 ft wide × 400 ft long × 20 ft deep. From 1974 to 1978, Pit 9 received retrievable TRU. When filled, the pit was covered with 3.3 ft of consolidated crushed tuff and 4 in. of topsoil and reseeded with native grasses. The TRU wastes in Pit 9 will be retrieved and processed for disposal at WIPP.
SWMU 54-014(c)	SWMU 54-014(c) consists of retrievable TRU waste storage shafts 200 through 233, located in the northeastern quadrant of Area G, TA-54. The shafts each measure 1 ft in diameter and 18 ft deep and are lined with concrete. Some of the shafts began receiving TRU waste in 1978 and were closed between 1979 and 1987. The shafts were used for wastes that required special packaging (primarily tritium), special handling (e.g., highly active metals), or segregation. When filled, the shafts typically were filled with waste to within 3 ft of the ground surface, backfilled with crushed tuff, and covered with a concrete dome. The TRU wastes in these shafts will be retrieved and processed for disposal at WIPP.
SWMU 54-014(d)	SWMU 54-014(d) consists of retrievable TRU waste storage trenches A, B, C, and D, which are located in the south-central portion of TRA-54's Area G. These trenches began receiving TRU in 1974. Trenches A, B, and C vary in size from 219 ft to 262.5 ft long × 13 ft wide × 6 ft to 8 ft deep. Trench D is 60 ft long × 13 ft wide × 6 ft deep. The TRU waste placed in these trenches was packaged in 30-gal. containers inside concrete casks. When filled, the trenches were backfilled with 3.3 ft of crushed tuff followed by 4 in. of topsoil. The surface was reseeded with native grasses. The TRU wastes in these trenches will be retrieved and processed for disposal at WIPP.
SWMU 54-015(k)	SWMU 54-015(k) consists of a layer of retrievable TRU waste in cement-filled sections of corrugated pipe located inside a mound of fill material that was placed on top of inactive Pit 29 in the northeast quadrant of TA-54's Area G. These TRU wastes will be retrieved and processed for disposal at WIPP.
SWMU 54-017	SWMU 54-017 consists of inactive disposal pits 1 through 8, 10, 12, 13, 16 through 22, and 24. Pits 1 through 8, 10, 12, 13, 16 through 22, and 24 were operational between 1959 and 1980 and received radioactive, mixed, and nonretrievable TRU wastes in the form of wing tanks, dry boxes, building debris, sludge drums, lab waste, contaminated soil, D&D waste, filter plenums, and uranium. Pits 1 through 8, 10, 12, 13, 16 through 22, and 24 are located in the eastern portion of Area G with volumes ranging from 1371 to 56,759 yd^3. When filled, the pits were covered with 3.3 ft of consolidated crushed tuff and 4 in. of topsoil, and reseeded with native grasses.
SWMU 54-018	SWMU 54-018 consists of disposal pits 25 through 33 and 35 through 37. Only Pit 29 (although no longer in use) is considered a regulated unit until RCRA closure is certified and approved by NMED. Pits 25 through 28 and 30 through 36 were operational between 1979 and 1980 and received radioactive, mixed, and TRU-contaminated waste in the form of reactor control rods, D&D waste, contaminated soil, transformers, glove boxes, asbestos, and lab waste and range in volume from 20,957 to 59,930 yd^3. Pit 29 operated until 1986. Pit 37 operated from 1990 to 1997 and primarily received circuit boards and contaminated soil. When filled, the pits were covered with 3.3 ft of consolidated crushed tuff and 4 in. of topsoil, and reseeded with native grasses.
SWMU 54-019	SWMU 54-019 consists of disposal shafts 1 through 20, 24 through 34, 38 through 92, 96, 109 through 112, and 150. These shafts, which were operational between 1966 and 1980, received LLW and hazardous and mixed waste. The shafts range in size from 1 ft to 6 ft in diameter and 25 ft to 60 ft deep and are located primarily in the northeast quadrant of Area G. Disposal shafts typically were filled with waste to within 3 ft of the ground surface, backfilled with crushed tuff, and covered with a concrete dome.

Table 1.0-2 (continued)

SWMU	Description
SWMU 54-019	SWMU 54-019 consists of disposal shafts 1 through 20, 24 through 34, 38 through 92, 96, 109 through 112, and 150. These shafts, which were operational between 1966 and 1980, received LLW and hazardous and mixed waste. The shafts range in size from 1 ft to 6 ft in diameter and 25 ft to 60 ft deep and are located primarily in the northeast quadrant of Area G. Disposal shafts typically were filled with waste to within 3 ft of the ground surface, backfilled with crushed tuff, and covered with a concrete dome.
SWMU 54-020	SWMU 54-020 consists of disposal shafts C1 through C10, C12, C13, 22, 35 through 37, 93 through 95, 99 through 108, 114, 115, 118 through 136, 138 through 140, 151 through 160, 189 through 192, and 196. These shafts were operational between 1970 and the early 1990s. Only shaft 124 (although no longer in use) is considered active until RCRA closure is certified and approved by NMED. The shafts contain one or a combination of the following waste types: PCB residues, LLW, hazardous and mixed waste. The shafts range in size from 1 ft to 8 ft in diameter and 25 ft to 65 ft deep, and are located throughout the eastern portion of Area G. Disposal shafts were typically filled with waste to within 3 ft of the ground surface, backfilled with crushed tuff, and covered with a concrete dome.

Table 1.0-3
Consent Order Requirement Crosswalk

No.	Consent Order Requirement	Consent Order Section Reference	CME Report Section or Other Source
1	The Respondents shall follow the Corrective Measures Evaluation Report format outlined in Section XI.F of this Consent Order.	VII.D.2	Table of Contents
2	The corrective measures evaluation shall evaluate potential remedial alternatives and shall recommend a preferred remedy that will be protective of human health and the environment and attain the appropriate cleanup goals.	VII.D.2	Sections 5–9. No goals in section 5 are exceeded in the MDA G investigation report risk assessment (LANL 2005, 090513).
3	1. A description of the location, status, and current use of the site.	VII.D.2	1.0, 2.0, 2.1
4	2. A description of the history of site operations and the history of releases of contaminants.	VII.D.2	2.1
5	3. A description of site surface conditions.	VII.D.2	3.1
6	4. A description of site subsurface conditions.	VII.D.2	3.2
7	5. A description of on- and off-site contamination in all affected media.	VII.D.2	2.3, 4.1
8	6. An identification and description of all sources of contaminants.	VII.D.2	2.3, 4.1
9	7. An identification and description of contaminant migration pathways.	VII.D.2	4.2
10	8. An identification and description of potential receptors.	VII.D.2	4.3
11	9. A description of cleanup standards or other applicable regulatory criteria.	VII.D.2	5
12	10. An identification and description of a range of remedy alternatives.	VII.D.2	7
13	11. Remedial alternative pilot or bench scale testing results.	VII.D.2	Pilot test scheduled in 3rd quarter of FY2008
14	12. A detailed evaluation and rating of each of the remedy alternatives, applying the criteria set forth in Section VII.D.4.	VII.D.2	7 rating is a qualitative screening
15	13. An identification of a proposed preferred remedy or remedies.	VII.D.2	9
16	14. Design criteria of the selected remedy or remedies.	VII.D.2	10
17	15. A proposed schedule for implementation of the preferred remedy.	VII.D.2	11.0
18	The Respondents shall select corrective measures that are capable of achieving the cleanup standards and goals outlined in Section VIII of this Consent Order including, as applicable, approved alternate cleanup goals established by a risk assessment.	VII.D.3	Section 8 evaluates short- and long-term human health and ecological effects.

Table 1.0-3 (continued)

No.	Consent Order Requirement	Consent Order Section Reference	CME Report Section or Other Source
19	The Respondents shall evaluate each of the remedy alternatives for the following threshold criteria. To be selected, the remedy alternative must: 1. Be protective of human health and the environment. 2. Attain media cleanup standards. 3. Control the source or sources of releases so as to reduce or eliminate, to the extent practicable, further releases of contaminants that may pose a threat to human health and the environment. 4. Comply with applicable standards for management of wastes.	VII.D.4.a	7.4
20	The remedy shall be evaluated for long-term reliability and effectiveness. This factor includes consideration of the magnitude of risks that will remain after implementation of the remedy; the extent of long-term monitoring, or other management that will be required after implementation of the remedy; the uncertainties associated with leaving contaminants in place; and the potential for failure of the remedy. Respondents shall give preference to a remedy that reduces risks with little long-term management, and that has proven effective under similar conditions.	VII.D.4.b.i	8.1.3, 8.2.3, 8.3.3, 8.4.3
21	The remedy shall be evaluated for its reduction in the toxicity, mobility, and volume of contaminants. Respondents shall give preference to remedy that uses treatment to more completely and permanently reduce the toxicity, mobility, and volume of contaminants.	VII.D.4.b.ii	8.1.5, 8.2.5, 8.3.5, 8.4.5
22	The remedy shall be evaluated for its short-term effectiveness. This factor includes consideration of the short-term reduction in existing risks that the remedy would achieve; the time needed to achieve that reduction; and the short-term risks that might be posed to the community, workers, and the environment during implementation of the remedy. Respondents shall give preference to a remedy that quickly reduces short-term risks, without creating significant additional risks.	VII.D.4.b.iii	8.1.3, 8.2.3, 8.3.3, 8.4.3
23	The remedy shall be evaluated for its implementability or the difficulty of implementing the remedy. This factor includes consideration of installation and construction difficulties; operation and maintenance difficulties; difficulties with cleanup technology; permitting and approvals; and the availability of necessary equipment, services, expertise, and storage and disposal capacity. Respondents shall give preference to a remedy that can be implemented quickly and easily, and poses fewer and lesser difficulties.	VII.D.4.b.iv	8.1.4, 8.2.4, 8.3.4, 8.4.4

Table 1.0-3 (continued)

No.	Consent Order Requirement	Consent Order Section Reference	CME Report Section or Other Source
24	The remedy shall be evaluated for its cost. This factor includes a consideration of both capital costs, and operation and maintenance costs. Capital costs shall include, without limitation, construction and installation costs; equipment costs; land development costs; and indirect costs including engineering costs, legal fees, permitting fees, startup and shakedown costs, and contingency allowances. Operation and maintenance costs shall include, without limitation, operating labor and materials costs; maintenance labor and materials costs; replacement costs; utilities; monitoring and reporting costs; administrative costs; indirect costs; and contingency allowances. All costs shall be calculated based on their net present value. Respondents shall give preference to a remedy that is less costly, but does not sacrifice protection of health and the environment.	VII.D.4.b.v	8.1.6, 8.3.6, 8.4.6
25	All investigation summaries, site condition descriptions, corrective action goals, corrective action options, remedial options selection criteria, and schedules shall be included in the corrective measures evaluations.	XI.F	Investigation summaries: 2.3; site condition descriptions: 3.0; corrective action goals: 5.0
26	In general, interpretation of historical investigation data and discussions of prior interim activities shall be presented only in the background sections of the corrective measures evaluations.	XI.F	2.3
27	At a minimum, detections of contaminants encountered during previous site investigations shall be presented in the corrective measures evaluations in table format with an accompanying site plan showing sample locations.	XI.F	2.3 figures and tables
28	The other text sections of the corrective measures evaluations shall be reserved for presentation of corrective action-related information regarding anticipated or potential site-specific corrective action options and methods relevant to the project.	XI.F	8.0
29	The title page shall include the type of document; Facility name; TA designation; SWMU or AOC name, site, and any other unit name; and the submittal date. A signature block providing spaces for the name and title of the responsible DOE and University of California (or co-operator) representative shall be provided on the title page in accordance with 20.4.1.900 NMAC incorporating 40 C.F.R. 270.11(d)(1).	XI.F.1	Title Page Signature Block Page
30	This executive summary or abstract shall provide a brief summary of the purpose and scope of the corrective measures evaluation to be conducted at the subject site. The executive summary or abstract shall also briefly summarize the conclusions of the evaluation. The SWMU, AOC, and site names, location, and TA designation shall be included in the executive summary.	XI.F.2	Executive Summary
31	The table of contents shall list all text sections, subsections, tables, figures, and appendices or attachments included in the corrective measures evaluation. The corresponding page numbers for the titles of each section of the report shall be included in the table of contents.	XI.F.3	Table of Contents

Table 1.0-3 (continued)

No.	Consent Order Requirement	Consent Order Section Reference	CME Report Section or Other Source
32	The Introduction section shall include the Facility name, TA designation, site location, and site status (e.g. closed, corrective action). General information on the current site usage and status shall be included in this section. A brief description of the purpose of the corrective measures evaluation and the corrective action objectives for the project also shall be provided in this section.	XI.F.4	1.0
33	The Background section shall describe the relevant background information. This section shall briefly summarize historical site uses by the U.S. Government and any other entity since the 1940s, including the locations of current and former site structures and features. A labeled figure shall be included in the document showing the locations of current and former site structures and features. The locations of any subsurface features such as pipelines, underground tanks, utility lines, and other subsurface structures shall be included in this section and labeled on the site plan, as appropriate.	XI.F.5	Section 2.0, Figure 1.0-3, structures and features, Figure 3.2-1, subsurface features
34	This section shall include contaminant and waste characteristics, a brief summary of the history of contaminant releases, known and possible sources of contamination, and the vertical and lateral extent of contamination present in each medium. This section shall include brief summaries of results of previous investigations, including references to pertinent figures, data summary tables, and text in previous reports. References to previous reports shall include page, table, and figure numbers for referenced information. Summary tables and site plans showing relevant investigation locations shall be referenced and included in the Tables and Figures sections of the document, respectively.	XI.F.5	2
35	A section on surface conditions shall describe current and historic site topography, features, and structures, including a description of topographic drainages, man-made drainages, vegetation, and erosional features. It shall also include a description of current uses of the site and any current operations at the site. This section shall also include a description of those features that could potentially influence corrective action option selection or implementation such as archeological sites, wetlands, or other features that may affect remedial activities. In addition, descriptions of features located in surrounding sites that may have an effect on the subject site regarding sediment transport, surface water runoff or contaminant transport shall be included in this section. A site plan displaying the locations of all pertinent surface features and structures shall be included in the Figures section of the corrective measures evaluation.	XI.F.6a	3.1

Table 1.0-3 (continued)

No.	Consent Order Requirement	Consent Order Section Reference	CME Report Section or Other Source
36	A section on subsurface conditions shall describe the site conditions observed during previous subsurface investigations. It shall include relevant soil horizon and stratigraphic information, groundwater conditions, fracture data, and subsurface vapor information. A site plan displaying the locations of all borings and excavations advanced during previous investigations shall be included in the Figures section of the corrective measures evaluation. A brief description of the stratigraphic units anticipated to be present beneath the site may be included in this section if stratigraphic information is not available from previous investigations conducted at the site.	XI.F.6b	3.2
37	A section shall provide a list of all sources of contamination at the subject site where corrective measures are to be considered or required. Sources that are no longer considered to be releasing contaminants at the site, but may be the point of origination for contaminants transported to other locations, shall be included in this section.	XI.F.7a	4.1
38	A section shall describe potential migration pathways that could result in either acute or chronic exposures to contaminants. It shall include such pathways as utility trenches, paleochannels, surface exposures, surface drainages, stratigraphic units, fractures, structures, and other features. The migration pathways for each contaminant and each relevant medium should be tied to the potential receptors for each pathway. A discussion of contaminant characteristics relating to fate and transport of contaminants through each pathway shall also be included in this section.	XI.F.7b	4.2
39	A section shall provide a listing and description of all anticipated potential receptors that could possibly be affected by the contamination present at the site. Potential receptors shall include human and ecological receptors, groundwater, and other features such as pathways that could divert or accelerate the transport of contamination to human receptors, ecological receptors, and groundwater.	XI.F.7c	4.3
40	A section shall set forth the applicable cleanup standards, risk-based screening levels, and risk-based cleanup goals for each pertinent medium at the subject site. The appropriate cleanup levels for each site shall be included, if site-specific levels have been established at separate sites or units. A table summarizing the applicable cleanup standards or levels, or inclusion of applicable cleanup standards or levels in the summary data tables shall be included in the Tables section of the document. The risk assessment shall be presented in a separate document or in an appendix to this report. If cleanup or screening levels calculated in a risk evaluation are employed, the risk evaluation document shall be referenced including pertinent page numbers for referenced information.	XI.F.8	5.0. Risk assessment in Appendix G of the MDA G investigation report (LANL 2005, 090513)

Table 1.0-3 (continued)

No.	Consent Order Requirement	Consent Order Section Reference	CME Report Section or Other Source
41	A section shall identify and describe potential corrective measures for source, pathway, and receptor controls. Corrective measures options shall include the range of available options including, but not limited to, a no action alternative, institutional controls, engineering controls, in-situ and on-site remediation alternatives, complete removal, and any combination of alternatives that would potentially achieve cleanup goals.	XI.F.9	7.0
42	A section shall provide an evaluation of the corrective measures options identified in Section XI.F.9 above. The evaluation shall be based on the applicability, technical feasibility, effectiveness, implementability, impacts to human health and the environment, and cost of each option. A table summarizing the corrective measures alternatives and the criteria listed below shall be included in the Tables section of this document.	XI.F.10	8.0
43	The assessment also shall include the anticipated duration for the technology to attain regulatory compliance. In general, all corrective measures described above will have the ability to mitigate the impacts of contamination at the site, but not all remedial options will be equally effective at achieving the desired cleanup goals to the degree and within the same time frame as other options. Each remedy shall be evaluated for both short-term and long-term effectiveness.	XI.F.10.c	8.0
44	Implementability characterizes the degree of difficulty involved during the installation, construction, and operation of the corrective measure. Operation and maintenance of the alternative shall be addressed in this section.	XI.F.10.d	8.0
45	This category evaluates the short-term (remedy installation-related) and long-term (remedy operation-related) hazards to human health and the environment of implementing the corrective measure. The assessment shall include whether the technology will create a hazard or increase existing hazards and the possible methods of hazard reduction.	XI.F.10.e	8.0
46	This section shall discuss the anticipated cost of implementing the corrective measure. The costs shall be divided into: 1) capital costs associated with construction, installation, pilot testing, evaluation, permitting, and reporting of the effectiveness of the alternative; and 2) continuing costs associated with operating, maintaining, monitoring, testing, and reporting on the use and effectiveness of the technology.	XI.F.10.f	8.0

Table 1.0-3 (continued)

No.	Consent Order Requirement	Consent Order Section Reference	CME Report Section or Other Source
47	The Respondents shall propose the preferred corrective measure(s) at the site and provide a justification for the selection in this section. The proposal shall be based upon the ability of the remedial alternative to: 1) achieve cleanup objectives in a timely manner; 2) protect human and ecological receptors; 3) control or eliminate the sources of contamination; 4) control migration of released contaminants; and 5) manage remediation waste in accordance with State and Federal regulations. The justification shall include the supporting rationale for the remedy selection, based on the factors listed in Section XI.F.10 and a discussion of short- and long-term objectives for the site. The benefits and possible hazards of each potential corrective measure alternative shall be included in this section.	XI.F.11	9.0
48	The Respondents shall present descriptions of the preliminary design for the selected corrective measures in this section. The description shall include appropriate preliminary plans and specifications to effectively illustrate the technology and the anticipated implementation of the remedial option at the subject area. The preliminary design shall include a discussion of the design life of the alternative and provide engineering calculations for proposed remediation systems.	XI.F.12	10.0
49	A section shall set forth a proposed schedule for completion of remedy-related activities such as bench tests, pilot tests, construction, installation, remedial excavation, cap construction, installation of monitoring points, and other remedial actions. The anticipated duration of corrective action operations and the schedule for conducting monitoring and sampling activities shall also be presented. In addition, this section shall provide a schedule for submittal of reports and data to the Department, including a schedule for submitting all status reports and preliminary data.	XI.F.13	11.0
50	1. A table summarizing regulatory criteria, background, and/or the applicable cleanup standards.	XI.F.14	Table 5.1-1
51	2. A table summarizing historical field survey location data.	XI.F.14	Information in Figures 2.3-1, 2.3-2, and 2.3-12
52	3. Tables summarizing historical field screening and field parameter measurements of soil, rock, sediments, groundwater, surface water, and air quality data.	XI.F.14	Appendix B of the MDA G investigation report (LANL 2005, 090513); Appendix C of the MDA G addendum to the investigation report (LANL 2007, 096110)
53	4. Tables summarizing historical soil, rock, or sediment laboratory analytical data. The summary tables shall include the analytical methods, detection limits, and significant data quality exceptions that would influence interpretation of the data.	XI.F.14	Information in Table 2.3-5 and Figures 2.3-2, 2.3-3, 2.3-8, 2.3-9, and 2.3-10

Table 1.0-3 (continued)

No.	Consent Order Requirement	Consent Order Section Reference	CME Report Section or Other Source
54	5. A table summarizing historical groundwater elevation and depth to groundwater data. The table shall include the monitoring well depths and the screened intervals in each well.	XI.F.14	Information in the MDA G investigation work plan, revision 1 (LANL 2004, 087833, pp. 33 and 34)
55	6. Tables summarizing historical groundwater laboratory analytical data. The analytical data tables shall include the analytical methods, detection limits, and significant data quality exceptions that would influence interpretation of the data.	XI.F.14	TA-54 well evaluation report, revision 1 (LANL 2007, 098548)
56	7. Tables summarizing historical surface water laboratory analytical data. The analytical data tables shall include the analytical methods, detection limits, and significant data quality exceptions that would influence interpretation of the data.	XI.F.14	No surface water at site
57	8. Tables summarizing historical air sample screening and analytical data. The data tables shall include the screening instruments used, laboratory analytical methods, detection limits, and significant data quality exceptions that would influence interpretation of the data.	XI.F.14	Table 2.3-2
58	9. Tables summarizing historical pilot or other test data, if applicable, including units of measurement and types of instruments used to obtain measurements.	XI.F.14	Pilot study of SVE to be conducted in FY2008
59	10. A table summarizing the corrective measures alternatives and evaluation criteria.	XI.F.14	Table 9.0-1
60	11. A table presenting the schedule for installation, construction, implementation, and reporting of selected corrective measures.	XI.F.14	Listed in text of Section 11 and shown in Figure 11.0-1
61	A section shall present the following figures for each site, as appropriate. All figures must include an accurate bar scale and a north arrow. An explanation shall be provided on each figure for all abbreviations, symbols, acronyms, and qualifiers. All figures shall have a date.	XI.F.15	See below
62	1. A vicinity map showing topography and the general location of the subject site relative to surrounding features or properties.	XI.F.15	Figures 1.0-2 and 1.0-3
63	2. A unit site plan that presents pertinent site features and structures, underground utilities, well locations, and remediation system locations and details. Off-site well locations and other relevant features shall be included on the site plan if practical. Additional site plans may be required to present the locations of relevant off-site well locations, structures, and features.	XI.F.15	Figures 1.0-2 and 3.2-1
64	3. Figures showing historical soil boring or excavation locations and sampling locations.	XI.F.15	Figures 2.3-1, 2.3-2, 2.3-12

Table 1.0-3 (continued)

No.	Consent Order Requirement	Consent Order Section Reference	CME Report Section or Other Source
65	4. Figures presenting historical soil sample field screening and laboratory analytical data, if appropriate.	XI.F.15	Figures 2.3-8, 2.3-9, and 2.3-10; Appendix B of the MDA G investigation report (LANL 2005, 090513); Appendix C of the MDA G addendum to the investigation report (LANL 2007, 096110)
66	5. Figures showing all existing wells including vapor monitoring wells and piezometers. The figures shall present historical groundwater elevation data and indicate groundwater flow directions.	XI.F.15	Figures 2.3-11, 3.2-6, and 4.2-1
67	6. Figures presenting historical groundwater laboratory analytical data including past data, if applicable. The analytical data corresponding to each sampling location may be presented as individual concentrations, in table form on the figure or as an isoconcentration map.	XI.F.15	TA-54 well evaluation report, revision 1 (LANL 2007, 098548)
68	7. Figures presenting historical surface water sample locations and analytical data including past data, if applicable. The laboratory analytical data corresponding to each sampling location may be presented as individual concentrations or in table form on the figure.	XI.F.15	No surface water exists at site
69	8. Figures presenting historical air sampling locations and presenting air quality data. The field screening or laboratory analytical data corresponding to each sampling location may be presented as individual concentrations, in table form on the figure or as an isoconcentration map.	XI.F.15	Figures 2.3-4, 2.3-5, and 2.3-6
70	9. Figures presenting historical pilot or other test locations and data, where applicable, including site plans or graphic data presentation.	XI.F.15	MDA G SVE Pilot Test Work Plan (LANL 2008, 102816)
71	10. Figures presenting geologic cross-sections based on outcrop and borehole data, if applicable.	XI.F.15	Figure 3.2-3
72	11. Figures presenting the locations of existing and proposed remediation systems.	XI.F.15	Pilot study of SVE to be conducted in FY2008
73	12. Figures presenting existing remedial system design and construction details.	XI.F.15	Not applicable
74	13. Figures presenting preliminary design and construction details for preferred corrective measures.	XI.F.15	Figures 8.2-1, 8.2-2, 8.3-1, 8.3-2, and 8.3-3
75	Each corrective measures evaluation shall include, as appropriate, as an appendix, the management plan for waste, including investigation derived waste, generated as a result of construction, installation, or operation of remedial systems or activities conducted.	XI.F.16	Will be developed as part of CMI based on remedy selection

Table 1.0-3 (continued)

No.	Consent Order Requirement	Consent Order Section Reference	CME Report Section or Other Source
76	Each corrective measures evaluation shall include additional appendices presenting relevant additional data, such as pilot or other test or investigation data, remediation system design specifications, system performance data, or cost analyses as necessary.	XI.F.16	Appendixes C through G

Table 2.1-1
MDA G Disposal Unit Information for Pits

Pit No.	Operational Period	Dimensions (length × width × depth)	Rectangular Vol. of Pit (yd^3)	Field Meas. Pit Vol. (yd^3)	Vol. of Waste in Pit (yd^3)	Waste Description
1	Jan 1959–Apr 1961	616 ft × 113 ft × 20 ft	51,561	37,080	5529	Wing tanks from Kirtland Air Force Base, Dry boxes, “normal trash.” Pit used to burn combustibles
2	Apr 1961–Jul 1963	618 ft × 104 ft × 26 ft	61,892	42,911	6407	Classified Bendix waste, 55-gal. drums, property numbers, D-38, hot dirt
3	Jun 1963–Mar 1966	655 ft × 115 ft × 33 ft	92,064	56,759	9473	Misc. material, lumber, pipe, 55-gal. drums, D&D, D-38, Bendix classified waste, soil from TA-10 - Bayo Canyon
4	Jan 1966–Dec 1967	600 ft × 110 ft × 34 ft	83,111	44,950	8212	D&D, graphite, wooden boxes, D-38, 55-gal. drums, classified Bendix waste, property numbers. Burning trench along south wall of pit
5	Jan 1967–Mar 1974	600 ft × 100 ft × 29 ft	64,444	41,258	6624	Scrap material, D&D, graphite hoppers, sludge drums (possibly aqueous solution from TA-50), property numbers
6	Jan 1970–Aug 1972	600 ft × 113 ft × 26 ft	65,289	43,933	6696	Misc. scrap, wood, D&D. Covered with topsoil from TA-1 with up to 20 pCi/g Pu contamination
7	Mar 1974–Oct 1975	600 ft × 50 ft × 30 ft	33,333	17,101	4343	Low-level TRU-contaminated waste. Replaced Pit 17 for low-level TRU-contaminated waste in 1974. Covered with topsoil from TA-1 with up to 20 pCi/g Pu contamination
8	Sep 1971–May 1974	400 ft × 25 ft × 25 ft	9,259	6528	2311	55 gal. drums of sludge from H-7 and nonretrievable TRU waste also drums from TA-50 (aqueous and nonretrievable TRU)
9	Nov 1974–Nov 1979	400 ft × 30 ft × 20 ft	8,889	9027	na*	Drums and fiberglass crates containing retrievable TRU wastes (>10 nCi/g Pu-239 or U-233 or >100 nCi/g Pu-238) bottom of pit is paved
10	May 1979–Mar 1980	380 ft × 57 ft × 27 ft	21,660	15,549	4016	Building debris, lab wastes, sludge drums (from TA-50 dewatering, possibly aqueous)
12	Sep 1971–Dec 1975	400 ft × 25 ft × 25 ft	9,259	7303	2363	Nonretrievable TRU waste. Originally contained retrievable TRU, but was transferred to Pit 9 (30 55-gal. drums)

Table 2.1-1 (continued)

Pit No.	Operational Period	Dimensions (length × width × depth)	Rectangular Vol. of Pit (yd³)	Field Meas. Pit Vol. (yd³)	Vol. of Waste in Pit (yd³)	Waste Description
13	Nov 1976–Sep 1977	400 ft × 42 ft × 28 ft	17,422	12,107	1931	Uranium, mixed fission products, mixed activation products. Uranium fission products and induced activity wastes
16	Sep 1971–Aug 1975	400 ft × 25 ft × 25 ft	9,259	8081	2235	Crates and drums containing uranium contaminated wastes
17	Aug 1972–Mar 1974	600 ft × 46 ft × 24 ft	24,533	17,399	4962	Low-level Pu TRU <10 nCi/g. Misc. scrap wastes, crates, filter plenums
18	Feb 1978–Aug 1979	600 ft × 75 ft × 40 ft	66,667	46,685	12,358	Contaminated dirt, lab wastes, noncompactible waste, D&D, drums
19	Nov 1975–Aug 1979	153 ft × 30 ft × 18 ft	3,060	1371	na	Asbestos and carcinogens, plastic layer placed in bottom
20	Nov 1975–Oct 1977	600 ft × 71 ft × 36 ft	56,800	37,454	14,899	Lab waste, oil, sludge drums, trash, contaminated dirt
21	Aug 1972–Dec 1974	402 ft × 56 ft × 26 ft	21,678	13,328	3607	U, classified material, boxes, drums, scrap metal
22	Sep 1976–Mar 1978	413 ft × 56 ft × 33 ft	28,268	17,690	3744	Filter plenum, sludge drums (possibly aqueous from TA-50), lab waste, graphite fuel rods, contaminated dirt
24	Jul 1975–Nov 1976	600 ft × 58 ft × 30 ft	38,667	23,388	7327	Graphite, lab wastes, 22 truck loads of soil. Uranium, tritium, mixed fission products, and mixed activation products
25	Jan 1980–May 1981	395 ft × 103 ft × 39 ft	58,767	47,000	6530	Reactor control rods, D&D, scrap drums, lab wastes, test drums, PCB-contaminated waste forms
26	Feb 1984–Feb 1985	310 ft × 100 ft × 36 ft	41,333	22,209	4312	Building debris, TRU culverts, asbestos, alpha box soil, lumber, PCBs
27	May 1981–Jul 1982	400 ft × 80 ft × 46 ft	54,519	26,946	7441	Laboratory waste, contaminated soil and pipe, D&D, PCBs, and unknown chemical waste
28	Dec 1981–Apr 1983	330 ft × 83 ft × 40 ft	40,578	21,381	4422	Ba nitrate, PCB soil, lab waste, property numbers, transformers, clay pipes, building debris, uranium graphite
29	Oct 1984–Oct 1986	658 ft × 80 ft × 50 ft	97,481	45,795	9784	TRU cement paste (recoverable), D&D soil, glove boxes, plywood boxes (4 ft × 4 ft × 8 ft), asbestos, PCBs, and unknown chemical waste
30	Oct 1988–Jun 1990	568 ft × 39 ft × 35 ft	28,716	42,843	13,464	Asbestos, PCBs, and unknown chemical waste

Table 2.1-1 (continued)

Pit No.	Operational Period	Dimensions (length × width × depth)	Rectangular Vol. of Pit (yd³)	Field Meas. Pit Vol. (yd³)	Vol. of Waste in Pit (yd³)	Waste Description
31	Jun 1990–Mar 2003	280 ft × 52 ft × 25 ft	13,481	na	2702	Asbestos, mixed fission products, and mixed activation products. Currently operational
32	Nov 1985–Aug 1987	518 ft × 74 ft × 51 ft	72,405	36,364	5367	PCB asphalt, transformers, contaminated soil, glove boxes, 4 ft × 4 ft × 8 ft plywood boxes, capacitors, building debris
33	Nov 1982–Jul 1984	425 ft × 115 ft × 40 ft	72,407	59,930	7776	Be in stainless steel, lab waste, building debris, asbestos, noncompactible trash, PCBs, and unknown chemical waste
35	Jun 1987–Feb 1988	363 ft × 83 ft × 40 ft	44,636	20,957	3361	CP. Trash, 4 ft × 4 ft × 8 ft plywood boxes, asbestos, lab waste, PCBs, and unknown chemical waste
36	Jan 1988–Dec 1988	435 ft × 83 ft × 43 ft	57,501	28,057	4491	4 ft × 4 ft × 8 ft plywood boxes, compactable nonnuclear. trash, rubble, building waste, beryllium, and PCB soil (<200 ppm)
37	Apr 1990–Apr 1997	731 ft × 83 ft × 61 ft	137,076	57,213	24,299	Ultra-High-Temperature Reactor Experiment reactor vessel and stack, asbestos, PCBs, and unknown chemical waste

*na = Not available.

Table 2.1-2
MDA G Disposal Unit Information for Trenches

Trench No.	Operational Period	Dimensions (length × width × depth)	Waste Description
A	1974	262.5 ft × 12.75 ft × 8 ft	Heat source Pu-238 (80% Pu-238, 16% Pu-239, 3% Pu-239, 1% other) in casks from (1) radiolytic heating, (2) radiolytic gas formation, and (3) radiation emitting from waste. Average of 18 g Pu-238 per cask, with max 40 g Pu-238.
B	1974–1977	218.75 ft × 12.75 ft × 8 ft	
C	1977–1981	218.75 ft × 12.75 ft × 10 ft (est.)	
D	1981–1985	250 ft × 12.75 ft × 10 ft (est.)	

Table 2.1-3
MDA G Disposal Unit Information for Shafts

Shaft No.	Operational Period	Diameter/ Depth (ft)	Lining	Shaft Volume (ft^3)	Waste Volume (ft^3)	Waste Description
1	1966–1967	2/25	N[a]	78.4	63	Cell trash, irradiated metal, animal tissue
2	1966–1967	2/25	N	78.4	42	DU[b] chips, animal tissue, irradiated Pu cell waste
3	1966–1967	2/25	N	78.4	35	Pu-contaminated Na and metal, neutron generators
4	1967–1968	2/25	N	78.4	44	U-contaminated metal, U-238 samples, DU
5	1967–1968	2/25	N	78.4	29	DU, tritium-contaminated materials, U-238 contaminated metal
6	1967–1968	2/25	N	78.4	21	Tritium-contaminated materials, U-235
7	1967–1968	2/25	N	78.4	52	Animal tissue, PTC waste, tritium DU
8	1968–1969	2/25	N	78.4	na[c]	Pu cell waste, animal tissue, end boxes
9	1968–1969	2/25	N	78.4	70	Hot cell waste, Pu cell waste, EBR-II waste, fuel elements
10	1969	2/25	N	78.4	54	Animal tissue, Pu-239 waste, U-contaminated chemicals
11	1967–1969	3/25	N	176.5	72	Pee Wee waste and trash, U-235 cell waste, graphite
12	1966–1970	3/25	N	176.5	83	Cell waste, rover waste, tritium
13	1966–1970	3/25	N	176.5	122	Animal tissue, EBR hardware, reactor parts
14	1966–1969	1/25	CMP[d]	19.7	na	U-235 vermiculite, neutralized solution HCL + U-235
15	1969–1970	1/25	CMP	19.7	8	Tritium in H_3PO_4, hot cell waste
16	1969	1/25	CMP	19.7	4	Tritium
17	1970–1974	1/25	CMP	19.7	1	Tritium pump, U-235 in Na
18	1970–1973	1/25	CMP	19.7	13	Neutralized NA, Cs-137 + Ba-140
19	1971–1974	1/25	CMP	19.7	3	Pu-239 solution, reacted Pu-239
20	1974–1975	1/25	CMP	19.7	8	Sorbed Pu-239 solution
22	1980–1993	1/25	CMP	19.7	7	Radioactive sources
24	1969–1970	2/25	N	78.4	44	Animal tissue, DU, unloaded fuel elements
25	1969–1971	2/25	N	78.4	45	DU, U-238 residue, U-238 contaminated metal
26	1969–1970	2/25	N	78.4	56	Hot cell trash, fuel elements, DU-contaminated metal
27	1970	2/25	N	78.4	13	Irradiated material, DU-contaminated material
28	1970	2/25	N	78.4	14	LA notebooks, U-235 residues
29	1970–1971	2/25	N	78.4	24	Thermocouple waste, U-235 residue
30	1970–1971	2/25	N	78.4	11	Animal tissue, Pu-239 hot cell waste
31	1970–1971	2/25	N	78.4	47	DU
32	1970–1971	2/25	N	78.4	33	LAMPRE-II lines and valves, animal tissue, irradiated stainless steel

Table 2.1-3 (continued)

Shaft No.	Operational Period	Diameter/ Depth (ft)	Lining	Shaft Volume (ft^3)	Waste Volume (ft^3)	Waste Description
33	1970–1971	2/25	N	78.4	15	Pu-239 hot cell waste
34	1970–1972	6/60	N	1709.2	932	U-contaminated oil
35	1971–1985	3/40	N	282.9	125	Hot cell wastes, animal tissues, herbicide containers, fission products
36	1970–1985	3/40	N	282.9	198	Hot cell wastes, spalation products
37	1970–1985	3/40	N	282.9	198	Animal and chemical wastes
38	1970–1974	3/40	N	282.9	69	Rover reactor parts, LAMPRE-II tank
39	1970–1973	6/60	N	1709.2	537	Tritium contaminated equipment
40	1971	2/25	N	78.4	28	Animal tissue
41	1971–1972	2/25	N	78.4	71	Animal tissue, graphite
42	1972	2/25	N	78.4	56	Animal tissue, U-contaminated metal
43	1971–1972	2/25	N	78.4	43	U-contaminated metal, DU
44	1971–1972	2/25	N	78.4	61	Animal tissue, Pu-239-contaminated vermiculite, DU with graphite
45	1971–1972	2/25	N	78.4	70	Pu-contaminated steel, U-235 residues
46	1972	2/25	N	78.4	38	Animal tissue, Pu-239-contaminated steel
47	1972	2/25	N	78.4	32	Animal tissue, contaminated metal, fuel waste (no vol.)
48	1972	2/25	N	78.4	19	Hot cell trash, fuel waste (no vol.)
49	1972	2/25	N	78.4	21	Animal tissue
50	1974–1976	6/60	N	1709.2	581	Tritium (1,110 Ci)
51	1975	2/25	N	78.4	52	Hot cell waste
52	1975–1976	2/25	N	78.4	6	Pu, U, mixed fission products, mixed activation products, hot cell wastes
53	1975–1976	2/25	N	78.4	3	Mixed fission products, cell wastes, Pu-239, U-235
54	1976	2/25	N	78.4	6	Mixed fission products, cell trash
55	1976–1977	2/25	N	78.4	20	Hot cell trash
56	1977	2/25	N	78.4	11	Cell waste, contaminated parts from Size Reduction Lab
57	1977	2/25	N	78.4	8	Hot cell waste
58	1972–1973	3/25	N	176.5	88	Hot cell waste, DU
59	1973–1974	6/60	N	1709.2	120	Tritium contaminated steel, tools, and waste
60	1972–1974	3/25	N	176.5	128	Oil contaminated with U-235, Pu-239
61	1973–1974	3/25	N	176.5	143	Be waste, U-238 contaminated metal, animal tissue
62	1976	3/25	N	176.5	141	Animal tissue, Pu-238, P-32
63	1976	3/25	N	176.5	28	DU, residues
64	1976–1977	3/25	N	176.5	32	Animal wastes, U-235
65	1976–1977	3/25	N	176.5	123	Classified U wastes, targets, animal tissue

Table 2.1-3 (continued)

Shaft No.	Operational Period	Diameter/ Depth (ft)	Lining	Shaft Volume (ft^3)	Waste Volume (ft^3)	Waste Description
66	1976–1979	3/25	N	176.5	25	Animal tissue
67	1977	2/25	N	78.4	48	Targets, cell trash
68	1977	2/25	N	78.4	23	Cell trash, classified notebooks
69	1977	2/25	N	78.4	20	AC parts from recovery
70	1975–1976	6/60	N	1709.2	917	Contaminated oil
71	1978	2/25	N	78.4	31	No description
72	1972–1973	2/25	N	78.4	61	Irradiated stainless steel, hot cell waste trash
73	1973	2/25	N	78.4	43	Hot cell trash
74	1973	2/25	N	78.4	69	Pu-239 waste
75	1973	2/25	N	78.4	61	Pu-238 waste, cell trash
76	1973–1974	2/25	N	78.4	75	Hot cell trash
77	1973–1974	2/25	N	78.4	33	Hot cell trash, Pu-239 hot cell trash
78	1974–1975	2/25	N	78.4	46	Cell wastes, reactor wastes, irradiated box ends
79	1974–1975	2/25	N	78.4	46	Hot cell waste, irradiated metal
80	1975–1976	2/25	N	78.4	25	Sodalime, Ta-182 chips, animal tissue
81	1976	2/25	N	78.4	na	Animal tissue (12 boxes)
82	1978	3/25	N	176.5	1	Trash, chemical wastes
83	1978	3/25	N	176.5	44	Animal tissue, DU
84	1978	3/25	N	176.5	17.3	Trash from Size Reduction Lab, cell trash
85	1978	3/25	N	176.5	12	Neutralized Na Dowanol, cell trash
86	1977	3/25	N	176.5	22	Spalation products, classified materials
87	1977	2/25	N	78.4	23	Cell wastes
88	1977	2/25	N	78.4	18	Cell wastes
89	1977–1978	2/25	N	78.4	12	Animal tissue (5 boxes), cell waste
90	1978	2/25	N	78.4	25	DU, hot cell trash
91	1977–1978	3/50	N	353.4	54	Spalation products, animal waste, cell trash, trash cans
92	1977–1978	3/50	N	353.4	60	Spalation products, uranyl-nitrate in HNO_3
93	1978–1984	3/50	N	353.4	139	Spalation products, fuel elements, cell waste, animal tissues
94	1978–1984	3/50	N	353.4	29	Hot cell waste, DU, control rods
95	1984	3/50	N	353.4	142	Cell wastes, animal tissues
96	1977–1979	6/50	N	1413.6	438	U-contaminated oil, nibbium, zirconium, chlorides, aluminum shell
99	1983–1984	3/60	N	424.1	189	Hot cell wastes, animal tissue, machine parts
100	1983	3/60	N	424.1	3	Hot cell waste, target and stinger
101	1980–1981	3/60	N	424.1	75	Spalation products, hot cell waste
102	1982–1983	3/60	N	424.1	184	No description

Table 2.1-3 (continued)

Shaft No.	Operational Period	Diameter/ Depth (ft)	Lining	Shaft Volume (ft^3)	Waste Volume (ft^3)	Waste Description
103	1981–1982	3/60	N	424.1	118	Hot cell waste, spent fuel elements
104	1982	3/60	N	424.1	10	U chips, scrap metal
105	1982–1983	3/60	N	424.1	2	Animal tissue
106	1980–1981	3/60	N	424.1	69	Spalation products, hot cell waste
107	1978–1981	3/60	N	424.1	27	Hot trash, animal tissue, chemical waste
108	1980–1982	3/60	N	424.1	230	Spalation products, solvent, animal tissue
109	1980	2/60	N	188.5	83	Spalation products, trash cans
110	1979	3/60	N	424.1	128	Spalation products, animal tissue, mixed combustible trash
111	1979–1980	2/60	N	188.5	134	Cell waste, spalation products, niobium and tantalum perchloride
112	1978–1979	3/60	N	424.1	149	Classified pieces, animal waste, cell waste, spalation products
114	1979–1982	6/60	N	1696.5	981	Shielding blocks, graphite design assembly
115	1979–1982	6/60	N	1696.5	539	Hot trash, tritium scrap
118	1983–1984	8/62	N	3267.3	461	Vials
119	1983	8/62	N	3116.5	549	DU chips, hydrocarbons, HF leach solids
120	1983–1984	8/63	N	3116.6	531	Shielding blocks, graphite design assembly
121	1984–1985	4/60	N	753.9	245	Animal tissue, cell trash
122	1984–1985	4/60	N	753.9	258	Hot cell waste, waste cans
123	1984	6/60	N	1696.5	516	DU chips and turnings, firing residue
124	1984–1991	6/65	N	1837.7	491	Vials, organics
125	1984	6/65	N	1837.7	597	DU chips and turnings
126	1985–1987	6/65	N	1837.7	781	Meson and hot cell waste
127	1985	6/65	N	1837.7	484	DU chips and turnings, U3 08 oil and wax
128	1985–1986	6/65	N	1837.7	417	Animal tissue, mustargem
129	1986	3/65	N	459.4	136	Mixed spalation products
130	1986–1987	6/65	N	1837.7	1110	DU chips, metal trash
131	1987–1995	6/65	N	1837.7	438	Activated shielding
132	1987–1993	6/65	N	1837.7	634	Classified material
133	1986–1987	4/65	N	816.8	96	Spalation products, hot cell waste
134	1986	3/65	N	459.4	239	Animal tissue
135	1986–1987	3/65	N	459.4	219	Animal tissue
136	1986–1995	6/65	N	1837.7	50	Low-level tritium
138	1987–1989	4/60	N	753.9	191	Animal tissue
139	1987–1988	4/60	N	753.9	308	Hot cell waste
140	1987–1991	6/61	N	1724.7	869	Animal tissue
150	1976–1979	6/60	CMPAC[e]	1696.5	86	Low-level tritium

Table 2.1-3 (continued)

Shaft No.	Operational Period	Diameter/ Depth (ft)	Lining	Shaft Volume (ft^3)	Waste Volume (ft^3)	Waste Description
151	1979–1986	3/60	CMPAC	424.1	131	Low-level tritium
152	1980–1983	3/60	CMPAC	424.1	147	Tritium scrap, tubing, hardware
153	1983–1984	3/60	CMPAC	424.1	12	Contaminated pump, property numbers
154	1984–1986	3/65	CMPAC	459.4	135	High-level tritium, molecular sieves
155	1988–1989	3/65	CMPAC	459.4	137	High-level tritium
156	1986–1987	3/45	CMPAC	318.2	59	Dry box trash, molecular sieves
157	1987–1988	3/45	CMPAC	318.2	88	Tritium
158	1989–1998	2/45	CMPAC	141.2	78	High-level tritium
159	1989	2/45	CMPAC	141.2	12	High-level tritium
160	1990–1993	2/45	CMPAC	141.2	89	High-level tritium
189	1987–1988	8/65	N	3267.3	1743	LAMPF activated shielding (triple shaft)
190	1983–1984	8/65	N	3267.3	1077	Scrap metal
191	1984–1986	8/65	N	3267.3	1470	LAMPF scrap metal, graphite target (double shaft)
192	1987–1989	8/65	N	3267.3	1537	LAMPF scrap metal (triple shaft)
196	1989–1993	6/53	N	2997.5	2050	LAMPF inerts
200	1980–1981	1/18	SPI[f]	56.5	44	Hot cell wastes
201	1978–1979	1/18	SPI	56.5	39	Hot cell wastes
202	1980	1/18	SPI	56.5	43	Hot cell wastes
203	1980	1/18	SPI	56.5	43	Hot cell wastes
204	1978–1979	1/18	SPI	56.5	38	Hot cell wastes, fuel cans
205	1980	1/18	SPI	56.5	45	Hot cell wastes, trash, fuel cans
206	1980–1981	1/18	SPI	56.5	67	Cell trash and fuel sample
207	1981	1/18	SPI	56.5	48	Cell trash, fuel cells
208	1981	1/18	SPI	56.5	48	Hot cell trash, waste
209	1981	1/18	SPI	56.5	48	Hot cell paint, trash
210	1981	1/18	SPI	56.5	48	Hot cell trash
211	1981	1/18	SPI	56.5	48	Hot cell trash
212	1980	1/18	SPI	56.5	75	LAMPF fuel vessel
213	1981	1/18	SPI	56.5	30	Hot cell wastes, trash
214	1982	1/18	SPI	56.5	30	Hot cell wastes
215	1982	1/18	SPI	56.5	30	Hot cell trash
216	1982	1/18	SPI	56.5	30	Hot cell wastes
217	1982	1/18	SPI	56.5	30	Hot cell wastes
218	1982	1/18	SPI	56.5	30	Hot cell wastes
219	1983	1/18	SPI	56.5	30	Hot cell wastes
220	1983	1/18	SPI	56.5	30	Hot cell wastes
221	1983	1/18	SPI	56.5	30	Hot cell wastes

Table 2.1-3 (continued)

Shaft No.	Operational Period	Diameter/ Depth (ft)	Lining	Shaft Volume (ft^3)	Waste Volume (ft^3)	Waste Description
222	1983	1/18	SPI	56.5	30	Hot cell wastes
223	1983	1/18	SPI	56.5	30	Hot cell wastes
224	1985	1/18	SPI	56.5	4	Hot cell wastes
225	1984	1/18	SPI	56.5	4	Hot cell wastes
226	1984	1/18	SPI	56.5	4	Hot cell wastes
227	1984	1/18	SPI	56.5	4	Hot cell wastes
228	1987	1/18	SPI	56.5	1	Hot cell wastes
229	1984	1/18	SPI	56.5	5	Hot cell wastes
230	1984	1/18	SPI	56.5	4	Hot cell wastes
231	1985	1/18	SPI	56.5	4	Hot cell wastes
232	1987	1/18	SPI	56.5	1	Hot cell wastes
233	na	1/18	SPI	56.5	na	Hot cell wastes
C1	na	6/60	N	1696.5	221	PCBs (no liquids)
C2	na	6/60	N	1696.5	357	PCBs (no liquids)
C3	na	6/60	N	1696.5	339	PCBs (no liquids)
C4	na	6/60	N	1696.5	385	PCBs (no liquids)
C5	na	6/60	N	1696.5	258	PCBs (no liquids)
C6	na	6/60	N	1696.5	449	PCBs (no liquids)
C7	na	6/60	N	1696.5	512	PCBs (no liquids)
C8	na	6/60	N	1696.5	498	PCBs (no liquids)
C9	na	6/60	N	1696.5	406	PCBs (no liquids)
C10	1984–1985	6/60	N	1696.5	534	PCBs (no liquids)
C12	1986–1990	6/65	N	1696.5	588	PCBs (no liquids)
C13	1987–1995	6/65	N	1696.5	1060	PCBs (no liquids)

[a] N = No.

[b] DU = Depleted uranium.

[c] na = Not available.

[d] CMP = Corrugated metal pipe.

[e] CMPAC = Corrugated metal pipe asphalt coated.

[f] SPI = Steel pipe insert.

Table 2.2-1
Summary of Total Volumes and Activities of Radioactive Waste Disposed of or Stored at MDA G

Disposal Unit/ Waste Form	Pre-1971 Waste		1971–July 24, 1990 Waste		Retrievably Placed TRU Waste	
	Volume (m^3)	Activity (Ci)	Volume (m^3)	Activity (Ci)	Volume (m^3)	Activity (Ci)
Pits						
Surface-contaminated waste	4.2E+04	1.6E+04	6.0E+04	4.1E+04	1.5E+03	1.3E+05
Soils	6.1E+03	3.9E+01	3.4E+05	2.4E+01	3.3E+01	1.0E+00
Concrete and sludges	7.5E+03	2.8E+03	6.3E+03	8.2E+01	5.4E+02	1.1E+04
Bulk-contaminated waste	1.1E+01	7.8E-02	1.5E+03	5.5E+02	—*	—
Shafts						
Surface-contaminated waste	1.5E+02	3.6E+04	8.2E+02	8.8E+05	2.7E+01	3.5E+03
Soils	2.1E-02	0.0E+00	2.2E+01	1.0E+02	—	—
Concrete and sludges	4.4E-01	0.0E+00	7.1E-01	1.0E+02	—	—
Bulk-contaminated waste	5.3E-01	5.5E+01	1.4E+02	7.8E+03	—	—

*— = None of this type of waste was generated.

Table 2.2-2
Summary of Transuranic Waste at Area G

Area G Transuranic Waste	Transuranic Ci Disposed	Transuranic Ci for Removal and Disposal	Transuranic Activity To Be Removed as Percentage of Total Ci Activity
Post-1970			
TWISP-Remaining	0	113,050	50.46%
Pit 9	0	6,100	2.72%
Pit 29 corrugated metal pipes	0	10,775	4.81%
Trenches A-D	0	93,870	41.90%
Hot Cell Liners (Shafts 302-306)	0	1	0.00%
33 Lined Shafts (Shafts 200-232)	0	97	0.04%
16 WIPP Canisters (Shafts 236-243, 246-253)	0	137	0.06%
Tritium Torpedoes (Shafts 262-266)	0	8	0.00%
Total		224,038	100%

Table 2.3-1
Average Concentrations of VOCs in Ambient Air from SUMMA Canisters Collected at Area G

Analyte	Area G Location 1 Average Concentration		Area G Location 2 Average Concentration	
	ppb	mg/m^3	ppb	mg/m^3
Acetone	0.75	0.0018	0.56	0.0013
Benzaldehyde	—*	—	0.045	0.00020
Benzene	0.079	0.00025	0.12	0.00038
Carbon tetrachloride	0.019	0.00012	0.017	0.00011
Chlorodifluoromethane	0.20	0.00072	—	—
Chloromethane	0.13	0.00028	0.11	0.00024
Dichlorodifluoromethane	0.12	0.00058	0.085	0.00042
Freon 113	0.024	0.00018	0.017	0.00013
Methanol	8.1	0.011	0.48	0.00063
Toluene	0.19	0.00071	0.20	0.00076
TCA	0.20	0.0011	0.029	0.00016
Trichlorofluoromethane	0.084	0.00047	0.04	0.00023
Xylene	0.075	0.00033	0.13	0.00055

Note: Data corrected for seasonal variability.
* — = the VOC was detected in fewer than four samples.

Table 2.3-2
Range of 2001 Ambient-Air Concentrations Measured at Area G and at Regional Air Stations

Analyte	Area G Air Stations		Regional Air Stations	
	Lowest Annual Average (Station Number)	Highest Annual Average (Station Number)	Lowest Annual Average	Highest Annual Average
Plutonium-238	0.0 aCi/m^3 (35)	3.2 aCi/m^3 (34)	0.0 aCi/m^3	0.1 aCi/m^3
Plutonium-239	0.1 aCi/m^3 (36)	25.1 aCi/m^3 (34)	0.0 aCi/m^3	0.6 aCi/m^3
Americium-241	0.0 aCi/m^3 (35,36)	66.6 aCi/m^3 (34)	0.0 aCi/m^3	0.1 aCi/m^3
Uranium-234	10.6 aCi/m^3 (36)	48.0 aCi/m^3 (45)	10.0 aCi/m^3	31.8 aCi/m^3
Uranium-235	0.2 aCi/m^3 (36)	3.1 aCi/m^3 (45)	0.1 aCi/m^3	2.9 aCi/m^3
Uranium-238	16.4 aCi/m^3 (36)	50.7 aCi/m^3 (45)	7.4 aCi/m^3	31.2 aCi/m^3

Note: The abbreviation aCi indicates attocuries (10^{-8} curie).

Table 2.3-3
Frequency of Detected Organic Chemicals in MDA G Pore-Gas Samples from 1999 to 2002

Analyte	Number of Analyses	Number of Detects	Concentration Range[a] (ppbv[b])	Frequency of Detects
Acetone	46	7	[1]–[57000]	7/46
Acetonitrile	32	1	0.6–[11000]	1/32
Acetophenone	13	0	[50]–[500]	0/13
Acrolein	32	1	[1.2]–[5700]	1/32
Acrylonitrile	32	0	[1.2]–[5700]	0/32
Benzene	48	6	[0.48]–[2300]	6/48
Benzonitrile	13	0	[50]–[500]	0/13
Benzyl Chloride	39	0	[0.48]–[2300]	0/39
Bromodichloromethane	46	1	[0.48]–[2300]	1/46
Bromoform	46	0	[0.48]–[2300]	0/46
Bromomethane	48	0	[0.48]–[2300]	0/48
Butadiene[1,3-]	46	0	[0.48]–[2300]	0/46
Butane[n-]	32	10	[0.49]–[2300]	10/32
Butanol[1-]	46	2	[1]–[5700]	2/46
Butanone[2-]	46	3	[1.2]–[5700]	3/46
Butene[1-]	13	2	[3.7]–[102]	2/13
Butene[cis-2-]	13	6	0.8–[50]	6/13
Butene[trans-2-]	13	3	4.4–[50]	3/13
Carbon Disulfide	46	1	[0.48]–[2300]	1/46
Carbon Tetrachloride	48	6	[0.48]–[2300]	6/48
Chloro-1,3-butadiene[2-]	13	0	[5]–[50]	0/13
Chloro-1-propene[3-]	32	0	[0.48]–[2300]	0/32
Chlorobenzene	48	0	[0.48]–[2300]	0/48
Chlorodibromomethane	46	1	[0.48]–[2300]	1/46
Chlorodifluoromethane	41	8	[0.4]–[2300]	8/41
Chloroethane	48	6	[0.48]–[2300]	6/48
Chloroform	48	13	[0.5]–[2300]	13/48
Chloromethane	48	1	[0.84]–[5700]	1/48
Cyclohexane	46	6	[0.5]–[5700]	6/46
Cyclohexanone	13	0	[50]–[500]	0/13
Cyclopentane	13	1	1.4–[50]	1/13
Cyclopentene	12	0	[5]–[50]	0/12
Decane[n-]	19	0	[0.48]–[2300]	0/19
Dibromoethane[1,2-]	39	1	[0.48]–[2300]	1/39
Dibromomethane	19	1	[0.48]–[2300]	1/19
Dichloro-1,1,2,2-tetrafluoroethane[1,2-]	39	2	[0.48]–[2300]	2/39
Dichlorobenzene[1,2-]	48	0	[0.48]–[2300]	0/48

Table 2.3-3 (continued)

Analyte	Number of Analyses	Number of Detects	Concentration Range[a] (ppbv[b])	Frequency of Detects
Dichlorobenzene[1,3-]	48	0	[0.48]–[2300]	0/48
Dichlorobenzene[1,4-]	48	0	[0.4]–[2300]	0/48
Dichlorodifluoromethane	39	28	6–[2300]	28/39
Dichloroethane[1,1-]	48	44	0.26–6100	44/48
Dichloroethane[1,2-]	48	7	[0.48]–[2300]	7/48
Dichloroethene[1,1-]	48	43	[0.49]–14000	43/48
Dichloroethene[cis-1,2-]	48	8	0.4–[2300]	8/48
Dichloroethene[trans-1,2-]	46	2	[0.48]–[2300]	2/46
Dichloropropane[1,2-]	48	2	[0.48]–[2300]	2/48
Dichloropropane[1,3-]	1	0	[10]–[10]	0/1
Dichloropropene[cis-1,3-]	48	0	[0.48]–[2300]	0/48
Dichloropropene[trans-1,3-]	48	0	[0.48]–[2300]	0/48
Diethyl Ether	32	0	[1.2]–[5700]	0/32
Dimethylbutane[2,2-]	13	4	1.8–[50]	4/13
Dimethylbutane[2,3-]	13	0	[5]–[50]	0/13
Dimethylpentane[2,3-]	13	2	0.2–[50]	2/13
Dioxane[1,4-]	27	0	[3.4]–[1400]	0/27
Dodecane[n-]	19	0	[0.48]–[2300]	0/19
Ethanol	27	5	[3.4]–18000	5/27
Ethyl Acrylate	13	0	[50]–[500]	0/13
Ethyl tert-Butyl Ether	13	0	[50]–[500]	0/13
Ethylbenzene	48	0	[0.48]–[2300]	0/48
Ethyltoluene[4-]	5	0	[29]–[1300]	0/5
Hexachlorobutadiene	48	4	[0.48]–[2300]	4/48
Hexane	46	4	0.4–[2300]	4/46
Hexanone[2-]	46	0	[1.2]–[5700]	0/46
Hexene[cis-3-]	13	0	[5]–[50]	0/13
Hexene[trans-2-]	13	0	[5]–[50]	0/13
Isobutane	13	7	2.4–297	7/13
Isooctane	13	1	0.2–[50]	1/13
Isopentane	13	8	[5]–[50]	8/13
Isoprene	13	0	[5]–[50]	0/13
Isopropylbenzene	32	0	[0.48]–[2300]	0/32
Methacrylonitrile	13	0	[50]–[500]	0/13
Methanol	46	6	[6.3]–[110000]	6/46
Methyl Methacrylate	13	0	[50]–[500]	0/13
Methyl tert-Butyl Ether	46	0	[1.2]–[5700]	0/46
Methyl-1-butene[3-]	13	1	0.4–[50]	1/13
Methyl-1-pentene[2-]	13	0	[5]–[50]	0/13
Methyl-1-pentene[4-]	13	0	[5]–[50]	0/13
Methyl-2-butene[2-]	13	2	[0.6]–[50]	2/13

Table 2.3-3 (continued)

Analyte	Number of Analyses	Number of Detects	Concentration Range[a] (ppbv[b])	Frequency of Detects
Methyl-2-pentanone[4-]	46	0	[1.2]–[5700]	0/46
Methylcyclohexane	13	4	0.9–[50]	4/13
Methylcyclopentane	13	7	1.4–[50]	7/13
Methylene Chloride	48	20	[0.49]–48000	20/48
Methylheptane[2-]	13	0	[5]–[50]	0/13
Methylheptane[3-]	13	0	[5]–[50]	0/13
Methylhexane[2-]	13	0	[5]–[50]	0/13
Methylhexane[3-]	13	0	[0.4]–[50]	0/13
Methylpentane[2-]	13	5	0.5–[50]	5/13
Methylpentane[3-]	13	5	1.9–[50]	5/13
Methylstyrene[alpha-]	32	0	[0.48]–[2300]	0/32
Naphthalene	19	1	[0.48]–2700	1/19
n-Heptane	46	1	[0.48]–[2300]	1/46
Nitrobenzene	13	0	[50]–[500]	0/13
Nitropropane[2-]	13	1	0.5–[500]	1/13
Nonane[1-]	32	0	[0.48]–[2300]	0/32
Octane[n-]	32	0	[0.48]–[2300]	0/32
Pentane	32	7	[0.1]–[5700]	7/32
Pentene[1-]	13	0	[1]–[50]	0/13
Pentene[cis-2-]	13	0	[5]–[50]	0/13
Pentene[trans-2-]	13	0	[5]–[50]	0/13
Pinene[alpha-]	13	0	[5]–[50]	0/13
Pinene[beta-]	13	1	[5]–120	1/13
Propanol[2-]	27	4	0.4–4500	4/27
Propionitrile	13	0	[50]–[500]	0/13
Propylbenzene[1-]	32	0	[0.48]–[2300]	0/32
Propylene	27	6	[3.4]–[1400]	6/27
Styrene	48	2	[0.48]–[2300]	2/48
Tetrachloroethane[1,1,2,2-]	48	0	[0.48]–[2300]	0/48
Tetrachloroethene	48	43	0.41–[2300]	43/48
Tetrahydrofuran	27	0	[3.4]–[1400]	0/27
Toluene	48	10	0.1–[2300]	10/48
Trichloro-1,2,2-trifluoroethane[1,1,2-]	48	33	2.1–15000	33/48
Trichlorobenzene[1,2,4-]	48	3	[0.48]–[2300]	3/48
Trichloroethane[1,1,1-]	48	48	7.5–167000	48/48
Trichloroethane[1,1,2-]	48	5	[0.48]–[2300]	5/48
Trichloroethene	48	39	0.37–3600	39/48
Trichlorofluoromethane	39	25	11–[2300]	25/39
Trimethylbenzene[1,2,4-]	48	0	[0.1]–[2300]	0/48
Trimethylbenzene[1,3,5-]	48	0	[0.48]–[2300]	0/48
Trimethylpentane[2,3,4-]	13	0	[5]–[50]	0/13

Table 2.3-3 (continued)

Analyte	Number of Analyses	Number of Detects	Concentration Range[a] (ppbv[b])	Frequency of Detects
Undecane[n-]	19	0	[0.48]–[2300]	0/19
Vinyl acetate	46	1	0.81–[5700]	1/46
Vinyl Chloride	48	0	[0.48]–[2300]	0/48
Xylene (Total)	21	0	[0.48]–[2000]	0/21
Xylene[1,2-]	48	1	[0.48]–[2300]	1/48
Xylene[1,3-]	13	0	[5]–[50]	0/13
Xylene[1,3-]+Xylene[1,4-]	14	0	[0.49]–[2300]	0/14

[a] Square brackets indicate detection limits for nondetected results.
[b] ppbv = Parts per billion by volume.

Table 2.3-4
2003 Pore-Gas Tritium Results for
MDA G Borehole Locations 54-01110 and 54-01111

Borehole	Sample ID	Depth (ft bgs)	Tritium (pCi/L)	Qualifier
54-01110	MD54-03-50390	20	5.85E+06	J+
54-01110	MD54-03-50391	48	6.83E+06	J+
54-01110	MD54-03-50392	60	1.63E+05	J+
54-01110	MD54-03-50393	70	2.67E+05	J+
54-01110	MD54-03-50394	85	3.38E+07	J+
54-01110	MD54-03-50395	90	5.27E+07	J+
54-01111	MD54-03-50396	20	8.82E+07	J+
54-01111	MD54-03-50397	39.5	1.24E+07	J+
54-01111	MD54-03-50398	50	3.01E+07	J+
54-01111	MD54-03-50399	70	1.50E+09	J+
54-01111	MD54-03-50403	70	1.43E+08	J+
54-01111	MD54-03-50400	78	3.83E+09	J+
54-01111	MD54-03-50402	100	1.65E+09	J+
54-01111	MD54-03-50401	139	1.58E+08	J+

Table 2.3-5
Fracture Sample Summary for Boreholes at MDA G

Borehole ID	Borehole Location	Sample ID	Media Code	Begin Depth (ft)	End Depth (ft)	Sample Description	Notes
BH 3	54-24362	MD54-05-57887	Qbt 2	35	40	Fracture (38–40 ft) filled with clay	Sample represents base of closest disposal unit
		MD54-05-57894					Duplicate of MD54-05-57887
BH 4	54-24363	MD54-05-57896	Qbt 2	42.8	45.2	Clay-filled fracture	Did not collect a paired sample above fracture because a sample was collected at 31.8–35.4 ft
BH 9	54-24369	MD54-05-57960	Qbt 2	65	70	2–3-mm-thick clay-filled fracture	Sample represents base of closest disposal unit
		MD54-05-57967					Duplicate of MD54-05-57967
BH 15	54-24375	MD54-05-58014	Qbt 2	62	64	Tuff sample collected above fracture	Paired fracture sample
		MD54-05-58015		64	65	1–2-mm-thick mud-filled fracture	
BH 25	54-24385	MD54-05-58103	Qbt 2	30	35	Fracture (31.8–32.0 ft) filled with 0.1 mm clay coating	Sample represents base of closest disposal unit
		MD54-05-58110					Duplicate of MD54-05-58103
BH 26	54-24386	MD54-05-58117	Qbt 2	56	58	Tuff sample collected above fracture	Paired fracture sample
		MD54-05-58118		58	59	2-mm-thick silt-filled fracture	
BH 30	54-24390	MD54-05-58149	Qbt 2	56	57	Fracture from 56–57 ft	Not enough material in core barrel to collect sample above the fracture
		MD54-05-58150	Qbt 1v	93	94	Tuff sample collected above fracture	Paired fracture sample
		MD54-05-58151		94	95	1–2-mm-thick clay-filled fracture	
BH 34	54-24394	MD54-05-58186	Qbt 2	50	55	Fracture (50–55 ft) filled with 3-mm-thick clay and organic material	Did not collect sample above fracture because a sample was collected at 40–45 ft
		MD54-05-58187	Qbt 1v	100	102	Tuff sample collected above fracture	Paired fracture sample

Table 2.3-6
VOCs Detected in 2005 Pore-Gas Samples Collected from MDA G

Borehole Location	Depth (ft)	Sample ID	Analyte	Result (µg/m³)
54-24361	30–32	MD54-05-60283	Chloroform	234
			Dichloroethane[1,1-]	688
			Dichloroethene[1,1-]	436
			Tetrachloroethene	9490
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	3140 (J)
			Trichloroethane[1,1,1-]	14700
			Trichloroethene	53700
	138–140	MD54-05-60282	Chloroform	381
			Dichloroethane[1,1-]	1130
			Dichloroethene[1,1-]	832
			Tetrachloroethene	3320
			Toluene	267
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	1460 (J)
			Trichloroethane[1,1,1-]	13600
			Trichloroethene	29000
54-24362	35–37	MD54-05-60285	Carbon Tetrachloride	32.0
			Chloroform	100
			Dichlorodifluoromethane	2400
			Dichloroethane[1,1-]	260
			Dichloroethene[1,1-]	330
			Styrene	45.0
			Tetrachloroethene	1100
			Toluene	400
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	1200
			Trichloroethane[1,1,1-]	8200
			Trichloroethene	6500
			Trichlorofluoromethane	130
	135–137	MD54-05-60284	Acetone	64.1 (J)
			Chloroform	151
			Dichloroethane[1,1-]	526
			Dichloroethene[1,1-]	753
			Methylene Chloride	55.5
			Styrene	51.1
			Tetrachloroethene	1150
			Toluene	324
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	3060 (J+)

Table 2.3-6 (continued)

Borehole Location	Depth (ft)	Sample ID	Analyte	Result (µg/m³)
54-24362 (continued)			Trichloroethane[1,1,1-]	10900
			Trichloroethene	5260
			Trichlorofluoromethane	286
54-24363	12–250	MD54-05-60286	Toluene	240
			Carbon Disulfide	2.9
			Chloroform	5.2
			Dichlorodifluoromethane	13
			Dichloroethane[1,1-]	11
			Dichloroethene[1,1-]	46
			Styrene	10
			Butanone[2-]	5
			Tetrachloroethene	96
			Acetone	70
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	120
			Trichloroethane[1,1,1-]	900
			Trichloroethene	45
			Trichlorofluoromethane	6.6
			Xylene[1,3-]+Xylene[1,4-]	8.4
54-24364	65–67	MD54-05-60289	Dichloroethane[1,1-]	129
			Dichloroethene[1,1-]	384
			Dichloropropane[1,2-]	25.9
			Methylene Chloride	29.9
			Tetrachloroethene	1760
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	1840 (J)
			Trichloroethane[1,1,1-]	5340
			Trichloroethene	2850
			Trichlorofluoromethane	225
	130–132	MD54-05-60288	Acetone	102
			Dichloroethane[1,1-]	105
			Dichloroethene[1,1-]	384
			Dichloropropane[1,2-]	42.0
			Methylene Chloride	45.1
			Tetrachloroethene	1290
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	1300 (J)
			Trichloroethane[1,1,1-]	4040
			Trichloroethene	1830
			Trichlorofluoromethane	180

Table 2.3-6 (continued)

Borehole Location	Depth (ft)	Sample ID	Analyte	Result (µg/m³)
54-24366	12–250	MD54-05-60290	Trichloroethane[1,1,1-]	29
			Acetone	17
			Toluene	20
54-24367	30–32	MD54-05-60293	Dichloroethane[1,1-]	259
			Dichloroethene[1,1-]	396
			Styrene	63.9
			Tetrachloroethene	481
			Toluene	527
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	2070 (J+)
			Trichloroethane[1,1,1-]	13100
			Trichloroethene	1290
			Trichlorofluoromethane	399
	153–155	MD54-05-60292	Dichloroethane[1,1-]	809
			Dichloroethene[1,1-]	2540
			Styrene	111
			Tetrachloroethene	881
			Toluene	1170
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	6360 (J+)
			Trichloroethane[1,1,1-]	31600
			Trichloroethene	2420
			Trichlorofluoromethane	483
54-24368	95–97	MD54-05-60295	Dichlorodifluoromethane	310
			Dichloroethane[1,1-]	660
			Dichloroethene[1,1-]	1900
			Styrene	160
			Tetrachloroethene	290
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	7100
			Trichloroethane[1,1,1-]	42000
			Trichloroethene	480
			Trichlorofluoromethane	770
	192–194	MD54-05-60294	Dichlorodifluoromethane	390
			Dichloroethane[1,1-]	430
			Dichloroethene[1,1-]	1600
			Propanol[2-]	210
			Styrene	500
			Tetrachloroethene	280
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	4000
			Trichloroethane[1,1,1-]	22000

Table 2.3-6 (continued)

Borehole Location	Depth (ft)	Sample ID	Analyte	Result (µg/m³)
54-24368 (continued)			Trichloroethene	470
			Trichlorofluoromethane	820
54-24369	65–67	MD54-05-61743	Dichlorodifluoromethane	2800
			Dichloroethane[1,1-]	2800
			Dichloroethene[1,1-]	4800
			Tetrachloroethene	3600
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	18000
			Trichloroethane[1,1,1-]	120000
			Trichloroethene	3200
			Trichlorofluoromethane	2500
	184–186	MD54-05-61742	Dichlorodifluoromethane	1000
			Dichloroethane[1,1-]	490
			Dichloroethene[1,1-]	1100
			Tetrachloroethene	500
			Toluene	140
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	3800
			Trichloroethane[1,1,1-]	20000
			Trichloroethene	500
			Trichlorofluoromethane	780
54-24370	37–39	MD54-05-60299	Dichlorodifluoromethane	10400
			Dichloroethene[1,1-]	2730
			Dichloroethene[cis-1,2-]	388
			Tetrachloroethene	1020
			Toluene	791
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	48300 (J+)
			Trichloroethane[1,1,1-]	92700
			Trichloroethene	12400
			Trichlorofluoromethane	10100
	148–150	MD54-05-60298	Dichlorodifluoromethane	12400
			Dichloroethane[1,1-]	6880
			Dichloroethene[1,1-]	3290
			Dichloroethene[cis-1,2-]	396
			Methylene Chloride	312
			Styrene	179
			Tetrachloroethene	624
			Toluene	1130
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	33700 (J+)
			Trichloroethane[1,1,1-]	65400

Table 2.3-6 (continued)

Borehole Location	Depth (ft)	Sample ID	Analyte	Result (µg/m³)
54-24370 (continued)			Trichloroethene	6980
			Trichlorofluoromethane	7300
54-24371	40–42	MD54-05-61745	Butanone[2-]	72.0
			Chloroform	100
			Dichlorodifluoromethane	730
			Dichloroethane[1,1-]	760
			Dichloroethene[1,1-]	290
			Methyl-2-pentanone[4-]	29.0
			Styrene	120
			Tetrachloroethene	460
			Toluene	4400
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	12000
			Trichloroethane[1,1,1-]	9100
			Trichloroethene	2400
			Trichlorofluoromethane	1300
	141–143	MD54-05-61744	Acetone	46.0
			Butanone[2-]	84.0
			Chloroform	92.0
			Dichlorodifluoromethane	690
			Dichloroethane[1,1-]	720
			Dichloroethene[1,1-]	330
			Methyl-2-pentanone[4-]	28.0
			Methylene Chloride	17.0
			Styrene	100
			Tetrachloroethene	410
			Toluene	4400
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	5900
			Trichloroethane[1,1,1-]	7500
			Trichloroethene	2600
			Trichlorofluoromethane	1200
54-24372	55–57	MD54-05-61747	Acetone	30.0
			Butanone[2-]	28.0
			Dichlorodifluoromethane	180
			Dichloroethane[1,1-]	25.0
			Dichloroethene[1,1-]	38.0
			Methyl-2-pentanone[4-]	10.0
			Styrene	90.0
			Tetrachloroethene	190

Table 2.3-6 (continued)

Borehole Location	Depth (ft)	Sample ID	Analyte	Result (µg/m³)
54-24372 (continued)			Toluene	1800
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	130
			Trichloroethane[1,1,1-]	970
			Trichloroethene	200
			Trichlorofluoromethane	360
	185–187	MD54-05-61746	Acetone	21.0
			Butanone[2-]	22.0
			Dichlorodifluoromethane	86.0
			Dichloroethane[1,1-]	25.0
			Dichloroethene[1,1-]	47.0
			Methyl-2-pentanone[4-]	10.0
			Methylene Chloride	57.0
			Styrene	95.0
			Tetrachloroethene	180
			Toluene	1400
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	63.0
			Trichloroethane[1,1,1-]	750
			Trichloroethene	210
			Trichlorofluoromethane	150
			Xylene[1,3-]+Xylene[1,4-]	7.40
54-24373	65–67	MD54-05-60305	Acetone	128
			Butanone[2-]	3.83
			Chloroform	9.76
			Dichlorodifluoromethane	939
			Dichloroethane[1,1-]	13.8
			Dichloroethene[1,1-]	31.7
			Dichloropropane[1,2-]	55.4
			Methylene Chloride	149
			Tetrachloroethene	94.9
			Toluene	3.50
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	605
			Trichloroethane[1,1,1-]	1200
			Trichloroethene	69.8
			Trichlorofluoromethane	1460
	187–189	MD54-05-60304	Acetone	28.5
			Dichlorodifluoromethane	203
			Dichloroethene[1,1-]	5.55
			Dichloropropane[1,2-]	9.24

Table 2.3-6 (continued)

Borehole Location	Depth (ft)	Sample ID	Analyte	Result (µg/m³)
54-24373 (continued)			Methylene Chloride	25.0
			Tetrachloroethene	18.3
			Toluene	4.90
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	115
			Trichloroethane[1,1,1-]	229
			Trichloroethene	10.2
			Trichlorofluoromethane	270
54-24374	10–12	MD54-05-60306	Dichloroethane[1,1-]	117
			Methylene Chloride	41.7
			Tetrachloroethene	217
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	4290 (J)
			Trichloroethane[1,1,1-]	8720
			Trichloroethene	193
			Trichlorofluoromethane	101
	139–141	MD54-05-60307	Acetone	228
			Dichloroethane[1,1-]	93.0
			Dichloroethene[1,1-]	365
			Dichloropropane[1,2-]	69.3
			Methylene Chloride	29.5
			Tetrachloroethene	183
			Toluene	32.0
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	1990 (J)
			Trichloroethane[1,1,1-]	5180
			Trichloroethene	274
			Trichlorofluoromethane	101
54-24375	30–32	MD54-05-60309	Dichloroethane[1,1-]	485
			Dichloroethene[1,1-]	1470
			Tetrachloroethene	11500
			Toluene	181
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	9190 (J)
			Trichloroethane[1,1,1-]	43100
			Trichloroethene	1130
			Trichlorofluoromethane	500
	157–159	MD54-05-60308	Dichloroethane[1,1-]	380
			Dichloroethene[1,1-]	1820
			Methylene Chloride	104
			Tetrachloroethene	11500
			Toluene	162

Table 2.3-6 (continued)

Borehole Location	Depth (ft)	Sample ID	Analyte	Result (µg/m³)
54-24375 (continued)			Trichloro-1,2,2-trifluoroethane[1,1,2-]	8420 (J)
			Trichloroethane[1,1,1-]	36000
			Trichloroethene	1400
			Trichlorofluoromethane	511
54-24376	35–37	MD54-05-60311	Dichloroethane[1,1-]	129
			Dichloroethene[1,1-]	246
			Styrene	93.7
			Tetrachloroethene	149
			Toluene	565
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	1230 (J+)
			Trichloroethane[1,1,1-]	6000
			Trichloroethene	258
			Trichlorofluoromethane	78.6
	158–160	MD54-05-60310	Acetone	49.9
			Butanone[2-]	5.89
			Dichloroethane[1,1-]	64.7
			Dichloroethene[1,1-]	166
			Methyl-2-pentanone[4-]	16.4
			Styrene	119
			Tetrachloroethene	74.6
			Toluene	1020
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	421 (J+)
			Trichloroethane[1,1,1-]	2340
			Trichloroethene	161
			Trichlorofluoromethane	33.7
54-24377	45–47	MD54-05-60313	Dichloroethane[1,1-]	76.9
			Dichloroethene[1,1-]	234
			Methylene Chloride	12.8
			Styrene	123
			Tetrachloroethene	122
			Toluene	603
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	1380 (J+)
			Trichloroethane[1,1,1-]	3540
			Trichloroethene	215
			Trichlorofluoromethane	73.0
	150–152	MD54-05-60312	Acetone	57.0
			Butanone[2-]	9.43
			Dichloroethane[1,1-]	48.5

Table 2.3-6 (continued)

Borehole Location	Depth (ft)	Sample ID	Analyte	Result (µg/m³)
54-24377 (continued)			Dichloroethene[1,1-]	178
			Methyl-2-pentanone[4-]	19.2
			Methylene Chloride	8.33
			Styrene	145
			Tetrachloroethene	67.8
			Toluene	1280
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	758 (J+)
			Trichloroethane[1,1,1-]	2020
			Trichloroethene	134
			Trichlorofluoromethane	43.2
			Xylene[1,3-]+Xylene[1,4-]	13.0
54-24378	30–32	MD54-05-60315	Dichloroethane[1,1-]	7280
			Dichloroethene[1,1-]	5550
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	22200 (J)
			Trichloroethane[1,1,1-]	464000
			Trichloroethene	4080
	136–138	MD54-05-60314	Dichloroethane[1,1-]	12900
			Dichloroethene[1,1-]	13900
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	28300 (J)
			Trichloroethane[1,1,1-]	709000
			Trichloroethene	7520
54-24379	20–22	MD54-05-60317	Dichloroethane[1,1-]	1460
			Dichloroethene[1,1-]	3650
			Tetrachloroethene	664
			Toluene	279
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	375 (J)
			Trichloroethane[1,1,1-]	32700
			Trichloroethene	1240
	144–146	MD54-05-60316	Dichloroethane[1,1-]	6070
			Dichloroethene[1,1-]	15100
			Tetrachloroethene	2030
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	1530 (J)
			Trichloroethane[1,1,1-]	98200
			Trichloroethene	4780
54-24380	20–22	MD54-05-60319	Chloroform	1850
			Dichloroethane[1,1-]	295
			Dichloroethene[1,1-]	396
			Tetrachloroethene	813

Table 2.3-6 (continued)

Borehole Location	Depth (ft)	Sample ID	Analyte	Result (µg/m³)
54-24380 (continued)			Toluene	128
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	2990 (J+)
			Trichloroethane[1,1,1-]	14700
			Trichloroethene	3440
			Trichlorofluoromethane	163
	155–157	MD54-05-60318	Chloroform	683
			Dichloroethane[1,1-]	445
			Dichloroethene[1,1-]	753
			Methylene Chloride	79.8
			Styrene	76.6
			Tetrachloroethene	813
			Toluene	716
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	2990 (J+)
			Trichloroethane[1,1,1-]	16900
			Trichloroethene	4030
			Trichlorofluoromethane	236
54-24381	15–17	MD54-05-60321	Dichloroethane[1,1-]	1660
			Dichloroethene[1,1-]	3800
			Tetrachloroethene	949
			Toluene	309
			Trichloroethane[1,1,1-]	54500
			Trichloroethene	462
	143–145	MD54-05-60320	Dichloroethane[1,1-]	1780
			Dichloroethene[1,1-]	5150
			Tetrachloroethene	746
			Toluene	377
			Trichloroethane[1,1,1-]	51300
			Trichloroethene	537
54-24382	28–29	MD54-05-60323	Chloroform	57.0
			Dichloroethane[1,1-]	950
			Dichloroethene[1,1-]	1100
			Ethanol	59.0 (J)
			Tetrachloroethene	310
			Trichloroethane[1,1,1-]	8400
			Trichloroethene	90.0
	107–109	MD54-05-60322	Acetone	83.0 (J)
			Butanone[2-]	8.50
			Chloroform	8.60

Table 2.3-6 (continued)

Borehole Location	Depth (ft)	Sample ID	Analyte	Result (µg/m³)
54-24382 (continued)			Dichloroethane[1,1-]	180
			Dichloroethane[1,2-]	9.00
			Dichloroethene[1,1-]	170
			Methylene Chloride	5.30
			n-Heptane	8.90
			Propanol[2-]	47.0
			Styrene	400
			Tetrachloroethene	37.0
			Toluene	44.0
			Trichloroethane[1,1,1-]	1100
			Trichloroethene	18.0
			Vinyl Chloride	2.90
			Xylene[1,3-]+Xylene[1,4-]	15.0
54-24383	10–11	MD54-05-60324	Acetone	23.0 (J)
			Butanol[1-]	13.0
			Butanone[2-]	4.30
			Dichloroethane[1,1-]	7.60
			Dichloroethene[1,1-]	13.0
			Ethyltoluene[4-]	13.0
			Styrene	8.10
			Trichloroethane[1,1,1-]	80.0
			Trimethylbenzene[1,2,4-]	10.0
			Xylene[1,3-]+Xylene[1,4-]	13.0
	107–109	MD54-05-60359	Acetone	27.0 (J)
			Butanone[2-]	2.80
			Dichloroethane[1,1-]	52.0
			Dichloroethene[1,1-]	95.0
			Propanol[2-]	8.90
			Styrene	220
			Tetrachloroethene	44.0
			Toluene	30.0
			Trichloroethane[1,1,1-]	440
			Trichloroethene	12.0
			Xylene[1,3-]+Xylene[1,4-]	8.40
54-24384	10–12	MD54-05-60327	Acetone	58.0 (J)
			Dichloroethane[1,1-]	4.40
			Dichloroethene[1,1-]	9.20
			Propanol[2-]	77.0

Table 2.3-6 (continued)

Borehole Location	Depth (ft)	Sample ID	Analyte	Result ($\mu g/m^3$)
54-24384 (continued)			Styrene	130
			Toluene	32.0
			Trichloroethane[1,1,1-]	68.0
			Trichloroethene	47.0
			Xylene[1,3-]+Xylene[1,4-]	12.0
	65–67	MD54-05-60326	Acetone	112
			Dichloroethane[1,1-]	113
			Dichloroethene[1,1-]	285
			Hexane	5.64
			Methyl-2-pentanone[4-]	16.8
			Tetrachloroethene	42.0
			Toluene	10.2
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	60.5
			Trichloroethane[1,1,1-]	1960
			Trichloroethene	41.9
			Xylene[1,3-]+Xylene[1,4-]	16.5
54-24385	30–32	MD54-05-60329	Dichloroethane[1,1-]	3880
			Dichloroethene[1,1-]	5550
			Tetrachloroethene	5630
			Toluene	162
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	1070 (J+)
			Trichloroethane[1,1,1-]	65400
			Trichloroethene	859
	134–136	MD54-05-60328	Dichloroethane[1,1-]	5660
			Dichloroethene[1,1-]	8320
			Tetrachloroethene	4880
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	1070 (J+)
			Trichloroethane[1,1,1-]	70900
			Trichloroethene	1130
54-24386	35–37	MD54-05-60331	Dichloroethane[1,1-]	4040
			Dichloroethene[1,1-]	4750
			Tetrachloroethene	1150
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	996 (J+)
			Trichloroethane[1,1,1-]	98200
			Trichloroethene	1020
	156–158	MD54-05-60330	Dichloroethane[1,1-]	33200
			Dichloroethene[1,1-]	59400
			Tetrachloroethene	5490

Table 2.3-6 (continued)

Borehole Location	Depth (ft)	Sample ID	Analyte	Result (µg/m³)
54-24386 (continued)			Trichloro-1,2,2-trifluoroethane[1,1,2-]	5440 (J+)
			Trichloroethane[1,1,1-]	447000
			Trichloroethene	8590
54-24387	10–11	MD54-05-60333	Acetone	51.0 (J)
			Butanone[2-]	5.50
			Dichloroethene[1,1-]	5.00
			Ethyltoluene[4-]	13.0
			Styrene	16.0
			Toluene	7.80
			Trichloroethane[1,1,1-]	41.0
			Trichloroethene	20.0
			Trimethylbenzene[1,2,4-]	23.0
			Trimethylbenzene[1,3,5-]	5.50
			Xylene[1,2-]	5.80
			Xylene[1,3-]+Xylene[1,4-]	14.0
	80–82	MD54-05-60332	Acetone	123
			Butanone[2-]	9.43
			Dichloroethane[1,1-]	5.66
			Dichloroethene[1,1-]	7.53
			Ethanol	9.04
			Hexane	7.75
			Methyl-2-pentanone[4-]	9.83
			Toluene	13.9
			Trichloroethane[1,1,1-]	65.4
			Trichloroethene	29.0
			Trimethylbenzene[1,2,4-]	4.91
			Xylene[1,3-]+Xylene[1,4-]	20.8
54-24388	25–27	MD54-05-60335	Dichloroethane[1,1-]	2180
			Dichloroethene[1,1-]	2810
			Tetrachloroethene	2030
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	5590 (J)
			Trichloroethane[1,1,1-]	125000
			Trichloroethene	2850
	129–131	MD54-05-60334	Dichloroethane[1,1-]	2670
			Dichloroethene[1,1-]	5150
			Tetrachloroethene	1970
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	7350 (J)

Table 2.3-6 (continued)

Borehole Location	Depth (ft)	Sample ID	Analyte	Result (µg/m³)
54-24388 (continued)			Trichloroethane[1,1,1-]	125000
			Trichloroethene	4190
54-24389	20–22	MD54-05-60337	Acetone	13.0 (J)
			Butanone[2-]	15.0
			Carbon Tetrachloride	16.0
			Chloroform	21.0
			Dichlorodifluoromethane	22.0
			Dichloroethane[1,1-]	28.0
			Dichloroethene[1,1-]	82.0
			Methyl-2-pentanone[4-]	7.90
			Styrene	85.0
			Tetrachloroethene	630
			Toluene	1200
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	320
			Trichloroethane[1,1,1-]	1700
			Trichloroethene	460
			Trichlorofluoromethane	12.0
			Xylene[1,3-]+Xylene[1,4-]	6.60
	147–149	MD54-05-60336	Acetone	35.0 (J)
			Butanone[2-]	28.0
			Carbon Tetrachloride	23.0
			Chloroform	42.0
			Dichlorodifluoromethane	110
			Dichloroethane[1,1-]	92.0
			Dichloroethene[1,1-]	310
			Methyl-2-pentanone[4-]	14.0
			Methylene Chloride	27.0
			Styrene	70.0
			Tetrachloroethene	920
			Toluene	2600
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	590
			Trichloroethane[1,1,1-]	3700
			Trichloroethene	1100
			Trichlorofluoromethane	57.0
54-24390	30–32	MD54-05-60339	Dichloroethane[1,1-]	2180
			Dichloroethene[1,1-]	3250
			Tetrachloroethene	1360
			Toluene	365

Table 2.3-6 (continued)

Borehole Location	Depth (ft)	Sample ID	Analyte	Result (µg/m³)
54-24390 (continued)			Trichloro-1,2,2-trifluoroethane[1,1,2-]	21400 (J)
			Trichloroethane[1,1,1-]	142000
	158–160	MD54-05-60338	Dichloroethane[1,1-]	1420
			Dichloroethene[1,1-]	3680
			Tetrachloroethene	2370
			Toluene	678
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	19100 (J)
			Trichloroethane[1,1,1-]	109000
			Trichloroethene	644
54-24391	25–27	MD54-05-60341	Dichloroethane[1,1-]	324
			Dichloroethene[1,1-]	325
			Styrene	97.9
			Tetrachloroethene	2780
			Toluene	377
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	1530 (J+)
			Trichloroethane[1,1,1-]	22400
			Trichloroethene	140
			Trichlorofluoromethane	432
	165–167	MD54-05-60340	Dichloroethane[1,1-]	186
			Dichloroethene[1,1-]	475
			Styrene	72.4
			Tetrachloroethene	949
			Toluene	829
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	1150 (J+)
			Trichloroethane[1,1,1-]	7630
			Trichloroethene	193
			Trichlorofluoromethane	376
54-24392	25–27	MD54-05-60343	Acetone	13.0 (J)
			Butanone[2-]	12.0
			Dichlorodifluoromethane	20.0
			Dichloroethane[1,1-]	14.0
			Dichloroethene[1,1-]	40.0
			Methyl-2-pentanone[4-]	6.40
			Styrene	60.0
			Tetrachloroethene	140
			Toluene	880
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	31.0
			Trichloroethane[1,1,1-]	580

Table 2.3-6 (continued)

Borehole Location	Depth (ft)	Sample ID	Analyte	Result (µg/m³)
54-24392 (continued)			Trichloroethene	150
			Trichlorofluoromethane	12.0
			Xylene[1,3-]+Xylene[1,4-]	4.60
	144–146	MD54-05-60342	Acetone	36.0 (J)
			Butanone[2-]	18.0
			Carbon Disulfide	4.50
			Chloroform	10.0
			Dichlorodifluoromethane	100
			Dichloroethane[1,1-]	35.0
			Dichloroethene[1,1-]	170
			Methyl-2-pentanone[4-]	8.20
			Methylene Chloride	4.80
			Styrene	66.0
			Tetrachloroethene	210
			Toluene	970
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	190
			Trichloroethane[1,1,1-]	1300
			Trichloroethene	220
			Trichlorofluoromethane	51.0
			Xylene[1,3-]+Xylene[1,4-]	14.0
54-24393	35–37	MD54-05-60345	Chlorodifluoromethane	3890
			Chloroform	29.3
			Dichlorodifluoromethane	1930
			Dichloroethane[1,1-]	190
			Dichloroethene[1,1-]	174
			Styrene	59.6
			Tetrachloroethene	305
			Toluene	414
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	4370 (J)
			Trichloroethane[1,1,1-]	4420
			Trichloroethene	156
			Trichlorofluoromethane	1120
			Xylene[1,3-]+Xylene[1,4-]	60.8
	156–158	MD54-05-60344	Chlorodifluoromethane	2050
			Chloroform	18.1
			Dichlorodifluoromethane	2080
			Dichloroethane[1,1-]	194
			Dichloroethene[1,1-]	317

Table 2.3-6 (continued)

Borehole Location	Depth (ft)	Sample ID	Analyte	Result (µg/m3)
54-24393 (continued)			Methylene Chloride	13.9
			Styrene	15.8
			Tetrachloroethene	393
			Toluene	226
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	4440 (J)
			Trichloroethane[1,1,1-]	4800
			Trichloroethene	193
			Trichlorofluoromethane	1240
54-24394	50–52	MD54-05-61749	Chloroform	150
			Dichlorodifluoromethane	1100
			Dichloroethane[1,1-]	1600
			Dichloroethene[1,1-]	930
			Tetrachloroethene	640
			Toluene	95.0
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	21000
			Trichloroethane[1,1,1-]	18000
			Trichloroethene	32000
			Trichlorofluoromethane	2200
	163–165	MD54-05-61748	Chloroform	120
			Dichlorodifluoromethane	1900
			Dichloroethane[1,1-]	960
			Dichloroethene[1,1-]	740
			Methylene Chloride	46.0
			Tetrachloroethene	580
			Toluene	120
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	9200
			Trichloroethane[1,1,1-]	13000
			Trichloroethene	12000
			Trichlorofluoromethane	2500
54-24395	40–42	MD54-05-60349	Bromodichloromethane	26.1
			Chloroform	73.2
			Dichlorodifluoromethane	1580
			Dichloroethane[1,1-]	48.5
			Methylene Chloride	11.8
			Tetrachloroethene	183
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	5280 (J)
			Trichloroethane[1,1,1-]	4360
			Trichloroethene	134

Table 2.3-6 (continued)

Borehole Location	Depth (ft)	Sample ID	Analyte	Result (µg/m³)
54-24395 (continued)			Trichlorofluoromethane	3870
	170–172	MD54-05-60348	Acetone	112
			Bromodichloromethane	23.4
			Chloroform	48.8
			Dichlorodifluoromethane	1090
			Dichloroethane[1,1-]	34.4
			Dichloropropane[1,2-]	18.0
			Methanol	301
			Methylene Chloride	30.9
			Tetrachloroethene	149
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	2680 (J)
			Trichloroethane[1,1,1-]	2560
			Trichloroethene	172
			Trichlorofluoromethane	2250
54-24396	10–12	MD54-05-60351	Acetone	126
			Dichloroethane[1,1-]	80.9
			Dichloroethene[1,1-]	242
			Dichloropropane[1,2-]	24.5
			Methylene Chloride	16.7
			Tetrachloroethene	156
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	1530 (J)
			Trichloroethane[1,1,1-]	4470
			Trichloroethene	231
			Trichlorofluoromethane	61.8
	131–133	MD54-05-60350	Acetone	109
			Dichloroethane[1,1-]	166
			Dichloroethene[1,1-]	674
			Dichloropropane[1,2-]	32.3
			Methylene Chloride	34.7
			Tetrachloroethene	291
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	2530 (J)
			Trichloroethane[1,1,1-]	7090
			Trichloroethene	537
			Trichlorofluoromethane	157
54-24397	15–17	MD54-05-60353	Acetone	209
			Butanone[2-]	7.37
			Dichloroethane[1,1-]	36.0
			Dichloroethene[1,1-]	119

Table 2.3-6 (continued)

Borehole Location	Depth (ft)	Sample ID	Analyte	Result (µg/m³)
54-24397 (continued)			Dichloropropane[1,2-]	17.1
			Methylene Chloride	10.1
			Tetrachloroethene	94.9
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	1380 (J+)
			Trichloroethane[1,1,1-]	2290
			Trichloroethene	80.6
			Trichlorofluoromethane	44.4
	125–127	MD54-05-60352	Acetone	147
			Butanone[2-]	7.37
			Dichloroethane[1,1-]	44.5
			Dichloroethene[1,1-]	214
			Dichloropropane[1,2-]	20.3
			Methylene Chloride	11.1
			Tetrachloroethene	81.3
			Toluene	13.6
			Trichloro-1,2,2-trifluoroethane[1,1,2-]	1150 (J+)
			Trichloroethane[1,1,1-]	2400
			Trichloroethene	107
			Trichlorofluoromethane	67.4
54-24523	485–700	MD54-05-60366	Acetone	71.2
			Butanone[2-]	5.89
			Toluene	7.53

Note*:* See Appendix A for data qualifier definitions.

Table 2.3-7
Tritium Detected in 2005 Pore-Gas Samples Collected from MDA G

Borehole Location	Depth (ft)	Sample ID	Result	Units
54-24361	30–32	MD54-05-61531	11890	pCi/L
	138–140	MD54-05-61530	3126	pCi/L
54-24362	35–37	MD54-05-61533	35630	pCi/L
	135–137	MD54-05-61532	24720	pCi/L
54-24363	12–14	MD54-05-61534	22510	pCi/L
54-24364	65–67	MD54-05-61537	5254	pCi/L
	130–132	MD54-05-61536	5846	pCi/L
54-24366	12–14	MD54-05-61538	37910	pCi/L
54-24367	30–31	MD54-05-61541	81190	pCi/L
	153–155	MD54-05-61540	7601	pCi/L
54-24368	95–97	MD54-05-61543	1886	pCi/L
	192–194	MD54-05-61542	3331	pCi/L
54-24369	65–67	MD54-05-61545	17310	pCi/L
	184–186	MD54-05-61544	3827	pCi/L
54-24371	40–42	MD54-05-61549	4515	pCi/L
	141–143	MD54-05-61548	8148	pCi/L
54-24372	55–57	MD54-05-61551	6210	pCi/L
	185–187	MD54-05-61550	6022	pCi/L
54-24373	65–67	MD54-05-60305	5700	pCi/L
	187–189	MD54-05-60304	1910	pCi/L
54-24374	10–12	MD54-05-61555	2659000	pCi/L
	139–141	MD54-05-61554	206800	pCi/L
54-24375	30–32	MD54-05-61557	6584	pCi/L
	157–159	MD54-05-61556	2135	pCi/L
54-24376	158–160	MD54-05-61558	26350	pCi/L
54-24377	150–152	MD54-05-61560	18810	pCi/L
54-24378	30–32	MD54-05-61563	3512000	pCi/L
	136–138	MD54-05-61562	1119000	pCi/L
54-24379	20–22	MD54-05-61565	3844	pCi/L
	144–146	MD54-05-61564	25410	pCi/L
54-24380	20–22	MD54-05-61567	2381	pCi/L
	155–157	MD54-05-61566	2131	pCi/L
54-24381	15–17	MD54-05-61569	4761	pCi/L
	143–145	MD54-05-61568	3614	pCi/L
54-24382	28–29	MD54-05-61571	2597	pCi/L
	107–109	MD54-05-61570	6406	pCi/L
54-24383	10–11	MD54-05-60325	1965	pCi/L

Table 2.3-7 (continued)

Borehole Location	Depth (ft)	Sample ID	Result	Units
54-24384	10–12	MD54-05-60327	7183	pCi/L
	65–67	MD54-05-60326	479	pCi/L
54-24385	30–32	MD54-05-61577	395300	pCi/L
	134–136	MD54-05-61576	13320	pCi/L
54-24386	35–37	MD54-05-61579	6963000	pCi/L
	156–158	MD54-05-61578	172100	pCi/L
54-24387	10–11	MD54-05-60333	2763	pCi/L
54-24388	25–27	MD54-05-61583	124200	pCi/L
54-24389	20–22	MD54-05-61584	6872	pCi/L
	147–149	MD54-05-61585	3953	pCi/L
54-24390	30–32	MD54-05-61587	5480	pCi/L
	158–160	MD54-05-61586	1888	pCi/L
54-24391	25–27	MD54-05-61589	4357	pCi/L
	165–167	MD54-05-61588	7632	pCi/L
54-24392	25–27	MD54-05-61591	7193	pCi/L
	144–146	MD54-05-61590	4837	pCi/L
54-24393	35–37	MD54-05-61593	1489	pCi/L
54-24394	163–165	MD54-05-61594	1458	pCi/L
54-24396	131–133	MD54-05-61598	17680	pCi/L
54-24397	15–17	MD54-05-61601	1257000	pCi/L
54-25105	485–700	MD54-05-61604	5150	pCi/L

Table 2.3-8
Gravimetric Moisture Content and Matric Potential in Samples Collected from MDA G

Sample Number	Sample Depth (ft)	Matrix	Gravimetric Moisture Content (%, g/g)	Matric Potential (bars)
MD54-05-59235	11.5	Qbt 2	3.0	8.0
MD54-05-59237	22.0	Qbt 2	4.5	1.3
MD54-05-59239	32.0	Qbt 2	2.1	2.9
MD54-05-59241	42.0	Qbt 2	4.8	6.0
MD54-05-59243	52.0	Qbt 2	6.4	2.0
MD54-05-59245	62.0	Qbt 2	2.4	4.0
MD54-05-59248	82.0	Qbt 1v	5.3	3.4
MD54-05-59250	92.0	Qbt 1vc	10.0	2.7
MD54-05-59252	102.0	Qbt 1g	10.8	5.0
MD54-05-59253	107.0	Qbt 1g	5.7	2.8
MD54-05-59255	117.0	Qbt 1g	5.4	2.9
MD54-05-59256	122.0	Qbt 1g	4.0	3.3
MD54-05-59258	142.0	Qbt 1g	6.4	3.0
MD54-05-59260	157.0	Qbt 1g	8.3	2.9
MD54-05-59261	162.0	Qbt 1g	7.8	2.1
MD54-05-59262	167.0	Qbt 1g	7.6	1.5
MD54-05-59264	177.0	Qct	6.1	2.4
MD54-05-59265	182.0	Qct	9.3	1.4
MD54-05-59266	185.0	Qct	7.3	4.9
MD54-05-59268	197.0	Qbog	27.2	0.6
MD54-05-59270	207.0	Tcb	0.4	48.0
MD54-05-59310	210.0	Tcb	1.2	3.7
MD54-05-59272	217.0	Tcb	2.7	19.6
MD54-05-59273	222.0	Tcb	2.1	2.1
MD54-05-59274	227.0	Tcb	0.7	7.9
MD54-05-59275	232.0	Tcb	0.5	14.8
MD54-05-59276	237.0	Tcb	0.2	95.1
MD54-05-59277	242.0	Tcb	0.4	27.6
MD54-05-59278	247.0	Tcb	2.1	50.6
MD54-05-59279	254.5	Tcb	0.9	7.3
MD54-05-59281	265.0	Tcb	0.2	15.1
MD54-05-59282	271.5	Tcb	1.4	5.5
MD54-05-59283	276.2	Tcb	0.8	15.7
MD54-05-59284	281.3	Tcb	2.1	1.1
MD54-05-59285	286.4	Tcb	0.7	11.6
MD54-05-59286	291.3	Tcb	1.6	2.4
MD54-05-59287	296.1	Tcb	3.1	3.3

Table 2.3-8 (continued)

Sample Number	Sample Depth (ft)	Matrix	Gravimetric Moisture Content (%, g/g)	Matric Potential (bars)
MD54-05-59289	301.1	Tcb	3.0	5.0
MD54-05-59288	301.5	Tcb	0.8	4.9
MD54-05-59291	316.7	Tcb	5.2	4.4
MD54-05-59292	321.8	Tcb	5.2	1.5
MD54-05-59293	326.9	Tcb	0.8	4.9
MD54-05-59294	331.6	Tcb	1.8	2.4
MD54-05-59295	336.0	Tcb	0.7	4.3
MD54-05-59296	341.9	Tcb	1.0	3.5
MD54-05-59297	346.8	Tcb	0.7	3.1
MD54-05-59298	351.0	Tcb	0.6	2.3
MD54-05-59299	356.9	Tcb	0.7	6.0
MD54-05-59301	366.9	Tcb	0.8	8.8
MD54-05-59302	371.4	Tcb	0.7	8.2
MD54-05-59303	376.1	Tcb	0.6	12.2
MD54-05-59304	381.3	Tcb	0.8	21.7
MD54-05-59305	386.7	Tcb	0.5	12.6
MD54-05-59306	391.6	Tcb	1.0	3.5
MD54-05-59307	396.7	Tcb	0.6	32.7
MD54-05-59308	401.4	Tcb	0.6	8.3
MD54-05-59309	407.0	Tcb	0.6	6.9
MD54-05-59311	436.5	Tcb	0.6	6.3
MD54-05-59312	456.7	Tcb	0.6	8.7
MD54-05-59313	482.3	Tcb	5.4	335.0
MD54-05-59314	494.0	Tcb	7.5	22.7
MD54-05-59315	545.0	Tcb	11.3	3.2

Table 2.3-9
Summary of MDA G Supplemental Investigation Pore-Gas Sampling Port Construction

Borehole ID	Sample Port Depths in ft (Unit Sampled)					
BH-2b (54-27436)	45 (Qbt 2)	70 (Qbt 1v)	115 (Qbt 1g)	163 (Qbo)	185 (Tb 4)	—*
BH-10 (54-24370)	40 (Qbt 2)	72.5 (Qbt 1v)	120 (Qbt 1g)	174.7 (Qct)	200 (Qbo)	243.7 (Tb 4)
BH-26 (54-24386)	40 (Qbt 2)	83 (Qbt 1g)	117 (Qct)	135 (Qbo)	195 (Tb 4)	—
BH-34 (54-24394)	50 (Qbt 2)	100 (Qbt 1v)	150 (Qbt 1g)	192.5 (Qct)	245.25 (Qbo)	300.5 (Tb 4)
BH-37 (54-24397)	50 (Qbt 1v)	90 (Qbt 1g)	130 (Qbt 1g)	165 (Qct)	188 (Qbo)	239.75 (Tb 4)

* — = Sixth sampling port not necessary.

Table 2.3-10
MDA G Supplemental Investigation VOC Pore-Gas Results

Sample ID	Location ID	Depth Interval (ft)	Acetone	Butanone[2-]	Carbon Disulfide	Chlorodifluoromethane	Chloroethane	Chloroform	Cyclohexane	Dichlorodifluoromethane	Dichloroethane[1,1-]
MD54-07-75257	54-24370	35–45	—*	—	—	—	—	660	—	13000	15000
MD54-07-75258	54-24370	67.5–77.5	—	—	—	—	—	740	—	17000	18000
MD54-07-75259	54-24370	115–125	—	—	—	—	—	510	—	19000	12000
MD54-07-75260	54-24370	169.5- 180	—	—	120	—	93	160	—	13000	4000
MD54-07-75262	54-24370	195–205	—	—	—	—	—	—	—	15000	3400
MD54-07-75261	54-24370	237.5–249.5	—	—	—	—	—	—	—	1500	240
MD54-07-75263	54-24386	37.5–42.5	—	—	2100	—	—	—	—	—	36000
MD54-07-75264	54-24386	80.5–86	—	—	1200	—	—	—	—	—	32000
MD54-07-75266	54-24386	115 –120	2600	—	1300	—	—	—	—	—	32000
MD54-07-75265	54-24386	130–136	—	—	620	—	—	—	—	—	17000
MD54-07-75267	54-24386	191–201	—	—	—	—	—	—	—	—	1900
MD54-07-75268	54-24394	45–55	—	—	190	—	—	—	—	1400	2300
MD54-07-75269	54-24394	95–105	—	—	—	—	—	140	340	1500	1700
MD54-07-75270	54-24394	145–154.8	—	—	—	—	—	130	270	1900	1200
MD54-07-75271	54-24394	190–195	—	—	—	130	—	110	210	2200	760
MD54-07-75272	54-24394	240 –250	—	—	—	140	—	71	150	2200	390
MD54-07-75273	54-24394	296.5–306.5	—	—	3.9	14	—	4.5	15	220	39
MD54-07-75251	54-27436	40–50	—	—	—	—	—	—	—	—	1100
MD54-07-75252	54-27436	65–75	—	—	—	—	—	—	—	—	1100
MD54-07-75253	54-27436	110–120	—	—	—	—	—	360	—	400	1200
MD54-07-75254	54-27436	160–166	—	—	—	—	—	330	—	290	940
MD54-07-75255	54-27436	180–191.5	20	4.6	—	—	—	34	27	64	130

Table 2.3-10 (continued)

Sample ID	Location ID	Depth Interval (ft)	Dichloroethene[1,1-]	Dichloroethene[cis-1,2-]	Methylene Chloride	Tetrachloroethene	Toluene	Trichloro-1,2,2-trifluoroethane[1,1,2-]	Trichloroethane[1,1,1-]	Trichloroethene	Trichlorofluoromethane
MD54-07-75257	54-24370	35–45	5100	470	—	1900	—	44000	170000	21000	14000
MD54-07-75258	54-24370	67.5–77.5	7000	700	—	2100	—	50000	190000	26000	15000
MD54-07-75259	54-24370	115- 125	6400	620	420	1500	—	39000	120000	16000	12000
MD54-07-75260	54-24370	169.5–180	4300	270	430	690	—	22000	53000	6000	7100
MD54-07-75262	54-24370	195–205	4900	280	460	740	—	23000	54000	6300	7900
MD54-07-75261	54-24370	237.5–249.5	630	15	37	120	170	2400	4900	560	800
MD54-07-75263	54-24386	37.5–42.5	41000	—	—	6500	—	4700	790000	6400	—
MD54-07-75264	54-24386	80.5–86	46000	—	—	6100	1200 (J)	4000	640000	7900	—
MD54-07-75266	54-24386	115–120	56000	—	—	5900	4700	2800	400000	8300	—
MD54-07-75265	54-24386	130–136	33000	—	—	3400	—	1600	240000	4800	—
MD54-07-75267	54-24386	191–201	3400	—	—	440	—	200	23000	600	—
MD54-07-75268	54-24394	45–55	1100	—	280	540	—	73000	32000	83000	3300
MD54-07-75269	54-24394	95–105	1100	—	—	450	—	28000	22000	30000	2600
MD54-07-75270	54-24394	145–154.8	1100	—	74	470	—	13000	16000	17000	2800
MD54-07-75271	54-24394	190–195	990	—	60	480	—	9000	13000	9400	3100
MD54-07-75272	54-24394	240–250	980	—	58	380	—	6000	9100	4200	3000
MD54-07-75273	54-24394	296.5–306.5	180	—	—	45	—	470	880	290	250
MD54-07-75251	54-27436	40–50	860	—	—	10000	—	1500	21000	190000	—
MD54-07-75252	54-27436	65–75	910	—	—	7300	—	1400	20000	130000	—
MD54-07-75253	54-27436	110–120	730	—	230	3900	—	910	16000	56000	—
MD54-07-75254	54-27436	160–166	680	—	100	1300	—	440	10000	21000	—
MD54-07-75255	54-27436	180–191.5	230	—	10	160	—	120	1700	1800	31

Note: All values are reported in µg/m^3.

* — = Analytical result was not detected.

Table 2.3-11
MDA G Supplemental Investigation Tritium Pore-Gas Results

Borehole ID	Sample Depth Interval (ft)	Sample ID	Result (pCi/L)
BH-37 (54-24397)	45–55	MD54-07-75283	4,480,000
	84–95	MD54-07-75284	536,000
	125–135	MD54-07-75285	270,000
	160–168	MD54-07-75286	53,900
	194–192	MD54-07-75287	102,800
	232.5–244	MD54-07-75288	1750

Table 5.1-1
Summary of Regulatory Criteria and Cleanup Levels

Media	Hazardous Constituents
Groundwater	– Water Quality Control Commission standards – Safe Drinking water Act standards
Soil	– NMED's "Technical Background Document for Development of Soil Screening Levels" – EPA Region VI Human Health Medium Specific Screening Levels

Table 7.3-1
Component Actions of Identified Corrective Measure Alternatives

Alternative	Alternative Component									Notes
	Enhanced Containment/Stabilization					Source Removal		Media	Institutional Controls	
	RCRA Cover	ET Cover	Biointrusion Barrier	Waste Stabilization	Sub-surface Barrier	Partial Excavation	Complete Excavation	Contaminant Extraction	100-yr Monitor & Maintenance	
1A									A[a]	Monitoring only, no maintenance
1B								X	X	Monitoring plus maintenance
2A	X[b]							X	X	RCRA Subtitle C design
2B		X	O[c]					X	X	Evaluated DOE O 435.1 base conceptual design
2C		X	X			X		X	X	Removes waste from potential high erosion areas
2D		X	X	O		O		X	X	Reduces cover thickness, optionally removes waste from potential high erosion areas, optionally stabilizes target higher radiation risk wastes, SVE extracts contaminants
3					X			X	X	Operational covers plus near-surface subsurface barriers for target high radiation risk wastes
4A				X				X	X	Operational covers plus near-surface stabilization
4B				X				X	X	Operational covers plus stabilization of all wastes to practical depth limits on technologies
4C				X				X	X	Operational covers plus near-surface stabilization of target high radiation risk wastes
5A						X		X	X	Removes TRU and waste from potential high erosion areas; off-site disposal
5B							X	X		Removes all wastes; disposal off-site

[a] A = Monitoring only, no maintenance.
[b] X = Included in alternative.
[c] O = Optional in alternative.

Table 7.4-1
Corrective Measure Alternative Qualitative Screening Matrix

Corrective Measure	Description	Screening				Retained
		Responsive to Threshold Criteria[a]	Implementable	Performs[b]	Timely	
Alternative 1A Monitoring Only, No Further Action	Baseline corrective measure alternative that is carried through the CME for comparison purposes. The baseline alternative includes continued monitoring of the subsurface vapor-phase VOC plumes and moisture monitoring. Monitoring of the existing cover is also required to verify attainment of the performance objectives under DOE Order 435.1	No	Yes	n/a[c]	n/a	Yes[d]
Monitoring only, no further action is not responsive to Threshold criteria because it is not protective of human health and the environment and does not attain media cleanup standards or control sources of releases. Monitoring only, no further action is technically and administratively implementable.						
Alternative 1B SVE, Monitoring and Maintenance of Existing Covers	This alternative includes the monitoring described in Alternative 1A and provides for upkeep of the existing containment systems. Any releases identified during monitoring will also be addressed through maintenance activities to the containment systems. Monitoring and maintenance would be performed for the first 100 yr following installation. SVE included for up to 30 yr	Partial	Yes	Yes	Yes	Yes
This alternative is generally protective of human health and the environment although water infiltration rates will not be minimized to the degree that would be achieved with a landfill final cover. Contaminants would migrate to points of exposure at a faster than desirable rate. Maintenance activities can extend the containment effectiveness and operational life for the existing covers indefinitely at MDA G. Long-term maintenance and monitoring controls are effective in maintaining the performance of corrective measures and in identifying unacceptable levels of contaminants in environmental media. Additional corrective measures could be undertaken if necessary in the future.						
Alternative 2A RCRA Subtitle C Final Cover , SVE, Monitoring and Maintenance	Installation of a final cover represents one of the primary containment alternatives for subsurface waste disposal units. This alternative includes installation of a RCRA Subtitle C cover design. Monitoring and maintenance would be performed for the first 100 yr following installation. SVE included for up to 30 yr	Yes	Yes	No	Yes	No
In the semiarid climate of MDA G, the components prescribed for a regulatory standard design RCRA Subtitle C cover do not perform well over time. The high clay content tends to produce cracking because of desiccation, leading to preferential pathways for surface water infiltration.						

Table 7.4-1 (continued)

Corrective Measure	Description	Screening				Retained
		Responsive to Threshold Criteria[a]	Implementable	Performs[b]	Timely	
Alternative 2B Engineered Alternative ET Cover – Performance Assessment Base Cover, SVE and Monitoring and Maintenance	This alternative includes an ET cover for the MDA G wastes, which is well-suited for the semiarid climate of MDA G. Effective in reducing infiltration through landfills in semiarid regions and provides a barrier to erosion and intrusion. This alternative represents the preliminary cover design concept prepared by the Laboratory for compliance with DOE Order 435.1 requirements that would also meet Consent Order Requirements. Monitoring and maintenance would be performed for the first 100 yr following installation. SVE included for up to 30 yr	Yes	Yes	Yes	Yes	Yes
The engineered alternative final cover Performance Assessment concept is designed to utilize ET and is directly responsive to Threshold Criteria. The cover thickness acts as a biotic barrier, increasing the responsiveness of the alternative. This alternative is technically and administratively implementable. Materials used to construct an engineered/ET cover are readily available. Performance of ET covers in semiarid regions is well demonstrated and regulatory acceptance of ET covers as alternative final covers is widespread in arid and semiarid regions.						
Alternative 2C Engineered Alternative ET Cover in Combination with Partial MDA G Waste Excavation, SVE, and Monitoring and Maintenance	This alternative includes an ET cover for the MDA G wastes in combination with excavation and off-site disposal of wastes from potential high erosion areas to facilitate a thinner cover. Monitoring and maintenance would be performed for 100 yr following installation. SVE included for up to 30 yr	Yes	Yes	Yes	Yes	Yes
Optimized cover slope combined with removal of wastes from vulnerable locations will enhance longevity of the remedy. This alternative is technically and administratively implementable. Materials used to construct an engineered/ET cover are readily available. Performance of ET covers in semiarid regions is well demonstrated and regulatory acceptance of ET covers as alternative final covers is widespread in arid and semiarid regions.						

Table 7.4-1 (continued)

Corrective Measure	Description	Screening				Retained
		Responsive to Threshold Criteria[a]	Implementable	Performs[b]	Timely	
Alternative 2D Optimized Engineered Alternative ET Cover in Combination with Optional Partial MDA G Waste Excavation, Waste Optional Stabilization, Biointrusion Barrier, SVE, and Monitoring and Maintenance	This alternative includes an ET cover for the MDA G wastes, optimized with enhancements over the Base Cover concept employed for compliance with DOE Order 435.1 Excavation and off-site disposal of wastes from potential high erosion areas is included in order to facilitate a thinner cover, a biointrusion barrier is included. Targeted near-surface waste stabilization is also included, to address near-surface wastes with higher release potential. Monitoring and maintenance for 100 yr. SVE included for 30 yr	Yes	Yes	Yes	Yes	No
The optimized engineered alternative final cover conceptualized for this alternative is directly responsive to Threshold Criteria. Cover properties combined with removal of wastes from vulnerable locations and stabilization of target wastes with a higher release potential will enhance longevity of the remedy. This alternative is technically and administratively implementable. Materials used to construct an engineered/ET cover are readily available. Performance of ET covers in semiarid regions is well demonstrated and regulatory acceptance of ET covers as alternative final covers is widespread in arid and semiarid regions. Near-surface stabilization technologies are well understood and demonstrated.						

Table 7.4-1 (continued)

Corrective Measure	Description	Screening				Retained
		Responsive to Threshold Criteria[a]	Implementable	Performs[b]	Timely	
Alternative 3 Near-surface Subsurface Barrier, SVE, and Monitoring and Maintenance	The operational covers installed over MDA G wastes following interim closure of the individual waste disposal units have provided demonstrated protection of the wastes from water infiltration. This alternative utilizes the covers and deploys near-surface subsurface barriers to enhance the biotic isolation of near-surface wastes. Existing operational waste covers at the MDA G site already provide a degree of infiltration protection. Near-surface subsurface barriers will employ soil grout mixing technology within the operational cover materials of select waste pits and trenches, based on waste contaminant contents and release potential. Existing covers will also be graded and extended as necessary to direct surface runoff to drainage channels away from waste disposal units to further enhance surface water management. Monitoring and maintenance would be performed for the first 100 yr following installation. SVE included for 30 yr	Yes	Yes	Yes	Yes	No
Near-surface subsurface barriers deployed for target wastes would enhance existing operational cover stability/longevity. Threshold Criteria would initially be met. Subsurface barriers are readily implementable, well-demonstrated, and could be in place relatively quickly relative to other alternatives considered; however, subsurface barriers would be expected to underperform relative to waste stabilization alternatives, such as those employed in Alternatives 4A, 4B, and 4C.						

Table 7.4-1 (continued)

Corrective Measure	Description	Screening				Retained
		Responsive to Threshold Criteria[a]	Implementable	Performs[b]	Timely	
Alternative 4A Near-surface Waste Stabilization, SVE, and Monitoring and Maintenance	As in Alternative 3, the operational covers are incorporated into this alternative. To further enhance the protection of the waste from water infiltration and/or biotic intrusion, vertical planar in situ vitrification technology will be deployed for the near-surface portion of the buried wastes. This alternative will vitrify the upper 3 ft of each waste unit (beneath operational cover soils) to provide an essentially impermeable monolith. The monolith will act as a barrier and will provide protection for deeper wastes, since surface water and biota will be unable to penetrate the mass. This alternative includes the grading and extension and augmentation of operational cover materials as necessary to direct surface runoff to drainage channels away from waste disposal units to further enhance surface water management. Monitoring and maintenance would be performed for the first 100 yr following installation. SVE included for 30 yr	Yes, although near-term risks increase	Yes	Yes	No	No
Waste stabilization is responsive to Threshold Criteria. However, in situ vitrification requires intrusive activity as preparatory steps for containerized buried wastes that could lead to increased site worker exposures. The technology is technically and administratively implementable, but expensive and relatively time-consuming to implement. Vitrification temperatures up to 2000º C have the potential to generate and release radioactive and hazardous vapors to the environment. Vitrification of only the upper fractions of deeper waste configurations could ultimately lead to saturation of the media below the vitrified mass, leading to enhanced mobility of unvitrified contaminants. Application of vitrification to only shallow waste configurations of higher release potential, as in Alternative 4C, would reduce the potential for deeper wastes to become saturated under the barrier, which could also act as an effective ET barrier.						

Table 7.4-1 (continued)

Corrective Measure	Description	Screening				Retained
		Responsive to Threshold Criteria[a]	Implementable	Performs[b]	Timely	
Alternative 4B Comprehensive MDA G Waste Stabilization, SVE, and Monitoring and Maintenance	As in Alternative 3, the operational covers are incorporated into this alternative. To further enhance the protection of the waste from water infiltration and/or biotic intrusion, vertical planar in situ vitrification technology will be deployed but to the depth limitations of the technology. Deeper wastes will be stabilized with jet grouting, as necessary. This alternative includes the grading, extension and augmentation of operational cover materials as necessary to direct surface runoff to drainage channels away from waste disposal units to further enhance surface water management. Monitoring and maintenance would be performed for the first 100 yr following installation. SVE included for 30 yr	Yes, although near-term risks increase	Yes, but depth limit of technologies may be reached	Yes	No	No
Waste stabilization is responsive to Threshold Criteria. However, in situ vitrification requires intrusive activity as preparatory steps for containerized buried wastes that could lead to increased site worker exposures. The technology is technically and administratively implementable, but very expensive and relatively time-consuming to implement and at the depth limit of the technology for this application. Vitrification production capacities are approximately 90 tons (~1500 ft^3) per day per unit. Vitrification temperatures up to 2000º C have the potential to generate and release radioactive and hazardous vapors to the environment and vitrified materials may retain dangerous levels of heat for more than a year after completion of treatment. Alternative 4C provides stabilization to only targeted areas that produce significant risk reduction and would be preferred over this alternative.						

Table 7.4-1 (continued)

Corrective Measure	Description	Screening				Retained
		Responsive to Threshold Criteria[a]	Implementable	Performs[b]	Timely	
Alternative 4C Near-surface Stabilization of Target MDA G Wastes, SVE, and Monitoring and Maintenance	As in Alternative 3, the operational covers are incorporated into this alternative. To further enhance the protection of the waste from water infiltration and/or biotic intrusion, vertical planar in situ vitrification technology will be deployed for the near-surface portion of shallow higher radiation dose potential buried wastes. This alternative includes the grading, extension and augmentation of operational cover materials as necessary to direct surface runoff to drainage channels away from waste disposal units to further enhance surface water management. Monitoring and maintenance would be performed for the first 100 yr following installation. SVE included for 30 yr	Yes, although near-term risks increase	Yes	Yes	Yes, since limited-scale targeted application	No
Targeted waste stabilization in addition to the existing operational covers is expected to be responsive to Threshold Criteria. However, in situ vitrification requires intrusive activity as preparatory steps for containerized buried wastes that could lead to increased site worker exposures. The technology is technically and administratively implementable, but very expensive and relatively time-consuming to implement. Vitrification production capacities and risks are similar to those identified in Alternative 4B, except on a limited scale relative to that alternative. Alternative 4C provides stabilization to only targeted areas that produce significant reduction of release potential.						
Alternative 5A Partial MDA G Waste Source Excavation, Ex Situ Treatment, Off-site Disposal, SVE, and Monitoring and Maintenance	As in Alternative 3, the operational covers are incorporated into this alternative. To further enhance the protection of the waste from water infiltration and/or biotic intrusion, wastes disposed of at MDA G that present the greatest potential for migration of chemical releases will be excavated and removed from MDA G, treated as necessary to meet disposal waste acceptance requirements, and disposed of off-site. SVE included for up to 30 yr; monitoring and maintenance for 30 yr	Partial, because of increased near-term risks	Yes, but waste retrieval from certain burial configurations is unproven	Yes	Yes	No
The alternative includes complex waste retrieval, packaging, and shipment of millions of cubic feet of waste via truck to off-site disposal locations. Because of the large number of truck shipments, short-term risks associated with traffic accidents and worker risks associated with retrieving certain configurations of buried wastes could be expected to be high relative to other options for the site. Risks include increased potential for injury and death as well as increased exposures to contaminants for workers and potentially to downwind residents. The scale of the excavation effort would require considerable time to implement.						

Table 7.4-1 (continued)

Corrective Measure	Description	Screening				Retained
		Responsive to Threshold Criteria[a]	Implementable	Performs[b]	Timely	
Alternative 5B Complete MDA G Waste Source Excavation Waste Treatment, and Off-site Disposal, SVE, and Monitoring and Maintenance	This alternative includes removal of all buried waste from the 32 pits, 193 shafts, and 4 trenches at MDA G with disposal to the maximum extent at alternate locations off-site. Ex situ waste treatment is included as required to meet waste acceptance and regulatory requirements. Future potential risks (long-term) from MDA G can be almost entirely mitigated with removal of wastes from the site. SVE included for up to 30 yr; monitoring and maintenance for 30 yr.	Yes, with significantly increased near-term risks due to excavation	Yes, but waste retrieval from certain burial configurations is unproven	Yes	No	Yes
The alternative involves shipment of over 96 million ft^3 of waste (including RACER calculated Residual Waste)via truck to off-site disposal locations. Because of the large number of truck shipments over distance, short-term risks associated with traffic accidents and worker risks associated with retrieving certain configurations of buried wastes could be expected to be high relative to other options for the site. Risks include increased exposures to contaminants for workers and potentially to downwind residents. Long-term risks would be the least of all alternatives considered. The scale of the excavation effort would require significant time to implement.						

[a] Threshold Criteria:

(1) Protects human health (e.g., <1 x 10^{-5} excess cancer risk)

(2) Protects the environment

(3) Attains media cleanup levels

(4) Provides source control to reduce or eliminate releases that may pose a threat

(5) Complies with waste management standards

[b] Performs: Likely to perform satisfactorily and/or reliably.

[c] n/a = Not applicable.

[d] Retained for comparison purposes, not for formal evaluation.

Table 8.1-1
Alternative 1B - Maintenance of Existing Covers, Monitoring, and SVE
Capital, Recurring, and Periodic Cost Estimate in 2008 Dollars and Present Value Analysis

Capital - Work Breakdown Structure (WBS) Element	Cost Estimate
WBS 1B.1.1 – Studies	$0
WBS 1B.1.2 – Remedial Design	$508,000
WBS 1B.1.3 – Site Preparation	$2,263,000
WBS 1B.1.4 – SVE System Installation	$350,000
WBS 1B.1.5 – Remedial Action Excavation	$0
WBS 1B.1.6 – Site Restoration	$2,875,000
WBS 1B.1.7 – Monitoring System Installation	$2,994,000
Start-up Cost	$218,000
Total Capital Cost	**$9,208,000**
Recurring and Periodic WBS Element – Annual Cost	Cost Estimate
WBS 1B.2.1 – SVE System Operation and Maintenance (O&M)	$2,000
WBS 1B.2.2 – Cap Maintenance	$116,000
WBS 1B.2.3 – Monitoring[a]	$56,000
Total Annual Cost	**$174,000**
Recurring and Periodic Cost Present Value at 3% 100 yr cap, 30 yr SVE/RCRA	$4,802,000
Recurring and Periodic Cost Present Value at 7% 100 yr cap, 30 yr SVE/RCRA	$2,375,000
Project Total Costs including PV	Cost Estimate
Project Costs with PV of 3%	**$14,010,000**
Project Total Costs with PV of 7%	**$11,583,000**
Project Total Costs including PV with 55% Contingency[b]	
Total Project Costs with PV of 3%	**$21,716,000**
Total Project Costs with PV of 7%	**$17,954,000**

[a] Long-term monitoring requirements contained in RCRA permit. Does not include additional requirements needed to satisfy DOE Order 435.1.

[b] Same contingency as that used at INL, “Feasibility Study for Operable Unit 7-13/14” (Holdren et al. 2000, 098642).

Table 8.2-1
CME Alternative 2B - Engineered ET Cover, Monitoring, and SVE
Capital, Recurring, and Periodic Cost Estimate in 2008 Dollars and Present Value Analysis

Capital - WBS Element	Cost Estimate
WBS 2B.1.1 – Study	$58,000
WBS 2B.1.2 – Remedial Design	$3,617,000
WBS 2B.1.3 – Site Preparation	$3,213,000
WBS 2B.1.4 – Remedial Action SVE System	$350,000
WBS 2B.1.5 – Remedial Action Excavation	$0
WBS 2B.1.6 – Remedial Action Cover	$50,684,000
WBS 2B.1.7 –Monitoring System Installation	$3,781,000
Start-up Cost	$239,000
Total Capital Costs	**$61,942,000**
Recurring and Periodic WBS Element – Annual Cost	Cost Estimate
WBS 2B.2.1 – SVE System O&M	$2,000
WBS 2B.2.2 – Cap Maintenance	$153,000
WBS 2B.2.3 – Monitoring[a]	$56,000
Total Annual Cost	**$211,000**
Recurring and Periodic Cost Present Value at 3% 100 yr cap, 30 yr SVE/RCRA	$5,971,000
Recurring and Periodic Cost Present Value at 7% 100 yr cap, 30 yr SVE/RCRA	$2,903,000
Project Total Costs including PV	Cost Estimate
Project Costs with PV of 3%	**$67,913,000**
Project Total Costs with PV of 7%	**$64,845,000**
Project Total Costs including PV with 55% Contingency[b]	
Total Project Costs with PV of 3%	**$105,265,000**
Total Project Costs with PV of 7%	**$100,510,000**

[a] Long-term monitoring requirements contained in RCRA permit. Does not include additional requirements needed to satisfy DOE Order 435.1.

[b] Same contingency as that used at INL, “Feasibility Study for Operable Unit 7-13/14” (Holdren et al. 2000, 098642).

Table 8.3-1
CME Alternative 2C - Engineered ET Cover, Partial Excavation, Monitoring, and SVE Capital, Recurring, and Periodic Cost Estimate in 2008 Dollars and Present Value Analysis

Capital - WBS Element	Preliminary Estimate
WBS 2B.1.1 – Study	$58,000
WBS 2B.1.2 – Remedial Design	$2,088,000
WBS 2B.1.3 – Site Preparation	$2,752,000
WBS 2B.1.4 – Remedial Action SVE System	$350,000
WBS 2B.1.5 – Remedial Action Limited Excavation Pit 28	$19,100,000
WBS 2B.1.6 – Remedial Action Cover	$16,910,000
WBS 2B.1.7 –SVE Monitoring Installation	$3,028,000
Start-up Cost	$218,000
Total Capital Costs	**$44,504,000**
Recurring and Periodic WBS Element – Annual Cost	Cost Estimate
WBS 2B.2.1 – SVE System O&M	$2,000
WBS 2B.2.2 – Cap Maintenance	$138,000
WBS 2B.2.3 – Monitoring[a]	$56,000
Total Annual Cost	**$196,000**
Recurring and Periodic Cost Present Value at 3% 100 yr cap, 30 yr SVE/RCRA	$5,497,000
Recurring and Periodic Cost Present Value at 7% 100 yr cap, 30 yr SVE/RCRA	$2,689,000
Project Total Costs including PV	Cost Estimate
Project Costs with PV of 3%	**$50,001,000**
Project Total Costs with PV of 7%	**$47,193,000**
Project Total Costs including PV with 55% Contingency[b]	
Total Project Costs with PV of 3%	**$77,502,000**
Total Project Costs with PV of 7%	**$73,149,000**

[a] Long-term monitoring requirements contained in RCRA permit. Does not include additional requirements needed to satisfy DOE Order 435.1.

[b] Same contingency as that used at INL, “Feasibility Study for Operable Unit 7-13/14” (Holdren et al. 2000, 098642).

Table 8.4-1
CME Alternative 5B - Complete Excavation, Monitoring, and SVE
Capital, Recurring, and Periodic Cost Estimate in 2008 Dollars and Present Value Analysis

Capital - WBS Element	Preliminary Estimate
WBS 5D.1.1 – Studies	$58,000
WBS 5D.1.2 – Remedial Design	$689,053,000
WBS 5D.1.3 – Site Preparation	$2,752,000
WBS 5D.1.4 – SVE System Installation	$349,000
WBS 5D.1.5 – Remedial Action Complete Excavation	$12,501,101,000
WBS 5D.1.6 – Site Restoration	$14,761,000
WBS 5D.1.7 – Monitoring System Installation	$3,028,000
Start-up Cost	$218,000
Total Capital Costs	**$13,211,320,000**
Recurring and Periodic WBS Element – Annual Cost	Cost Estimate
WBS 5D.2.1 – SVE System O&M	$2,000
WBS 5D.2.2 – Cap Maintenance	$93,000
WBS 5D.2.3 – Monitoring[a]	$56,000
Total Annual Cost	**$151,000**
Recurring and Periodic Cost Present Value at 3% 100 yr cap, 30 yr SVE/RCRA	$4,076,000
Recurring and Periodic Cost Present Value at 7% 100 yr cap, 30 yr SVE/RCRA	$2,047,000
Project Total Costs including PV	Cost Estimate
Project Costs with PV of 3%	$13,215,396,000
Project Total Costs with PV of 7%	$13,213,367,000
Project Total Costs including PV with 55% Contingency[b]	
Total Project Costs with PV of 3%	**$20,483,863,000**
Total Project Costs with PV of 7%	**$20,480,719,000**

[a] Long-term monitoring requirements contained in RCRA permit. Does not include additional requirements needed to satisfy DOE Order 435.1.

[b] Same contingency as that used at INL, “Feasibility Study for Operable Unit 7-13/14” (Holdren et al. 2000, 098642).

Table 9.0-1
Comparative Analysis of Corrective Measure Alternatives

Criteria	Alternative 1B: Maintenance of Existing Covers and Monitoring with SVE (Rank 1 to 5)*	Alternative 2B: Engineered Alternative ET Cover and Monitoring with SVE (Rank 1 to 5)*	Alternative 2C: Engineered Alternative ET Cover, Partial MDA G Waste Excavation, and Monitoring with SVE (Rank 1 to 5)*	Alternative 5B: Complete MDA G Waste Source Excavation, Waste Treatment, and Off-site Disposal with SVE (Rank 1 to 5)*
Achieve Cleanup Objectives in a Timely Manner (Consent Order Ref: XI.F.11-1)	Not applicable, no cleanup objectives are currently exceeded.	Not applicable, no cleanup objectives are currently exceeded.	Not applicable, no cleanup objectives are currently exceeded.	Not applicable, no cleanup objectives are currently exceeded.
Protect Human and Ecological Receptors (Consent Order Ref: XI.F.11-2)	Incremental cancer risk (ICR), HI are likely to exceed corrective action objectives (CAOs) over the long-term postclosure period due to extensive erosion and release of waste when maintenance is discontinued after the assumed 100-yr institutional control period. MCLs not exceeded in groundwater over the long-term postclosure period. (Rank = 1)	ICR, HI, dose, and radon levels less than CAOs over the long-term postclosure period and for workers during the assumed 100-yr institutional control period. MCLs not exceeded in groundwater over the long-term postclosure period. (Rank = 4)	ICR, HI, dose, and radon levels less than CAOs over the long-term postclosure period and for workers during the assumed 100-yr institutional control period. MCLs not exceeded in groundwater over the long-term postclosure period. (Rank = 4)	ICR, HI, dose, and radon levels may be exceeded during the construction period if a 25-yr, 15-min storm occurs. MCLs not exceeded in groundwater over the long-term postclosure period. (Rank = 3)
Control or Eliminate the Sources of Contamination (Consent Order Ref: XI.F.11-3)	The existing cover would not eliminate or control sources of contamination once maintenance is discontinued after the assumed 100-yr institutional control period. (Rank = 2)	The cover would not eliminate sources of contamination, but would control sources. (Rank = 4)	The cover would not eliminate sources of contamination, but would control sources. (Rank = 4)	The excavation with off-site disposal would eliminate sources of contamination. However, some risk exists during excavation regarding control of storm events. (Rank = 4)

Table 9.0-1 (continued)

Criteria	Alternative 1B: Maintenance of Existing Covers and Monitoring with SVE (Rank 1 to 5)*	Alternative 2B: Engineered Alternative ET Cover and Monitoring with SVE (Rank 1 to 5)*	Alternative 2C: Engineered Alternative ET Cover, Partial MDA G Waste Excavation, and Monitoring with SVE (Rank 1 to 5)*	Alternative 5B: Complete MDA G Waste Source Excavation, Waste Treatment, and Off-site Disposal with SVE (Rank 1 to 5)*
Control Migration of Released Contaminants (Consent Order Ref: XI.F.11-4)	The SVE system would control migration of release contaminants during the operating period. (Rank = 4)	The cover would limit infiltration reducing migration potential. The SVE system would control migration of release contaminants during the operating period. (Rank = 5)	The cover would limit infiltration reducing migration potential. The SVE system would control migration of release contaminants during the operating period. (Rank = 5)	The SVE system would control migration of release contaminants during the operating period. (Rank = 4)
Manage Remediation Waste in Accordance with State and Federal Regulations (Consent Order Ref: XI.F.11-5)	Limited wastes generated would easily be managed to regulations. (Rank = 5)	Minor wastes generated would readily be managed to regulations. (Rank = 4)	Limited wastes generated would easily be managed to regulations. (Rank = 3)	Enormous quantities of wastes generated would be extremely difficult to manage to regulations. (Rank = 1)
Applicability (Consent Order Ref: XI.F.10a)	Cover systems have been shown to be applicable. However, without rock erosion protection and without maintenance, non-engineered covers have limited applicability. SVE systems are applicable. (Rank = 2)	Cover systems have been shown to be applicable. SVE systems are applicable. (Rank = 5)	Cover systems have been shown to be applicable. SVE systems are applicable. (Rank = 5)	Excavation has reduced applicability due to handling, transportation, disposal, and aesthetics issues. SVE systems are applicable. (Rank = 2)
Technical Feasibility (Consent Order Ref: XI.F.10b)	Existing cover maintenance and SVE have been shown to be technically feasible. (Rank = 5)	Engineered ET covers, maintenance, and SVE have been shown to be technically feasible. (Rank = 5)	Engineered ET covers, partial excavation, maintenance, and SVE have been shown to be technically feasible. (Rank = 5)	Excavation and SVE have been shown to be technically feasible, however wastes excavated from shafts and pits reduce the feasibility. (Rank = 3)

Table 9.0-1 (continued)

Criteria	Alternative 1B: Maintenance of Existing Covers and Monitoring with SVE (Rank 1 to 5)*	Alternative 2B: Engineered Alternative ET Cover and Monitoring with SVE (Rank 1 to 5)*	Alternative 2C: Engineered Alternative ET Cover, Partial MDA G Waste Excavation, and Monitoring with SVE (Rank 1 to 5)*	Alternative 5B: Complete MDA G Waste Source Excavation, Waste Treatment, and Off-site Disposal with SVE (Rank 1 to 5)*
Effectiveness: short- and long-term (Consent Order Ref: XI.F.10c)	Short-term: effective Long-term: not effective (Rank = 2)	Short-term: effective Long-term: less effective if excessive erosion (Rank = 4)	Short-term: effective Long-term: Partial excavation decreases chance of excessive erosion (Rank = 4)	Short-term: less effective Long-term: most effective (Rank = 4)
Implementability (Consent Order Ref: XI.F.10.d)	Designed and constructed in less than 12 months with normal construction equipment. (Rank = 5)	Designed and constructed in about 24 months with normal construction equipment. (Rank = 4)	Designed and constructed in about 48 months with normal construction equipment. Requires an area for characterization, sorting, and packaging. (Rank = 3)	Designed, excavated, and completed in approximately 30 yr. Requires characterization, sorting and packaging facility. Requires remote excavator and engineered barriers. (Rank =2)
Human Health and Ecological Protectiveness (Consent Order Ref: XI.F.10e)	Long-term potential effect on human health and biological resources. No effect on cultural resources. Potential long-term ecological risk. (Rank = 1)	Minimal effect on human health and biological resources. No effect on cultural resources. No long-term ecological risk. (Rank = 5)	Potential short-term effect on human health and biological resources during partial excavation. No effect on cultural resources. No long-term ecological risk. (Rank = 4)	Significant potential short-term effect on human health and biological resources during excavation. No effect on cultural resources. No long-term ecological risk. (Rank = 3)
Cost (Consent Order Ref: XI.F.10f)	Lowest total cost (Rank = 5)	Higher cover capital cost (Rank = 3)	Lower cover capital cost (Rank = 4)	Highest total cost (Rank = 1)
Total Capital Cost	$9,208,000	$61,942,000	$44,504,000	$13,211,320,000
Total Project Costs with PV of 3% + 55% Contingency	$21,716,000	$105,265,000	$77,502,000	$20,483,863,000

Table 9.0-1 (continued)

Criteria	Alternative 1B: Maintenance of Existing Covers and Monitoring with SVE (Rank 1 to 5)*	Alternative 2B: Engineered Alternative ET Cover and Monitoring with SVE (Rank 1 to 5)*	Alternative 2C: Engineered Alternative ET Cover, Partial MDA G Waste Excavation, and Monitoring with SVE (Rank 1 to 5)*	Alternative 5B: Complete MDA G Waste Source Excavation, Waste Treatment, and Off-site Disposal with SVE (Rank 1 to 5)*
Benefits and Possible Hazards (Consent Order Ref: XI.F.11)	Lowest cost and defers final action for potential better solution. Maintenance required for protectiveness. (Rank = 4)	Requires greatest influx of off-site soils and creates the greatest visual impact to surrounding communities. (Rank = 2)	Best balances costs and protectiveness. (Rank = 4)	Causes greatest movement of hazardous materials across public highways. (Rank = 1)
TOTAL (Average) SCORE	36 (3.3)	45 (4.1)	46 (4.2)	28 (2.5)

* Ranks from 1 being least beneficial to 5 being most beneficial.

Table 9.0-2
Summary of Capital and Recurring Cost Estimates for Corrective Measure Alternatives

Activity	Alt 1B Maintenance of Existing Cover	Alt 2B ET Cover with SVE	Alt 2C ET Cover, Partial Excavation with SVE	Alt 5B Complete Excavation, Off-site Disposal, and SVE
Study	$0	$58,000	$58,000	$58,000
Remedial Design	$508,000	$3,617,000	$2,088,000	$689,053,000
Site Preparation	$2,263,000	$3,213,000	$2,752,000	$2,752,000
Remedial Action SVE System	$350,000	$350,000	$350,000	$349,000
Remedial Action Excavation	$0	$0	$19,100,000	$12,501,101,000
Remedial Action Cover/Site Restoration	$2,875,000	$50,684,000	$16,910,000	$14,761,000
Monitoring System Installation	$2,994,000	$3,781,000	$3,028,000	$3,028,000
Start-up Cost	$218,000	$239,000	$218,000	$218,000
Total Capital Cost	**$9,208,000**	**$61,942,000**	**$44,504,000**	**$13,211,320,000**
Annual Cost				
SVE System O&M	$2,000	$2,000	$2,000	$2,000
Cap Maintenance	$116,000	$153,000	$138,000	$93,000
Monitoring[a]	$56,000	$56,000	$56,000	$56,000
Total Annual Cost	**$174,000**	**$211,000**	**$196,000**	**$151,000**
Collective Summary of Capital and Operating Costs				
Project Costs with PV of 3%	**$14,010,000**	**$67,913,000**	**$50,001,000**	**$13,215,396,000**
Project Costs with PV of 7%	**$11,583,000**	**$64,845,000**	**$47,193,000**	**$13,213,367,000**
Total Project Costs with PV of 3% + 55% Contingency[b]	**$21,716,000**	**$105,265,000**	**$77,502,000**	**$20,483,863,000**
Total Project Costs with PV of 7% + 55% Contingency[b]	**$17,954,000**	**$100,510,000**	**$73,149,000**	**$20,480,719,000**

[a] Long-term monitoring requirements contained in RCRA permit. Does not include additional requirements needed to satisfy DOE Order 435.1.

[b] Same contingency as that used at INL, "Feasibility Study for Operable Unit 7-13/14" (Holdren et al. 2000, 098642).

Table 10.2-1
MDA G Conceptual Cover Profile Layer Specifics and Justification

Cover System Layer	Design Specifics	Design Justification
Vegetation	The site is to be seeded with native vegetation composed of both cool and warm weather species (grasses).	The vegetation will help stabilize the cover surface, minimize erosion, and remove infiltrated water via transpiration.
Surface Treatment	Mixture of cover soil and gravel. The gravel is to be mixed into the cover soil at a rate of 33% by weight. The gravel will be 1.75 in. (4.4 cm) to 3 in. (7.6 cm) in diameter. The cover soil will be capable of maintaining native vegetation with adequate storage capacity and nutrient availability. This layer will be a minimum of 18 in. (0.5 m) thick.	The gravel/soil admixture is designed to minimize erosion due to both wind and surface runoff.
Cover Soil	The cover soil depth will be a minimum of 3.5 ft (1 m). The layer will consist of soil from TA-61 with a determined mix of soil amendments. The cover soil will be capable of maintaining native vegetation with adequate storage capacity and nutrient availability.	Hydraulic characteristics of a typical sandy loam were used to determine the required soil depth because it is recommended that the TA-61 borrow soils be amended to possess the storage capacity of this soil type. The soil depth was determined using modeling where a depth of soil was determined to minimize flux. The modeling utilized the wettest decade on record as the upper boundary condition. It was estimated that the added storage capacity offered by the inclusion of a biobarrier that creates a capillary barrier was more than adequate to store any infiltration events that would occur.
Filter Layer	This layer is composed of sand and gravel that meet determined filter criteria to prevent the overlying finer cover soils from migrating into the underlying biobarrier.	A thin layer placed directly on the biobarrier to serve as a filter medium to prevent the overlying finer soils from migrating into the underlying biobarrier.
Biobarrier	A minimum layer of 6-in. (15-cm) diameter cobble composed of rock or concrete. The layer is to be a minimum of 1 ft (0.3 m) thick.	The layer prevents biointrusion (burrowing animals and plant roots) from entering the underlying source material.
Subgrade	The upper foot of existing interim cover soil shall be scarified and recompacted to a minimum of 95% of the maximum dry density and dry of the optimum moisture content as determined per ASTM D698.	Provide a firm foundation for the construction of the cover profile. Provide the final grades and slopes for installation of a uniform cover profile.

Appendix A

Acronyms and Abbreviations,
Metric Conversion Table, and Data Qualifier Definitions

A-1.0 ACRONYMS AND ABBREVIATIONS

ACZ	acceptable compaction zone
A/E	architect/engineer
asl	above sea level
B&K	Brüel and Kjaer
bgs	below ground surface
BH	borehole
BV	background value
CFR	Code of Federal Regulations
CM	construction manager
CME	corrective measures evaluation
CMI	corrective measures implementation
COPC	chemical of potential concern
CSU	container storage unit
CY	calendar year
D&D	decontamination and decommissioning
DOE	Department of Energy (U.S.)
EO	Executive Order
EPA	Environmental Protection Agency (U.S.)
ESL	ecological screening level
ET	evapotranspiration
FY	fiscal year
HAZWOPER	Hazardous Waste Operations and Emergency Response
HEM	Hillslope Erosion Model
HI	hazard index
HHMSSL	human health medium-specific screening level
IFWGMP	Interim Facility-Wide Groundwater Monitoring Plan
INL	Idaho National Laboratory
LANL	Los Alamos National Laboratory
LLW	low-level waste
MCL	maximum contaminant level
MDA	material disposal area
MDD	maximum dry density
MLLW	mixed low-level waste

NMAC	New Mexico Administrative Code
NMED	New Mexico Environmental Department
NMEID	New Mexico Environmental Improvement Division (New Mexico Environment Department before 1991)
NMHWA	New Mexico Hazardous Waste Act
NMWQCC	New Mexico Water Quality Control Commission
NNMCAB	Northern New Mexico Citizens Advisory Board
NOAA	National Oceanic and Atmospheric Administration
NRC	Nuclear Regulatory Commission
NWS	National Weather Service
O&M	operation and maintenance
OMB	Office of Management and Budget
PA	performance assessment
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PE	professional engineer
PET	potential evapotranspiration
PL	Public Law
PLS	pure live seed
PPE	personal protective equipment
QA	quality assurance
QC	quality control
RA	remedial action
RACER	Remedial Action Cost Engineering and Requirements
RCRA	Resource Conservation and Recovery Act
RD	remedial design
RH	remote handling
RLD	root length density
RFI	RCRA facility investigation
RUSLE	Revised Universal Soil Loss Equation
SL	screening level
SME	subject matter expert
SVE	soil vapor extraction
SSL	soil screening level

SVOC	semivolatile organic compound
SWMU	solid waste management unit
SWPPP	stormwater pollution prevention plan
T&E	threatened and endangered
TA	technical area
TCA	1,1,1-trichloroethane
TCE	trichloroethene
TDR	time-domain reflectometry
TEDE	total effective dose equivalent
TRU	transuranic
TSCA	Toxic Substances Control Act
TSD	treatment, storage, and disposal (facilities)
U.S.C	United States Code
VA	value assessment
VOC	volatile organic compound
WBS	work breakdown structure
WIPP	Waste Isolation Pilot Plant
WM	Waste Management (Committee)

A-3.0 METRIC CONVERSION TABLE

Multiply SI (Metric) Unit	by	To Obtain US Customary Unit
kilometers (km)	0.622	miles (mi)
kilometers (km)	3281	feet (ft)
meters (m)	3.281	feet (ft)
meters (m)	39.37	inches (in.)
centimeters (cm)	0.03281	feet (ft)
centimeters (cm)	0.394	inches (in.)
millimeters (mm)	0.0394	inches (in.)
micrometers or microns (µm)	0.0000394	inches (in.)
square kilometers (km^2)	0.3861	square miles (mi^2)
hectares (ha)	2.5	acres
square meters (m^2)	10.764	square feet (ft^2)
cubic meters (m^3)	35.31	cubic feet (ft^3)
kilograms (kg)	2.2046	pounds (lb)
grams (g)	0.0353	ounces (oz)
grams per cubic centimeter (g/cm^3)	62.422	pounds per cubic foot (lb/ft^3)
milligrams per kilogram (mg/kg)	1	parts per million (ppm)
micrograms per gram (µg/g)	1	parts per million (ppm)
liters (L)	0.26	gallons (gal.)
milligrams per liter (mg/L)	1	parts per million (ppm)
degrees Celsius (°C)	9/5 + 32	degrees Fahrenheit (°F)

A-4.0 DATA QUALIFIER DEFINITIONS

Data Qualifier	Definition
U	The analyte was analyzed for but not detected.
J	The analyte was positively identified, and the associated numerical value is estimated to be more uncertain than would normally be expected for that analysis.
J+	The analyte was positively identified, and the result is likely to be biased high.
J-	The analyte was positively identified, and the result is likely to be biased low.
UJ	The analyte was not positively identified in the sample, and the associated value is an estimate of the sample-specific detection or quantitation limit.
R	The data are rejected as a result of major problems with quality assurance/quality control (QA/QC) parameters.

Appendix B

Public Outreach Activities

Public Outreach Activities for the Closure of Material Disposal Area G Completed Through August 2008

October 16, 2005	Los Alamos National Laboratory (LANL) presented information regarding results of the investigation of Material Disposal Area (MDA) G, stipulated under the March 1, 2005, Compliance Order on Consent, to the Northern New Mexico Citizen's Advisory Board (NNMCAB) Waste Management (WM) Committee.
March 3, 2006	The U.S. Department of Energy (DOE) and LANL presented information on the corrective measures evaluation (CME) progress and alternatives for closure of MDA Ls and G to a meeting at the full NNMCAB.
July 2006	LANL discussed moisture content profiles for MDA G with NNMCAB WM committee members.
July 26, 2006	LANL presented an overview of the DOE Performance Assessment for Area G to the NNMCAB WM committee.
February 28, 2007	LANL sponsored an evening, open house, poster and roundtable discussion session for topics related to closure of MDAs L and G at the Best Western Hilltop House in Los Alamos, New Mexico.
August 15, 2007	LANL presented updated information about the DOE Performance Assessment for Area G to the NNMCAB WM Committee.
April 16, 2008	LANL and DOE participated in the MDA G Closure Forum sponsored by the NNMCAB. Event included presentations, posters, and a recorded question and answer panel discussion.

Appendix C

Predesign Engineering Options Value Assessment

C-1.0 INTRODUCTION

This appendix describes the value assessment (VA) process and results from a team meeting conducted on February 22, 2007. This process was aimed at identifying issues of importance in the development of cover alternatives for a remedy for Material Disposal Area (MDA) G at Los Alamos National Laboratory (the Laboratory). During the design phase of the selected remedy, a formal value engineering or equivalent study will build on this assessment.

The VA was conducted for approximately 7 h. The participants included subject matter experts (SMEs) in cover design, hydrology, waste management, Resource Conservation and Recovery Act (RCRA) and U.S. Department of Energy (DOE) regulatory compliance, chemical engineering, mechanical engineering, and civil engineering.

VA Team

- Frank Bosiljevac, DOE project lead
- Kent Bostick, hydrology SME
- Todd Clark, chemical engineer/regulatory SME
- Steve Dwyer, PhD, Professional Engineer (PE), arid cover SME
- Joe English, regulatory SME
- Debbie Finfrock, PE, arid cover SME
- Sean French, waste management SME
- Brandon Gutierrez, DOE–Los Alamos National Laboratory Site Office engineer
- Rebecca Hollis, PhD, chemist, facilitator
- John Hopkins, PhD, Laboratory project lead
- Jim Orban, DOE project consultant
- Ron Rager, civil engineering SME
- Joe Ritchey PE project manager/geological engineering SME

C-2.0 BACKGROUND

MDA G at Technical Area 54 (TA-54) includes disposed and stored wastes subject to DOE orders, New Mexico Environment Department (NMED) regulations, and the Compliance Order on Consent (the Consent Order).

A corrective measures evaluation (CME) for MDA G was recommended in the approved MDA G investigation report (LANL 2005, 090513; NMED 2007, 096716) and required by the Consent Order. The CME, following the RCRA corrective measures study process, will evaluate and screen potentially applicable technologies to meet cleanup objectives and propose several alternative potential remedies for long-term protectiveness from future risks from contaminant migration and inadvertent intrusion into the wastes disposed at MDA G.

The CME must meet protectiveness standards of the Consent Order and additional performance requirements defined in DOE Orders 435.1 and 5400.5.

C-3.0 VA OBJECTIVES FOR THE CME

General VA objectives include

- building consensus with partners to encourage positive impacts on project delivery,
- developing standards for future projects using innovative cost avoidance ideas, and
- reducing life-cycle costs of items to lower future maintenance costs.

The VA objectives for this CME were limited to considering features that could make a difference in the cover alternatives evaluation, including

- building consensus on priority of included cover features,
- brainstorming on additional cover options and maintenance requirements, and
- capturing lessons learned from completed covers at the Laboratory, Uranium Mill Tailings Remedial Action sites, and other locations, and observations of natural analogs in similar environments.

C-4.0 VA APPROACH

The VA process breaks components of a project into functions. The team of SMEs then identifies solutions that will satisfy the functions. The VA team formulates the solutions into recommendations, and the CME team incorporates the valid recommendations into corrective measures alternatives.

The five phases of a study include

- investigation (determine background information, perform function analysis, develop team focus),
- speculation (be creative, brainstorm, propose alternatives),
- evaluation (analyze alternatives, identify life-cycle costs),
- development (develop technical and economic supporting data), and
- presentation (present recommendations and team findings).

In this assessment, functions were determined by evaluation of a conceptual cover proposed to comply with requirements defined by DOE Order 435.1 instead of beginning with a formal function analysis. Also, because this assessment was performed in the preliminary stages of the overall corrective action project, the speculation and evaluation stages relied heavily on qualitative information about function and costs provided by the participants.

This resulted in the following CME VA process for MDA G:

- Establishing the VA team
- Providing introductory, background, and premeeting materials to the team
    - ❖ Introductory materials include CME VA plan and agenda.
    - ❖ Background materials include waste layout and existing design information.
    - ❖ Premeeting materials include preassessment brainstorming ideas and VA evaluation form.

- Reviewing brainstorming ideas before the meeting
- Performing a VA workshop
    - ❖ Define functions of conceptual cover
    - ❖ Brainstorm ideas for new cover alternatives
    - ❖ Eliminate and consolidate like ideas
    - ❖ Rank ideas against Consent Order requirements
- Developing a report on results to be used for finalizing alternative for CME

To accomplish the CME VA process for MDA G, the VA team spent an hour sharing information regarding operational and closure issues pertinent to the site. This session was followed by brainstorming to identify potential features that add value to a cover system.

The identified features were then given a score based on protectiveness, implementability, and cost.

These three characteristics were selected because they summarize the Consent Order objectives for alternatives performance measures. The rankings were based on a consensus of the participants' engineering judgment and were not based on detailed analyses.

C-5.0 VA RESULTS

As a result of brainstorming and ensuing discussion, several fundamental cover features achieved consensus of the participants, including the following:

- Optimized cover is to be used in one or more alternatives.
- Soil vapor extraction (SVE) should be proposed to remove volatile organic compounds (VOCs) as a proactive measure.
- Elements of the cover to be recommended include
    - ❖ south-facing orientation to optimize evapotranspiration,
    - ❖ ~2% grade to reduce runoff and erosion and enhance water retention capabilities within the upper portion of the cover, and
    - ❖ a biobarrier to reduce cover thickness.
- Additional features include
    - ❖ collecting eroded material at the base of drainage channels to trap possible contaminants on-site,
    - ❖ implementing a long-term (1000-yr) maintenance plan with a "legal basis" to ensure extended compliance,
    - ❖ using on-site soils removed during future waste storage placement, to be used as fill, and
    - ❖ potentially using materials from demolition activities across the Laboratory.

Table C-5.0-1 shows the positive brainstorming ideas as ranked through the evaluation process. Table C-5.0-2 shows brainstorming ideas that were similar to other ideas or were deemed to be low ranking.

6.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID number. This information is also included in text citations. ER ID numbers are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau; the U.S. Department of Energy–Los Alamos Site Office; the U.S. Environmental Protection Agency, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

DOE (U.S. Department of Energy), June 13, 2000. "Procedure for the Release of Residual Radioactive Material from Real Property," U.S. Department of Energy memorandum to D. Glenn, I.R. Triay, M. Zamorski, E. Sellers, D. Gurule, and D. Bergman-Tabbert from C.L. Soden, Albuquerque, New Mexico. (DOE 2000, 067489)

LANL (Los Alamos National Laboratory), September 2005. "Investigation Report for Material Disposal Area G, Consolidated Unit 54-013(b)-99, at Technical Area 54," Los Alamos National Laboratory document LA-UR-05-6398, Los Alamos, New Mexico. (LANL 2005, 090513)

NMED (New Mexico Environment Department), June 8, 2007. "Approval for the 'Investigation Report for Material Disposal Area G, Consolidated Unit 54-013(b)-99, at Technical Area 54'," New Mexico Environment Department letter to D. Gregory (DOE LASO) and D. McInroy (LANL) from J.P. Bearzi (NMED HWB), Santa Fe, New Mexico. (NMED 2007, 096716)

Table C-5.0-1
VA Positive Brainstorming Ideas

Brainstormed Ideas (Ranking 1 = Positive, 5 = Negative)	Protectiveness	Implementability	Cost	Total
SVE to reduce VOC contamination concerns	1	1	1	3
Place emphasis on high-risk areas (e.g., contamination, erosion)	1	1	1	3
Maximize a south-facing surface to increase evapotranspiration and reduce trees	1	1	1	3
Develop top layer that impedes runoff and promotes evaporation	1	1	1	3
Ensure additional waste placement does not negatively impact optimization of cover	1	1	1	3
Specify gravel admix to prevent surface erosion	1	1	1	3
Promote synergy of all design features	1	1	1	3
Capture contaminated sediment before movement off-site	1	1	1	3
Specify topsoil-type material requiring minimal amendments	2	1	1	4
Prepare slope to natural slope of mesa (2.5%)	1	2	1	4
Control drainage into fortified fingers to south	1	1	2	4
Assess long-term (1000-yr) climate	1	1	2	4
Employ biobarrier to reduce thickness of cover while protecting for radon gas release	1	1	2	4
Use 1000-yr institutional control, maintenance	1	3	1	5
Optimize shape geometry, slope, minimize thickness of cover	1	1	3	5
Consider cover functionality in absence of vegetation	1	1	3	5
Use roller-compacted concrete as biobarrier/intrusion barrier	3	1	1	5
Beneficial reuse of concrete or asphalt demolition materials	3	1	1	5
Stabilize area surrounding waste in high-erosion areas	3	1	3	7
Promote surface runoff toward center not edges of mesa	3	2	3	8
Vitrify shallow waste to reduce cover thickness	1	3	5	9
Tailor-remedy to high radon areas	2	4	3	9
Specify soil with optimal water retention properties	1	3	5	9
Consider tight compaction in lower layers of the cover and less compaction in upper rooting zone to act as a biobarrier and increases soil water storage capacity	5	1	3	9
Relocate wastes away from high erosion potential areas	1	5	5	11
Relocate wastes that cause cover to be higher or steeper	3	5	5	13

Table C-5.0-2
VA Low-Ranking Ideas

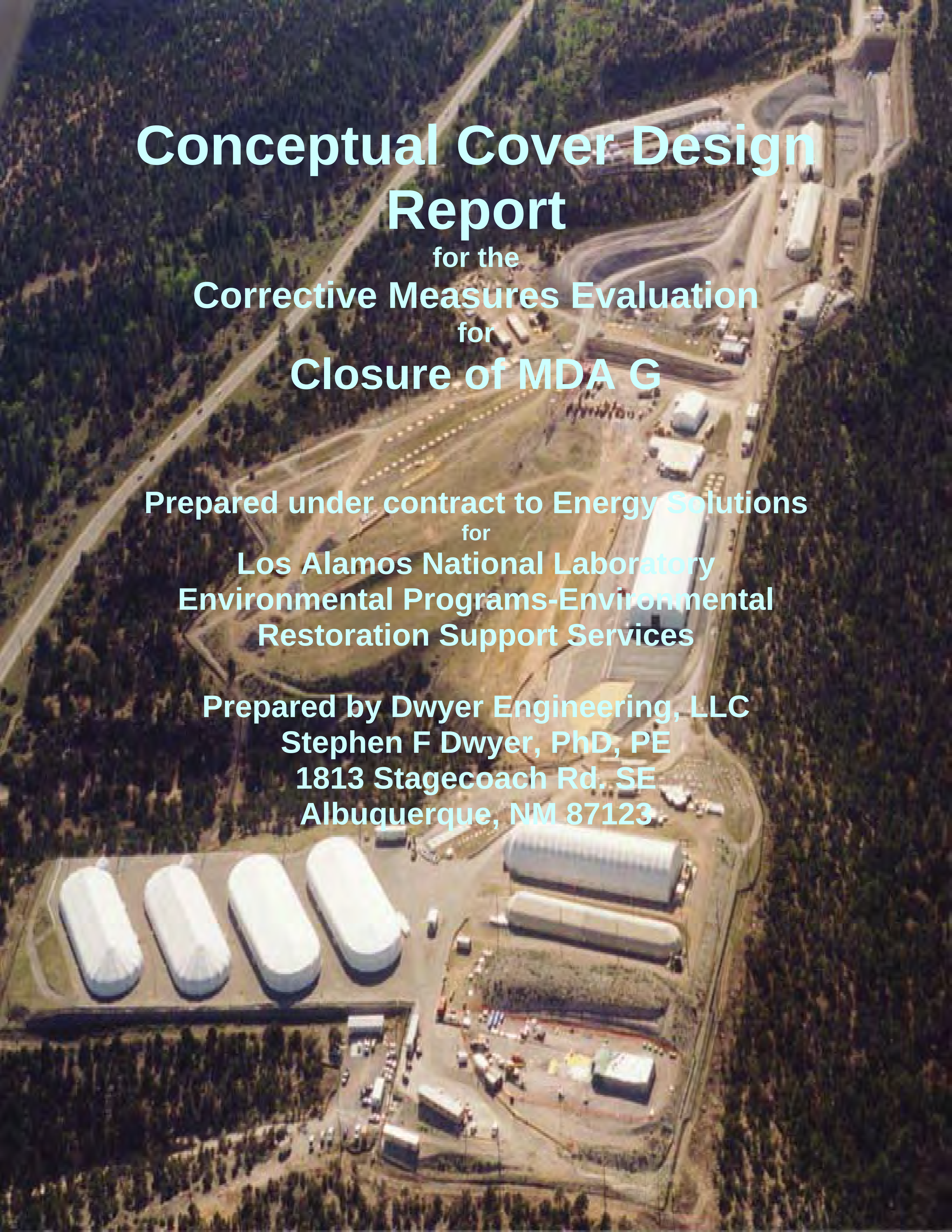
Eliminate VOC hot spots
Potential for borrow material on-site above pits
Amend material from TA-61 to be suitable for topsoil
Examine minimization of volume of cover used to reduce cost
Rock armour that meets Nuclear Regulatory Commission requirements that are closer to site
Rock material from closest source
Native seed mix for cover
Evaluate cliff retreat to reduce 50-ft setback
Fill in drainage areas to eliminate corners
Use hostile plants as plant barrier
Place sand dunes upwind as source for surface deposition
Use biobarrier to encourage grass, not tree growth; shallow not deep roots
Use downed trees as source material
Use topsoil from canyon and allow it to regenerate itself
Solidify/stabilize near-surface portions of the waste as an alternative to a cover, in addition to existing covers or in addition to a thin cover
Consider long-term (1000-yr) erosion maintenance and active biotic intrusion control • Underlying potential issue of when site could meet unrestricted release criteria from DOE Order 5400.5 and DOE-Albuquerque position memo (2000, 067489) • Trades up-front design and construction costs for future maintenance costs
Remove mounds/high spots on mesa that conflict with optimal cover geometry
Select hostile plant species to limit unwanted deep-rooted species growth • For example, creosote bushes limit other plants by poisoning soils in the vicinity of the plant.
Favorable compass orientation of cover slope for maximal evaporation (S or SE)
Low-profile physical barrier to roots and burrows • Use stainless wire mesh sized to limit burrows
Determine thickness of existing cover
Construct a system that will create a caliche layer as part of a natural biobarrier concept
Excavate and move wastes at the edges of the main surface at Area G toward the center of the mesa, taking advantage of the “roofline” cause by the pitch of a cover
Reduce the need to prepare engineering designs for unique geometries • Simplifies cover construction • Reduces the need for rock armor, which requires an angular high-durability material that might be harder to obtain at the Laboratory
Solidify near-surface portion of wastes near cliffs and on mesa fingers
Place new-generation low-level waste at locations on the mesa where cover geometry dictates (roofline)
Identify wastes or nonwaste areas that do not require a cover to meet DOE Order 435.1 1000-yr criteria
Reduce/eliminate sharp inside edges
Create sand dunes upwind as windward source for surface deposition

Table C-5.0-2 (continued)

Reduce wind speed to allow deposition of sediment on leeward side
Use thicker cover to allow sacrificial material for the period of performance
Reduce desirability of area for agriculture and residence • Cover Area G surface with large boulders
Isolate Area G from rest of mesa • Excavate a deep channel across the mesa at the west end of the area • Enhance cliff faces where not severe
Install sensor array into mesa from the sides in horizontal boreholes • Optimize on opportunity to use horizontal boreholes to function as future leachate capture network (or desiccation barrier)
Construct mesa-top drainage channel on the southern edge of the cover that connects to existing drainages instead of letting surface water flow off mesa
Isolate mesa to reduce access and use material as borrow material

Appendix D

Conceptual Cover Design Report for the Corrective Measures Evaluation for Closure of MDA G



Conceptual Cover Design Report

for the

Corrective Measures Evaluation

for

Closure of MDA G

Prepared under contract to Energy Solutions

for

Los Alamos National Laboratory
Environmental Programs-Environmental Restoration Support Services

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1.0 EXECUTIVE SUMMARY

Dwyer Engineering, LLC was tasked to provide engineering input into the development of a conceptual cover profile for final closure of the Material Disposal Area (MDA) G site located at Los Alamos National Laboratory (LANL) in Los Alamos, New Mexico. Specifically, Dwyer Engineering was to provide a recommended cover profile based on storage capacity, erosion, and biointrusion considerations. Other considerations such as radon attenuation were completed by others. This conceptual profile was determined based on the best available information including assumptions required to overcome data gaps.

A conceptual cover profile was derived for the Corrective Measures Evaluation to remediate and close MDA G. The conceptual cover profile (Figure 3.1), consists of a soil profile referred to as an Evapotranspiration (ET) Cover. This cover is designed to store infiltrated water until it is removed by the combination of plant transpiration and surface evaporation (collectively referred to as ET). The cover system will use locally available soils and native vegetation to create a long-lasting cover that has a performance and design life commensurate with the projected hazardous life of the contained wastes. The Performance Assessment (PA) for MDA G indicated that the primary contaminant release vectors from the site are erosion and biointrusion. To minimize erosion, the cover surface was enhanced with a gravel admixture. A bio-barrier was placed beneath the soil cover to minimize the intrusion of flora and fauna into the underlying waste.

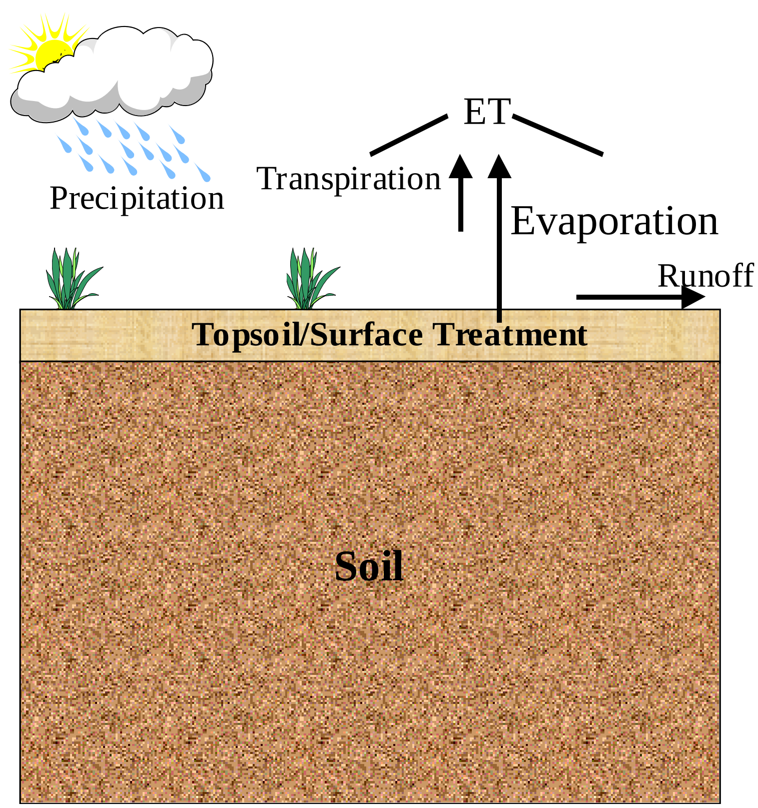
Unsaturated flow modeling of the proposed conceptual cover design determined that flux through the profile would essentially be zero thus satisfying the DOE Order 435.1 and RCRA-equivalence. The MDA G PA suggested a flux less than 1 mm/yr would limit the migration of contaminants due to surface infiltration. However, because MDA G contains Resource Conservation and Recovery Act (RCRA) wastes, regulations governing RCRA require the flux through a cover to be minimized. Soil from the TA61 proposed borrow site were modeled to determine their effectiveness in an ET Cover. The modeling revealed that a soil depth greater than 6.6 ft (2m) would be required to minimize flux. The TA61 soils were classified as a sandy loam (Shaw 2006), but have marginal storage capacity. Consequently, hydraulic properties of a typical sandy loam were modeled to verify if the soil depth requirement could be reduced. The modeling output showed that the typical sandy loam would minimize flux with a depth of about 5 ft (1.5 m). It is therefore recommended a soil amendment be included with the TA61 borrow soils to increase the storage capacity and soil nutrient availability. This site is also governed by Department of Energy (DOE) Order 435.1 which states that the cover should be designed to perform for 1000 year time period; the upper boundary condition should ideally be expanded to include climate scenarios that are expanded beyond the available weather data. However, this data is not available at this time. Engineering judgment was used to determine that 5 ft (1.5 m) of cover soil would offer adequate storage capacity even under an enhanced set of climate scenarios representative of a 1000 year return period to reduce infiltration to less than 1 mm/year. Especially considering that the inclusion of a bio-barrier in the cover profile introduced a capillary barrier that further enhances the storage capacity of the cover soil.

2.0 INTRODUCTION

MDA G is located within Technical Area (TA) 54 at the Los Alamos National Laboratory in Los Alamos, New Mexico. TA-54 is located on Mesita del Buey and spans the boundary of the Cañada del Buey and Pajarito Canyon watersheds. TA-54 ranges in elevation between 6700 and 6800 ft with a depth to groundwater ranging between 900 and 980 ft. The major industrial activity at TA-54 has been waste storage and disposal. MDA G is a 100-acre site that has served as the Laboratory's principal radioactive solid waste storage and disposal site since routine operations began in 1959. The majority of stormwater runoff from MDA G enters the Pajarito Canyon watershed with a much smaller portion draining into Cañada del Buey, which is located within the Mortandad Canyon watershed.

This report provides a summary of the basis for the conceptual cover design for MDA G as part of the Corrective Measures Evaluation (CME) for remediation of the site. An ET Cover with an erosion resistant surface treatment and a bio-barrier will be constructed to provide adequate protection and risk reduction. The ET Cover consists of a single, vegetated soil layer constructed to represent an optimum mix of soil texture, soil thickness, and vegetation cover (Figure 2.1).

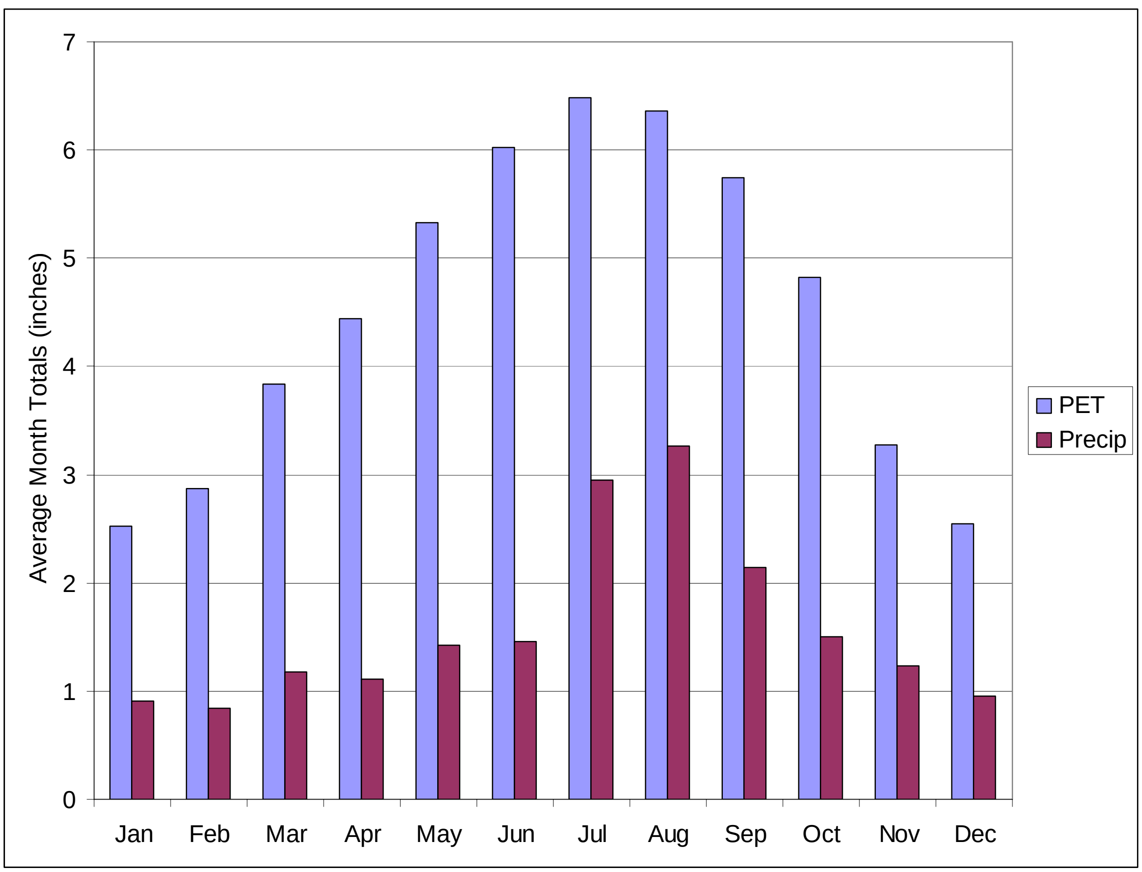
Figure 2.1
TYPICAL ET COVER PROFILE



The ET Cover concept relies on the soil to act like a sponge (Dwyer 2003). Infiltrated water is held in this "sponge" until it can be removed via ET. ET is defined as the combination of water removal due to both evaporation from the surface and transpiration through vegetation. Previous research has shown that a simple soil cover can be very effective at minimizing percolation and erosion, particularly in dry environments (http://www.clu-in.org/download/remed /epa542f03015.pdf#search ='evapotranspiration%20epa%20fact%20sheet).

The MDA G site is an ideal site for an ET Cover. First, it contains long-lived waste and source material such as radionuclides. Prescriptive covers that depend on geosynthetics cannot effectively be used for these sites because the geosynthetics will not last as long as the waste poses a significant risk nor will they meet the 1000 year performance period dictated under DOE Order 435.1. Additionally, the climate's demand for water or potential evapotranspiration (PET) far exceeds the actual supply of water (precipitation) as shown in Figure 2.2. The ET Cover offers another important advantage in that it provides for a deeper rooting medium that will provide an opportunity for native vegetation to survive lengthy drought periods because the water storage of the ET Cover is greater than that of a prescriptive cover.

Figure 2.2
Climate's demand for water (PET) vs. supply of water (precipitation) for Los Alamos, NM



3.0 CONCEPTUAL DESIGN

The cover system proposed for final closure as part of the CME for MDA G located at Los Alamos National laboratory in Los Alamos, NM is shown in figure 3.1. A brief description of each layer in the cover profile is contained in Table 3.1 with expanded descriptions contained in sections 3.1 to 3.5.

Figure 3.1
MDA G CME Conceptual Cover Profile

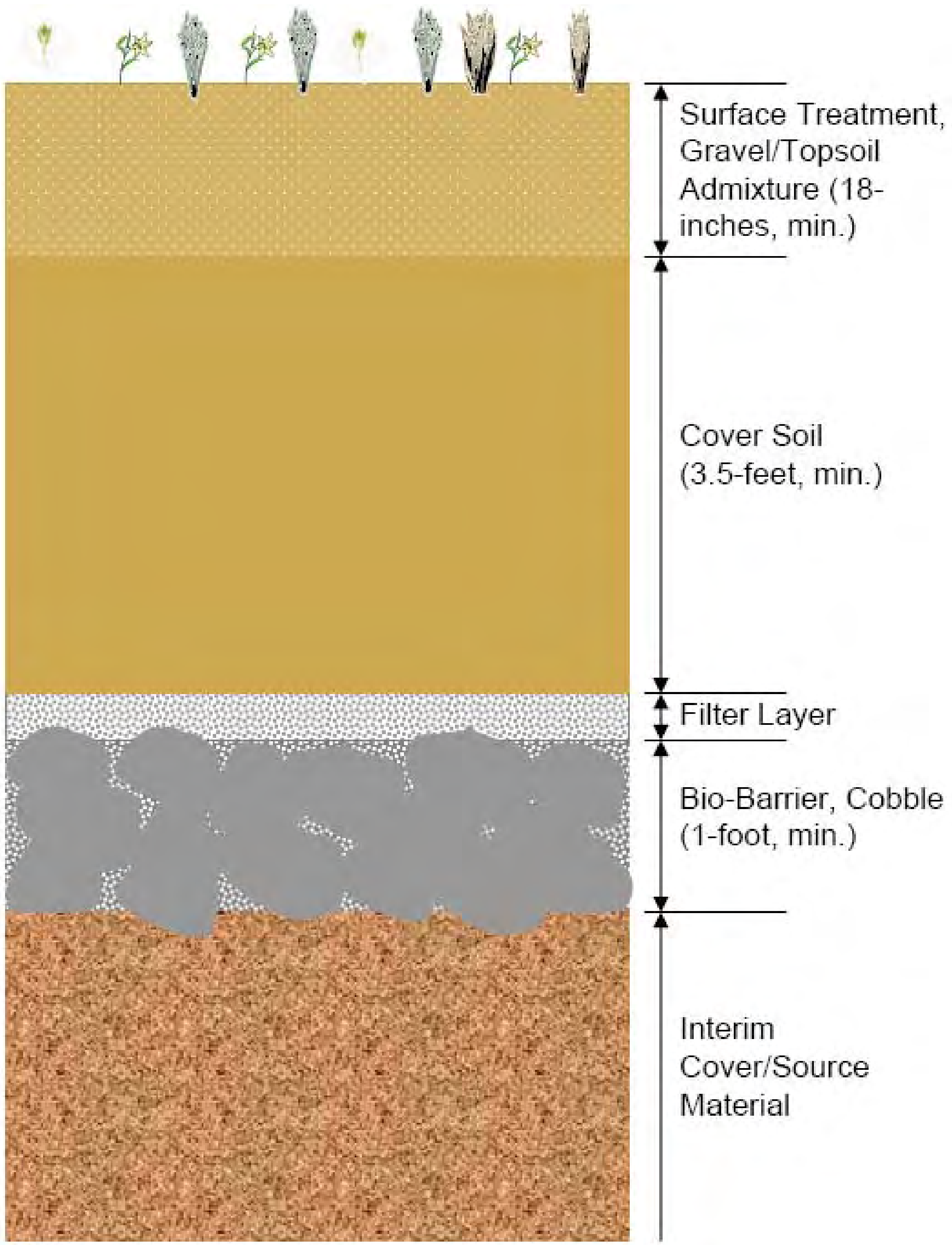


Table 3.1
MDA G CME Conceptual Cover Profile Layer Specifics and Justification

Cover System Layer	Design Specifics	Design Justification
Vegetation	The site is to be seeded with native vegetation composed of both cool and warm weather species (grasses). Refer to Table 3.1 for a recommended seed mix.	The vegetation will help stabilize the cover surface, minimize erosion, and remove infiltrated water via transpiration.
Surface Treatment	Mixture of cover soil and gravel. The gravel is to be mixed into the cover soil at a rate of 33% by weight. The gravel will be 1.75-inch (4.4 cm) to 3-inches (7.6 cm) in diameter. The cover soil will be capable of maintaining native vegetation with adequate storage capacity and nutrient availability. This layer will be a minimum of 18-inches thick (0.5 m).	The gravel/soil admixture is designed to minimize erosion due to both wind and surface runoff.
Cover Soil	The cover soil depth will be a minimum of 3.5-feet (1 m). The layer will consist of soil from TA61 with a determined mix of soil amendments. The cover soil will be capable of maintaining native vegetation with adequate storage capacity and nutrient availability.	Hydraulic characteristics of a typical sandy loam were used to determine the required soil depth because it is recommended that the TA 61 borrow soils be amended to possess the storage capacity of this soil type. The soil depth was determined using modeling where a depth of soil was determined to minimize flux. The modeling utilized the wettest decade on record as the upper boundary condition. However, because the site requires a 1000-year performance period, it was estimated that the added storage capacity offered by the inclusion of a bio-barrier that creates a capillary barrier was more than adequate to store any infiltration events that would occur over a

		1000-year return period.
Filter Layer	This layer is composed of sand and gravel that meet determined filter criteria to prevent the overlying finer cover soils from migrating into the underlying bio-barrier.	A thin layer placed directly on the bio-barrier to serve as a filter medium to prevent the overlying finer soils from migrating into the underlying bio-barrier.
Bio-barrier	A layer of minimum 6-inch (15 cm) diameter cobble composed of rock or concrete. The layer is to be a minimum of 1-foot thick (0.3 m).	The layer prevents biointrusion (burrowing animals and plant roots) from entering the underlying source material.
Subgrade	The upper foot of existing interim cover soil shall be scarified and recompacted to a minimum of 95% of the maximum dry density and dry of the optimum moisture content as determined per ASTM D698.	Provide a firm foundation for the construction of the cover profile. Provide the final grades and slopes for installation of a uniform cover profile.

3.1 VEGETATION

Seed and/or live plants used to revegetate disturbed areas at LANL shall be native to the Los Alamos vicinity. The following is the seed mix to be employed for the cover system at MDA G (Table 3.2).

Table 3.2
Seed Mix

Common Name	Scientific Name	% of mix	PLS (lbs/acre)
Sideoats grama	Bouteloua curtipendula	15%	3.75
Blue grama	Bouteloua gracilis	15%	3.75
Indian ricegrass	Oryzopsis hymenoides	10%	2.5
Western wheatgrass	Agropyron smithii	15%	3.75
Sand dropseed	Sporobolus cryptandrus	10%	2.5
Sheep fescue	Festuca ovina	20%	5
Firewheel	Gaillardia pulchella	3%	.75
Western yarrow	Achillea millefoium	2%	.5
Prairie coneflower	Ratibida columnifera	4%	1
Blue flax	Linum perenne lewisii	6%	1.5
TOTAL			**25 (drilled)**

SEED APPLICATION

Seeding of native vegetation on the cover systems shall be performed in the spring, after the last frost of the season and prior to the arrival of the summer rains that typically occur in July and August. Seeding shall not be done August 1 to September 30 to avoid germination too close to the first frost, as this can kill the new seedlings.

Revegetation shall be done by first preparing the soil by tilling and applying fertilizer. Care must be taken to ensure the rock/soil surface treatment maintains the desired ratio during this activity. Care must also be taken to ensure the rock/soil surface treatment layer is not mixed deeper into the cover profile. Slow-release organic fertilizers shall be applied as necessary to eliminate any deficiencies of the topsoil. Refer to Table 3.3 for recommended levels of available plant nutrients. Bio-Sol or similar fertilizer shall be applied at up to 1500 lbs/acre. Analyses of cover soils used will dictate the actual fertilizer rate required. Granular humate can be applied at 400-500 lbs/acre if in a hydroseeding slurry and up to 1800 lbs/acre if it is incorporated into the top 4 inches of the soil. Application rates of composted manure vary depending on the source (chicken, horse, etc.) and the type of materials (wood chips, paper, soil, etc.) used to compost. If composted manure is to be applied, nutrient content shall be tested and interpreted before it is used.

Drill seeding shall be the method used to apply the seed mix. Drilling introduces seed directly into the prepared seedbed by machine. Seeding shall be performed by drilling at a minimum rate of 25 Pure Live Seed (PLS) pounds per acre. In areas that limit equipment access, broadcast seeding may be used at a rate of 40 PLS pounds per acre.

3.2 SURFACE TREATMENT

The Performance Assessment for MDA G states that biointrusion and erosion are the two primary mechanisms to control contaminant releases from the site. To address the potential erosion of the cover system, a surface treatment is to be used composed of a mixture of gravel and cover soil. This admixture was designed following the procedure described in Dwyer et al (1999), and Dwyer et al (2006).

The gravel to soil mixture and gravel size was determined based on the most critical drainage section (north-south). With the addition of the gravel/soil admixture to the surface, annual soil loss due to both wind and runoff was estimated to be minimal. The gravel admixture shall include a mixture of 33% gravel by weight. The cover soil shall exhibit the storage capacity and soil nutrients described in section 3.3. Salts in this soil shall also be limited in the cover soil as described in section 3.3. The critical gravel size was determined to be 1.5 inches (3.8 cm) [use gravel between 1.5 inches (3.8 cm) to 3 inches (7.6 cm) in diameter] and the total gravel/soil admixture thickness is to be no less than 18 (0.5 m) inches. The design methodology and procedure with input and output specifics are included in Appendix A. Many of the input parameters required to calculate the specifics of this gravel admixture, surface treatment such as bulk density and percentage of silt/clay in the soil were estimated based on soil amendment requirements. Furthermore, slopes and slope lengths were estimated based on preliminary contours provided by PRO2SERVE. These estimates will be replaced with measured values during the final design phase as uncertainties are overcome.

Because the gravel is used to control erosion and is subject to weathering, it shall meet the durability requirements described in NUREG (1999). Refer to table 3.2 below.

Table 3.2
Scoring Criteria for Determining Rock Quality (NUREG 1999)

	Weighting Factor			Score										
	Limestone	Sandstone	Igneous	10	9	8	7	6	5	4	3	2	1	0
Specific Gravity (SSD)	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.40	2.25
Absorption (%)	13	5	2	0.1	0.3	0.5	0.67	0.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate (%)	4	3	11	1	3	5	6.7	8.3	10	12.5	15	20	25	30
Abrasion (%)[1]	1	8	1	1	3	5	6.7	8.3	10	12.5	15	20	25	30
Schmidt Hammer	11	13	1	70	65	60	54	47	40	32	24	16	8	0
Tensile Strength (psi)	5	4	10	1400	1200	1000	833	666	500	400	300	200	100	<100

[1] 100 revolutions. Use only ASTM C131 for scoring purposes for consistency with basis for scoring system (DePuy 1965).

Notes:
1. Scores derived from Tables 6.2 and 6.7 of NUREG/CR-2642.
2. Any rock to be used must be qualitatively rated at least “fair” in a petrographic examination conducted by a geologist experienced in petrographic analysis.
3. Weighting Factors are derived from Table 7 of DePuy (1965), based on inverse of ranking of test methods for each rock type.
4. Test methods shall be standardized (e.g., ASTM) and shall be those described in DePuy (1965).

SOIL PLACEMENT

The gravel/soil admixture used as a surface treatment shall be placed in one uncompacted lift if practical. Two lifts are also acceptable provided the bottom lift is not overcompacted due to placement of the top lift. This surface treatment layer shall be placed as dry as possible, but no wetter than the optimum moisture content as determined by ASTM D698. Any excessive compaction this layer receives during placement shall be scarified. The loose-state of placement is to provide the best means for vegetation establishment. Over-compaction is one of the primary problems with revegetation efforts.

3.3 COVER SOIL

The cover soil layer beneath the gravel/soil admixture shall be a minimum of 3.5 feet (1 m) of amended soil meeting the water storage capacity properties of a typical sandy loam soil (ROSETTA 2000). The cover soil including the soil in the surface treatment (gravel admixture) must possess adequate storage capacity to retain infiltrated water until that water can be removed via ET. Furthermore, this soil must be able to provide a quality rooting medium to maintain native vegetation. This involves ensuring the soil has acceptable levels of plant available nutrients and its salt content is below acceptable levels.

The depth of the cover soil was determined based on water storage requirements to meet RCRA-equivalency. That is, the depth of soil required to minimize flux per 40CFR264.310. The MDA G PA stated that as long as the flux through the cover was less than 1 mm/year, significant risk due to radionuclides would be mitigated and thus DOE Order 435.1 would be satisfied. Modeling using UNSAT H (Fayer 2000) was performed to determine the minimum thickness required to provide adequate storage capacity for an upper boundary condition consisting of the wettest decade in recorded history in Los Alamos (1985 to 1994).

Average hydraulic properties (Shaw 2006) from the TA61 soil borrow site were used as input parameters. The modeling output determined that a depth greater than 6.6 ft (2 m) would be required to minimize flux largely due to the lack of water storage capacity in the TA61 soils (Figure 3.2). The TA61 soils consist of crushed tuff and were classified as a sandy loam, but are on the coarser side of sandy loam soils. Another modeling exercise was performed utilizing typical sandy loam hydraulic properties (ROSETTA 2000) to ascertain if this soil type would decrease the soil depth requirement. This output (Figure 3.3) determined that approximately 1.5 m (5ft) of typical sandy loam soil would minimize flux to a point of diminishing returns (Dwyer et al 2006).

The depth of the surface treatment was determined to be a minimum of 1.5 ft (0.5 m). Therefore the additional cover soil depth required to minimize flux is 3.5 ft (1 m). This provides for a minimum cover soil depth of 5 ft (1.5 m). A third modeling exercise was performed to capture the entire conceptual design that includes all layers above the existing subgrade. This modeling output determined that flux through the cover will be negligible with the conditions modeled. It is important to note that the inclusion of a filter medium above the bio-barrier and the inclusion of a bio-barrier create a capillary barrier. Details of the modeling performed including specific input and output parameters are included in Appendix C.

Figure 3.2
TA 61 Soil: Point of Diminishing Returns (greater than 200 cm)

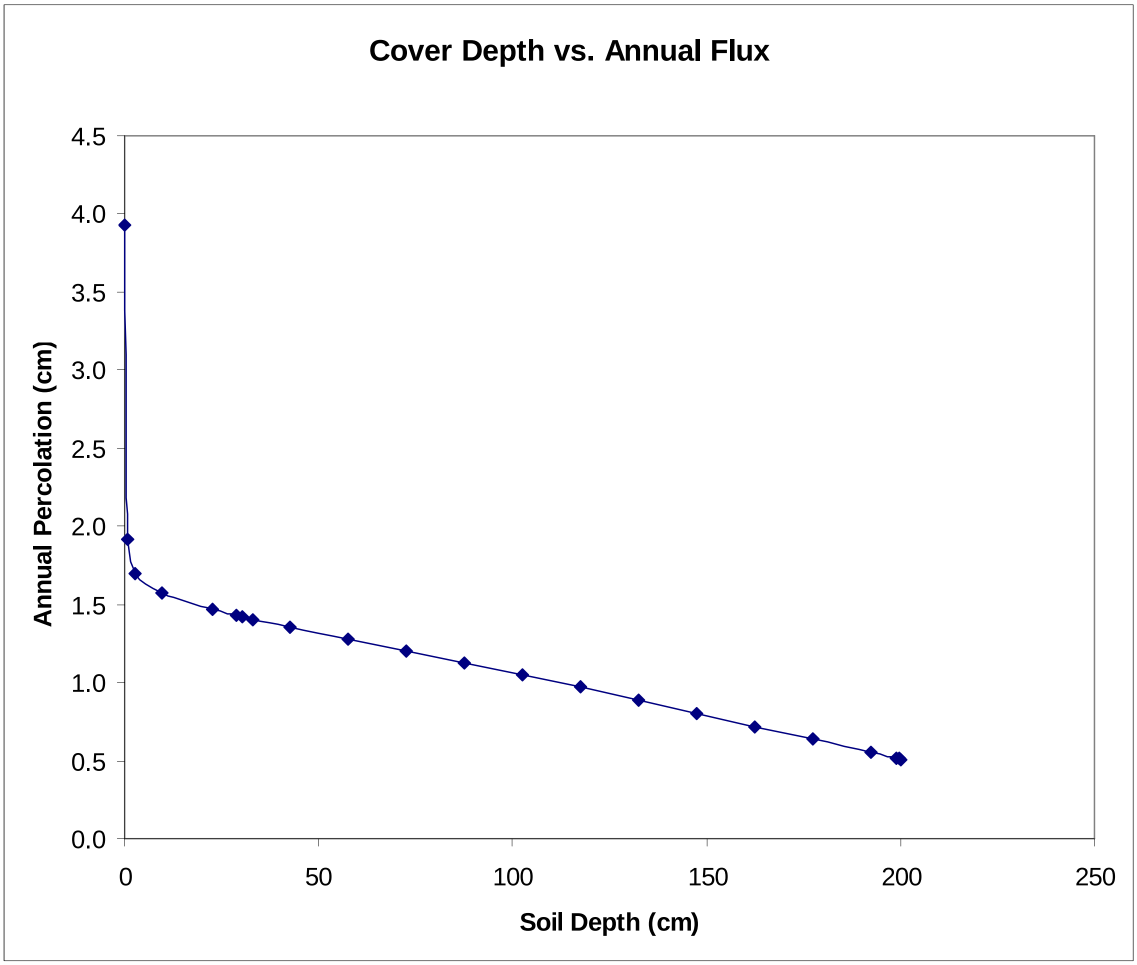
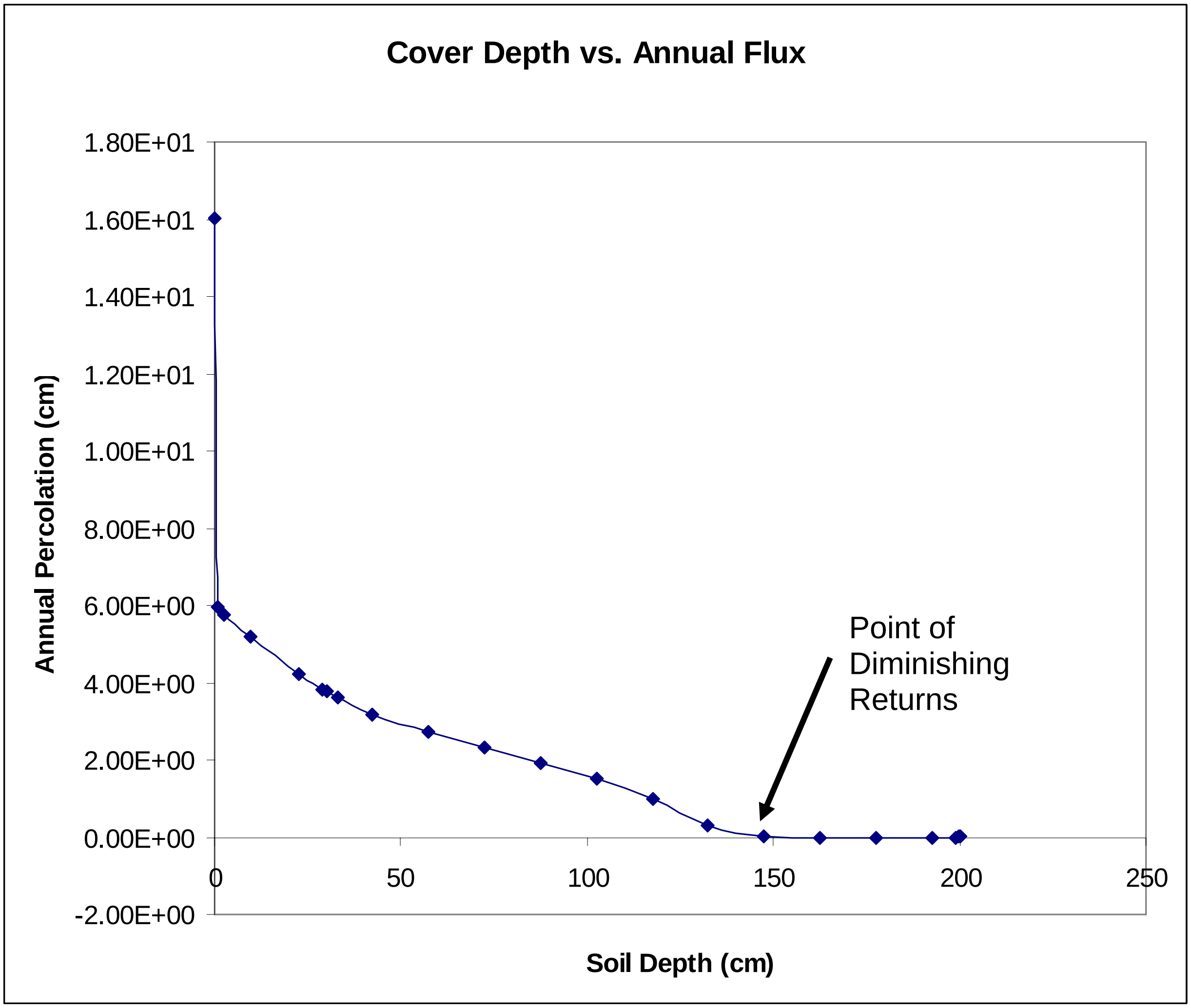


Figure 3.3
Typical Sandy Loam Soil: Point of Diminishing Returns (1.5 m)



The amendments shall ensure the cover soil is capable of maintaining a desired stand of native vegetation. The plant nutrients should allow for the final amended soil to meet the requirements listed in the following table.

Table 3.3
Recommended Available Plant Nutrients for Cover Soil

Test	Limits
CEC	Greater than 15
Percent organic matter	Greater than 2% (g/g)
N	Greater than 6 parts per million (ppm)
P	4 to 7ppm
K	61 to 120 ppm

Because it is unknown at this time where the amendments to the TA 61 will come from, it is also important to verify that the cover soils have tolerable quantities of salts. That is, the salt content in the soils shall be below levels that would hinder the establishment and growth of native vegetation. The final amended soils shall comply with the requirements outlined in the following table.

Table 3.4
Recommended Limitations of Salt in Cover Soil

Test	Limits
EC	Less than 8 µS/cm
SAR	Less than 6
ESP	Less than 15% (g/g)
$CaCO_3$	Less than 15% (g/g) – to 3-ft (91 cm) depth of cover; No limit below 3 ft (91 cm)

SOIL PLACEMENT

An important aspect involved with the construction of a soil cover system is that the soils are placed in a uniform manner. This will help limit preferential flow through the cover. Dwyer (2003) describes the impact of preferential flow in landfill covers. Preferential flow cannot be avoided, but necessary precautions shall be employed to ensure it is minimized. An important feature of the design specifications will involve determining an acceptable density range for installation of the cover soils. Furthermore, to increase the initial storage capacity of the cover system and mitigate the potential for desiccation cracking, the soils will be placed as dry as possible, but no greater than the optimum moisture content as determined by ASTM D698. The acceptable density and moisture content placement range is described as the acceptable compaction zone (ACZ).

The ACZ (Figure 3.4) is unknown as of the date of this report because the desired soil will require amendment to meet the performance objectives of the cover system. Therefore, the process involved in determining this ACZ is briefly described here. For further details refer to Dwyer et al (2006).

Determination of the ACZ for placement of cover soil:

1. Cover soil shall be placed at the goal density. The goal density is best determined from the borrow soil's in situ density. That is, over an extended period of time, a given soil will move toward its "natural" density state. Therefore, it is the goal of the soil installation to place the soil at a density that is as close to that "goal" density as possible from the onset. In this case because the soil will be amended, the goal density shall be assumed to be between 85 to 90% of the maximum dry density (MDD) as determined by ASTM D698.

2. Determine a standard proctor curve for the amended soil used per ASTM D 698, Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort, to obtain the respective maximum dry density (MDD) and optimum moisture content.

3. The allowable dry unit weight or soil density during construction shall then be the goal density plus or minus 5 pounds per cubic foot (pcf) (metric units).

4. The cover soils shall be placed as dry as possible not to exceed the optimum moisture content per ASTM D 698 derived for each borrow soil used. Installing soil dry will provide for a maximum initial water storage capacity in the cover and minimize the potential for desiccation cracking. This is particularly important when using clays (Suter et al. 1993, Dwyer 2003). This moisture

content is applicable for all soils in the cover system, including the upper foot (31 cm) of the interim cover or subgrade.

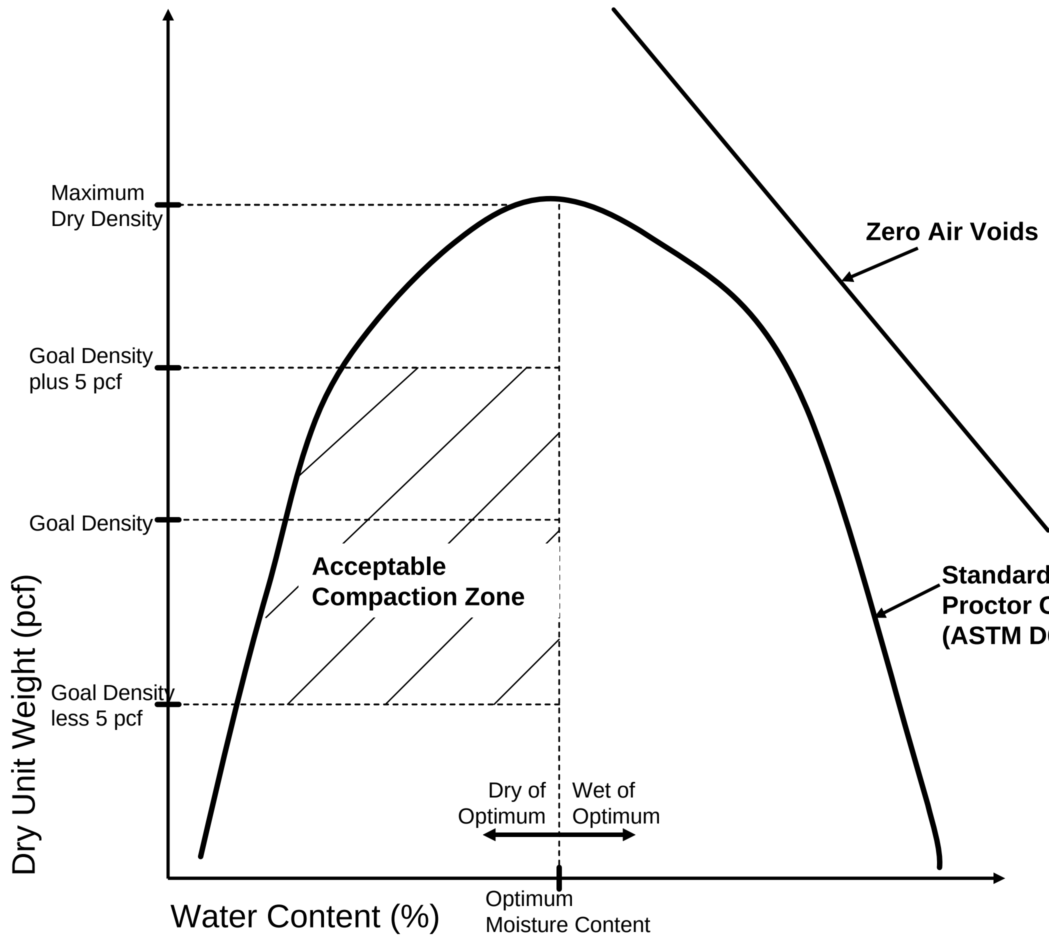


Figure 3.4. ACZ for Soil Placement shown in Hatch Marks

3.4 FILTER MEDIUM

A filter medium composed of sand and /or gravel shall be placed above the bio-barrier, between the bio-barrier and the overlying cover soil layer. This layer is designed to prevent the mixing of soil layers and meet specified filter criteria. The depth of this layer is to be determined in the field and will be the minimum depth required to completely cover the bio-barrier layer and provide a smooth and continuous surface layer for placement of the cover soil. For estimating purposes, this layer shall be assumed to be 6-inches (15 cm) thick.

The Performance Assessment performed for MDA G stated that the two primary mechanisms of concern for transport of contaminants from the site were biointrusion and erosion. There was significant uncertainty with regard to the analysis of biointrusion and erosion in the PA as well. Burrowing animals and roots are both of concern because they can bring contaminants to the surface. A bio-barrier is included in the conceptual design to minimize the potential for burrowing animals and roots from accessing the buried source materials. The bio-barrier is composed of large cobble. To prevent the mixing of finer cover soil into the cobble layer, a filter layer is included. A geotextile or other geosynthetics were not used as a filter fabric because they have limited performance lives that are significantly less than the 1000 year performance criteria (DOE Order 435.1) applied to the site.

The filter medium will be composed of coarse material (sand and/or gravel) that meet specific filter criteria to prevent the mixing of materials. These criteria are as follows:

$$\frac{D_{15}}{d_{85}} \leq 5$$

Equation 3.1

where:

D_{15} = particle size of the coarse soil for which 15% of the particles are finer,

d_{85} = particle size of the fine soil for which 85% of the particles are finer.

The filter design criteria summarized in Table 4.2-3 (DOE 1989) as well as the following requirements shall also be used:

- The filter material shall pass the three-inch sieve for minimizing particle segregation and bridging during placement. Smaller maximum particle sizes may be specified if practical. Also, filters must not have more than 5% passing the No. 200 mesh sieve to prevent excessive movement of fines in the filter.

- Filter material shall be reasonably well graded throughout the in-place layer thickness.

A capillary barrier will be formed with the inclusion of the filter medium beneath the fine cover soils. A second capillary barrier may also be formed between the filter medium and the cobble bio-barrier. Consequently, all requirements for a capillary barrier must be followed as outlined in Dwyer et al (2006). Of particular concern are long slope lengths and consequently the diversion capacity of the capillary barrier. The interface between the materials forming the capillary barrier(s) shall maintain a smooth and continuous interface. Discontinuities in this interface may result in significant preferential flow and must be prevented.

3.5 BIO-BARRIER

As stated in section 3.4, a bio-barrier is included in the cover profile to minimize the intrusion of flora and fauna into the buried source materials. The Performance Assessment for MDA G stated that biointrusion is a significant concern as a transport vector for contaminant release from the site. It is of particular concern for radionuclides that pose a risk to the surrounding environment for longer periods of time. A minimum 1-foot (0.3 m) thick layer of cobble with a minimum diameter of 6-inches (15 cm) will be included in the cover profile. This layer will minimize the potential burrowing of the animal of most concern at the site - gophers; as well as the intrusion of woody roots from plants such as shrubs, pinon, and juniper.

Biointrusion in a landfill cover system refers to the flora and fauna (including insects) interactions or intrusion into the cover system. Biointrusion is important in that it can represent a mechanism leading to vertical transport of contaminants to the ground surface via plant root uptake or soil excavation by burrowing animals and insects. Furthermore, biointrusion can lead to increased infiltration and preferential flow of surface water through the cover system as well as contribute to the change in the soil layer's hydraulic properties. However, the increased soil moisture resulting from burrowing effects on infiltration can actually stimulate increased plant growth, leading to an increase in plant transpiration (Hakonson 2000, Gonzales et al. 1995) and a resulting net decrease in flux.

Vertical transport by biota may be small over a short time scale; however, over many decades these processes may become dominant in mobilizing buried waste (Hakonson 1998). Burrowing by animals and insects have the potential to access buried waste several meters below ground surface, which may lead to chemical and radiation exposures to organisms and physical transport of waste upward in the soil profile to ground surface, to biota, and across the landfill surface to offsite areas. These processes are enhanced by erosion (wind/water), transport of animals moving on/off the landfill, deposition of soil particles on biological surfaces from rain splash and wind re-suspension, and wind transport of senescent vegetation to offsite areas.

There are many studies, many of which are summarized in Dwyer et al (2006) that discuss the effects of biointrusion on cover systems and waste sites. Several specifically applicable to MDA G are summarized in Appendix B.

3.6 SUBGRADE/INTERIM COVER PREPARATION

MDA G currently has an interim soil cover over it. This site will require being cleared and grubbed as well as some regrading including cut/fill operations to bring the site to grade prior to placement of the final cover system. The elevations and grades shall comply with those shown on the project drawings provided by others. At a minimum depth, the upper foot (31 cm) of the interim cover or subgrade shall be scarified and recompacted prior to placement of the bio-barrier. This recompacion shall produce a density not less than 95% of the maximum dry density as determined by ASTM D698.

Furthermore, the moisture content shall be placed dry of the optimum moisture content as determined by ASTM D698.

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47.

APPENDIX A
GRAVEL ADMIXTURE DESIGN

DESIGN RAINFALL EVENT

The rainfall intensity value used to calculate the runoff volume was determined using data supplied by the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) Hydrometerological Design Studies Center and is available on the internet on NOAA's Precipitation Frequency Data Server (http://hdsc.nws.noaa.gov/hdsc/pfds/sa/nm_pfds.html). The data from NOAA Atlas 14 for Los Alamos, NM was used whereby the 30 minute precipitation frequency estimate for a 1000 return period is 2.46 inches (6.25 cm). The 30 minute time of concentration is conservative for any contributory area less than 50 acres (20 hectares) (Lindeburg 1989).

RUNOFF PREDICTION

The "rational method" was used to estimate runoff volumes. This method is commonly used in civil engineering applications and is a method approved by DOE (1989) for design of cover systems for sites regulated by the Uranium Mill Tailings Radiation Control Act of 1978 (i.e., UMTRA sites). Refer to "LANL Engineering Standards Manual," Section G20 (http://engstandards.lanl.gov/engrman/3civ/pdfs/Ch3_G20-R1.pdf). The rational method is based on the assumption that rainfall occurs uniformly over the watershed at a constant intensity for a duration equal to the time of concentration.

Using the rational method, the peak rate of runoff, (Q), in cubic feet per second (cfs) (runoff is actually in acre-inches/hour but is rounded to cfs is given by the following expression:

$$Q = C\ I\ A$$ **Equation A.1**

where:

C = Runoff coefficient (dimensionless)

I = Rainfall intensity (in/hr)

A = Surface area that contributes to runoff (acres)

The value for "I" in this case was 2.46 inches/hour (6.25 cm/hr). For storms with return periods longer than 100 years, DOE recommends the use of C = 1.0 (DOE 1989). The surface area was calculated based on the assumed configuration shown in figure A.1 where L is the critical slope length. Slopes and slope lengths were estimated from proposed contoured plans of the MDA G conceptual cover. Because most of the drainage areas from the cover were irregularly shaped, the slopes and slope lengths were estimated to match the area configuration described here.

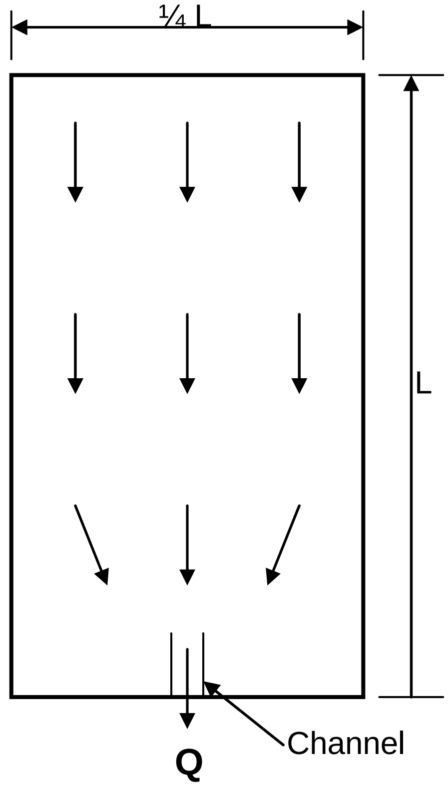


Figure A.1
Contributory area for gully formation

Channel Geometry

The channel geometry shown in Figure A.2 is that assumed for the gully formation.

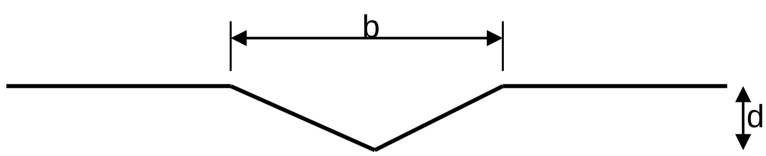


Figure A.2
Channel geometry

The geometry of the channel that forms is based on regression equations developed from analysis of a large number of channels (Simon, Li & Assoc. 1982). The channel width is given by:

$$b = 37\ (Q_m^{0.38} / M^{0.39})$$ **Equation A.2**

where:

b = width of flow (ft);

Q_m = mean annual flow (cfs);

M = percentage of silts and clays in soils.

The mean annual flow (Q_m) is assumed to be between 10% and 20% of the peak rate of runoff (Q) (Dwyer et al. 1999). In this case 20% was conservatively used.

For the given discharge point of geometry, the hydraulic depth (d_h), defined as the flow cross-sectional area divided by the width of water surface, is half of the gully depth (d).

For flows at the critical slope:

$$b = 0.5\, F^{0.6}\, F_r^{-0.4} Q^{0.4}$$ **Equation A.3**

where:

F = width to depth ratio = b/dh;

F_r = Froude Number ≈ 1.0.

These equations were solved simultaneously to yield the channel width and depth for the given peak flow rate and percentage of silt and clay. Refer to Table A.1 for the summary of calculations performed.

Incipient Particle Size

The incipient particle size is the particle that is on the brink of movement at the assumed conditions. Any increase in the erosional forces acting on the particle, due to an increase in velocity or slope, for example, will cause its movement. This incipient particle size (D_c) was calculated using the Shield's Equation:

$$D_c = \tau / F_s(\gamma_s - \gamma)$$ **Equation A.4**

where:

τ = total average shear stress (pcf);

F_s = Shield's dimensionless shear stress = 0.047;

γ_s = specific weight of soil (pcf);

γ = water density = 62.4 pcf.

The total average shear stress is given by:

$$\tau = \gamma\, d_h\, S$$ **Equation A.5**

where:

S = slope (ft/ft).

d_h = hydraulic depth (ft)

Depth of Scour and Armoring Required

The incipient particle size defines the maximum size of particle that will be eroded for a given set of conditions. The material larger than the incipient particle size will not be displaced or eroded, and can form an armoring that will protect the channel from further erosion from similar or lesser storm events.

The depth of scour (Ys) (Figure A.3) to establish an armor layer is given by (Pemberton and Lara 1984):

$Y_s = Y_a\ [(1/P_{c)}\text{-}1]$ **Equation A.6**

where:

Y_s = scour depth;

Y_a = armor layer thickness;

P_c = decimal fraction of material coarser than the incipient particle size.

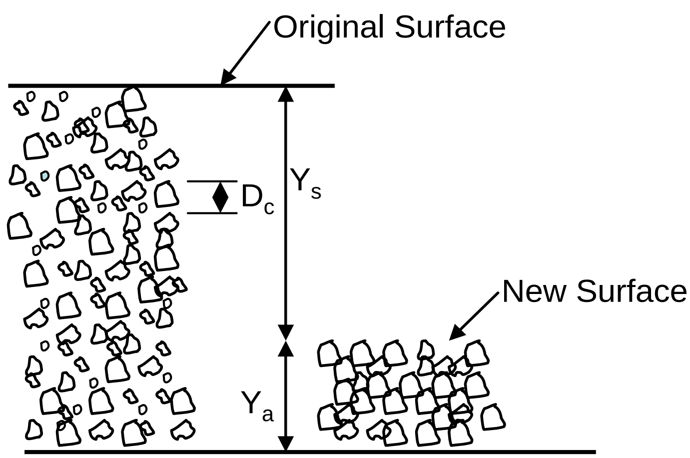


Figure A.3
"Desert Pavement" development

Table A.1 summarizes the gravel admixture calculations performed including critical input and output parameters. The slopes and slope lengths were estimated based on approximate drainage paths and contributory areas as they relate to that assumed in this set of calculations. The first column describes the section that is related to the project drawings produced by PRO2SERVE (not part of this report).

TABLE A.1
GRAVEL ADMIXTURE CALCULATIONS SUMMARY

Section	C Value	I (in/hr)	S (%)	Slope Length (ft)	Q (cfs)	Q_m (cfs)	% silt/clay[1]	Bulk Density[1] (pcf)	Critical Gravel Size [2] (in)	Ratio	Total depth req'd (inches)
DA1	1.0	2.46	2.7	350	1.73	0.17	20	115	0.75	33%	9
DA2	1.0	2.46	3	500	3.53	0.35	20	115	1.25	33%	15
DA3	1.0	2.46	4	375	1.99	0.20	20	115	1.25	33%	15
DA4	1.0	2.46	2.8	800	9.04	0.90	20	115	1.50	33%	18
DA5	1.0	2.46	3.5	500	3.53	0.35	20	115	1.25	33%	15
DA6	1.0	2.46	2	750	7.94	0.79	20	115	1.00	33%	12
DA7	1.0	2.46	2	750	7.94	0.79	20	115	1.00	33%	12

[1] assumed values based on amendments and gravel mixture
[2] value rounded up to nearest quarter inch

APPENDIX B
BIOINTRUSION STUDIES

Plutonium is the best example of a radionuclide whose transport to animals in arid ecosystems is dominated by physical processes. Data from many field sites and source conditions show that gut availability of plutonium and other contaminants bound to soil in a variety of animals including rodents, deer and cattle is very low (gut to blood transfer $<10^{-5}$) leading to very low concentrations of contaminant in internal tissues and organs (Smith, 1977; Moore et al., 1977; Hakonson and Nyhan, 1980; Arthur et al., 1987). Highest concentrations of most soil contaminants in dry, dusty environments are usually found in tissues exposed to the external environment. Those tissues include the pelt, gastro-intestinal tract, and lungs. At Los Alamos, about 96% of the plutonium body burden in rodents from the canyon liquid waste disposal areas was in the pelt and gastro-intestinal tract (Hakonson and Nyhan, 1980).

Because soil passes through the gastro-intestinal tract of free-ranging animals on a daily basis, there is a potential to redistribute soil radionuclides across the landscape. Studies at Nevada Test Site with cattle (Moore et al., 1977), at Rocky Flats Plant with mule deer and small mammals (Little, 1980; Arthur, 1979), and at Idaho National Engineering Laboratory with small mammals and coyotes (Arthur and Markham, 1983; Arthur et al., 1980) demonstrate that horizontal (and vertical in the case of burrowing animals) redistribution of soil plutonium does occur as animals move within and outside contaminated areas. However, the magnitude of this transport was shown to be very small over the short-term (Arthur, 1979; Arthur and Markham, 1983; Arthur et al., 1980).

There are circumstances where animal transport of soil contaminants can assume more importance. For example, fission product sludge containing 90Sr and 137Cs in a salt form was released to unlined cribs at Hanford and the cribs were backfilled with clean soil. A large animal, probably a coyote or badger then burrowed down to the sludge and created direct access for other animals seeking the salts including jackrabbits (O'Farrell and Gilbert, 1975). Jackrabbits ingested the radioactive salts, became contaminated and then excreted 90Sr on the ground surface. Levels of 90Sr in excreta were found over a 15 km^2 surface area (O'Farrell and Gilbert, 1975). This incident with 90Sr and jackrabbits was a special case that involved liquid waste sludge disposal trenches that were not adequately covered.

Potentially more soluble strontium and cesium transport to animals in arid ecosystems involves a combination of physical and physiological processes. The more tightly bound these radionuclides are to soil (related to clay content of soil and local climate); the more their transport will be governed by soil particle transport. Data on Sr90 and Cs137 in small mammals from the Nevada Test Site (Romney et al., 1983) and at a burial ground at Idaho National Engineering Laboratory (Arthur et al., 1987) show relatively high concentrations of these radionuclides in lung, pelt and gastro-intestinal tract similar to plutonium. This suggests that physical transport of these more "soluble" radionuclides is also important as with plutonium. The bioavailability of radionuclides such as cesium and strontium will depend on chemical form, local environmental conditions, and the structure and function of the relevant food webs.

Tritium would be one of the few exceptions to the general observation that physical transport mechanisms dominate in the transport of soil surface contaminants to biota. Uptake by roots or sorption through the leaf surface would dominate in tritium transport to vegetation. Levels of tritium in animals would reflect levels in the source (i.e., concentration ratios are 1 or less) since tritium is not concentrated as it moves through abiotic and biotic pathways. Furthermore, tritium in vegetation is available to nectivorous organisms such as honeybees as well as herbivores. While tritium is readily transported through ecosystems, it is rapidly turned over in biological systems at rates corresponding to water turnover in these systems. In humans, body water turnover is about 3 days (RHH, 1970).

Although vegetation is very important in controlling erosion and percolation in landfill covers (Nyhan et al., 1984), deeply penetrating plant roots have the potential to access buried waste and bring plant available constituents including landfill contaminants to the surface of the site (Klepper et al., 1979; Foxx et al., 1984; Tierney and Foxx, 1987). Contaminants such as tritium can be incorporated within plant tissue and enter the food web of herbivorous or nectivorous organisms. For example, at Los Alamos National Laboratory tritium transport away from a controlled low-level waste site occurred via the soil moisture/plant nectar/honey bee/ honey pathway (Hakonson and Bostick, 1976). As another example, deep-rooted Russian Thistle (Salsola kali) growing over the waste burial cribs at Hanford penetrated into the waste, mobilized 90Sr, and then transferred it to the ground surface. The contaminated surface foliage was transferred away from the cribs when the matured Thistle (tumbleweeds) blew away from the site (Klepper et al., 1979). Two mechanisms for soil contaminant transport to terrestrial plants are absorption by roots and deposition of contaminated soil particles on foliage surfaces. Field studies suggest that deposition of soil particles on foliage surfaces is a major transport mechanism for soil associated contaminants under many arid site and contaminant source conditions (Romney and Wallace, 1976; Romney et al., 1987; White et al., 1981; Arthur and Alldredge, 1982).

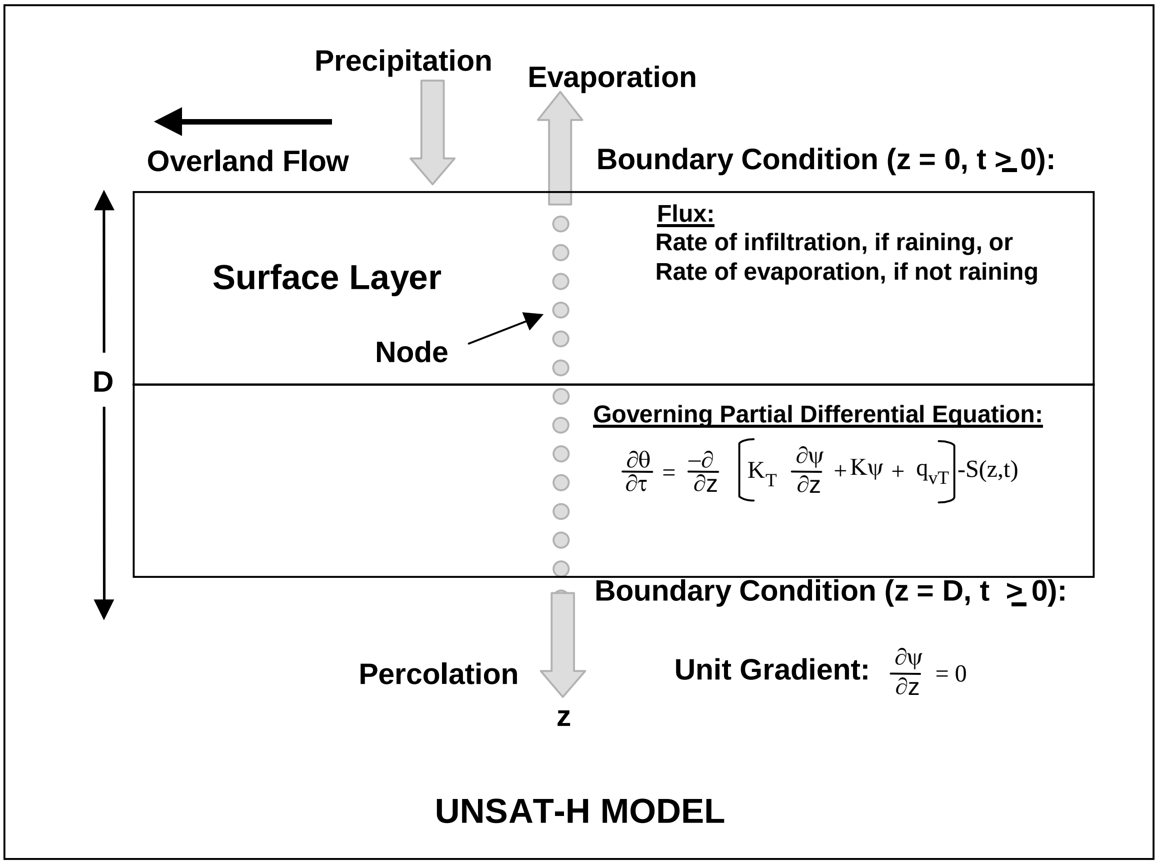
APPENDIX C
MODELING

Overview of UNSAT-H

UNSAT-H has been used to design many recent alternative earthen cover designs (Dwyer 2003). Unlike most unsaturated flow programs, UNSAT-H was specifically developed for the evaluation of earthen covers. UNSAT-H is a one-dimensional, finite-difference computer program developed at the Pacific Northwest National Laboratory by Fayer and Jones (1990). UNSAT-H can be used to simulate the water balance of earthen covers as well as soil heat flow (Fayer 2000). UNSAT-H simulates water flow through soils by solving Richards' equation and simulates heat flow by solving Fourier's heat conduction equation.

A schematic illustration showing how UNSAT-H computes the water balance is shown in Figure C.1. UNSAT-H separates precipitation falling on an earthen cover into infiltration and overland flow. The quantity of water that infiltrates depends on the infiltration capacity of the soil profile immediately prior to rainfall (e.g., total available porosity). Thus, the fraction of precipitation shed as overland flow depends on the saturated and unsaturated hydraulic conductivities of the soils characteristic of the final cover. If the rate of precipitation exceeds the soil’s infiltration capacity, the extra water is shed as surface runoff. UNSAT-H does not consider absorption and interception of water by the plant canopy, or the effect of slope and slope-length when computing surface runoff.

Figure C.1
SCHEMATIC REPRESENTATION OF WATER BALANCE COMPUTATION BY UNSAT-H (modified from Khire 1995)



Water that has infiltrated a soil profile during an UNSAT-H simulation moves upward or downward as a consequence of gravity and matric potential. Evaporation from the cover surface is computed using Fick's law. Water removal by transpiration of plants is treated as a sink term in Richards' equation. Potential evapotranspiration (PET) is computed from the daily wind speed, relative humidity, net solar radiation, and daily minimum and maximum air temperatures using a modified form of Penman's equation given by Doorenbos and Pruitt (1977). Soil water storage is computed by integrating the water content profile. Flux from the lower boundary is via percolation. UNSAT-H, being a one-dimensional program, does not compute lateral drainage.

UNSAT-H Input Parameters

A set of input parameters were developed for simulations using UNSAT-H for the given cover profiles. These parameters were developed based on field and laboratory measurements, values from the literature, and expert opinion.

Model Geometry

The model geometry was based on the depth of the cover profile modeled.

Boundary Conditions

The MDA G site in Los Alamos, NM is located in a dry environment where the climate's demand for water referred to as PET far exceeds the actual supply of water or precipitation (Figure 2.2). These are ideal conditions for deployment of an earthen soil cover such as an ET Cover.

The flow of water across the surface and lower boundary of the cover profile is determined by boundary condition specifications. The UNSAT-H program partitions PET into potential evaporation (E_p) and potential transpiration (T_p). Potential evaporation is estimated or derived from daily weather parameters (Fayer 2000). Potential transpiration is calculated using a function (Equation C.1) that is based on the value of the assigned leaf area index (LAI) and an equation developed by Ritchie and Burnett (1971) as follows:

$$T_p = PET\,[a + b(LAI)^c] \quad \text{where } d \leq LAI \leq e$$ **Equation C.1**

Where:

a,b,c,d, and e are fitting parameters;
a = 0.0, b = 0.52, and c = 0.5, d = 0.1, and e = 2.7 (Fayer 2000)

The UNSAT-H program partitioned PET into E_p and T_p. PET was derived from daily weather parameters obtained from this weather data. T_p was calculated using a function developed by Equation 1 above.

The lower boundary condition was a unit gradient. With the unit gradient, the calculated drainage flux depended upon the hydraulic conductivity of the lower boundary node. The unit gradient corresponded to gravity-induced drainage and was most appropriate when drainage was not impeded.

Upper Boundary Condition - Climate Data

The surface boundary condition during evaporation was modeled as a flux that required daily weather data. The wettest decade on record was used (1985 to 1994) from Los Alamos National Laboratory (weather.lanl.gov). The annual precipitation totals for this decade are summarized in Tables C.2 to C.4. Because the RCRA requirements to minimize flux was the regulatory driver for determining the storage capacity requirements of the cover profile, it was determined that the wettest decade on record would provide a conservative measure to evaluate the RCRA-equivalency of the cover profile.

VEGETATION DATA

Vegetation will generally increase ET from the cover because a plant's matric potential or suction is orders of magnitude higher than that of the soil (Figure C.2). The input parameters representing vegetation include the LAI, rooting depth and density, root growth rate, the suction head values that corresponds to the soil's field capacity, wilting point, and water content above which plants do not transpire because of anaerobic conditions. The onset and termination of the growing season for the site are defined in terms of Julian days. The root length density (RLD) is assumed to follow an exponential function such as that defined in Equation C.2:

$$RLD = a \exp(-bz) + c \qquad \textbf{Equation C.2}$$

where:
- a,b, and c are fitting parameters
- z = depth below surface

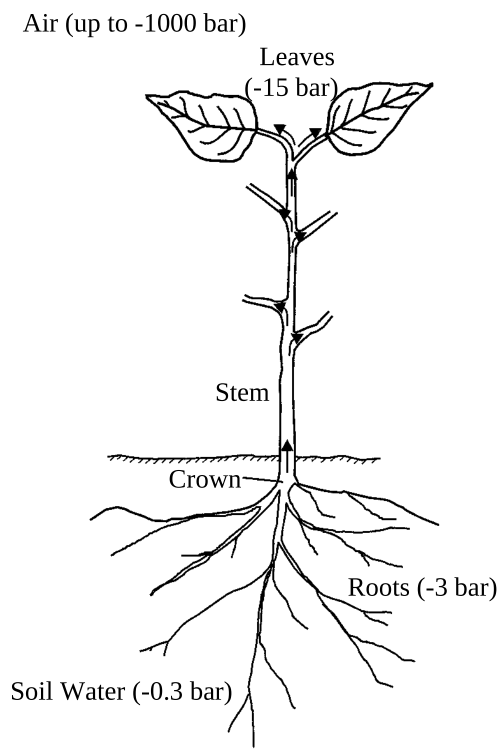
The parameters used for the RLD functions in Equation C.2 were: a = 0.315, b=0.0073, and c = 0.076 (Fayer 2000). The time required for maximum rooting depth establishment was set at full depth beginning on day 1. The rooting depth was set at 6.6-feet (200 cm) (Foxx et al 1984). An average LAI of 0.65 was used (McDowell et al 2005). This value represents an average of values reported for the site of 0.3 and 1.0. The onset and termination of the growing season for the site were Julian days 74 and 288, respectively (EIS, Appendix E). The LAI was transitioned from 0 to 0.65 starting with Julian day 74 to 90. Day 91 through 270, the full LAI equal to 0.65 was utilized. The LAI was then transitioned down from 0.65 to 0 from Julian day 271 to 288. This was conservative since it is realistic that plants can transpire longer than indicated at this site. An average percent bare area of 84.4% was used. This value represents an average of reported values for the area of 91.5% and 77.3 % (Tierney and Foxx 1982). The relative humidity for the site was set at 51% based on the average conditions for Los Alamos (Los Alamos Climatology internet site).

SOIL PROPERTIES RELATED TO VEGETATION

Suction head values corresponding to the wilting point, field capacity, and a head value corresponding to the water content above which plants do not transpire because of anaerobic conditions were defined. Matric potential or suction heads are generally written as positive numbers, but in reality are negative values. Consequently, the higher the value, the greater the soil suction. The maximum water content a soil can hold after all downward drainage resulting from gravitational forces is referred to as its field capacity. Field capacity is often arbitrarily reported as the water content at about 330 cm of matric potential head (Jury et al, 1991). Below field capacity, the hydraulic conductivity is assumed to be so low that gravity drainage becomes negligible and the soil moisture is held in place by suction or matric potential.

Not all of the water stored in the soil can be removed via transpiration. Vegetation is generally assumed to reduce the soil moisture content to the permanent wilting point. The wilting point was conservatively assumed to be 20,000 cm (typical for native grasses) used although the shrubs present at the site could remove water from the soil to a suction of 100,000 cm (Figure C.2). Evaporation from the soil surface can further reduce the soil moisture below the wilting point toward the residual saturation, which is the water content at an infinite matric potential.

Figure C.2
TYPICAL SOIL-PLANT-ATMOSPHERE WATER POTENTIAL VARIATION
(Hillel 1998)



Soil Properties

Soil hydraulic properties were obtained from laboratory testing of soil samples collected from the TA61 borrow site (Shaw 2006). The saturated hydraulic conductivity of the soils were obtained using flexible wall permeameters in accordance with ASTM D 5084. Unsaturated soil properties were obtained from data using pressure plates and water columns (depending on the suction values) to develop values of water content as a function of pressure head (ASTM D 6836). These data were then used as input into the RETC code (van Genuchten et al 1991) to compute curve fitting parameters used to estimate the moisture characteristic curve (van Genuchten 1980). The Mualem conductivity function was used to describe the unsaturated hydraulic conductivity of the soils. The van Genuchten 'm' parameter for this function is assumed to be'1-1/n'; 'n' being one of the established van Genuchten parameters. The initial soil conditions are expressed in terms of suction head values that correspond to the average moisture content between each soil layer's field capacity and permanent wilting point determined from each respective soil layer's moisture characteristic curve. The soil properties used as input parameters are summarized in Table C.1.

Table C.1
COVER SOIL PROPERTIES

Cover Profile	Soil Layer Type	Soil Layer Depth	van Genuchten Parameters				Sat. Hydr. Cond. (cm/hr)
			θ_s	θ_r	α	n	
TA61 BORROW SOILS USED (BH1 @ 15 TO 25-FT DEPTH)							
Cover Soil Only	Cover Soil	6.6 ft (200 cm)	0.2454	0	0.0027	1.6175	17.64
TYPICAL SANDY LOAM (ROSETTA 2000)							
Cover Soil Only	Cover Soil	6.6 ft (200 cm)	0.387	0.039	0.0267	1.4488	1.5951
CONCEPTUAL COVER DESIGN WITH TYPICAL SANDY LOAM							
Conceptual Cover Profile	Gravel/ Soil Admixture	1.5 ft (46 cm)	0.383	0.039	0.0267	1.4488	1.5951
	Cover Soil	3.5 ft (108 cm)	0.383	0.039	0.0267	1.4488	1.5951
	Filter Layer	6 in (15 cm)	0.34	0.026	0.0597	2.81	65.52
	Bio-barrier	1 ft (31 cm)	0.374	0.017	2.5075	2.47	15912.0

Modeled Percolation

Percolation results from the redistribution of water through a soil profile in response to gradients formed by differences in the energy state of the water. Flux is defined as the volume flow rate per unit area (Jury et al 1991) through a given soil profile. Other mechanisms that might induce water redistribution, such as geothermal gradients and barometric pressure fluctuations, have been shown to be minor contributors to water flow in most instances (Jones 1978, Gee and Simmons 1979). Tables C.2 TO C.4 present predicted annual flux values for the modeled cover profiles under the typical or average annual precipitation volumes.

Table C.2 summarizes a monolithic soil profile modeled with hydraulic soil properties from the TA61 borrow site. The soil sample that possessed a saturated hydraulic conductivity closest to the overall average of all soil samples tested form the site was used. The overall average was calculated to be 6.6E-03 cm/sec. This soil sample was BH1 taken from a depth of 15 to 25-ft. The saturated hydraulic conductivity for sample BH1 was 4.9E-03 cm/sec. As seen in figure 3.2, the Point of Diminishing Returns (Dwyer et al 2006) was greater than 6.6 ft (200 cm). Consequently, it was determined that the soil would require amendment to improve its water storage capacity and thus decrease the soil depth required. The soil amendment will also provide for adequate plant available nutrients.

The TA61 soils were characterized as sandy loams. However, they were relatively coarse sandy loams. Table C.3 summarizes a monolithic soil profile that used a typical sandy loam with somewhat better storage capacity than the TA61 soils. This value was obtained from ROSETTA (2000). These soils are commonly found throughout New Mexico. These soils significantly improved the cover performance by producing a Point of Diminishing Returns at about 5 ft (1.5 m).

Table C.4 summarizes the output from the actual conceptual cover profile that includes all layers. The addition of the bio-barrier created a capillary barrier. The final predicted flux through the cover profile utilizing a sandy loam soil overlying a coarse material was zero.

Table C.2.
WETTEST DECADE CLIMATE DATA WITH TA61 SOILS

Cover Depth (cm)	Annual Flux (cm/year)										
	1985	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**Average**
50	5.53	4.11	3.14	4.68	3.17	3.92	6.01	0.98	2.05	4.43	3.80
100	2.84	1.70	1.42	2.37	1.31	1.51	3.06	0.47	1.22	2.04	1.79
150	1.12	0.56	0.71	0.95	0.40	0.06	1.19	0.30	0.49	0.72	0.65
200	.05	0.03	0.03	0.03	0.29	0.26	0.03	0.04	0.02	0.02	0.08
Precipitation (cm)	49.76	47.48	40.34	42.55	35.74	43.31	47.78	32.11	32.54	43.05	41.47

Table C.3.
WETTEST DECADE CLIMATE DATA WITH TYPICAL SOILS FOR SANDY LOAM (ROSETTA 2000)

Cover Depth (cm)	Annual Flux (cm/year)										
	1985	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**Average**
50	4.31	3.37	2.94	4.28	1.69	3.03	5.39	1.19	2.07	3.64	3.20
100	7.16E-2	1.13	1.59	1.94	8.43E-1	8.17E-1	2.31	1.37	6.15E-1	7.31E-1	1.14
150	0	0	5.41E-4	9.12E-2	5.33E-1	1.69E-1	1.96E-1	7.70E-1	2.29E-1	9.21E-2	2.08E-1
200	0	0	0	0	0	6.93E-6	6.72E-6	7.25E-6	9.14E-6	1.71E-5	4.71E-6
Precipitation (cm)	49.76	47.48	40.34	42.55	35.74	43.31	47.78	32.11	32.54	43.05	41.47

Table C.4.
WETTEST DECADE CLIMATE DATA WITH CONCEPTUAL COVER PROFILE THAT UTILIZED TYPICAL SOILS FOR SANDY LOAM (ROSETTA 2000)

Cover Depth (cm)	Annual Flux (cm/year)[1]										
	1985	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**Average**
Base of Cover	0	0	0	0	0	0	0	0	0	0	0
Precipitation (cm)	49.76	47.48	40.34	42.55	35.74	43.31	47.78	32.11	32.54	43.05	41.47

[1] values less than 1E-10 cm/year were approximated to be zero

Appendix E

Evaluation of the Surface Cover

E-1.0 INTRODUCTION

The surface cover placed over Material Disposal Area (MDA) G at Los Alamos National Laboratory (LANL or the Laboratory) is required to protect human health and the environment over a 1000-yr period. Erosion modeling was used to determine the ability of the design to maintain the required cover thickness to minimize human and biological intrusion into the waste and to maintain the thickness needed for precipitation storage and evaporation. Erosion modeling was restricted to that resulting from precipitation runoff, not wind. Modeling of wind erosion in the performance assessment (PA) (Wilson et al. 2005, 092034) has shown wind erosion to be negligible. The erosion modeling was also used to provide an estimate of the time interval for cover maintenance. Erosion modeling was performed for Alternative 1C and two preliminary versions of Alternative 2C (Option 1 and Option 2). The difference between Option 1 and Option 2 is the latter has 6 ft of waste removed from Pit 28 to decrease the amount of fill required in the cover. Only Option 2 is carried forward for discussion in the corrective measures evaluation (CME) report because there was minimal difference in erosion potential between the two options. Erosion modeling of Alternative 2B is presented in the PA (Wilson et al. 2005, 092034).

The Rational Method and the Hillslope Erosion Model (HEM) were used to simulate erosion modeling of the cover. The Rational Method was used to predict runoff for 10-yr, 25-yr, 50-yr, and 100-yr design storms, and HEM was used to estimate erosion from those storms because the storms are more likely to have a severe effect on erosion. A modified Revised Universal Soil Loss Equation (RUSLE) was used to estimate annual erosion amounts. Descriptions of these models and references for them are provided in sections E-2.2.1, E-2.2.2, and E-2.2.4.

E-2.0 COVER EROSION MODELING

Erosion modeling is necessary to determine whether the MDA G cover has adequate thickness to minimize infiltration over the 1000-yr period and to support surface vegetation growth. Erosion can also cause surface contamination to be transported off-site, but that effect is considered in the human health exposure modeling and not in this appendix. Wind erosion was studied for the Alternative 2B evapotranspiration (ET) cover during the PA and was estimated to cause minor suspended soil loss from the cover compared with water erosion; these results are summarized below. Wind erosion of the Alternative 2C optimized ET cover is similar to that modeled for Alternative 2B because both covers have gravel mixed into the top soil layer to reduce wind erosion. Therefore, no further wind erosion modeling was performed as part of the CME.

To minimize wind and water erosion for Alternative 2C, 18 in. (0.5 m) of soil/gravel admixture containing 33% gravel by weight with diameters ranging from 1.5 in. (3.8 cm) to 3 in. (7.6 cm) was added to the top of the cover. This cover was designed to minimize erosion during the 1000-yr storm event (Appendix D, pp. 2–3).

E-2.1 Wind Erosion

Wind erosion of an MDA G cover is considered a long-term performance issue because semiarid ecosystems have been shown to have higher wind erosion rates than water erosion rates (Whicker and Breshears 2005, 098643, p. 1). To estimate soil loss and the potential for wind-driven contaminant transport from an MDA G cover, a mass transport study was performed in 2004 at two analog sites on Mesita del Buey, west of MDA G. MDA J, a closed landfill site, was chosen because it was covered with native grasses in June 2002. Grasslands at MDA J are representative of the surface soil and vegetation conditions at MDA G in the early years following closure of the facility (French 2007, 099306). A piñon-juniper woodland at Technical Area 51 (TA-51) was chosen as a site that would represent the MDA G cover after successional changes in vegetation over a 1000-yr period.

Horizontal mass flux transports larger soil particles close to the surface and redeposits them locally (Whicker and Breshears 2005, 098643, p. 1). This horizontal flux was higher at the grassland site because of higher ground-level wind velocities (Whicker and Breshears 2005, 098643, p. 12). Higher rates of wind erosion occurred in the piñon-juniper woodland surrounding the MDA J site following tree-thinning operations (Whicker and Breshears 2005, 098643, p. 24). Rain splash significantly increased the horizontal mass flux near the ground at both sites during precipitation periods. A small net soil loss accumulated over the 10 mo of the study (Whicker and Breshears 2005, 098643, p. 12). Vertical mass flux transports smaller soil particles at heights more than 3.3 ft (1 m) for longer distances into and out of an area (Whicker and Breshears 2005, 098643, p. 1). The average vertical flux 6.6 ft (2 m) above the surface at MDA J was 0.013 ± 0.054 ton/acre/yr (0.03 ± 0.12 tonne/ha/yr) (Whicker and Breshears 2005, 098643, p. 19). This small amount indicates little net loss from an area of suspended soil.

E-2.2 Water Erosion

The study simulated only long-term erosion from stormwater flow because short-term erosion protection during cover construction is covered in stormwater pollution prevention plans (SWPPPs) required for all land-disturbing construction projects at the Laboratory. These SWPPPs require erosion controls that will be left in place until vegetation is established on the surface of the cover. Therefore, all long-term erosion modeling assumed that vegetation is present, covering a similar percentage of soil as undisturbed native vegetation. Cover erosion rates depend on many factors, including slope angle and length, surface soil characteristics, rainfall intensity and duration, and vegetation. All covers of the Laboratory MDAs are being designed to reduce sheet flow erosion to less than 2 tons/acre/yr (4.5 tonne/ha/yr) (LANL 2002, 095739).

MDA G is on the easternmost downslope end of a long finger mesa that extends from the Jemez Mountains east of the Laboratory to TA-54, so stormwater flows generally eastward and off the sides of the mesas. To minimize the amount of stormwater that runs onto the MDA G cover, disposal of waste in areas to the west of MDA G will create a drainage divide so that there will be no run-on to the MDA G cover. This divide will divert stormwater flowing from the west toward the canyons north and south of the mesa. Stormwater on the cover is assumed to be limited to precipitation that falls on the cover surface area.

E-2.2.1 HEM Description

HEM was used to estimate the overland flow erosion created by precipitation impacting the surface of the cover and flowing in sheets into the adjacent canyons. For the purposes of this modeling, a conservative assumption was made that all precipitation would run off as stormwater, and none would infiltrate the cover. HEM simulates overland flow with kinematic wave equations and regression equations that conserve the total runoff volume for a variety of slopes, slope lengths, surface roughnesses, soil classes, and rainfall distributions (LANL 2002, 095739, pp. 91-93).

Erosion is greatly affected by rainfall intensity because higher intensities increase stormwater runoff velocities. The erosive force of the stormwater flow increases as the square of the velocity, so high-intensity storms create the most erosion (LANL 2002, 095739, pp. 101–102). Therefore, for Alternative 2C, erosion modeling was performed using the high-intensity events characterized as the 10-yr, 25-yr, 50-yr, and 100-yr return period storms for Los Alamos, New Mexico. Erosion modeling for

Alternative 1B was performed using the 25-yr design storm recommended in the Laboratory engineering standards, which showed such unacceptable results that modeling erosion from the other storms was deemed unnecessary. The Laboratory previously performed extensive erosion modeling using weather prediction methods and landform evolution modeling for Alternative 2B, so no further erosion modeling of that option was performed for this study. Alternative 5B removes the waste that requires protection from infiltration and erosion, so no erosion modeling was necessary for that option. However, residual contamination in environmental media for Alternative 5B will be susceptible to erosion as simulated for Alternative 1B.

E-2.2.2 Input Parameters

Surface runoff depth, slope angles, and slope lengths were input into HEM to calculate erosion estimates for hillslope overland flow. The slope angles and lengths were generated from the cover profiles developed after infiltration modeling was completed for Alternatives 1B and 2C.

Surface runoff was calculated using the Rational Method, which is typically used for areas less than 200 acres (80 ha) (DOE 1989, 099296, p. 56). The Rational Method assumes that rainfall occurs uniformly over an entire surface at a constant intensity for a period equal to the drainage area's time of concentration. The U.S. Department of Energy (DOE) approved the use of this method for covers at Uranium Mill Tailings Radiation Control Act of 1978 sites. The following is the Rational Method formula:

$$Q = C*i*A = q*W$$

where Q = peak discharge rate (ft^3/s),

C = runoff coefficient (dimensionless),

i = rainfall intensity for time of concentration (in./h),

A = surface area (acre),

q = peak discharge per unit width ($ft^3/s/ft$), and

W = width of drainage area (ft).

DOE recommends that C = 1 be used for the runoff coefficient for storm return periods greater than 100 yr, so this coefficient was used for the 100-yr storm. Although the 100-yr storm is the recommended return period for Resource Conservation and Recovery Act-equivalent covers, this study evaluated 10-yr, 25-yr, 50-yr, and 100-yr storm intensities as approximations for the 10-yr, 20-yr, 30-yr, and 100-yr return periods required in the scope of work (LANL 2002, 095739, pp. 101-102). The runoff coefficient for the shorter return periods was calculated using rural factors supplied in the Laboratory Engineering Standards Manual ISD 341-2, Chapter 3, Civil, Section G20, Site Improvements (available at http://engstandards.lanl.gov/).

$$C = 1 - \text{topography factor} - \text{soil factor} - \text{cover factor}$$

$$C = 1 - 0.2 - 0.4 - 0.0 = 0.4$$

For MDA G, rolling topography, open sandy loam soil, and a relatively barren cover were used. Therefore, the runoff coefficient used for 10-yr, 25-yr, and 50-yr return period storms was 0.4. Design storm intensities to input into the Rational Method equation were taken from the National Oceanic and Atmospheric Administration (NOAA) Precipitation Frequency Data Server (http://hdsc.nws.noaa.gov/hdsc/pfds/), which provides updated data from the NOAA Atlas 14 for latitude and longitude. The time of concentration was calculated using the following formula (Kent 1972, 097066, p. 15-3):

$$tc = L/(60*V)$$

where tc = time of concentration (min),

L = hydraulic length (m), and

V = velocity of precipitation particle (m/s).

The hydraulic length used was 1530 ft (466 m), the average length of section cuts A–A', B–B', and C–C'. The 1.7 ft/s (0.52 m/s) velocity was averaged from nearly bare hillsides with slopes from 2% to 4%, the range of slopes on the Alternative 2C cover (Kent 1972, 097066, p. 15-8). Using the nearly bare velocity instead of that for short grass pasture makes this time of concentration calculation conservative. A 15-min time of concentration was calculated for the MDA G drainage area as an approximation of the time that precipitation impacting the remotest portion of the area would take to run off the surface of that drainage.

This time is an average for slopes from 2% to 4% using overland flow velocities for untilled land (Kent 1972, 097066, p. 15-8). Table E-2.2-1 shows the 15-min design storm intensities used for erosion modeling from the Laboratory Engineering Standards compared with the NOAA Atlas 14 storm intensities data (http://hdsc.nws.noaa.gov/hdsc/pfds/), such as those used in Appendix D for gravel admixture calculations.

The 10-yr return period does not mean that such a storm will occur every 10 yr. It means that if a storm of that intensity occurs, another storm of that intensity is not statistically expected to occur for another 10 yr.

Surface runoff flow was converted to a runoff depth using Manning's equation and the average width of the drainage areas shown in Figure 8.1-1 for Alternative 1B, Figure 8.2-2 for Alternative 2B, and Figure 8.3-1 for Alternative 2C. Figure 8.3-1 shows the contours for the top of the cover for Alternative 2C along with cover features, including the riprap apron, underdrains, locations of rock buttresses, and location of section cuts. A sample section showing slopes within the drainage areas for Alternative 2C is in Figure 8.3-2.

$$D = [(q*n)/(S^{0.5})]^{0.6}$$

where D = depth of runoff (m),

q = peak discharge per unit width (m^3/s/m),

n = Manning's runoff coefficient (dimensionless), and

S = slope (m/m).

The Manning's runoff coefficient for overland flow used for the soil gravel admixture surface in Alternative 2C was 0.012 and for the tuff/soil mixture currently in place at MDA G for Alternative 1B was 0.13. This runoff depth, cover slopes, and slope lengths for the seven sections were input into HEM to predict erosion results.

E-2.2.3 Water Erosion Modeling Results

Table E-2.2-2 shows HEM results for the four 15-min design storms impacting the Alternative 2C optimized ET cover. The assumptions used were similar to those used in the PA modeling for Alternative 2B; high-erosion estimates used loam as the soil (with a relative soil erodibility default in HEM of 1.84) with 30% canopy cover and 30% ground cover, and moderate-erosion estimates used sandy loam as the soil (with a relative erodibility default of 2.34) with 30% canopy cover and 70% ground cover (Wilson et al. 2005, 092034, p. 16). Sandy loam is considered to approximate the properties of the TA-61 borrow soil, which will be used to construct the cover (LANL 2002, 095739, p. 22).

Sensitivity analyses were performed to determine the effect of varying the relative soil erodibility and the percentages of ground and canopy cover on the estimated erosion. The sensitivity analysis in Table E-2.2-3 was based on comparisons to Alternative 2C, DA-4 section results for moderate erosion from a 100-yr, 15-min storm, and the base case. According to HEM documentation, the relative soil erodibility of sandy loam can vary from 0.33 to 4.29 (Lane et al. 1988, 073650). The impact of nearly doubling the soil erodibility from 2.31 to 4.29 doubled the erosion estimate. Decreasing the relative soil erodibility to 0.33 minimized the erosion estimate as expected. Varying the groundcover and canopy cover percentages produced the expected results; changes in ground cover had a significant impact on erosion, while changes in canopy cover had less impact. Very low vegetation coverage, such as might be expected during a drought period, could double or triple the expected erosion amount in a 100-yr storm. The low vegetation cover had a similar result to the very low vegetation growth at cover A, demonstrating the minimal effect of a 20% difference in canopy cover on the result. This minimal effect is confirmed by comparing the base case with the high vegetation cover B case, where a 20% difference in canopy cover is barely detectable in the erosion result. The medium vegetation cover case shows that a 20% reduction in the ground cover versus the base case increases the erosion estimates by 58% for a 100-yr storm. The high vegetation cover A has 10% higher canopy cover and 10% less ground cover than the base case and has 24% more expected erosion. Therefore, high erodibility soil with low ground cover percentages has the highest expected erosion.

E-2.2.4 RUSLE for Average Annual Soil Loss

Because the design storms have much higher rainfall intensities than expected in a normal year, an average annual soil loss was calculated for the Alternative 1B and Alternative 2C covers based on the RUSLE calculator, available online at http://landfilldesign.com/cgi-bin/erosion.pl. RUSLE uses a regional rainfall and an erosivity index soil erodibility factors based on average particle diameter, slope length, and steepness factors; cover management factors; and support practice factors to calculate an average soil loss per year. The rainfall and erosivity index for Los Alamos County was 25, the cover management factors were set to 0.01 for poor grass, and the support practice factor used was 1. The steepest slope and the approximate drainage slope length for each cover section were used to compute the average annual soil loss. An average particle diameter of 2.38 in. (60 mm) was used to represent the soil/gravel admixture, which will have a surface similar to desert pavement because fines are lost over time. The results for Alternative 1B and Alternative 2C are shown in Table E-2.2-4.

Both covers have acceptable annual erosion rates if the covers remain well vegetated, but the rates for Alternative 2C are acceptable under both vegetated and bare soil conditions. Alternative 1B will exceed the 2 ton/acre/yr (4.5 tonne/ha/yr) design goal if the soil became bare, which may occur in extended drought conditions. The estimated annual erosion rate for Alternative 2C is much lower than that goal. These estimates also show that a minimal amount of soil will be lost in an average year if the cover becomes well vegetated, even though poor grass was used as the cover factor for these calculations. They also show that cover maintenance could be minimal and infrequent if no high-intensity storms occur.

E-3.0 COMPARISON OF WATER EROSION RESULTS AMONG ALTERNATIVES

The following comparison is based on HEM results for the alternatives, which can estimate only what erosion may occur as a result of uniformly intense storms. The actual erosion of various covers depends upon the actual storm intensities that will occur in the 1000-yr period, the recovery time between major storms, the formation of rills and the deposition of sediment in those rills during milder storms, and the effects of vegetation changes on the cover surface.

Table E-3.0-1 for HEM erosion shows the estimates for Alternative 1B versus Alternative 2C. According to the table, Alternative 1B has significant sediment erosion yields, which indicate the cover is not protective in high-intensity storms. Alternative 1B also has steep slopes, as recommended in the 25-yr design storm construction in the Laboratory Engineering Standard. The slopes produce high-erosion estimates that exceed the 2 ton/acre/yr (4.5 tonne/ha/yr) annual design standard for the high-erosion scenario and approach that limit in one section in the moderate-erosion scenario. If one storm removes that much soil from the cover surface could potentially expose waste. Alternative 1B also has higher runoff velocities because the surface is not roughened by the gravel admixture used in Alternatives 2B and 2C. Alternative 1B erosion estimates are significantly higher than those predicted for the optimized ET cover, Alternative 2C. None of the Alternative 2C erosion estimates in Table E-3.0-1 reached half of the annual limit for either design storm.

For comparison, Alternative 2B cover modeling in the PA used Los Alamos, New Mexico climate data and the IRS9 climate generator currently embedded in the U.S. Department of Agriculture Watershed Erosion Prediction Project model to generate runoff depths for a simulated 30-yr period of storms. The SIBERIA model was used to predict the long-term evolution of the cover surface. The moderate erosion scenario for the 1000-yr erosion model was performed using runoff depths calculated for the 5-yr, 6-h storm. Figure 8 in Appendix I of the PA showed that there was little difference between the HEM results and the SIBERIA results for hillslope lengths up to 459 ft (140 m). Table E-3.0-2 shows SIBERIA erosion results for Alternative 2B compared with total mass erosion calculations for Alternative 1B and Alternative 2C, using the same runoff depth of 0.28 in. (7 mm). Alternatives 1B and 2C had better estimated annual sediment yields than Alternative 2B. This may be because Alternative 2B used a climate generator to vary the precipitation over 1000 yr, which calculated an estimated sediment yield for many storms over that period of time. It may also be due to the gentler slopes used on the Alternative 2C cover.

The soil replacement requirements were calculated using several of the RUSLE and HEM erosion results from above. These are summarized in Table E-3.0-3 as the total sediment mass requiring replacement and the average cover depth requiring replacement after 100 yr. The first row compares RUSLE annual erosion estimates for bare soil with the PA model average annual erosion rate. The second row compares Alternatives 1B and 2C sediment replacement requirements if the covers remain well vegetated. The last four rows compare soil replacement requirements after a variety of design storms.

E-4.0 SUMMARY

Erosion modeling was performed to optimize the cover design for Alternative 2C. It was used to determine the size and amount of soil/gravel admixture for the surface layer, as described in Appendix D. Alternatives 2B and 2C have soil/gravel admixtures on the surface to minimize wind and water erosion. HEM erosion modeling predicted that the Alternative 2C will erode less than the required goal of 2 ton/acre/yr (4.5 tonne/ha/yr), even if impacted by high-intensity storms. As expected, erosion estimates are highly sensitive to the soil erodibility and the groundcover percentages used. Cover maintenance to repair erosion damage should be infrequent, based on the average annual soil losses predicted by RUSLE. Alternative 1B exceeded the annual erosion goal if impacted by either design storm. Modeling of Alternative 2C shows lower erosion estimates than Alternative 2B using the same runoff depth, possibly because it has more gradual slopes.

Erosion rates were predicted using HEM for a 25-yr storm with a time of concentration of 15 min for high and moderate erosion scenarios. These erosion rates could be compared with a design goal of 2 ton/acre/yr (4.5 tonne/ha/yr) as a measure of effectiveness. Alternative 1B exceeded that goal under the high-erosion scenario. Using the moderate-erosion scenario, Alternative 1B approached that goal when impacted by the 100-yr storm. It is presumed that Alternative 1B will exceed the design goal at sometime during a 1000-yr period and expose waste. Alternative 5B would have similar rates of erosion because it has similar slopes and materials as Alternative 1B. Although waste will not be present in Alternative 5B, erosion could expose residual contaminated media between the former pits. In simulations, Alternative 2C had less than 0.7 ton/acre (1.6 tonne/ha) and 0.4 ton/acre (0.9 tonne/ha) soil loss under the high and moderate erosion scenarios, respectively, which are significantly below the annual design goal. All covers have acceptable annual erosion rates if the covers remain well vegetated, but the rates for Alternative 2C are acceptable under both vegetated and bare soil conditions.

In the PA, erosion rates were simulated for 2-yr and 5-yr storms, so it was not possible to directly compare the results of PA modeling with those time intervals required for the CME report. However, a comparison of erosion rates between Alternatives 1B, 2B, and 2C was made using the 0.28 in. (7 mm) maximum runoff depth and the moderate erosion scenario. Because slopes are gentler on the Alternative 2C cover and northern slopes are minimized, the Alternative 2C cover outperforms the Alternative 1B cover. Qualitatively, the Alternative 2C cover will perform better than the Alternative 2B cover because there are no internal corners that would concentrate stormwater flow and create gullies.

Maintenance frequency for Alternative 2C can be calculated based on an assumed conservative average erosion rate for bare soil of 29 ton/yr (26 tonne/yr). If cover soil is constructed to have the bulk density of 115 lb/ft^3 (1.84 g/cm) recommended in Appendix D, the depth of soil removed could be 0.0028 in./yr (0.0071 cm/yr). Routine inspection and maintenance will be needed to replace approximately 0.003 in. (0.008 cm) of soil following every 100-yr, 15-min storm. Inspections will occur after every 25-yr, 15-min storm. The maintenance frequency for Alternative 2B will be similar to that of 2C, except up to three times as much material will need to be added to the cover. A maintenance frequency for Alternative 1B was not proposed because it did not meet the threshold design criteria for a 25-yr storm.

E-5.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID number. This information is also included in text citations. ER ID numbers are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau; the U.S. Department of Energy–Los Alamos Site Office; the U.S. Environmental Protection Agency, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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Table E-2.2-1
Design Storm Intensities

Storm Return Period	Intensity[a] in./h (mm/h)	NOAA Atlas Intensity[b] in./h (mm/h)
10-yr, 15-min	3.3 (84)	3.19 (81)
25-yr, 15-min	3.9 (99)	3.9 (99)
50-yr, 15-min	4.3 (109)	4.44 (109)
100-yr, 15-min	4.75 (121)	5.02 (128)

[a] Data from Laboratory Engineering Standards, p. 4.

[b] Data from NOAA Atlas for latitude 35.83N, longitude -106.24W.

Table E-2.2-2
HEM Model Design Storm Erosion Estimates for Alternative 2C Optimized ET Cover

Cover	High-Erosion Sediment Yield ton (tonne)				Moderate-Erosion Sediment Yield ton (tonne)			
Design Storm	10-yr, 15-min	25-yr, 15-min	50-yr, 15-min	100-yr, 15-min	10-yr, 15-min	25-yr, 15-min	50-yr, 15-min	100-yr, 15-min
Alt. 2C	16 (14)	18 (16)	19 (17)	32 (30)	7.9 (7.2)	8.8 (7.9)	9.3 (8.4)	16 (15)
Cover	High-Erosion Sediment Yield ton/acre (tonne/ha)				Moderate-Erosion Sediment Yield ton/acre (tonne/ha)			
Alt. 2C	0.32 (0.72)	0.36 (0.80)	0.38 (0.84)	0.65 (1.5)	0.16 (0.36)	0.18 (0.39)	0.19 (0.42)	0.32 (0.73)

Table E-2.2-3
Sensitivity of HEM Model Results to Varied Inputs on Alternative 2C, DA-4 Medium Erosion, 100-Yr Storm Results

Sensitivity Variations	Relative Soil Erodibility	Canopy Cover (%)	Ground Cover (%)	Estimated Sediment Yield ton/acre (tonne/ha)	Percentage of Base Case (%)
Base Case	2.31	30	70	0.46 (1.0)	100
High Erodibility	4.29	30	70	0.99 (2.2)	214
Low Erodibility	0.33	30	70	0.03 (0.07)	7
Very Low Vegetation Cover A	2.31	10	30	1.2 (2.7)	263
Very Low Vegetation Cover B	2.31	20	20	1.6 (3.7)	357
Low Vegetation Cover	2.31	30	30	1.2 (2.7)	260
Medium Vegetation Cover	2.31	30	50	0.73 (1.6)	158
High Vegetation Cover A	2.31	40	60	0.57 (1.3)	124
High Vegetation Cover B	2.31	50	70	0.44 (0.99)	95

Table E-2.2-4
RUSLE Average Annual Soil Loss Alternative 1B Versus Alternative 2C

Cover	Average Annual Soil Loss ton/acre/yr (tonne/ha/yr)	
	Bare Soil	Vegetated
Alternative 1B	24 (54)	0.24 (0.55)
Alternative 2C	0.58 (1.3)	0.01 (0.01)

Table E-3.0-1
Comparison of HEM Estimates Alternative 1B Versus Alternative 2C

Cover	High-Erosion Sediment Yield ton (tonne)		Moderate-Erosion Sediment Yield ton (tonne)	
	25-yr, 15-min	100-yr, 15-min	25-yr, 15-min	100-yr, 15-min
Alt. 1B	130 (120)	260 (230)	52 (47)	100 (92)
Alt. 2C	18 (16)	32 (30)	8.8 (7.9)	16 (15)
Cover	High-Erosion Sediment Yield ton/acre (tonne/ha)		Moderate-Erosion Sediment Yield ton/acre (tonne/ha)	
	25-yr, 15-min	100-yr, 15-min	25-yr, 15-min	100-yr, 15-min
Alt. 1B	2.6 (5.9)	5.1 (12)	1.0 (2.3)	2.0 (4.5)
Alt. 2C	0.36 (0.80)	0.65 (1.5)	0.18 (0.39)	0.32 (0.73)

Table E-3.0-2
Comparison of HEM Estimates Using Same Runoff Depth

Alternative	Runoff Depth in. (mm)	Estimated Sediment Mass[a] ton/yr (tonne/yr)	Sediment Source Area acre (ha)	Estimated Sediment Yield ton/acre/yr (tonne/ha/yr)
1B	0.28 (7)	19 (17)	50 (20)	0.38 (0.85)
2B	0.28 (7)	n/a[b]	n/a	0.45 (1.00)
2C	0.28 (7)	9.4 (8.5)	50 (20)	0.19 (0.42)

[a] Summary data taken from Wilson et al. (2005, 092034, p. 16).
[b] n/a = Not applicable.

Table E-3.0-3
Comparison of Soil Replacement Requirements Every 100 Yr

Climate Scenario	Sediment Replacement Mass after 100 Yr ton (tonne)			Average Sediment Replacement Depth after 100 Yr in. (m^3)		
	Alternative 1B	Alternative 2B	Alternative 2C	Alternative 1B	Alternative 2B	Alternative 2C
Average Annual, Bare Soil	120,000 (110,000)	7900 (7200)	2900 (2600)	15 (39)	0.35 (0.89)	0.28 (0.71)
Average Annual, Vegetated	1200 (1100)	n/a*	27 (25)	0.15 (0.39)	n/a	0.003 (0.007)
One 100-yr, 15-min High-Erosion Storm	260 (230)	n/a	33 (30)	0.02 (0.06)	n/a	0.003 (0.008)
One 100-yr, 15-min Medium-Erosion Storm	100 (92)	n/a	16 (15)	0.01 (0.02)	n/a	0.002 (0.004)
Four 25-yr, 15-min High-Erosion Storms	520 (480)	n/a	71 (64)	0.05 (0.13)	n/a	0.007 (0.017)
Four 25-yr, 15-min Medium-Erosion Storms	210 (190)	n/a	35 (32)	0.02 (0.05)	n/a	0.003 (0.009)

*n/a = Not applicable.

Appendix F

Information Supporting Soil Vapor Extraction

F-1.0 INTRODUCTION

This appendix describes implementation of soil vapor extraction (SVE) to remove volatile organic compounds (VOCs) in the unsaturated subsurface beneath the waste disposal units at Material Disposal Area (MDA) G at Los Alamos National Laboratory (LANL or the Laboratory). Information in this appendix is to be used only to compare alternatives and preliminary costing because no pilot test or transport modeling has been completed at MDA G to date. However, because the geology of MDA G is similar to that of nearby MDA L, a pilot test and the modeling performed at MDA L are applicable to the conditions at MDA G (LANL 2006, 094152). Although MDA G is much larger than MDA L, with multiple areas of contamination, its highest VOC concentrations are orders of magnitude lower than at MDA L.

The approved revised MDA G SVE work plan for a pilot test (LANL 2008, 102816) includes information on sampling, monitoring, and equipment. The pilot test is scheduled to be completed in October 2008. Existing pore-gas monitoring boreholes will be used to calibrate a numerical model to observe manometer readings and change in concentrations with time as the pilot test proceeds. The model will be used to design active and/or passive SVE systems at MDA G, if required.

Additional description of relevant modeling of a pilot test at MDA L and site conditions at MDA G are provided in the following sections.

F-2.0 RELEVENT MODELING OF A PILOT TEST AT MDA L

A site-scale numerical model was previously developed to evaluate the impact of subsurface processes of contaminants associated with waste disposed at the site. One important goal of the model development was to support future corrective measure assessment activities. A modeling report by Stauffer et al. (2007, 097871) presents analysis of the SVE tests. The model was extensively tested and used to confirm a conceptual model for transport within the very dry mesa-top setting. The modeling also simulated the SVE pilot test at MDA L and how the site may behave in the event of a sudden release of VOC from subsurface drums.

Results of the modeling indicate that the current monitoring network at MDA L will be able to detect sudden VOC release of 1800 lb to 3100 lb (800 kg to 1400 kg) within 1 yr. Subsequent simulations of SVE show that the two SVE boreholes at the site will likely be sufficient to remove a substantial portion of the total sudden release within a 1-yr period. These simulations showed that some modification to the current system may be required to extract VOCs from deeper in the mesa, such as installing two new SVE holes with casing to greater depth. These simulations were performed using a finite volume heat and mass transport code, Finite Element Heat and Mass, that solves the diffusion equation and includes Henry’s law partitioning between the liquid and vapor phases (Zyvoloski et al. 1997, 070147). The calculations were performed on a numerical grid that incorporates local topography and honors existing knowledge of subsurface geology in three dimensions. Results from this modeling permitted refining the conceptual model for plume growth at this site.

Because the modeling was conducted using parts per million by volume (ppmv) and characterization of pore vapor is presented in $\mu g/m^3$, Stauffer et al. (2007, 097871) has provided an example of a conversion between the units. To convert between the two units, one must know the molecular weight of the contaminant and that of air. Air is a mixture of many gasses, but can be approximated as having a molecular weight of 29 g/mol. The primary VOC at MDA L, 1,1,1-trichloroethane (TCA), has a molecular weight of 133 g/mol. Assuming that the density of air on the mesa top (6800 ft and 50 F) is approximately 1 kg/m^3, a concentration of 1000 ppmv TCA can be converted to µg/m^3 as:

1000 ppmv = 1000 moles TCA/1E-06 moles Air

1000 moles TCA * 133 g/mol * 1E-06 µg/g = 133E-09 µg TCA

1E-06 moles Air * 29 g/mol * 1 m^3/kg = 29000 m^3

yielding

133E-09 ug/29000 m3 = 4.6E-06 µg/m^3

This conversion doesn't account for the volume of contamination in air, which is assumed to be negligible at low concentrations. Conversions for TCA in µg/m^3 were performed by multiplying by 2.17E-04 to obtain the ppmv value.

The VOC source release at MDA L and probably at MDA G is from leaking of TCA vapor, leading to a relatively constant source region. The concentrations of TCA at MDA L are in the range of 3000 ppmv (1.38-E07 µg/m^3), well below the saturated vapor pressure of 160,000 ppmv (7.37E-08 µg/m^3) when TCA vapor is in equilibrium with a liquid source. Transport away from the source region is primarily by diffusion, with model diffusion coefficients falling very close to values measured on core samples from the site. This implies that barometric pumping and wind effects are not effective in increasing the in situ diffusion of TCA. Furthermore, the inclusion of Henry's law partitioning between the liquid and vapor phases was required to achieve the best fit.

Finally, the asphalt at MDA L appears to be acting as a diffusive barrier, leading to a broader plume within the subsurface and higher concentrations in the shallow subsurface near the source region. The subsurface most likely behaves as a dual continuum during the SVE test, with higher-permeability conduits and lower-permeability regions contributing to the total air flow that is captured by the extraction wells. The effective porosity of the higher-permeability pathways is on the order of 10% to 15%. Because traditional fractures have a porosity of only 0.1% or less, the fractures are most likely not well connected over large distance, yet they provide increased local permeability. However, the long-term VOC extraction tail of decreasing concentrations and rebound after system shutoff can be calibrated in a numerical model as a single continuum.

F-3.0 SITE CONDITIONS AT MDA G

The Laboratory is located on the Pajarito Plateau between the Jemez Mountains and the Rio Grande. Bandelier Tuff is a thick sequence of ash-fall pyroclastics that covers the plateau. Erosion of the tuff over time has created a series of canyons separating the narrow, fingerlike mesas that comprise Pajarito Plateau. MDA G is sited on top of Mesita del Buey, a mesa bounded to the north by Cañada del Buey and to the south by Pajarito Canyon.

The strata below MDA G are composed of nonwelded to moderately welded rhyolitic ash-flow and ash-fall tuff interbedded within pumice beds. The rhyolitic units overlie a thick basalt unit which, in turn, overlies a conglomerate formation. Canyons on either side of MDA G (Cañada del Buey to the north and Pajarito Canyon to the south) lie approximately 100 ft (30.5 m) below the steep-sided mesa. The regional aquifer is located approximately 930 ft below the disposal pits; no perched aquifers are known to occur below the mesa. Perched water was not encountered in a borehole drilled to a depth of 660 ft (201 m).

The Bandelier Tuff is the uppermost formation and consists of the Tshirege and Otowi Members, separated by the Cerro Toledo interval (Qct). Three upper units make up the Tshirege Member of the Bandelier Tuff. Unit 2 (Qbt 2) and the upper portion of unit 1v (Qbt 1v) are fractured, and the fractures are often filled with calcite and/or clay. The Cerro Toledo interval is made up of volcanoclastic sediments interbedded with minor pyroclastic flows. The Otowi Member (Qbo) underlies the Cerro Toledo interval and is made up of nonwelded to poorly welded tuff containing little evidence of fracturing.

The Cerros del Rio basalts lie beneath the tuff and make up roughly 35% of the vadose zone.

Characteristics of this unit vary widely, ranging from extremely dense with no effective porosity to highly fractured to very vesicular so as to appear foamy. The Puye Formation underlies the Cerros del Rio basalts and extends from the base of the vadose zone well into the saturated zone.

F-3.1 Contaminant Concentrations and Distributions

During characterization of the MDA G site (LANL 2005, 090513), pore-gas samples were sent to an off-site analytical laboratory for analysis of VOCs and tritium. Sample results from 39 boreholes (including deep BH 15-3 [location 54-25105]) installed during the investigation reported concentrations of multiple VOCs and tritium. VOCs were detected in 39 boreholes at MDA G. In total, 30 VOCs were detected in some or all the pore-gas samples beneath MDA G. The primary VOC detected in 75 of 76 samples was TCA. Other VOCs detected included trichloroethene (TCE), tetrachloroethene (PCE), and trichloro-1,2,2-trifluoroethane[1,1,2-] (Freon 113). The concentrations of TCA ranged from 41 µg/m^3 (9E-03 ppmv) to 709,000 µg/m^3 (154 ppmv). The highest VOC concentrations were detected in boreholes in the eastern portion of the site, in the vicinity of Pits 1– 5 and the nearby shaft field. The highest concentration of TCA was collected from location 54-24378 in the eastern portion of MDA G, near the disposal shafts, at a depth of 136 ft (41 m). Two additional areas of high VOC concentrations occurred in the central portion of MDA G, near Pits 8, 9, 10, 12, 13, 15, 16, and 19, and in the western portion of the site, near Pits 29, 32, 33, 35, and 36. Plate 6.6-1 of the MDA G investigation report (LANL 2005, 090513) shows the VOCs detected in the subsurface vapor samples. An analysis of the VOCs detected in pore-gas samples indicates that VOC contamination in the eastern, central, and western portions of the site may be the result of releases from different sources of VOCs from disposal units in these areas. The highest levels of TCA in the central and western portions of MDA G were detected in samples collected from BH-30 (location 54-24390) and BH 34 (location 54-24394), respectively. Although TCA is still the dominant contaminant in these areas, the relatively higher concentrations of other VOCs, including TCE and PCE, in these samples indicate releases from different sources. However, the levels of VOCs in the subsurface vapor in these portions of MDA G are an order of magnitude less than in the eastern portion.

F-3.2 Vadose Zone Transport Properties

This section describes the physical properties that are relevant for the SVE modeling and system design. Table F-3.2-1 lists physical properties relevant for TCA transport, the major contaminant at MDA G. Table F-3.2-2 lists the mean measured porosity, saturation, and effective diffusion coefficient determined from the best-fit model at MDA L, which are similar at MDA G. Tables F-3.2-3 and F-3.2-4 present measured air permeability ranges for the geologic units beneath the MDA L site for both straddle packer measurements and core measurements. The straddle packer permeability measurements were made on seven boreholes directly to the east of MDA L. The packer interval was 2 ft (0.6 m) and the data provide a high-resolution view of variability that is typical of the Bandelier Tuff. Straddle-packer measurements were not made in the SVE boreholes used for the MDA L pilot test; thus, the measured values provide the best initial estimate as to the likely range of values expected around the SVE boreholes. The mean core permeability measurements are generally at least an order of magnitude lower than the mean straddle-packer measurements, showing the role that fractures play in the rocks at MDA L. The permeability data show that increased permeability because of fractures at this site is not limited to the more welded Units Qbt 2 and Qbt 1vc but is apparently ubiquitous throughout the Tshirege Member of the Bandelier Tuff.

F-3.2.1 Conceptual Site Model

VOC contamination in the unsaturated zone at MDA G is controlled by vapor diffusion through variably saturated rock with partitioning into the liquid phase. A zero concentration atmospheric boundary following the topography of the mesa and canyon is necessary to simulate the current plume. The rock saturation and porosity limit the ability of vapor to diffuse and the numerical representation of an effective diffusion coefficient. Henry's law partitioning between the vapor and liquid phases and greatly reduced diffusion across the asphalt at the site are both very important at MDA L. The best-fit land/air interface diffusion coefficient is slightly lower than the value used for the surface rock to represent the effects of a soil horizon that may contain more water than is found in the deeper mesa. Finally, the plume appears to be growing slowly because most of the source release is following steep concentration gradients toward the atmosphere.

Generally, TCA transport can be described by the advection-dispersion equation. In addition to being a diffusive barrier, it could be assumed that the MDA G Cover has a permeability of 1.1E-12 ft^2/s (1.0E-13 m^2/s). The role of fractures appears to be important for simulating the concentration rebounds in the SVE tests (Stauffer et al. 2007, 097871) but can be simulated accurately as a single continuum of porous rock.

Movement of liquid water at this site is assumed to be negligible (<0.04 in./yr, or <1 mm/yr) and basis for this assumption can be found in the conceptual site model for flow and transport of liquid water beneath the Pajarito Plateau (Birdsell et al. 2005, 092048). Temperatures vary only by a few degrees centigrade within the region of interest in the mesa and we assume isothermal conditions are assumed for all simulations presented. Because measured effective diffusion coefficients of TCA on crushed tuff columns were very similar to those required to best fit the plume growth, barometric pumping within the mesa is not leading to increased apparent diffusion.

F-4.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID number. This information is also included in text citations. ER ID numbers are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau; the U.S. Department of Energy–Los Alamos Site Office; the U.S. Environmental Protection Agency, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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LANL (Los Alamos National Laboratory), September 2005. "Investigation Report for Material Disposal Area G, Consolidated Unit 54-013(b)-99, at Technical Area 54," Los Alamos National Laboratory document LA-UR-05-6398, Los Alamos, New Mexico. (LANL 2005, 090513)

LANL (Los Alamos National Laboratory), November 2006. "Summary Report: 2006 In Situ Soil Vapor Extraction Pilot Study at Material Disposal Area L, Technical Area 54, Los Alamos National Laboratory," Los Alamos National Laboratory document LA-UR-06-7900, Los Alamos, New Mexico. (LANL 2006, 094152)

LANL (Los Alamos National Laboratory), May 2008. "Work Plan for the Implementation of an In Situ Soil-Vapor Extraction Pilot Study at Technical Area 54, Material Disposal Area G, Los Alamos National Laboratory, Revision 1," Los Alamos National Laboratory document LA-UR-08-3174, Los Alamos, New Mexico. (LANL 2008, 102816)

Stauffer, P.H., J.K. Hopkins, T. Anderson, and J. Vrugt, July 11, 2007. "Soil Vapor Extraction Pilot Test at Technical Area 54, Material Disposal Area L: Numerical Modeling in Support of Decision Analysis," Los Alamos National Laboratory document LA-UR-07-4890, Los Alamos, New Mexico. (Stauffer et al. 2007, 097871)

Zyvoloski, G.A., B.A. Robinson, Z.V. Dash, and L.L. Trease, July 1997. "Summary of the Models and Methods for the FEHM Application — A Finite-Element Heat- and Mass-Transfer Code," Los Alamos National Laboratory report LA-13307-MS, Los Alamos, New Mexico. (Zyvoloski et al. 1997, 070147)

Table F-3.2-1
TCA Physiochemical Parameters

Physiochemical Parameter	Value
Chemical Formula	1,1,1-TCA ($C_2H_3CL_3$)
Molecular weight [12]	133 g/mol
Liquid density [12]	1325 kg/m^3 (at 293 K)
Vapor pressure [12]	100 mmHg (at 293 K)
Water solubility (mg/L) [12]	950 mg/L (at 293 K)
Tuff sorption coefficient K_d [13]	<0.08 mL/kg fully saturated
Henry's law constant (H_{TCA}) [14]	62 MPa/(liquid mole fraction) equal to 0.458 $(g/L)_{vapor}/(g/L)_{liquid}$ (at 285 K)
Diffusion coefficient in crushed Bandelier Tuff assumed to be nearly equal to TCE $J = -\theta_a D \text{ grad} C$ where J is flux, θ_a is volumetric air content, C is the concentration, and D is the diffusion coefficient. [15]	4.6 e-6 to 9.3 e-6 m^2/s at 2%–7% relative saturation 4.4e-7 to 1.4e-6 m^2/s at 29%–36% relative saturation

Source: Stauffer et al. (2007, 097871).

Table F-3.2-2
Porosity, Saturation, and Effective
Diffusion Coefficient Values Used in the Simulations

Unit	Effective Porosity	In situ Saturation	D* (m^2/s) (Porous Medium Coefficient)
Qbt 2	0.41[a]	0.06[b]	3×10^{-6}
Qbt 1vu	0.49[a]	0.15[b]	2×10^{-6}
Qbt 1vc	0.49[a]	0.15[b]	2×10^{-6}
Qbt 1g	0.46[a]	0.15[b]	2×10^{-6}
Cerro Toledo	0.45[a]	0.40[b]	5×10^{-7}
Otowi Member	0.44[a]	0.35[b]	5×10^{-7}
Cerros del Rio basalt	0.1[b]	0.02[c]	3×10^{-6}
Land surface	0.48[c]	0.02[c]	3×10^{-6}
Asphalt	0.5[c]	0.02[c]	1×10^{-14}
Shafts	0.5[c]	0.02[c]	3×10^{-6}
Wellbore	1.0	0.001	3×10^{-6}
Well Casing	0.5	0.001	1×10^{-14}

Source: Stauffer et al. (2007, 097871).

[a] Fixed to mean measured value.

[b] Fixed to measured values.

[c] Assigned fixed value for the simulations.

Table F-3.2-3
In Situ and Core Permeability Data for the MDA L Area

Geologic Unit	0.6 m Packer Permeability (m^2) Includes Fractures [18]			Mean Core Permeability (m^2) Matrix Only [16]
	Min	Mean	Max	
Qbt 2	5.3E-13	1.7E-12	3.8E-12	2.0E-13
Qbt 1vu	4.7E-13	2.9E-12	1.6E-11	1.2E-13
Qbt 1vc	8.5E-14	1.5E-12	1.2E-11	1.2E-13
Qbt 1g	1.1E-13	2.5E-12	5.4E-11	1.3E-13
Qbtt	9.3E-13	7.5E-12	1.7E-11	na[a]
Qbct	1.2E-12	5.7E-12	1.1E-11	na
Qbo	5.5E-13	6.1E-13	7.1E-13	2.3E-13[b]

Source: Stauffer et al. (2007, 097871).

[a] na = Not available.

[b] Cañada del Buey data.

Table F-3.2-4
Calibrated Permeabilities in Both the Horizontal and Vertical Directions Used for the SVE Pilot Test Simulations at MDA L

Unit	SVE West Permeability (m^2)		SVE East Permeability (m^2)	
	x, y	z	x, y	z
Qbt 2	2.0E-12	1.0E-11	9.0E-13	9.0E-13
Qbt 1vu	4.0E-12	1.0E-11	9.0E-13	9.0E-13
Qbt 1vc	1.0E-12	3.0E-12	7.5E-12	7.5E-12
Qbt 1g	1.0E-13	5.0E-13	1.0E-13	1.0E-13
Tsankawi Pumice	5.0E-13	5.0E-13	5.0E-13	5.0E-13
Cerro Toledo interval	5.0E-13	5.0E-13	5.0E-13	5.0E-13
Otowi Member	1.5E-13	1.5E-13	1.5E-13	1.5E-13
Asphalt	5.0E-19	5.0E-19	5.0E-19	5.0E-19
Wellbore	1.0E-4	1.0E-4	1.0E-4	1.0E-4
Well Casing	5.0E-19	5.0E-19	5.0E-19	5.0E-19

Source: Stauffer et al. (2007, 097871).

Appendix G

Supporting Information for Cost

G-1.0 INTRODUCTION

This appendix provides the basis for the cost estimates, summary cost information, assumptions, estimate details, and material and labor pricing data Los Alamos National Laboratory (LANL or the Laboratory) used to develop the cost estimates for corrective measures evaluation (CME) alternatives for Material Disposal Area (MDA) G at Technical Area 54 (TA-54). The estimates are intended to be consistent with U.S. Environmental Protection Agency (EPA) guidance on developing and documenting costs estimated during feasibility studies (EPA 2000, 071540).

The estimates were developed using the Remedial Action Cost Engineering and Requirements (RACER) system, a parametric cost-modeling tool widely used by U.S. Department of Energy (DOE) projects. RACER 2007, Version 9.1.0, was used under a license from EarthTech. The estimates are feasibility estimates under DOE Guidance 430.1, with an expected accuracy range of –30% +80%.

G-1.1 Method of Accomplishment

The estimates are developed by using an approach wherein an operations and maintenance (O&M) prime contractor (the Laboratory) will invite and award bids for design, construction management, and remedial action (RA) by a yet-to-be determined procurement long-term O&M contracts strategy, such as fixed-price subcontract.

The same methodology will be used to award in multiyear increments for specific activities. The following outline represents a sample work breakdown structure (WBS) used in generating the cost estimates; XX stands for the alternative number:

WBS XX.1 Capital Project Costs

WBS XX.2 Recurring Operations, Maintenance, and Monitoring Costs

This approach is consistent with the March 1, 2005, Compliance Order on Consent (the Consent Order), which requires breaking out the costs as capital costs, including construction, installation, pilot testing, evaluation, permitting, and reporting of the effectiveness of the alternatives and continuing costs associated with operating, maintaining, monitoring, testing, and reporting on the use and effectiveness of the technology.

As presented in guidance documents, confusion often exists with the terms “direct” and “indirect” costs. Therefore, in this document the term “capital” costs is meant to include planning, design, construction, management-related activities, and both labor and professional services for installation of the corrective action. Recurring operations, maintenance, and monitoring costs, including regular annual costs and periodic costs, are separated from capital costs. Periodic costs include 5-yr reviews, equipment replacement, and major cover repairs.

Capital project costs are estimated using the standard phase categories available in RACER, including

- studies,
- remedial design (RD),
- site preparation, and
- RA.

Recurring project costs are estimated using the standard phase categories available in RACER, including O&M and monitoring.

Startup costs were calculated for the O&M and monitoring phases and are not included as recurring costs.

G-1.2 Studies

Additional studies may be conducted before the RD, including a traffic flow study to determine truck volume and hauling on Pajarito Road for Alternatives 2B, 2C, and 5B. Additional studies are not anticipated for Alternative 1B.

G-1.3 RD

Before initiation of RD, the architect/engineer (A/E) will prepare the RD work plan, which will state the objectives of RD, potential problems with the site, etc. The plan shall contain the following: site description, site history, summary of existing data, technical information on the tasks to be performed, schedule of completion, and project management plan. The RD work plan will be reviewed by a construction manager (CM) and submitted for regulatory approval.

The A/E will develop the RD report, which will include Titles I and II design-related activities resulting in an approved certified for construction design package to be used as the basis for RAs. The report will also discuss permit requirements, procurement methods and availability concerns, and need for any land acquisition/easement requirements for the site access. Finally, the report will include a preliminary description of O&M activities along with a cost estimate projected annually.

The CM will develop the RA work plan, which will include the constructability review based on the RD report. It will also include the work description of all RA activities assigned to a general contractor and subcontractors, detailed schedule of the activities, overall construction schedule, and site requirements of various plans.

The A/E will provide Title III engineering support services, including bid evaluation and inspections during construction, both in the office and the field. The A/E will ensure that the work is done according to all the applicable codes, to the intent of the RD report, and to the plans submitted by the contractors.

The Laboratory has the overall responsibility for all project management, including bid invitations, bid evaluations, contract award, project control, and contract management. The Laboratory will manage the RA and long-term O&M for the project.

The RD costs were calculated in RACER using the tool’s percentage methodology. This method calculates design costs as a percent of the total marked-up costs of the selected RA phases. Percentages for each alternative are documented in the RACER reports.

G-1.4 Site Preparation

Site preparation accounts for construction activities to facilitate the RA. Two key assumptions are (1) the site will be “cold and dark” before remediation and (2) existing facilities will be utilized (e.g., for radiological control and access control). No costs are included in the estimate alternatives for construction or modification of the existing facilities, except in the case of declassification domes in Alternative 5B. Replacing the existing fencing and conducting site readiness activities are assumed for all alternatives. In addition, a water tank is included for some alternatives to use for dust suppression.

G-1.5 RA

Activities associated with the RA alternatives include constructing an evapotranspiration (ET), installing a soil vapor extraction (SVE) system, excavating waste material, transport and off-site disposal of waste volumes, restoring the site, installing a long-term monitoring system, and monitoring construction. All the activities are not included in every alternative. In other words, the alternatives are distinguished by which activities they consist of.

Each of the activities within an alternative are estimated using RACER "technologies." In RACER, technologies represent activities such as clearing and grubbing or excavating. Wherever possible, standard technologies available within the RACER software are used. However, in some case, no standard RACER technology was suitable, and the estimator created a user-defined technology to account for expected costs.

G-1.6 Operation

Operation activities varied between the alternatives. All alternatives included operation of an SVE system. Because of the low concentration of volatile organic compounds (VOCs) present in the subsurface soil, a relatively simple system that will operate intermittently over several years and then discontinued is anticipated.

G-1.7 Maintenance

Maintenance activities vary greatly among the alternatives. All alternatives include O&M of the SVE system and long-term monitoring for 30 yr. Two alternatives include O&M of the cover for 100 yr. The final alternative includes maintenance of smaller covers for waste areas that are within the purview of the Consent Order where an ET cover was installed.

G-2.0 MATERIAL AND LABOR PRICING

RACER technologies are used to develop the quantities and costs for each component within an alternative. Professional labor rates and appropriate analytical rates are customized to reflect approved costs from the Laboratory resource dictionary. The remainder of the unit costs for material, labor, and equipment utilized the RACER cost database. The basic estimating units generally reflect a normal standard for construction costs. Special work situations and job conditions may require additional material or labor work hours.

G-2.1 Wage Rates

Professional labor wage rates are customized from the approved Laboratory resource dictionary and mapped to appropriate RACER resources. Table G-2.1-1 lists the rates for an hour of productive work for each resource.

G-2.2 Prime and Subcontractor Markups, Overhead, and Profit

Costs presented in this estimate include markups, overhead, and profit. The professional labor rates are fully burdened and no additional markups are applied to work performed by the prime contractor. Subcontracted work is marked up an additional 44.9% to account for subcontractor markups, overhead, and profit to more accurately estimate a contract price.

G-2.3 Contingency/Risk

A contingency is applied to the final total cost of each alternative as shown in Tables 8.1-1, 8.2-1, 8.3-1, and 8.4-1 of the CME report.

G-3.0 PRESENT VALUE ANALYSIS

The present value analysis method is used to compare different remedial alternatives with different operating time periods on the basis of a single cost figure.

The present value was calculated using the following formula:

$$PV = \frac{1}{(1+i)^t} \cdot x_i$$

where *PV* = the present value,

i = the discount rate, and

x_i = year *t*.

G-4.0 ALTERNATIVE 1B: MAINTENANCE OF EXISTING COVER, SVE, AND MONITORING

This alternative includes monitoring and maintenance of the site and implementing institutional controls. The highlights of this alternative are as follows:

- Assumes the site is 64 acres
- RD activities are estimated by the RACER percentage method
- Site preparation to replace fencing and perform readiness activities
- RA to install the SVE system
- Maintenance of the existing operational cover
- Assume operation of the SVE system for 30 yr
- Monitoring using time-domain reflectometry (TDR) for 30 yr
- O&M for the cover for 100 yr
- Long-term monitoring including sediment sampling for 30 yr

Details of the cost estimate are provided as Attachment G-1.

G-4.1 Project (General and WBS-Specific) Assumptions and Basis of Estimate

The following assumptions were followed during the development of the alternatives for various overall site conditions and operating parameters.

G-4.2 Project General Assumptions

The estimate was based on an 8-hour work day and 5-day work week. No overtime was included. On-site activities will be conducted under Hazardous Waste Operations and Emergency Response (HAZWOPER) requirements. The RACER parameter for safety level was used to account for the work conditions at the site. The RACER safety levels are based on the Occupational Safety and Health Administration (OSHA) regulations in 29 Code of Federal Regulations (CFR) Part 1910. Most RA activities in this alternative are set to safety level D.

G-4.3 Project-Specific Assumptions by WBS

WBS 1B.1.1 Study

No studies are necessary for Alternative 1B.

WBS 1B.1.2 RD

RD is needed for the SVE system. The RD is estimated using RACER's percentage method. It is assumed that the design costs are represented by 6.5% of the total marked-up costs for each RA phase included in the alternative.

WBS 1B.1.3 Site Preparation

Site preparation for Alternative 1B includes developing a site readiness health and safety plan, mobilization and demobilization, preparing for and conducting readiness activities, and replacing the existing fencing. Under the cold and dark assumption, activities are not required to modify existing utilities. In addition, existing facilities will be utilized for radiological and site access control.

WBS 1B.1.4 RA SVE Construction

SVE construction activities account for the active extraction of the subsurface VOC plume. The SVE system will be designed based on the results of the MDA G SVE pilot study.

All appropriate site-related plans (e.g., general safety plan, quality assurance [QA] plan, waste management plan, work plan, hoisting and rigging plan, and health and safety plan) will be prepared and submitted by the contractor. All plans will be reviewed and approved as necessary so as not to adversely impact the project schedule.

The RACER estimate includes managing residual waste from the SVE installation, including containerizing, loading, transporting, and disposing of secondary solid waste generated during construction (e.g., drill cuttings and personal protective equipment [PPE]). The solid waste is considered low-level radioactive waste (LLW) and will be disposed of at an off-site disposal facility. There is no characterization cost estimated for LLW wastes.

WBS 1B.1.5 RA Excavation

No excavation construction activity is required for Alternative 1B.

WBS 1B.1.6 RA Site Restoration

The area over the shafts and pits will be graded and seeded with a mixture of local vegetation.

WBS 1B.1.7 RA Monitoring Installation

Monitoring equipment will consist of a TDR system to monitor runoff, interflow, and seepage. The TDR system includes 12 locations per acre, with three probes per location (at ground level, 3 ft belowgrade, and 6 ft belowgrade). This phase includes the installation of a sprinkler system.

WBS 1B.2.1 SVE O&M

The SVE system is assumed to operate approximately 2 m out of every 22 m for a period of 30 yr. The RACER parameter for run-time percentage was set to reflect this operational schedule.

In addition, the estimate includes analysis for TO-14 Volatiles in Air at a rate of 20 samples per year. The prime contractor (LANL) is expected to perform all work for this activity.

WBS 1B.2.2 Cover Maintenance

Site maintenance includes visual inspection, removal of debris and large woody plants, and erosion control over 64 acres for a period of 100 yr. Mowing is assumed for the entire site every 5 yr and one seeding and fertilization are assumed during each 5-yr period.

WBS 1B.2.3 Monitoring

Long-term monitoring includes sediment sampling and five-year reviews. Sediment will be sampled in two locations twice a year, and a quality control (QC) sample will also be collected. Five-year reviews will be conducted over the 30-yr period.

It is assumed that groundwater monitoring will be accomplished by the LANL Water Stewardship Project. As a result, no costs for groundwater monitoring are included in this estimate.

Analytical services are assumed to be provided by an off-site laboratory.

G-5.0 ALTERNATIVE 2B: ALTERNATIVE ENGINEERED ET COVER, MONITORING AND MAINTANANCE, AND SVE

This alternative includes constructing an ET cover and SVE system, monitoring and maintenance of the site, and implementing and maintaining institutional controls. This alternative reflects the current baseline and does not include the excavation of any waste material. The highlights of this alternative are as follows:

- Assumes the site is 80 acres
- Includes a study for traffic control on Pajarito Road
- RD activities are estimated by the RACER percentage method
- Site preparation to replace fencing and perform readiness activities
- Site preparation to provide on-site water storage for dust suppression
- Site preparation to construct temporary office and crew facilities
- Site preparation replace existing fencing
- Site preparation to develop plan and perform readiness activities

- RA to construct the ET cover
- RA to install the SVE system
- RA to install monitoring systems and sprinklers
- Maintenance of the existing operational cover for 100 yr
- Assumes O&M of the SVE system for 30 yr
- Monitoring using TDR for 30 yr
- Long-term monitoring for 30 yr

Details of the cost estimate are provided as Attachment G-2.

G-5.1 Project (General and WBS-Specific) Assumptions and Basis of Estimate

The following assumptions were followed during the development of the alternatives for various overall site conditions and operating parameters.

G-5.2 Project General Assumptions

The estimate is based on an 8-hour work day and 5-day work week. No overtime is included. On-site activities will be conducted under HAZWOPER requirements. The RACER parameter for safety level is used to account for the work conditions at the site. The RACER safety levels are based on the OSHA regulations in 29 CFR Part 1910. Since this alternative does not include excavation of waste, most RA activities in this alternative are set to safety level D.

Abandonment of wells and boreholes is not included in this cost evaluation.

G-5.3 Project-Specific Assumptions by WBS

WBS 2B.1.1 Study

A traffic flow study is planned for traffic control on Pajarito Road to determine truck volume and hauling requirements.

WBS 2B.1.2 RD

RD will be needed for the cover and the SVE system. The cover design will address grading, sediment control, side slopes, and material specifications will be included. The RD for the SVE system is based on use of a few wells that will be operated via a skid-mounted SVE unit that can be moved from location to location and operated as needed.

The RD for the SVE system is estimated using RACER’s percentage method. It is assumed that the design costs are represented by 6.5% of the total marked-up costs for each RA phase included in the alternative

WBS 2B.1.3 Site Preparation

Site preparation for Alternative 2B includes developing a readiness health and safety plan, mobilization and demobilization, installing a water tank to provide an on-site water source for dust suppression, preparing for and conducting readiness activities, and replacing the existing fencing. Under the cold and dark assumption, activities are not required to modify existing utilities. In addition, existing facilities will be utilized for radiological and site access control.

WBS 2B.1.4 RA SVE Construction

SVE construction activities account for the active extraction of the subsurface VOC plume. The SVE system will be designed based on the results of the MDA G SVE pilot study.

All appropriate site-related plans (e.g., general safety plan, QA plan, waste management plan, work plan, hoisting and rigging plan, and health and safety plan) will be prepared and submitted by the contractor. All plans will be reviewed and approved as necessary so as not to adversely impact the project schedule.

The RACER estimate includes managing residual waste from installing the SVE system, including containerizing, loading, transporting, and disposal of secondary solid waste generated during construction (e.g., drill cuttings and PPE). The solid waste is considered LLW and will be disposed of at an off-site disposal facility. There is no characterization cost estimated for LLW wastes.

WBS 2B.1.5 RA Excavation

No excavation construction activity is required for Alternative 2B.

WBS 2B.1.6 RA Cover

The alternative engineered ET cover (Alternative 2B) is an approximately 8-ft-thick crushed tuff biointrusion cover over the entire site. Under the estimated design, the resulting cover is expected to be 80 acres. The material quantities for the cover components are based on the performance assessment design and the default materials and quantities in the RACER estimate were overridden to reflect this design. Construction of an access road on top of the cover is included in the estimate. This road is necessary for O&M of the cover.

WBS 2B.1.7 RA Monitoring Installation

Monitoring equipment will consist of a TDR system to monitor runoff, interflow, and seepage. The TDR system includes 12 locations per acre, with three probes per location (ground level, 3 ft belowgrade, and 6 ft belowgrade). This activity includes the installation of a sprinkler system for the site.

WBS 2B.2.1 SVE Operations

The SVE system is assumed to operate approximately 2 m out of every 22 m for a period of 30 yr. The RACER parameter for run-time percentage was set to reflect this operational schedule.

In addition, the estimate includes analysis for TO-14 Volatiles in Air at a rate of 20 samples per year. The prime contractor (LANL) is expected to perform all work for this activity.

WBS 2B.2.2 Cover Maintenance

Site maintenance includes visual inspection, removal of debris and large woody plants, and erosion control over the 80-acre site for a period of 100 yr. Mowing is assumed for the entire site every 5 yr, and seeding and fertilization are included during each 5-yr period.

WBS 2B.2.3 Monitoring

Long-term monitoring includes sediment sampling and five-year reviews. Sediment will be sampled in two locations twice a year, and a QC sample will also be collected. Five-year reviews will be conducted over the 30-yr period.

It is assumed that groundwater monitoring will be accomplished by the LANL Water Stewardship Project. As a result, no costs for groundwater monitoring are included in this estimate.

Analytical services are assumed to be provided by an off-site laboratory.

G-6.0 ALTERNATIVE 2C: ALTERNATIVE ENGINEERED ET COVER, PARTIAL WASTE EXCAVATION, MONITORING AND MAINTENANCE, AND SVE

This alternative includes partial waste removal from Pit 28, constructing an engineered ET cover and SVE system, monitoring and maintenance of the site, and implementing and maintaining institutional controls. The highlights of this alternative are as follows:

- Assumes the site is 64 acres
- Includes a study for traffic control on Pajarito Road
- RD activities are estimated by the RACER percentage method
- Site preparation to replace fencing and perform readiness activities
- Site preparation to provide on-site water storage for dust suppression
- RA to remove partial waste from Pit 28, including waste transport and disposal off-site
- RA to construct the ET cover
- RA to install the SVE system
- RA to install monitoring systems and sprinklers
- Maintenance of the ET cover for 100 yr
- Assumes O&M of the SVE system for 30 yr
- Monitoring using TDR for 30 yr
- Long-term monitoring for 30 yr

Details of the cost estimate are provided as Attachment G-3.

G-6.1 Project (General and WBS-Specific) Assumptions and Basis of Estimate

The following assumptions were followed during the development of the alternatives for various overall site conditions and operating parameters.

G-6.2 Project General Assumptions

The estimate is based on an 8-hour work day and 5-day work week. No overtime is included. On-site activities will be conducted under HAZWOPER requirements. The RACER parameter for safety level is used to account for the work conditions at the site. The RACER safety levels are based on the OSHA regulations in 29 CFR Part 1910. Excavation activities utilized safety level B, and most other RA activities in this alternative are set to safety level D.

Allowances for mobilization and demobilization of heavy equipment are included.

All appropriate site-related plans (e.g., general safety plan, QA plan, waste management plan, work plan, hoisting and rigging plan, and health and safety plan) will be prepared and submitted by the contractor. All plans will be reviewed and approved as necessary so as not to adversely impact the project schedule.

G-6.3 Project-Specific Assumptions by WBS

WBS 2C.1.1 Study

A traffic flow study is planned for traffic control on Pajarito Road to determine truck volume and hauling requirements.

WBS 2C.1.2 RD

RD will be needed for the excavations, the ET cover and the SVE system. The cover design will address grading, sediment control, side slopes, and material specifications will be included. The RD for the SVE system is based on use of a few wells that will be operated via a skid-mounted SVE unit that can be moved from location to location and operated as needed.

The RD is estimated using RACER's percentage method. For the ET cover and SVE system, it is assumed that the design costs are represented by 6.5% of the total marked-up costs for all RA activities, excluding excavations. The RD for the excavation phase uses RACER's default 8% design percentage.

WBS 2C.1.3 Site Preparation

Site preparation for Alternative 2C includes developing a readiness health and safety plan, mobilization and demobilization, installing a water tank to provide on-site water source for dust suppression, preparing for and conducting readiness activities, and replacing the existing fencing. Under the cold and dark assumption, activities are not required to modify existing utilities. In addition, existing facilities will be utilized for radiological and site access control.

WBS 2C.1.4 RA SVE Construction

SVE construction activities account for the active extraction of the subsurface VOC plume. The SVE system will be designed based on the results of the MDA G SVE pilot study.

All appropriate site-related plans (e.g., general safety plan, QA plan, waste management plan, work plan, hoisting and rigging plan, and health and safety plan) will be prepared and submitted by the contractor. All plans will be reviewed and approved as necessary so as not to adversely impact the project schedule.

The RACER estimate includes managing residual waste from the SVE installation, including containerizing, loading, transporting, and disposal of secondary solid waste generated during construction (e.g., drill cuttings and PPE). The solid waste is considered LLW and will be disposed of at an off-site disposal facility. There is no characterization cost estimated for LLW wastes.

WBS 2C.1.5 RA Excavation

Alternative 2C includes excavation of waste material from the upper 6 ft of Pit 28. The horizontal extent of contamination is assumed to not extend beyond the edges of the pit, and the vertical extent of contaminants is assumed to be bottom of the shafts and pits.

The excavation activity is estimated with RACER and includes material volumes of residual waste resulting from the excavation activity and transport of all waste material to EnviroCare in Utah. It is assumed that none of the excavated material is suitable for backfill. It is assumed that crushed tuff backfill from a nearby site (e.g., TA-61) will be used to fill the pit to bring it up to grade before the cover is installed.

WBS 2C.1.6 RA Cover

Alternative 2C represents an optimized engineered cover approximately 6 ft thick over the 64-acre site. RACER was used to generate the estimate, but the default material and quantities were overridden to reflect the anticipated design. Costs for the cover materials are based on the RACER resource dictionary. Construction of an access road on top of the cover is included in the estimate. This road is necessary for O&M of the cover. The estimated volume of quantities of cover material is presented in Table G-6.3-1.

WBS 2C.1.7 RA Monitoring Installation

Monitoring equipment will consist of a TDR system to monitor runoff, interflow, and seepage. The TDR system includes 12 locations per acre, with 3 probes per location (ground level, 3 ft belowgrade, and 6 ft belowgrade). This activity includes the installation of a sprinkler system for the site.

WBS 2C.2.1 SVE Operations

The SVE system is assumed to operate approximately 2 m out of every 22 m for a period of 30 yr. The RACER parameter for run-time percentage was set to reflect this operational schedule.

In addition, the estimate includes analysis for TO-14 Volatiles in Air at a rate of 20 samples per year. The prime contractor (LANL) is expected to perform all work for this activity.

WBS 2C.2.2 Cover Maintenance

Site maintenance includes visual inspection, removal of debris and large woody plants, and erosion control over the 64-acre site for a period of 100 yr. Mowing is assumed for the entire site every 5 yr, and seeding and fertilization are included during each 5-yr period.

WBS 2C.2.3 Monitoring

Long-term monitoring includes sediment sampling and five-year reviews. Sediment will be sampled in two locations twice a year, and a QC sample will also be collected. Five-year reviews will be conducted over the 30-yr period.

It is assumed that groundwater monitoring will be accomplished by the LANL Water Stewardship Project. As a result, no costs for groundwater monitoring are included in this estimate.

Analytical services are assumed to be provided by an off-site laboratory

G-7.0 ALTERNATIVE 5B: COMPLETE WASTE-SOURCE EXCAVATION, WASTE TREATMENT, OFF-SITE DISPOSAL, AND SVE

This alternative includes complete removal of all waste material at MDA G, except what is contained in the DOE-regulated shafts and pits. In addition, the cost estimate includes the installation and operation of an SVE system, monitoring and maintenance of the site, and implementing and maintaining institutional controls. The highlights of this alternative are as follows:

- Assumes the site is 64 acres
- Includes a study for traffic control on Pajarito Road
- RD activities are estimated by the RACER percentage method
- Site preparation to provide on-site water storage for dust suppression
- Site preparation to replace fencing and perform readiness activities
- RA to remove consolidated Unit 54-013(b)-99 waste, including waste transport and disposal off-site
- RA to construct ET covers over remaining DOE-regulated shafts and pits.
- RA to install the SVE system
- RA to install monitoring system and sprinkler
- Assumes O&M of the SVE system for 30 yr
- Monitoring using TDR for 30 yr
- Long-term monitoring of sediment for 30 yr

Details of the cost estimate are provided as Attachment G-4.

G-7.1 Project (General and WBS-Specific) Assumptions and Basis of Estimate

The following assumptions were followed during the development of the alternatives for various overall site conditions and operating parameters.

G-7.2 Project General Assumptions

The estimate is based on an 8-hour work day and 5-day work week. No overtime is included. On-site activities will be conducted under HAZWOPER requirements. The RACER parameter for safety level is used to account for the work conditions at the site. The RACER safety levels are based on the OSHA regulations in 29 CFR Part 1910. Excavation activities utilized safety level B, and most other RA activities in this alternative are set to safety level D

All appropriate site-related plans (e.g., general safety plan, QA plan, waste management plan, work plan, hoisting and rigging plan, and health and safety plan) will be prepared and submitted by the contractor. All plans will be reviewed and approved as necessary to not adversely impact the project schedule.

G-7.3 Project-Specific Assumptions by WBS

WBS 5B.1.1 Study

A traffic flow study is planned for traffic control on Pajarito Road to determine truck volume and hauling requirements.

WBS 5B.1.2 RD

RD will be needed for the excavations, the ET covers and the SVE system. The cover design will address grading, sediment control, side slopes, and material specifications will be included. The RD for the SVE system is based on use of a few wells that will be operated via a skid-mounted SVE unit that can be moved from location to location and operated as needed.

The RD is estimated using RACER's percentage method. For the ET cover and SVE system, it is assumed that the design costs are represented by 6.5% of the total marked-up costs for all RA activities, excluding excavations. The RD for the excavation phase uses RACER's default 8% design percentage.

WBS 5B.1.3 Site Preparation

Site preparation for Alternative 5B includes developing a readiness health and safety plan, mobilization and demobilization, installing a water tank to provide on-site water source for dust suppression, preparing for and conducting readiness activities, and replacing the existing fencing. Under the cold and dark assumption, activities are not required to modify existing utilities. In addition, existing facilities will be utilized for radiological and site access control.

WBS 5B.1.4 RA SVE Construction

SVE construction activities account for the active extraction of the subsurface VOC plume. The SVE system will be designed based on the results of the MDA G SVE pilot study.

All appropriate site-related plans (e.g., general safety plan, QA plan, waste management plan, work plan, hoisting and rigging plan, and health and safety plan) will be prepared and submitted by the contractor. All plans will be reviewed and approved as necessary so as not to adversely impact the project schedule.

The RACER estimate includes managing residual waste from the SVE installation, including containerizing, loading, transporting, and disposing of secondary solid waste generated during construction (e.g., drill cuttings and PPE). The solid waste is LLW and will be disposed of at an off-site disposal facility. There is no characterization cost estimated for LLW wastes.

WBS 5B.1.5 RA Excavation

Alternative 5B includes excavating all waste material at MDA-G that is covered by the Consent Order. ET covers will be constructed over waste materials that are not excavated. Details about these ET covers are presented below in WBS 5B.1.6.

The horizontal extent of contamination is assumed to not extend beyond the edges of the shafts and pits, and the vertical extent of contaminants is assumed to be at the bottom of the shafts and pits. The estimated volume of contaminated soil is presented in Table G-7.3-1.

The shafts and pits were grouped to determine the estimated costs. A total of seven groups were established. Detailed estimates of waste quantity associated with each group are presented in a separate table in Attachment G-4 following the RACER cost estimate reports.

Excavation activities are estimated using RACER and include the material volumes of residual wastes resulting from the excavations and transportation of all waste volumes for disposal at EnviroCare in Utah. The excavation costs are based on dimensions of the areas to be excavated. For the shaft groupings, dimensions were estimated from Figure 1.0-3 of the CME report. The depth of the shaft excavations is limited by the RACER maximum of 40 ft. The pit dimensions are based on values published in "Radioactive Waste Inventory for Los Alamos National Laboratory Technical Area 54, Material Disposal G" (LANL 2005, 094156).

In addition, it is assumed that none of the excavated material is suitable for backfill. Crushed tuff from a nearby site (e.g., TA-61) will be used to backfill the excavations.

All excavation/retrieval operations will be conducted within a large metal-framed fabric retrieval enclosure equipped with air locks. These air locks will house drum-packaging stations, including glove boxes, for inspecting waste and loading drums. In addition, air locks will be used to control contamination during ingress and egress from retrieval operations. Waste excavation will occur within this large retrieval enclosure and within tent structures. Excavators modified for operation within a contaminated environment, dust-suppression capabilities, and camera optics will be used for retrieval. The estimate includes costs for this facility.

Waste excavated from Pits 1 through 5 is assumed to contain 10% buried pre-1970 waste with TRU elements. Currently, WIPP is the only facility that can receive TRU waste for disposal. However, WIPP may not have sufficient capacity to receive the volume of potentially acceptable waste from Pits 1 through 5, necessitating that the U.S. Congress modify the WIPP Land Withdrawal Act.

WBS 5B.1.6 RA Site Restoration

The cost estimate assumes closure and site restoration of DOE regulated pits and shafts using an engineered cover. The estimated design is for an 8-ft cover over each specified area. RACER was used to generate the costs for the ET covers, but the material quantities were over-ridden to reflect the anticipated design. The ET cover costs include final grading and reseeding. In addition, grading and seeding is estimated over the remainder of the 64-acre site. An access road is included in the estimate to facilitate O&M on the site.

WBS 5B.1.7 RA Monitoring Installation

Monitoring equipment will consist of a TDR system to monitor runoff, interflow, and seepage. The TDR system includes 12 locations per acre, with three probes per location (ground level, 3 ft belowgrade, and 6 ft belowgrade). This phase includes the installation of a sprinkler system.

WBS 5B.2.1 SVE Operations

The SVE system is assumed to operate approximately 2 m out of every 22 m for a period of 30 yr. The RACER parameter for run-time percentage was set to reflect this operational schedule.

In addition, the estimate includes analysis for TO-14 Volatiles in Air at a rate of 20 samples per year. The prime contractor (LANL) is expected to perform all work for this activity.

WBS 5B.2.2 Site Maintenance

Site maintenance includes visual inspection, removal of debris and large woody plants, and erosion control over the 64-acre site for a period of 100 yr. Mowing is assumed for the entire site every 5 yr and seeding and fertilization are included during each 5-yr period.

WBS 5B.2.3 Monitoring

Long-term monitoring includes sediment sampling and five-year reviews. Sediment will be sampled in two locations twice a year, and a QC sample will also be collected. Five-year reviews will be conducted over the 30-yr period.

It is assumed that groundwater monitoring will be accomplished by the LANL Water Stewardship Project. As a result, no costs for groundwater monitoring are included in this estimate.

Analytical services are assumed to be provided by an off-site laboratory

G-8.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID number. This information is also included in text citations. ER ID numbers are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau; the U.S. Department of Energy–Los Alamos Site Office; the U.S. Environmental Protection Agency, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

Daniel B. Stephens & Associates Inc., April 12, 2005. "Borrow Source Survey for Evapotranspiration Covers at Los Alamos National Laboratory," Albuquerque, New Mexico. (Daniel B. Stephens 2005, 089548)

EPA (U.S. Environmental Protection Agency), July 2000. "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study," EPA 540-R-00-002, prepared by the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency Office of Emergency and Remedial Response, Washington, D.C. (EPA 2000, 071540)

LANL (Los Alamos National Laboratory), September 2005. "Radioactive Waste Inventory for Los Alamos National Laboratory Technical Area 54, Material Disposal Area G," Los Alamos National Laboratory document LA-UR-05-6996, Los Alamos, New Mexico. (LANL 2005, 094156)

Table G-2.1-1
Professional Wage Rates

Assembly	Description	Labor Rate $/h
33220101	Senior Project Manager	188.10
33220102	Project Manager	159.06
33220103	Office Manager	188.10
33220104	Senior Staff Engineer	173.14
33220105	Project Engineer	159.06
33220106	Staff Engineer	144.55
33220107	Senior Scientist	173.14
33220108	Project Scientist	159.06
33220109	Staff Scientist	144.55
33220110	QA/Quality Control (QC) Officer	144.55
33220111	Certified Industrial Hygienist	126.50
33220112	Field Technician	117.84
33220113	Secretarial/Administrative	67.48
33220114	Word Processing/Clerical	63.15
33220115	Draftsman/CADD	32.88
33220119	Health and Safety Officer	131.57

Table G-6.3-1
Estimated Material Quantities for Alternative 2C Engineered ET Cover

Materials	Estimated Cover Material Quantities (yd^3)	Cover Material Unit Cost per Ton*
Contour Fill/Base	171,235	$6.07
Biobarrier	80,100	$18.23
Cover Soil	280,350	$6.07
Rock Mulch	120,150	$18.23
Side Slope Soil	78,850	$18.23
Side Slope Riprap	21,510	$22.10
Buttress Riprap	4200	$22.10
Rock Apron Riprap	5725	$22.10
Underdrain Stone	75	$14.92

* Adopted from Borrow Source Survey report (Daniel B. Stephens & Associates Inc. 2005, 089548, p. 79).

Table G-7.3-1
RACER Estimated Volume Waste/Import Material in MDA G

Alternative	Total Waste Vol (yd^3)	Imported Material Vol (yd^3)
Alt 1B, Maintenance of Existing Covers, Monitoring, and SVE (64 acres)	9	66,671
Alt 2B, Alternative Engineered ET Cover, Monitoring, and SVE (Current Baseline) 80 Acres	6444	1,800,911
Alt 2C, Alternative Engineered ET Cover, Partial Excavation, Monitoring, and SVE (64 Acres)	31,514	749,244
Alt 5B, Complete Excavation, Monitoring and SVE (64 acres)	3,570,933	2,074,242

Note: Total waste volumes include residual waste per RACER estimate.

Attachment G-1

Cost Estimate Details for Alternative 1B
(on CD included with this document)

Attachment G-2

Cost Estimate Details for Alternative 2B
(on CD included with this document)

Attachment G-3

Cost Estimate Details for Alternative 2C
(on CD included with this document)

Attachment G-4

Cost Estimate Details for Alternative 5B
(on CD included with this document)

Appendix H

Interim Subsurface Vapor-Monitoring Plan for Material Disposal Area G at Technical Area 54

H-1.0 INTRODUCTION

The following plan describes proposed subsurface vapor monitoring activities and the frequencies at which they will be conducted within the vadose zone beneath Material Disposal Area (MDA) G. The objective of the monitoring is to evaluate trends in volatile organic compound (VOC) and tritium concentrations over time.

H-2.0 HISTORICAL DATA REVIEW

Routine monitoring of VOCs in subsurface pore gas has been ongoing at Area G from 1992 to the present. Data were last reported in the “Periodic Monitoring Report for Vapor-Sampling Activities at Material Disposal Area G, Technical Area 54, for Fiscal Year 2007” (LANL 2007, 101771). Monitoring since 1992 has been conducted in 32 boreholes, including 4 boreholes drilled for the MDA G Phase I Resource Conservation and Recovery Act facility investigation (RFI) and 9 boreholes installed by Facility Waste Operations at Area G. Most monitoring events consisted of collecting two pore-gas samples from each borehole using SUMMA canisters from selected depths and screening all ports for VOCs in pore gas using the Brüel and Kjaer (B&K) multigas monitor.

Results from routine monitoring completed in 2007 indicate that trichloroethane[1,1,1-] (TCA) is the dominant VOC contaminant present as a vapor beneath MDA G. Maximum concentrations are closely associated with the location of the earliest MDA G disposal operations in the eastern portion of the area. The highest TCA concentration detected during 2007 was 790,000 $\mu g/m^3$ at location 54-24386 from a depth interval of 37.5 ft to 42.5 ft below ground surface (bgs). Trichloroethene (TCE) is the predominant VOC detected in the western areas of MDA G. The highest TCE concentrations detected during 2007 was 190,000 $\mu g/m^3$ at location 54-27436 from a depth interval of 45 ft to 50 bgs.

Following completion of the 39 boreholes in 2005, all ports were screened using the B&K multigas monitor and pore-gas samples were collected from each borehole at the base depth of the nearest adjacent disposal unit and at total depth of the borehole. Samples were collected using a downhole straddle-packer system to isolate the desired sampling interval. Samples were collected in SUMMA canisters for VOC analysis and in silica gel columns for tritium analysis. Purge gas was screened during the sampling process for percent oxygen and carbon dioxide.

Results from the 2005 investigation confirmed the presence of VOCs in subsurface pore gas at MDA G. Thirty VOCs were detected, with TCA being the dominant contaminant. Concentrations of TCA generally decreased from east to west across the site. The highest concentration of TCA was detected at location 54-24378. TCA concentrations in nearby locations 54-24388, 54-24379, 54-24386, and 54-24385 were also elevated compared to the rest of the site indicating the greatest release of TCA is at the east end of MDA G near Pits 1 through 5 and the adjacent shaft fields. Higher concentrations of other VOCs relative to TCA, including TCE and tetrachloroethene (PCE), were detected in samples collected from locations 54-24390 and 54-24394, within the central and western portions of MDA G. The relatively higher concentrations of these VOCs indicate releases from different sources. However, levels of VOCs in the subsurface vapor in these portions of MDA G were an order of magnitude less than those in the eastern portion.

The concentrations of VOCs in subsurface vapor measured during 2006 and 2007 are similar to or less than the concentrations measured in 1997 (LANL 2004, 087624, Appendix B). Concentrations of VOCs in pore gas are not large enough to pose an immediate threat of groundwater contamination by the VOC plume (LANL 2007, 101771).

Borehole locations 54-01110 and 54-01111 are sited next to the active and inactive tritium disposal shafts in the south-central portion of MDA G. Core, subsurface vapor, and flux samples collected at MDA G all indicate this is the region with the highest levels of tritium (LANL 2004, 089304). Analysis of vapor samples collected in 2003 from locations 54-01110 and 54-01111 indicated that tritium levels increase with depth to 90 ft and 139 ft, respectively. The results from the 2005 field investigation confirm tritium is elevated in the south-central portion; however, the maximum tritium concentrations were detected in samples from locations 54-24386 and 54-24378, located in the eastern portion. Tritium concentrations generally decrease with distance and depth from these two portions of MDA G.

During 2007, borehole BH-37 (location 54-24397) near locations 54-01110 and 54-01111 was extended into the basalt at 239.75 ft bgs. Tritium concentrations in this borehole were consistent with earlier investigations and show an overall decrease with depth to the basalt. The concentration of tritium detected from pore-gas moisture collected from the basalt at location 54-24397 was 2400 pCi/L. This value is 12% of the maximum contaminant level for drinking water.

H-3.0 MONITORING METHODS

Monitoring methods were selected to provide both precise and accurate data on the concentrations of tritium and VOCs in subsurface vapor beneath MDA G to determine trends through time. The method for monitoring pore gas at MDA G includes purging the sampling port and field-screening purge gas and collecting samples in SUMMA canisters and silica gel columns from prescribed locations for off-site laboratory analysis. The proposed frequency of sampling and the locations to be sampled are defined in section H-4.0, Proposed Monitoring Distribution and Frequency. Field screening of subsurface vapor at MDA G will include measuring the percent carbon dioxide, percent oxygen, static subsurface pressure, and organic vapors. Vapor samples for laboratory analysis will be collected using SUMMA canisters and silica gel columns. SUMMA canister samples will be analyzed for VOC concentrations by the U.S. Environmental Protection Agency (EPA) Method TO-15. Silica gel column samples will be analyzed for tritium by EPA Method 906.0.

Monitoring of pore gas at MDA G will be conducted in accordance with the current version of EP-ERSS Standard Operating Procedure 5074, Sampling Subatmospheric Air*.* In accordance with this procedure, field screening will be performed before analytical samples are collected. Each port will be purged and monitored with a Landtec GEM2000 instrument or equivalent, until the percent carbon dioxide and oxygen levels have stabilized at values representative of subsurface pore-gas conditions and are consistent with previously recorded measurements. The vapor will then be screened for VOCs using a B&K multigas analyzer, Type 1302, which measures four VOCs: TCA, TCE, PCE, and Freon 11. The B&K analyzer also measures percent carbon dioxide to 0.01%. Once purge and field screening are completed, vapor samples will be collected using SUMMA canisters and silica gel columns, as prescribed in section H-4.0.

During each sampling event, three types of field quality assurance (QA) samples will be collected and analyzed for VOCs using SUMMA canisters: a field duplicate sample, an equipment blank of zero-grade air (a common term for air certified to be free from VOC contamination) or nitrogen drawn through the sampling apparatus in the working area, and a performance evaluation sample/calibration gas sample taken from a tank of a certified gas mixture. Analytical laboratory QA for EPA Method TO-15 includes internal standards, surrogates, replicates, blanks, laboratory control samples, and reference standards. A field duplicate silica gel column QA sample will be collected and analyzed for tritium.

H-4.0 PROPOSED MONITORING DISTRIBUTION AND FREQUENCY

The pore-gas monitoring locations are shown in Figure H-4.0-1 and listed in Table H-4.0-1. Four boreholes drilled in 2005 and one drilled in 2007 are equipped with sampling ports for pore-gas monitoring. The 12 older monitoring locations and 5 newer investigation locations will allow monitoring within and adjacent to areas of maximum VOC and tritium concentrations at MDA G. Locations 54-27436, 54-24370, and 54-24394 will monitor the areas of maximum VOC levels. Location 54-24386 will be one of the monitoring locations within the eastern portion of MDA G where the maximum levels of tritium and VOCs have been detected. A table of port depths for these boreholes is listed in Table H-4.0-1. The remainder of the boreholes listed in Table H-4.0-2 will be abandoned to minimize potential contaminant pathways to the subsurface.

Location 54-25105, the open borehole within the Puye Formation, will remain available for packer sampling from the end of the casing at 485 ft to the total depth of 701 ft. Because of the instability and irregular diameter of the open portion of the borehole, installing a membrane or deploying a straddle packer below the casing is not feasible. This location will allow for continued monitoring at depth beneath MDA G.

Every port in the pore-gas monitoring locations listed in Table H-4.0-1 will be monitored annually by field measurement of percent carbon dioxide, percent oxygen, and organic vapors using the methods described in section H-3.0. These data will be compared to the historical record to evaluate spatial extent and trends of the dominant VOCs released from MDA G.

Vapor samples will be collected annually using SUMMA canisters for VOCs and silica gel columns for tritium from the port nearest the lowest base elevation of the adjacent disposal unit, and at the total depth of the locations listed in Table H-4.0-1 with two exceptions: location 54-25105 will be sampled across the open portion using a single packer, and location 54-22116 will be sampled from the two ports containing the highest level of TCA, as measured by the B&K analyzer. Annual subsurface vapor monitoring will include the collection of a minimum of 20 vapor samples from subsurface monitoring locations at MDA G. Additionally two duplicates, two equipment blanks, and one performance-evaluation sample will be collected during each event using SUMMA canisters. One duplicate sample will be collected during each event using a silica gel column. During the second year, vapor samples will be collected semiannually.

Annual monitoring will continue until a final remedy for MDA G is selected. Final long-term monitoring requirements will be determined as part of the corrective measure implementation (CMI) process based on the remedy selected. The frequency of annual monitoring is based on the following:

- the concentrations of VOCs and tritium in the deepest samples collected are not high enough to pose an immediate threat of groundwater contamination based on screening evaluations,
- historical monitoring data have shown little change in plume concentrations over time, and
- annual monitoring will provide sufficient lead time to implement corrective measures (e.g., soil vapor extraction) if concentrations in deep samples did increase to levels posing a potential threat to groundwater.

Monitoring data will be reported annually in a periodic monitoring report per the requirements of the March 1, 2005, Compliance Order on Consent, Section XI.D. These monitoring reports may include recommendations for future monitoring and remedial actions based on data results and trends.

H-5.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID number. This information is also included in text citations. ER ID numbers are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the New Mexico Environment Department–Hazardous Waste Bureau; the U.S. Department of Energy–Los Alamos Site Office; EPA, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

LANL (Los Alamos National Laboratory), November 2004. "Investigation Work Plan for Material Disposal Area L, Solid Waste Management Unit 54-006 at Technical Area 54, Revision 2," Los Alamos National Laboratory document LA-UR-04-8245, Los Alamos, New Mexico. (LANL 2004, 087624)

LANL (Los Alamos National Laboratory), November 2004. "Quarterly Technical Report, July–September 2004," Los Alamos National Laboratory document LA-UR-04-7387, Los Alamos, New Mexico. (LANL 2004, 089304)

LANL (Los Alamos National Laboratory), December 2007. "Periodic Monitoring Report for Vapor-Sampling Activities at Material Disposal Area G, Technical Area 54, for Fiscal Year 2007," Los Alamos National Laboratory document LA-UR-07-8192, Los Alamos, New Mexico. (LANL 2007, 101771)

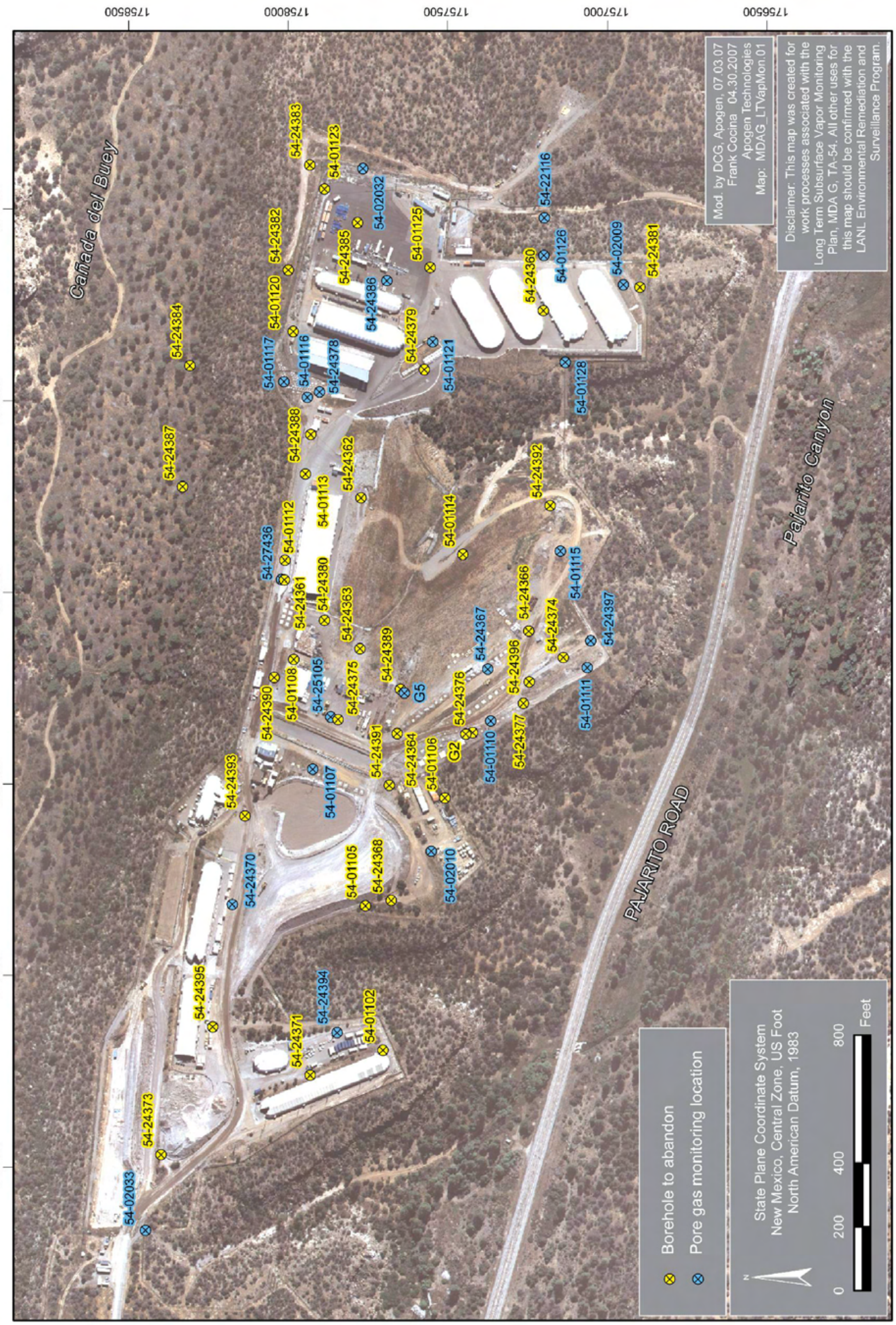

Figure H-4.0-1 Locations of boreholes for interim pore-gas monitoring

Table H-4.0-1
MDA G Pore-Gas Monitoring Locations

Well ID	Depths of Ports (ft)
54-01107	20, 44.5, ***56.5***, 74, 91, ***100***
54-01110	20, 48, ***60***, 70, 85, ***90***
54-01111	***20***, 39.5, 50, 70, 78, 100, ***139***
54-01115	7, 26, ***40***, 53, 63, ***68***
54-01116	***22.5***, 42.5, 67.5, 82.5, 97.5, 132.5, 151.5, 165, ***187.8***
54-01117	**20**, 42.5, 67.5, 82, 97.5, 132.5, 150, 159.5, and **179.8**
54-01121	***20***, 26, 61.5, 70, 76, 98, ***121***
54-01126	7, 17, 28, **35**, 42, ***49***
54-01128	7.5, 15, ***20***, 30, ***39***
54-02009	***37***, 62, 79, ***92***
54-02010	***30***, 53, ***95***
54-02032	***20***, 60, 100, 130, ***156***
54-02033	20, ***60***, 100, 200, 220,260, ***277***
54-22116*	28, 46, 64, 82, 100, 118 136, 154, ***172***, ***190***, 208, 226, 244, 262, **280**
54-24370	***40***, 72, 120, 174, 200, ***243***
54-24386	***40***, 83,117, 135, ***195***
54-24394	***50***, 100, 150, 192, 245, ***300***
54-24397	***50***, 90, 130, 165, 188, ***239***
54-25105	**485-701** (open borehole)
54-27436	***45***, 70, 115, 163, ***185***

Note: VOC and tritium sampling is to be performed on borehole port depths in bold and italic.

* VOC and tritium samples to be collected from the two ports with highest TCA field-screening results at the time of monitoring. Historically, this has occurred at 172 ft and 190 ft beneath Pit 3.

Table H-4.0-2
MDA G Boreholes
To Be Abandoned

Well ID	
54-01102	54-24375
54-01105	54-24376
54-01106	54-24377
54-01108	54-24379
54-01112	54-24380
54-01113	54-24381
54-01114	54-24382
54-01120	54-24383
54-01123	54-24384
54-01124	54-24385
54-01125	54-24387
54-24360	54-24388
54-24361	54-24389
54-24362	54-24390
54-24363	54-24391
54-24364	54-24392
54-24366	54-24393
54-24368	54-24395
54-24371	54-24396
54-24373	54-24523
54-24374	G-2, G-5