TA-03

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Date: October 29, 2003
Refer to: ER2003-0680

Mr. John Young, Corrective Action Project Leader
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SUBJECT: SUBMITTAL OF THE GROUNDWATER INVESTIGATION WORK PLAN (IWP) FOR SOLID WASTE MANAGEMENT UNIT (SWMU) 3-010(a) AT TECHNICAL AREA (TA) 3

Dear Mr. Young:

Enclosed are two copies of the "Groundwater Investigation Work Plan for SWMU 03-010(a) at Technical Area 3." Additional copies are available upon request.

The work plan describes the activities to be conducted at SWMU 3-010(a) per a "Response to Request for Supplemental Information Resource Conservation and Recovery Act (RCRA) Facility Investigation Report Addendum for Potential Release Site (PRS) 3-010(a) LANL NM0890010515 HWB-LANL-01-005 (NMED 2002, 73405.1)." This investigation will be conducted through an iterative approach to address all issues outlined in the Request for Supplemental Information (RSI). Also, a report of the geophysical investigation performed in 2002, not previously submitted to the New Mexico Environment Department (NMED), is included as Appendix B. As agreed in discussions with NMED-Hazardous Waste Bureau (HWB) personnel, this work plan does not include a Historical Investigation Report appendix, as all existing analytical data for SWMU 03-010(a) have been previously reported.

If you have any questions, please contact Gabriela Lopez Escobedo at (505) 665-7352 or David Gregory at (595) 667-5808.

Sincerely,

David McInroy, Deputy Project Director
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Sincerely,

David Gregory, Federal Project Director
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5726

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Enclosures: (1) Groundwater Investigation Work Plan for SWMU 3-010(a) at Technical Area 3
(2) Certification by RRES-RS

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CERTIFICATION

CERTIFICATION BY THE RISK REDUCTION AND ENVIRONMENTAL STEWARDSHIP-REMEDIATION SERVICES (RRES-RS) PROJECT TECHNICAL REPRESENTATIVES

Document Title: Groundwater Investigation Work Plan for SWMU 3-010(a) at Technical Area 3

I certify under penalty of law that these documents and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violation.

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October 2003
ER2003-0636

Groundwater Investigation Work Plan for Solid Waste Management Unit 3-010(a) at Technical Area 3

Los Alamos
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This document contains data regarding radioactive wastes, the management of which is regulated under the Atomic Energy Act and specifically excluded from regulation under the Resource Conservation and Recovery Act and the New Mexico Hazardous Waste Act. These data are provided to the New Mexico Environment Department for information purposes only.

Prepared by Risk Reduction and Environmental Stewardship–Remediation Services

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LA-UR-03-7349
ER2003-0636

Groundwater Investigation Work Plan for SWMU 3-010(a) at Technical Area 3

October 2003

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EXECUTIVE SUMMARY

This groundwater investigation work plan outlines the steps needed to investigate the contaminated shallow groundwater associated with Solid Waste Management Unit (SWMU) 3-010(a) at Technical Area (TA-) 3, Los Alamos National Laboratory (LANL or the Laboratory). This work is being conducted at the direction of the New Mexico Environment Department (NMED) per a "Response to Request for Supplemental Information RCRA Facility Investigation Report Addendum for Potential Release Site 3-010(a) LANL NM0890010515 HWB-LANL-01-005."

The request for supplemental information (RSI) states that the investigation shall establish (1) the source of the shallow groundwater; (2) identify and characterize all sources of groundwater contamination; (3) characterize the spatial extent of groundwater contamination; (4) measure groundwater flow rates; and (5) determine whether the shallow groundwater and deeper zones of saturation are connected.

An iterative approach is proposed to address the objectives outlined above. Previous investigations indicate that the shallow alluvial groundwater (approximately 5.5 ft thick) is likely the result of localized seepage and recharge at the facility. The runoff from these areas will be rerouted away from the immediate area of SWMU 3-010(a). Several measures will be taken, including leak testing of the drain system, clearing vegetation, and rehabilitating the shallow drainage channel along the north side of Building SM-30 to decrease ponding and travel time. Water levels in well MW-1 will be monitored to determine the effectiveness of these measures in controlling recharge to the shallow alluvial saturated zone in the immediate area.

To determine the extent of groundwater contamination, groundwater flow rates, and possible connections between shallow and deeper zones, at least six boreholes are planned.

- A 40 ft vertical borehole will be located upgradient of SWMU 3-010(a) within SWMU 3-001(e) to investigate other potential contaminant sources and to determine the eastern extent of the shallow groundwater.
- Four 10-ft hand auger holes in the immediate area of SWMU 3-001(e) will be sampled to further define the extent of contamination.
- A 260-ft angled borehole will be drilled to determine the vertical extent of contamination and saturation associated with the shallow system.

In the event that data gathered from best management practices and additional boreholes are not sufficient to identify to a path forward in the RCRA corrective action process, a tracer may be used to determine groundwater flow rates and pathways in the vicinity of SWMU 3-010(a).

The overall approach of this work plan is iterative, building upon information from earlier studies and assimilating information to better understand shallow groundwater contamination associated with SWMU 3-010(a).

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1.0 INTRODUCTION

This groundwater investigation work plan (hereafter, the work plan) outlines the steps needed to address shallow groundwater at the Solid Waste Management Unit (SWMU) 3-010(a) at Technical Area (TA-) 3 at Los Alamos National Laboratory (LANL or the Laboratory). These activities are being conducted at the direction of the New Mexico Environment Department (NMED) per a "Response to Request for Supplemental Information RCRA [Resource Conservation and Recovery Act] Facility Investigation Report Addendum for Potential Release Site 3-010(a) Los Alamos National Laboratory NM0890010515 HWB-LANL-01-005" (NMED 2002, 73405). The objectives of the investigation are to identify and characterize all sources of groundwater and groundwater contamination; characterize other contaminants sources and their contribution to groundwater contamination, characterize the vertical and lateral extent of groundwater contamination; determine the groundwater source, flow rates, and direction; and determine if the shallow groundwater has any connection to a possible intermediate saturated zone or the regional aquifer.

This work plan addresses the requirements of the request for supplemental information (RSI) and provides summary background information. It describes surface and subsurface site conditions, proposes a scope of activities to meet objectives, defines investigation methods, describes subsequent monitoring and sampling activities, and presents a schedule. It also includes the results of a geophysical investigation conducted in 2002.

This document contains data on radioactive wastes, including source, special nuclear, and by-product material. The management of these materials is regulated under the Atomic Energy Act and is specifically excluded from regulation under the Resource Conservation and Recovery Act (RCRA) and the New Mexico Hazardous Waste Act. These data are provided to the New Mexico Environment Department for informational purposes only.

2.0 BACKGROUND

SWMU 3-010(a) was initially identified as a waste site because liquid wastes from a vacuum repair shop were discharged to the ground between 1950 and 1957 near the southwest corner of Building SM-30, also known as TA-3-30 (Figure 1). Former site workers estimated that more than 100 lbs of mercury were dumped at this SWMU. The site encompasses an area approximately 40 ft long by 15 ft wide on a moderately steep slope that drains into Twomile Canyon (Figure 2).

SWMU 3-001(e) represents the footprint of the storage area for vacuum pump repair waste used from 1957 through 1992 and is associated with the SWMU 3-010(a) outfall (Figure 2). In the early 1960s a large holding tank with a secondary containment berm replaced storage drums that sat outside of Building SM-30. Then, in 1984, a concrete containment sump was constructed in the storage area, over which a metal grate was placed. No samples have been collected beneath SWMU 3-001(e), and very few operational records exist. This site is the only other known source of potential contamination in the vicinity of MW-1.

2.1 SWMU 3-010(a)

This section summarizes information collected to date that relates to the shallow groundwater system at SWMU 3-010(a). It presents data from the RCRA facility investigation (RFI), a voluntary corrective action ([VCA] LANL 1995, 55638), follow-up well development and sampling, and a geophysical investigation.

2.1.1 RFI, VCA, and Groundwater Sampling

In 1992, five soil and sediment samples were collected to identify potential contaminants, with results indicating the presence of elevated levels of both mercury and total petroleum hydrocarbons (TPH). Additional sampling was done in 1993 to determine the horizontal and vertical extent of mercury in the soil, define the TPH concentrations around the site, and determine if surface water at the site exceeded water quality standards. Samples were collected from each of ten rows and columns of a 50-point sampling grid that was established over the visible erosion channel. The results from this sampling event showed elevated levels of radionuclides, lead, mercury, and TPH. Surface water samples collected downstream from SWMU 3-010(a) did not show elevated concentrations of mercury.

In 1994, a VCA was conducted as part of the RFI investigation to remove soils containing mercury above 20 parts per million (ppm) and TPH above 100 ppm. Approximately 120 y^3 of soil containing mercury and radionuclides were removed. During the VCA soil removal, volatile organic compounds (VOCs) were detected in soil at the site. Because VOCs were present, the VCA could not be considered as the final remedy, and further investigation of the site was required

Following completion of the VCA, two screening assessments were completed to identify concentrations of contaminants remaining at the site. Screening assessment of results of soil sample analysis identified benzene, chloroform, 1,1-dichloroethane (DCA), 1,1-dichloroethene (DCE), and cis-1, 3-dichloropropene as the human health contaminants of potential concern at SWMU 3-010(a). In 1994, as part of further RFI investigations to identify the extent of VOCs, seven boreholes were augered to depths between approximately 30 and 100 ft below ground surface (bgs) at SWMU 3-010(a) (Figure 3). Free water was encountered in two of the seven boreholes, B1 and B4, approximately 23 ft bgs; water was present in the sample collected near the same depth in borehole B6, but standing water was not encountered and the hole was advanced to approximately 100 ft bgs. Water samples from the subsurface source showed low concentrations of VOCs.

In 1995, the results of the VCA and RFI investigations were reported and concluded that the surface water did not represent a viable exposure pathway for humans and contaminants concentrations were below a level of concern for nonhuman receptors (LANL 1995, 55638). The RFI report stated that the VCA successfully accomplished its intent, and SWMU 3-010(a) was recommended for no further action (NFA). In fall 1995, a notice of deficiency ([NOD] EPA 1995, 67307) for the RFI was submitted to the Laboratory from the EPA (copied to the NMED) requesting further investigations to determine the nature and extent of the shallow groundwater and possible contaminants.

A response to the NOD was submitted to the EPA and NMED in February 1996 (LANL 1996, 54084). Further studies conducted in response to the NOD included inspecting and maintaining best management practices (BMPs) and collecting surface water and sediment samples.

In 1999, the NMED responded to the Laboratory NOD response (NMED 1999, 64614) and requested further characterization at SWMU 3-010(a). The response requested additional investigations that would allow for a more refined analysis of the hydrogeologic conceptual model. Field activities consisted of developing MW-1 and collecting additional groundwater, surface water, and sediment samples. The data collected over the following year showed contaminant concentrations at nearly the same level or lower than the results from sampling events upstream and downstream of SWMU 3-010(a). The investigation concluded that the only potentially complete exposure pathway was inhalation of vapors from subsurface soil using two scenarios: long-term workers and trail users. Water was not considered a complete pathway because contaminants were not detected in the surface water.

The data acquired in the 1999 and 2000 investigations, combined with six years of observation, indicated that water levels in the borehole varied slightly throughout the year, but overall the fill material beneath Building SM-30 remained saturated, and water was present in the stream channel only as a result of storm water runoff from the parking lots and roof drains. Therefore, since the investigation concluded that the groundwater and surface water were not connected, the RFI report (LANL 1995, 55638) addendum based on these investigations recommended NFA of SWMU 3-010(a) because risk values were within the 1E-04 to 1E-06 risk range for inhalation, the only potentially complete exposure pathway.

In 2002, the NMED issued an RSI to the Department of Energy (DOE) and the Laboratory and requested further investigation of SWMU 3-010(a) to further define the nature and extent of the shallow groundwater and all possible contaminant sources.

2.1.2 Analytical Results

The analytical data collected from the groundwater identified seven organic compounds in the shallow water, as well as tritium and metals. Five VOCs were detected in the samples collected in 1994 and 1995, and the same five organic compounds along with two additional organic compounds, chloroform and trichloroethene, were detected in 1999. The VOCs are chloroform; DCA; 1,2-dichloroethane (EDC); DCE; 1,2,2-trichloro-1,1,2-trifluoroethane (TCTF); 1,1,1-trichloroethane (TCA); and trichloroethene (TCE). Table 1 summarizes the analytical data from the 1999 sampling event for VOCs and tritium.

2.1.3 Geophysical Investigation

A geophysical investigation was conducted in August 2002 by hydroGeophysics, Inc., in an attempt to define the extent of the shallow groundwater around MW-1. The geophysical methods selected were high resolution resistivity (HRR), residual potential mapping (RPM), and conventional electromagnetics (EM). Five lines of HRR, six lines of RPM, and twelve lines of EM were completed. Data from the geophysical investigations were compromised by the presence of subsurface features associated with Building SM-30. However, the geophysical data indicated that there may be a shallow saturated zone within the fill beneath the foundation of Building SM-30, and no saturated zone is present to a depth of 60 ft. A complete report detailing the activities and field methods used in this geophysical investigation is presented in Appendix B.

3.0 SITE CONDITIONS

3.1 Surface Conditions and Topography

SWMU 3-010(a) is located outside the west end of Building SM-30, which is a large rectangular warehouse. The original footprint of SWMU 3-010(a) extends from an exit on the west side of Building SM-30 (Figure 4), across a flat paved road, and down a steep graded slope to a small channel that is a tributary to Twomile Canyon.

Building SM-30 is 248 ft wide and 452 ft long, oriented east to west, and covers more than 3 ac. The building is surrounded by asphalt parking areas and roadways (Figure 4). Building SM-30 rests atop a concrete slab foundation with concrete footers.

MW-1 is located in the middle of an asphalt-covered fire lane that runs parallel to the west side of Building SM-30. It is approximately 7 ft from Building SM-30. The ground surface in the vicinity of MW-1 is covered in asphalt that extends up to the concrete footer (Photograph 1). However, because expansion and contraction of the two materials differ, there is a continuous gap between the asphalt and concrete around

the perimeter of the building. The asphalt has many cracks and consists of several layers of chip seal and asphalt patch. The cracks are generally elevated compared to the adjacent material because patch material has been added.

The surface north and west of the asphalt fire lane consists of fill material, outcrops of the Bandelier Tuff, and/or soils. The fill material is composed of crushed tuff, base-coarse mixtures, and native soil. The soil 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. Native soil in the vicinity of Building SM-30 has been disturbed by Laboratory construction operations over much of the surrounding area.

In general, soils on the surface are thin and poorly developed; they tend to be sandy near the surface and more clay-rich beneath the surface. Soil-forming processes are evident along fractures of the exposed tuff along the north road cut. A discussion of soil in the Los Alamos area can be found in Section 2.5.1.3 of the installation work plan for the Environmental Restoration Project (LANL 1998, 62060).

3.1.1 Surface Water Conditions

No perennial streams flow in the vicinity of SWMU 3-010(a). Surface water flows from the area into a channel that runs along the perimeter of the paved fire lane of Building SM-30. This channel flows west along the northern boundary, then bends south along the western side, past SWMU 3-010(a), and ultimately drains into Twomile Canyon. The northern and western portions of the channel contain water only after precipitation events and during spring snowmelt. The channel drains the runoff from a portion of the asphalted area about 45,000 ft^2, over ten ac of the land north of the site, and the roof of Building SM-30 (106,563 ft^2).

Ponds of water have been observed several days after rain events along the drainage north of Building SM-30 and atop the asphalt across the site. During winter, snow accumulates from plowing the north and west roads, resulting in piles of snow along the sides of Building SM-30 and within the northern drainage (Photograph 2). These piles remain until warmer spring temperatures cause melting and subsequent runoff, and water can pond in these areas for several months during normal snowfall years.

Other surface water sources that may contribute to the shallow groundwater include potential leaks from near-surface roof drains, sewers, or water supply lines. Santa Fe Engineering inspected sewer and drains at Building SM-30 in October 1992 and found that two sinks and one fire line discharged into the roof drainage system. These drains were plugged or re-routed to the sewer line, after which the roof drains only storm water outfall. Water supply lines are routinely pressure tested. In July 2001, a leakage control survey was performed on the water supply lines around Building SM-30, and no leaks were detected.

Two roof-drain culverts discharge into the western channel. These drain lines receive water from precipitation and snow melt runoff from the 3-ac roof through 43 drains atop Building SM-30. The southern culvert has been extended down the steep slope to drain directly into the western channel (Photographs 3 and 4). The integrity of the roof drain system has not been thoroughly evaluated. However, on September 23, 2003, video logging of the northern culvert showed no structural damage to the culvert that would be an obvious point source for water discharge into the subsurface (Photograph 5).

3.2 Subsurface Conditions

This section describes the stratigraphy, structural setting, vadose zone, and groundwater associated with SWMU 3-010(a). Additionally, the known nature and extent of the shallow groundwater system at MW-1 is described.

3.2.1 Stratigraphy

The stratigraphy expected to be encountered by drilling at SWMU 3-010(a) consists of units 2, 3, and 4 of the Tshirege Member of the Bandelier Tuff. The following description of each geologic unit is based on the borehole log from boring 03-22098 drilled in April 2003 for a geotechnical investigation south of Building SM-30, observations made at outcrops near the site, and other previous geologic investigations at TA-3. The stratigraphy in the vicinity SWMU 3-010(a) is shown in Figure 5.

The construction of Building SM-30 included leveling outcrops and filling a small basin (Figure 6). A maximum of 25 ft of crushed tuff and fill material was placed on the underlying stratigraphy. This fill contains primarily reworked native materials graded from the site.

Unit 4 is a moderately welded, devitrified ignimbrite that is about 40 ft thick in borehole 03-02680. The upper 25 ft of unit 4 in this borehole showed numerous fractures, many of which contained small amounts of clay (smectite) infilling.

A sandy surge bed deposit marks the base of unit 4 beneath SWMU 3-010(a) and ranges in thickness at TA-3 from 0 in. up to 30 in. in borehole SHB-SCC-1 (Krier et al. 1998, 77964). Analysis of core shows the bed to be a massive, well sorted, poorly indurated sand, making recovery of undisturbed core difficult. In borehole 03-02680, this interval was not definitively identified because the tuffs in the bottom 15 ft of Qbt 4 and the top 10 ft of Qbt 3 were largely unwelded.

Unit 3 is estimated to be 130 to 140 ft thick beneath SWMU 3-010(a) based on outcrop mapping in Los Alamos Canyon and Twomile Canyon (Gardner et al. 1999, 63492). No boreholes on the mesa top at TA-3 have penetrated the full thickness of this unit. Fractures are common in the welded cliff-forming unit where exposed to the surface and may contain clays and calcite (Broxton and Reneau 1995, 49726)

The top of unit 2 is approximately 200 ft below SWMU 3-010(a) (Gardner et al. 1999, 63492). Previous drilling has not penetrated this unit beneath TA-3. Unit 2 is a competent tuff, and where it is exposed it forms nearly vertical cliffs on the sides of the mesa. Unit 2 is extensively fractured as a consequence of contraction during post-depositional cooling. The cooling-joint fractures are visible on the 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.

Deeper stratigraphic units beneath TA-3 have not been penetrated, nor are they exposed by outcrop in the adjacent canyon walls. However, the stratigraphy beneath TA-3 can be inferred from drilling done at other TAs across the Pajarito Plateau. Beneath unit 2 is approximately 500 ft of additional volcanic ash, pumice, and flow deposits belonging to the Bandelier Tuff. These volcanic rocks are underlain by 1100 ft or more of the Puye Formation fanglomerate, the now consolidated alluvial fan of the Valles Caldera. The regional aquifer is anticipated to occur at an elevation of approximately 6300 ft above sea level (asl) within the Puye Formation beneath TA-3 or approximately 1000 ft bgs.

3.2.2 Faults in the Vivinity of SWMU 3-010(a)

Two small faults have been mapped in the tributary of Twomile Canyon adjacent to SWMU 3-010(a): one fault lies directly west of Building SM-30, and the other is approximately 300 ft to the west. These faults form a narrow zone of normal faulting. The strike of the faults is north-to-northwest, and they have a relatively small displacement, not exceeding 3 ft. This narrow zone of faulting is most likely a secondary cross structure related to flexing between the Pajarito Fault Zone to the west, the Rendija Fault Zone to the east, and the northern dipping of the Diamond Drive Graben. Figure 7 shows the faulting in the vicinity

of SWMU 3-010(a). A complete discussion of faulting in the northwestern portion of the Laboratory can be found in Gardner et al. (1999, 63492) and Lewis et al. (2002, 73785).

3.2.3 Vadose Zone

The region beneath the ground surface and above the regional aquifer is called the vadose (unsaturated) zone. The source of moisture in the vadose zone beneath SWMU 3-010(a) is infiltration of precipitation and potential leaks from near surface roof drains, sewers, and/or water supply lines. Evapotranspiration is limited in the area of SWMU 3-010(a) because of the overlying building and asphalt; therefore, most of the water reaching the subsurface will accumulate and possibly percolate according to the matrix properties of the underlying unit.

Beneath SWMU 3-010(a) saturation was encountered in three boreholes at approximately the contact of the fill and weathered surface of unit 4 of Tshirege Member of the Bandelier Tuff. Only borehole 1 produced sufficient water to be established as a monitoring well (MW-1).

Two geologic properties of the Bandelier Tuff that influence the fluid flow in the unsaturated zone are the degree of welding and the devitrification, both effects of the prolonged presence of residual gases and high temperatures when the rock was deposited. Because the tuff units were deposited at different temperatures and because individual units were laid out in variable thicknesses over varying landscapes, cooling was not uniform. Consequently, welding varies spatially, both between and within separate depositional layers. Welded tuffs tend to be more fractured than nonwelded tuffs.

Several competing effects determine moisture content and fluid flux in welded, devitrified tuff. While water moves slowly through the unsaturated tuff matrix, it can move relatively rapidly through fractures if nearly saturated conditions exist. The gravimetric moisture content measured around SWMU 3-010(a) is relatively low, less than 12% in borehole 03-22098 (Table 2), except in the isolated saturated portions around MW-1. At a moisture content less than 12%, most of the fractures beneath SWMU 3-010(a) are relatively dry. Only when substantial infiltration occurs from the ground surface do the fractures become wet and conduct water. However, the unconsolidated ash fall deposits and basal surge bed at the contact of units 4 and 3 of the Tshirege Members do not show evidence of fractures, and moisture is absorbed into the matrix.

3.2.4 Groundwater

Groundwater beneath the Laboratory occurs in the regional aquifer at depths ranging from 600 to 1200 ft bgs and as perched intermediate or shallow alluvial aquifers in larger drainages. Perched groundwater has been detected only in wells beneath relatively wet canyons (e.g., Los Alamos Canyon). It exists as two types: (1) shallow alluvial groundwater that occurs in some wet canyons (generally at depths less than 100 ft), and (2) deeper "intermediate" perched groundwater that occurs in zones separated from both alluvial and regional groundwater by unsaturated rock. Currently, there is no information about the depth of the regional aquifer or the presence of deep intermediate perched zones in the western part of Pajarito Plateau. Planned deep borehole R-6, to be drilled in upper Los Alamos Canyon, will be the first to penetrate these depths near TA-3.

3.2.4.1 Shallow Groundwater at MW-1

Groundwater at SWMU 3-010(a) was encountered in two of seven boreholes drilled to define the extent of soil contaminated with VOCs. Free water was encountered in two of the seven boreholes, B-1 and B-4, at

approximately 23 ft bgs. Water was present in the sample collected near the same depth in borehole B-6, but standing water was not encountered and the hole was advanced to approximately 100 ft bgs.

In October 1994, borehole B-1 was completed as a monitoring well, MW-1, with a 2 in. diameter, stainless steel casing; the total depth (TD) of the well is 29.5 ft, and it has a 5-ft screened interval. The depth to water in MW-1 has ranged between approximately 20 and 26 ft since it was installed. MW-1 was developed in 1999, and the report summarizing development and sampling activities states that prior to development approximately 4 ft of sediment had accumulated in the bottom of the well, giving a water column height of only 4 ft (LANL 1995, 55638). After development, approximately 2.5 ft of sediment remained in the bottom of the well. If additional sediment has not accumulated, the effective depth of the well is about 27 ft. The most recent water level data collected in August 2003 (Table 3) shows a depth to water of about 21.6 ft, with a water column height of approximately 5.6 ft.

According to the boreholes logs in Appendix B of the RFI report (LANL 1995, 55638), groundwater was encountered in B-1 and B-4 at depths of approximately 23 ft bgs in the Bandelier Tuff; water was noted in the sample collected at 21 ft in B-6, also drilled in the tuff. The borehole logs indicate that the contact between the artificial fill or soil and the tuff was 12 and 13 ft bgs for B-1 and B-4, respectively, and 9 ft bgs at B-6. Therefore, the shallow groundwater occurs beneath the fill/tuff contact. A core sample removed from borehole B-1 contained fractures at the depth where groundwater was encountered (Section 2.3.3 of the RFI Report), so it can be inferred that water encountered in both B-4 and B-1 is associated with a fracture network within the Bandelier Tuff.

Figure 3 shows the locations of the seven boreholes drilled in 1994. Standing water was not encountered in borehole B-6, indicating that the shallow groundwater system does not extend to the north beyond borehole B-6. Water was not encountered in borehole B-2, located west of B1/MW-1, and denotes the western extent of the system. Although there are no borings west of B-4, it can be inferred from the close proximity of B-2 and B-1/MW-1 that the shallow system probably does not extend much farther west of B-4. Borehole B-3, to the south of B-1/MW-1, was also dry so the system does not extend farther south. No free water was encountered in borehole 03-22098, recently drilled about 200 ft southeast of MW-1 to a depth of 40 ft bgs as part of a geotechnical investigation for a proposed parking structure (Figure 3). The moisture content of core samples was less than 12% (Table 2), indicating that the shallow system does not extend to the southeast. This information suggests that the shallow system with 5.5 ft of water at MW-1 is very localized. It should be noted that one of two roof drain lines from Building SM-30 discharged to a location between B-1/MW-1 and B-4 for 45 years (Figures 3 and 6). It is possible that the thin, shallow system is related to draining from the roof or to pipe leaks in the area.

Additionally, 11 boreholes drilled at TA-3 east of Building SM-30 as part of the Laboratory Seismic Hazards Program did not encounter free water in the shallow subsurface (Figure 8). Ten of the boreholes were drilled to depths between 75 and 90 ft bgs (Krier et al. 1998, 77964). The eleventh borehole, Seismic Hazard Program borehole 2, was drilled to 200 ft approximately 1050 ft east of SWMU-3-010 (a), also did not encounter saturated zones (Gardner et al. 1993, 12582).

3.2.4.2 Regional Aquifer

The regional aquifer of the Pajarito Plateau is the only one capable of supplying large-scale municipal water (Purtymun 1984, 6513). The regional aquifer extends throughout the Española Basin (an area roughly 2300 mi^2 [6000 km^2]) and reaches its maximum thickness beneath the Pajarito Plateau. Depths to the regional aquifer range between about 1200 ft along the western edge of the plateau and about 600 ft at the eastern edge. Figure 9 shows the regional water table elevations beneath the Plateau. Beneath SWMU 3-010(a), the regional water table elevation is approximately 6310 ft asl or 1148 ft bgs. Planned

regional well R-6 will be installed in upper Los Alamos Canyon to provide baseline information about geology, hydrology, and water quality of the Laboratory's western boundary.

4.0 SCOPE OF ACTIVITIES

The following sections describe the iterative process used to identify potential sources of surface water associated with the SWMU and thereby reduce or eliminate the current water volume. The activities will occur in two steps to allow modifications that incorporate the information gained from each activity and take advantage of lapses between seasonal recharge. Results and recommendations made between each step will be submitted in periodic monitoring reports.

Initial activity at SWMU 3-010(a) will attempt to eliminate infiltration of surface water and improve monitoring capabilities. This step will include replacing the damaged well vault of MW-1, conducting leak tests of the roof drains; installing BMPs along surface water diversions, removing snow from the north and west sides of SM-30; and monitoring water levels through the spring melt. These activities are planned for fall 2003, prior to the winter months and subsequent infiltration from the spring melt.

In 2004, prior to the summer monsoon rains and after the spring melt, the data collected from MW-1 will be evaluated to identify water level response to precipitation and spring melt. Results of monitoring and initial artificial recharge source remedial activities will be presented in a periodic monitoring report as required by NMED (NMED 2002, 75910). Recommendations for further activities will be presented as part of the monitoring report.

If the water level in MW-1 does not respond to potential recharge events as previously observed, then the well will continue to be monitored. If the water level continues to respond to episodic and seasonal recharge events, anticipated activities will include drilling boreholes and improving the BMPs. The proposed boreholes will include a 45-degree angled borehole that will pass beneath the saturated zone and a vertical borehole drilled approximately 7 ft of east of MW-1 within SWMU 3-001(e). The deep angled monitoring borehole will be installed beneath the shallow groundwater to evaluate interconnectivity to the regional aquifer, to monitor tracer studies undertaken, and to determine the vertical extent of possible contamination. The vertical borehole will determine the lateral extent to the east of the shallow groundwater, characterize SWMU 3-001(e), and provide a point source for possible tracer studies. Additional boreholes may be drilled to determine the lateral extent of contamination. Additional BMPs may include re-asphalting of the western and northern roadways, applying asphalt concrete to the northern channel, and installing a drip shield along the asphalt/concrete footer contact around Building SM-30.

A bromide tracer may be deployed to determine shallow groundwater flow rates, direction, and source if the removing the potential artificial recharge sources does not eliminate the shallow groundwater. The location of deployment will depend on an evaluation of data collected during the initial investigations discussed above. Point source bromide tracer discharge may include MW-1 or the proposed boreholes that encounter saturation beneath Building SM-30. If the roof-drain system appears to be a source of the artificial recharge, the bromide tracer may be deployed at the roof. All local shallow groundwater wells and the deep angled borehole will be monitored for the tracer.

4.1 Replacement of MW-1 Well Vault

Wellhead Status

The MW-1 wellhead is currently constructed with the well vault cover flush with the asphalt surface of the road (Photograph 4). Recent surface water runoff was observed entering the well vault, accumulating, or

possibly entering the well casing. The existing well vault cover has been impacted by vehicular traffic and snow removal equipment, which have damaged the bolts and the rubber gasket securing the cover and compromised the watertight seal. The well vault will be replaced and the design improved to prevent surface water from entering the well vault.

4.2 Leak Tests

Potential artificial recharge sources near MW-1 include the roof drains, sewers, and water supply lines of Building SM-30. A July 2001 survey found the building's water system to be intact; another test is scheduled for October 2003. The northern culvert and roof drain were video logged on September 23, 2003, and no obvious signs of leaks were observed. The southern culvert closest to MW-1 was not logged because access was restricted. However, because of the volume of water discharged through the complex roof-drain system, a leak test will pump a known volume of water at the roof and measure the output from the culverts. In addition, the pressurized water supply for the building will be leak tested, and sewage lines will be leak logged.

During video logging of 115 ft of line, the northern culvert (Photograph 5) of the Building SM-30 roof drain system shows good structural integrity with no obvious point source for water discharge into the subsurface. An additional 3212 ft will be examined by camera, including the 43 vertical drainpipes from the roof, to identify potential point sources of water into the subsurface.

Following video logging, a leak test will be performed to assess the integrity of the system. If the logging identifies any weakened or damaged joints or sections, the leak test will focus on that portion of the system. The test will consist of discharging a measured volume of water through the system from the farthest east roof drain or any vertical pipes that appear to be weakened. The discharge will be measured the next morning at either the northern or southern culvert associated with the roof drain input. The output should be within 95% of the volume introduced after taking into account a loss rate of 5% from evaporation and water remaining in the drain system. If the water discharged is less than 95%, a bromide tracer test will be used (Section 4.5).

4.3 Best Management Practices (BMPs)

Ponds of water have been observed on the northern and western roadways and in the drainages several days after rain events and during winter snowfalls along the. Furthermore, snow is plowed such that piles accumulate along the northern side of the building atop the concrete/asphalt contact and at the western slope. Prior to the winter of 2003–2004, BMPs will be implemented to improve drainage, remove snow accumulation, and reduce potential infiltration at the site, which may contribute to the shallow groundwater. The northern drainage currently contains humus debris and sediments, which limit drainage from the area. The channel will be cleaned and graded to remove water from the area more rapidly. Currently, snow is removed by piling it in the northern drainage and the western slope directly atop SWMU 3-010(a). During the winter, snow will be removed to eliminate accumulation in the northern drainage and atop the western slope. Additionally, snow will be removed along the northern side of Building SM-30 to eliminate infiltration into the asphalt/concrete contact at the building edge.

Following the spring thaw and if the water level in MW-1 does not decrease, additional BMPs will be added, including repaving the western and northern roadways, installing a drip shield along the footer of the building, extending the northern roof culvert down the channel, and adding an asphalt concrete lining to the northern channel.

4.4 Drilling

One angled borehole will be drilled beneath Building SM-30 to investigate the possible connection observed between perched water and unknown deeper perched water or the regional aquifer. This borehole will be drilled at a 45-degree angle from horizontal and advanced beneath Building SM-30 from west to east. The total length of the borehole will be 260 ft and will have a TD of 184 ft beneath Building SM-30. The location of the proposed borehole is presented in Figure 10, and Figure 11 shows the profile of the planned borehole and the sampling locations.

One vertical borehole will be auger drilled within SWMU 3-001(e) to determine its potential as a source of contamination and the lateral eastern extent of the shallow groundwater (Figure 12). If shallow groundwater is encountered, an additional borehole will be located within Building SM-30. The exact location will be determined by interior access restrictions. At least four hand auger locations will be sampled at 5 ft. intervals until refusal or saturation is encountered along the three sides of the concrete surrounding SWMU 3-001(e). One vertical borehole will be drilled near B-4 to confirm the presence of shallow groundwater. Temporary single-cased wells will be installed as shallow groundwater is encountered.

After drilling is completed, all boreholes will be filmed and logged with natural gamma, neutron, and induction tools down to the shallow groundwater. A positive-pressure membrane equipped with absorbent liners and electrical wire pairs to signal the presence of saturated conditions will be installed in the angled borehole. The farthest borehole from MW-1 will be used for bromide tracer studies to determine the flow rate and direction of the groundwater. The drilling and sampling protocol is discussed in Section 5.4.

4.5 Tracer Study

The specific design criteria for the bromide tracer study will be presented in the March 2004 periodic monitoring report if the bromide tracer is used. A bromide tracer may be deployed to determine shallow groundwater flow rates, direction, and source if eliminating the sources of artificial recharge does not eliminate the shallow groundwater. The location of the tracer will depend on the results of the data collected during the initial investigations discussed above. A point-source bromide tracer may be discharged MW-1 or at additional boreholes that encounter saturation at Building SM-30. If evidence indicates that the roof-drain system appears to be a source of artificial recharge, the bromide tracer may be deployed on the roof. All local shallow groundwater wells and the deep angled borehole will be monitored for the bromide tracer.

5.0 INVESTIGATION METHODS

The most recent revision of the following LANL-RRES standard operating procedures (SOPs) is applicable to the investigation methods proposed in this plan. The most current versions of these SOPs are available at http://erproject.lanl.gov/documents/procedures.html.

ER-SOP-1.01, General Instructions for Field Investigations

ER-SOP-1.02, Sample Containers and Preservation

ER-SOP-1.03, Handling, Packaging, and Shipping of Samples

ER-SOP-1.04, Sample Control and Field Documentation

ER-SOP-1.05, Field Quality Control Samples

ER-SOP-1.08, Field Decontamination of Drilling and Sampling Equipment

ER-SOP-3.11, Condition and Evaluating Geodetic Surveys

ER-SOP-4.04, Contract Geophysical Logging

ER-SOP-5.01, Well Construction

ER-SOP-5.02, Well Development

ER-SOP-5.03, Monitor Well and RFI Borehole Abandonment

ER-SOP-5.07, Operation of LANL Owned Borehole Logging Trailer

ER-SOP-6.01, Purging and Sampling Methods for Single Completion Wells

ER-SOP-6.02, Field Analytical Measurements of Water

ER-SOP-6.03, Sampling for Volatile Organic Compounds in Groundwater

ER-SOP-6.10, Hand Auger and Thin-Wall Tube Sampler

ER-SOP-6.26, Core Barrel Sampling for Subsurface Earth Materials

ER-SOP-7.01, Pressure Transducers

ER-SOP-7.02, Water Level Measurements

ER-SOP-7.05, Subsurface Moisture Measurements Using a Neutron Probe

ER-SOP-12.01, Field Logging, Handling and Documentation of Borehole Materials

Additional procedures may be added as needed to describe and document quality-affecting activities.

All proposed work will be completed following all applicable quality requirements as stated in the RRES-RS Quality Management Plan.

5.1 Design Improvements for MW-1

The following design improvements are recommended to prevent surface water from entering the monitoring well. The primary changes include elevating the protective vault so it is slightly above-grade and installing a concrete apron that slopes away from the wellhead to shed water. A 1:10 slope is recommended for the concrete apron to provide a gentle transition for snow-removal equipment and other vehicles.

- The existing well vault will be carefully removed to prevent any damage to the wellhead. The well casing will be capped or otherwise protected to prevent debris or fluids from entering the well during construction.
- A square excavation area will be dug around the wellhead that measures 4 ft in length and 4 ft in width, with a minimum depth of 8-in. The asphalt will be cut to prevent damage to the paving outside the excavated area. The asphalt will be removed to expose the underlying road base.
- A 12-in. diameter, heavy duty, traffic-rated, watertight well vault with a 12-in. skirt will be installed. The vault will extend from the top of the annular seal to approximately 2 in. above the surface of the asphalt paving. The base of the vault will be set into cement-based sealing material in the annular space of the well bore. The vault will contact the annular seal so it forms a water-tight and structurally sound connection.

- The excavation outside the well vault will be filled with 3000 per square inch reinforced concrete and finished as a slab with a 1:10 slope and broom finish. The top rim of the vault will be flush with the surrounding concrete.
- The well vault lid will be securely bolted in place with the gasket properly seated. The gasket should be inspected periodically and replaced if it becomes worn or damaged.
- The top of the well casing contained within the vault will be capped with a sanitary seal. Any openings for cables from down-hole instruments will be run through watertight fittings.

5.2 Leak Test

Prior to performing the proposed leak test on the roof drains of Building SM-30, an attempt will be made to camera log all lengths of drain pipe usinga borehole camera. Vertical roof drains will be accessed from the roof of Building SM-30, and the camera will be inserted down hole. For horizontal entry into the drain system the camera will be mounted on a wooden skid, and pushed into the pipe using lengths of polyvinyl chloride (PVC) pipe. The video logs of the drains will be recorded for future playback and analysis.

If no major structural flaws are found in the video logs, a leak test will be performed on the roof drain system. To perform this test, water will be introduced into the drains farthest from the discharge or to drains that show some structural weakness at a rate of 10 gallons per minute (gpm) for 60 min. for a total of 600 gal. to the two roof drains. The water expelled through the discharge pipe will be measured using a calibrated mechanical flow meter. The volume of water leaving the drain system should be at least 95% of the volume entering the system. If the volume leaving the system is less than 95%, a bromide tracer study will be used (Section 4.5).

5.3 Best Management Practices (BMPs)

Several BMPs will be implemented at SWMU 3-010(a) and Building SM-30 to prevent precipitation infiltration and promote storm water runoff according to the Laboratory Storm Water/Surface Water Pollution Prevention Best Management Practices Guidance Document (LANL 1998, 62950). The following BMPs will be implemented in the fall of 2003.

North Drainage Ditch: The small drainage ditch to the north of Building SM-30 will be cleaned of all debris, and will be regraded to promote storm water runoff away from the site. The improved drainage ditch will have a 2% slope, and will be lined with crushed rock (minimum 2 in. in diameter) to provide soil stabilization.

Snow Removal: During winter months no snow will be pushed towards, or piled, in the drainage ditch to the north and west of Building SM-30, or against the structure itself. All snow will be removed from the paved areas around Building SM-30.

Water-Level Monitoring: The water level in MW-1 will be monitored during the winter of 2003–2004 to determine the effectiveness of the BMPs previously used at SWMU 3-010(a). These BMPs may include paving the drainage ditch to the north of Building SM-30 with asphalt concrete, repaving the asphalt surrounding the building, installing flashing around the bottom of Building SM-30 to prevent infiltration between the asphalt and the building's footer, and extending the roof drain discharge culverts farther down the Twomile Canyon tributary channel.

5.4 Methods for Drilling and Sampling Proposed Borehole

5.4.1 Angled Drilling Protocol

One angled borehole will be drilled to determine the vertical extent of the shallow groundwater. The borehole will be drilled at a 45-degree angle from horizontal and advanced beneath Building SM-30 from west to east. The total length of the borehole will be 260 ft bgs and will have a TD of 184 ft. Drilling an angled borehole will increases the likelihood of encountering contamination associated with the possible vertical migration of water crossing vertical (fast path) fractures beneath SWMU 3-010(a) and identifying faults.

The proposed angled borehole will be drilled using the hollow-stem auger method because it is proven to be effective for collecting undisturbed samples of core within the Tshirege Members of the Bandelier Tuff. The borehole will be started with a large diameter auger (>24 in.), which will then be replaced by the top hammer method using a small diameter split-spoon sampler when the unconsolidated ash beds at the base of Qbt 4 are encountered. This method will allow unconsolidated core to be collected with minimal disturbance and the well to be completed in the unconsolidated layer should saturation be encountered. Once this interval has been sampled, the drilling method will be switched to a small diameter air-rotary using casing advance to penetrate the unconsolidated interval again and drill to TD.

Figure 10 shows the proposed borehole in map view relative to Building SM-30; Figure 11 shows the vertical cross section. The exact location of the borehole will be determined after a field survey of utilities and other surface and subsurface conditions that could restrict access. The well will be completed as a monitoring well according to LANL-ER-SOP5.01, Well Construction.

5.4.2 Vertical Drilling Protocol

Vertical boreholes will be drilled by a hollow-stem auger method. The auger drilling will involve using 2-in. inner diameter augers that collect continuous core to the maximum depth of 40 ft bgs. If the borehole is not in a saturated unit at 40 ft bgs, it will be abandoned according to the LANL-ER SOP-5.03. Casing will be installed once a borehole has been drilled within a saturated formation. This casing will be 1.75-in. pre-packed PVC casing/screen installed down through the center of the auger drill string. This size of casing/screen has been selected to maximize contact with borehole annulus when the auger string is retracted. The new vertical well will be temporary, and at the end of the tracer studies, the casing will be pulled and borehole abandoned following LANL-ER-SOP-5.03.

5.4.3 Collection of Tuff Samples

Subsurface tuff samples will be collected from the split-barrel sampler into sealed sleeves or core-protect bags to preserve the core moisture content.

When collected, all core will be field screened for gross radioactivity and organic vapors using hand-held instruments and then submitted to the Laboratory's sample management office. An ESP-1 with pancake probe will be used to detect gross beta/gamma radiation. A photoionization detector (PID) will be used to detect organic vapors with an 11.7 (eV) lamp. Samples will be collected for submittal to an analytical laboratory every 20 ft of borehole length. Additional samples will be collected from intervals where contamination is suspected because of elevated field screening and/or visual inspection identifies fractures, fault zones, unconsolidated sediments at depth, or staining.

Field documentation of samples collected from fractures will include a detailed physical description of the fracture fill material and rock matrix sampled. The volumes of fracture fill and rock matrix material

included in the sample will be estimated from field measurements. An additional sample will be collected from the rock matrix adjacent to the fracture sample material to allow for comparison. Paired fracture sampling is discussed in Section 5.4.4.

All tuff samples from the proposed borehole will be analyzed for VOCs, EPA target analyte list (TAL) metals, and radionuclides using analytical methods specified by contract requirements of the Laboratory's analytical statement of work ([SOW] LANL 2000, 71233). Quality assurance/quality control (QA/QC) samples for analytes will include duplicate samples collected according to the applicable SOPs listed in Section 5.0 as well as rinsate blanks to confirm that the equipment used during sample collection has been decontaminated.

5.4.4 Collection of Hydrogeological Samples

Samples for moisture content, saturated and unsaturated hydraulic conductivity, porosity, and bulk density will be collected every 20 ft along the length of the proposed angle borehole and analyzed using analytical methods specified by contract requirements of the Laboratory's analytical SOW (LANL 2000, 71233). One duplicate sample will also be collected and analyzed. Samples will be collected, handled, packaged, and analyzed according to applicable LANL-ER-SOPs-1.02, 1.03, 1.04, and 1.05.

5.4.5 Collection of Paired Fracture Samples

Empirical evidence has documented the role fractures play contaminant transport in tuff. Information about transport may be obtained by collecting paired samples of fracture material and tuff matrix when tuff fractures are encountered during drilling. Because fracture fill may not be present, or may exist in minute quantities, fracture samples will consist of 3 in. of tuff from above and below the fracture. Detailed descriptions and photographs will be made for each fracture sample. Then, to compare contaminant concentrations between fractured and unfractured tuff, a second sample of unfractured tuff will be collected 24 in. above the fracture sample (Figure 13). These paired samples collected from the proposed boreholes will be submitted to a laboratory for analysis of VOCs, TAL metals, tritium, and gamma spectroscopy using analytical methods specified by contract requirements of the Laboratory's analytical SOW (LANL 2000, 71233).

5.4.6 Geophysical Logging and Monitoring

After drilling is completed, all boreholes will be logged with natural gamma, camera, neutron, and induction tools down to the shallow groundwater. Logging will be conducted at 1-ft intervals to TD following the LANL-ER-SOP- 4.04, Contract Geophysical Logging.

Once the angled borehole has been logged, an adsorbent liner on which electric wire pairs have been installed will be inserted in the borehole. The wire pairs will indicate the presence of water, the level of saturation, and the vertical migration of water beneath SWMU 3-010(a). These data will be collected by an on-site data logger. If high levels of saturation are indicated by the wire pairs, then the membrane will be pulled and sections sent to a laboratory for VOC, TAL metals, tritium, and gamma spectroscopy analysis.

5.5 Hand-Auger Sampling at SWMU 3-001(e)

A hand auger will be used to collect subsurface soil/fill samples under the asphalt drive surrounding SWMU 3-001(e). Four hand-auger holes will be placed through the asphalt using powered auger equipment or asphalt-cutting tools until fill material is reached. Auger holes will then be completed to a TD

of 10 ft, and samples collected from two depths, 5 ft and 10 ft, at four locations for a minimum of eight samples.

When collected, all samples will be field screened using hand-held instruments for gross radioactivity and organic vapors before the samples are submitted to the Laboratory's sample management office. An ESP-1 with pancake probe will be used to detect gross beta/gamma radiation. A PID will be used to detect organic vapors with an 11.7 (eV) lamp. Should screening indicate that the contaminant concentration is not decreasing, two adjacent locations will be augered and sampled. If continued beyond 10 ft, then one additional sample will be collected at TD. A maximum of three samples will be collected at each location.

All samples will be submitted for fixed laboratory for analysis of VOCs, TAL metals, and radionuclides using analytical methods specified by contract requirements of the Laboratory's analytical SOW (LANL 2000, 71233). QA/QC samples for analytes will include duplicate samples collected according to applicable SOPs listed in Section 5.0, and rinsate blanks will be collected to confirm that the equipment used to collect samples is decontaminated.

5.6 Tracer Study Methods

Specific design criteria for the bromide tracer study will be presented in the recommendations presented in the periodic monitoring report. A potassium bromide solution will be used to further evaluate discharge from the roof drain and determine the flow direction and rate of groundwater. The tracer will also provide a signal that would indicate deeper percolation from the shallow groundwater to the deep angled borehole. The concentration and volume of the tracer release will be designed according to the discharge location and extent of shallow groundwater as determined by site boreholes and well R-6. Bromide is easily detected in 100 ml samples using a simple bromide electrode.

6.0 MONITORING AND SAMPLING PROGRAM

The water level monitoring of well MW-1 will be continued through the proposed field activities and after well completion. These data will be collected using the current system consisting of a pressure transducer and an on-site data logger. The water level information collected in this monitoring well will provide data relating to the performance of proposed measures at SWMU 3-010(a) to remove the sources of the perched water and will guide possible future activities.

All storm water management features installed during these activities will be inspected biweekly and within 24 hr of any precipitation event totaling 0.5 in. or more. Any performance deficiency of these features will be evaluated and repaired or modified as necessary to minimize infiltration of surface water in the vicinity of Building SM-30.

Future long-term monitoring and sampling programs will be based upon the results of the proposed field activities.

7.0 SCHEDULE

The replacement the MW-1 well vault, the leak tests, and the BMPs described in Sections 4.1 through 4.3 will be completed immediately precluding recharge from early season snowfall. This work plan will be delivered to NMED on October 31, 2003. The first periodic monitoring report will be submitted to NMED by March 31, 2004, and quarterly thereafter through the calendar year. The first quarterly report will make

a recommendation on the boreholes to be drilled in June 2004. A Groundwater Investigation Report will be submitted by December 31, 2004.

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Purtymun, W. D., January 1, 1984. "Hydrologic Characteristics of the Main Aquifer in the Los Alamos Area: Development of Ground Water Supplies," Los Alamos National Laboratory report LA-9957-MS, LA, Los Alamos, New Mexico. (Purtymun 1984, 6513)

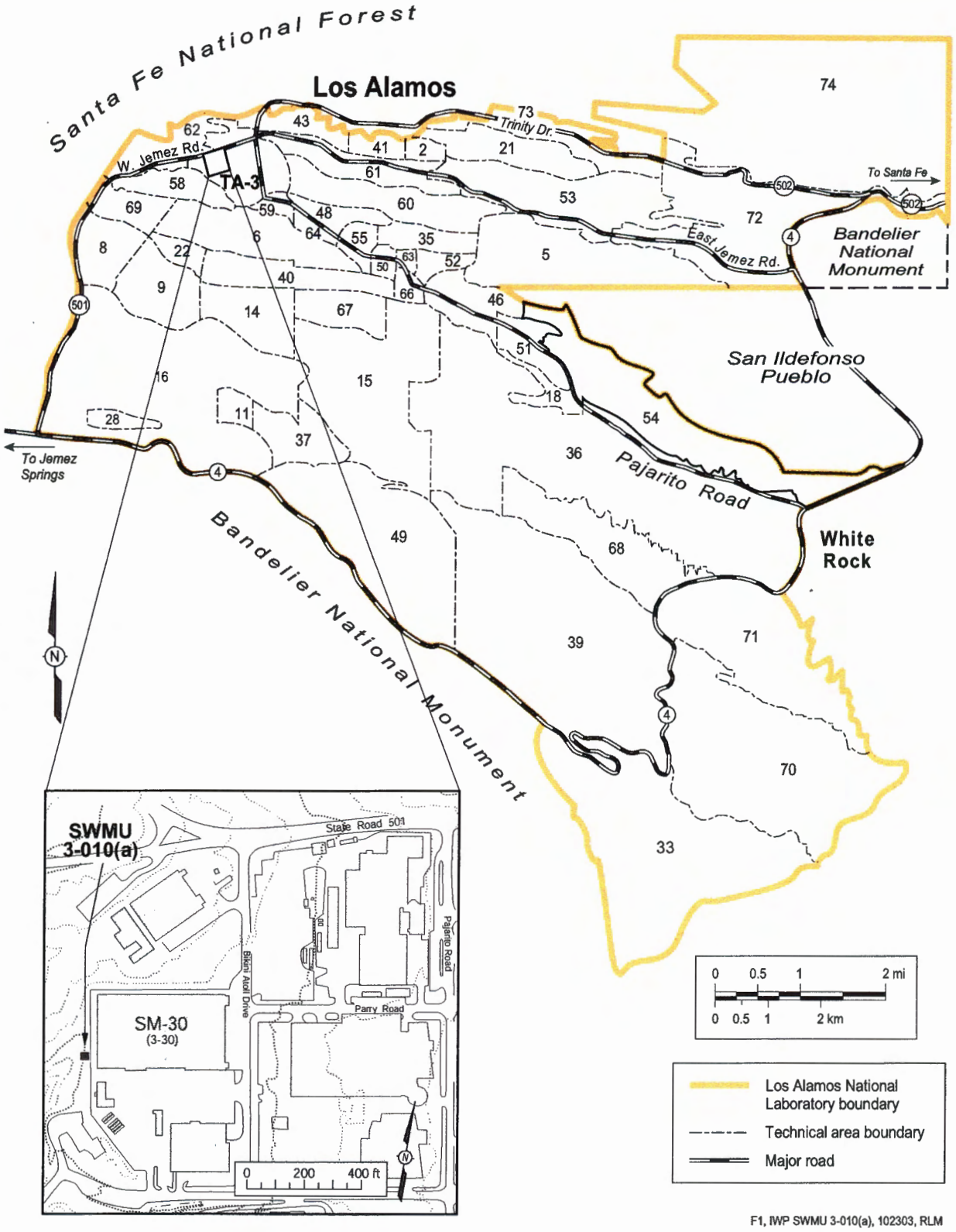


Figure 1. Site location map

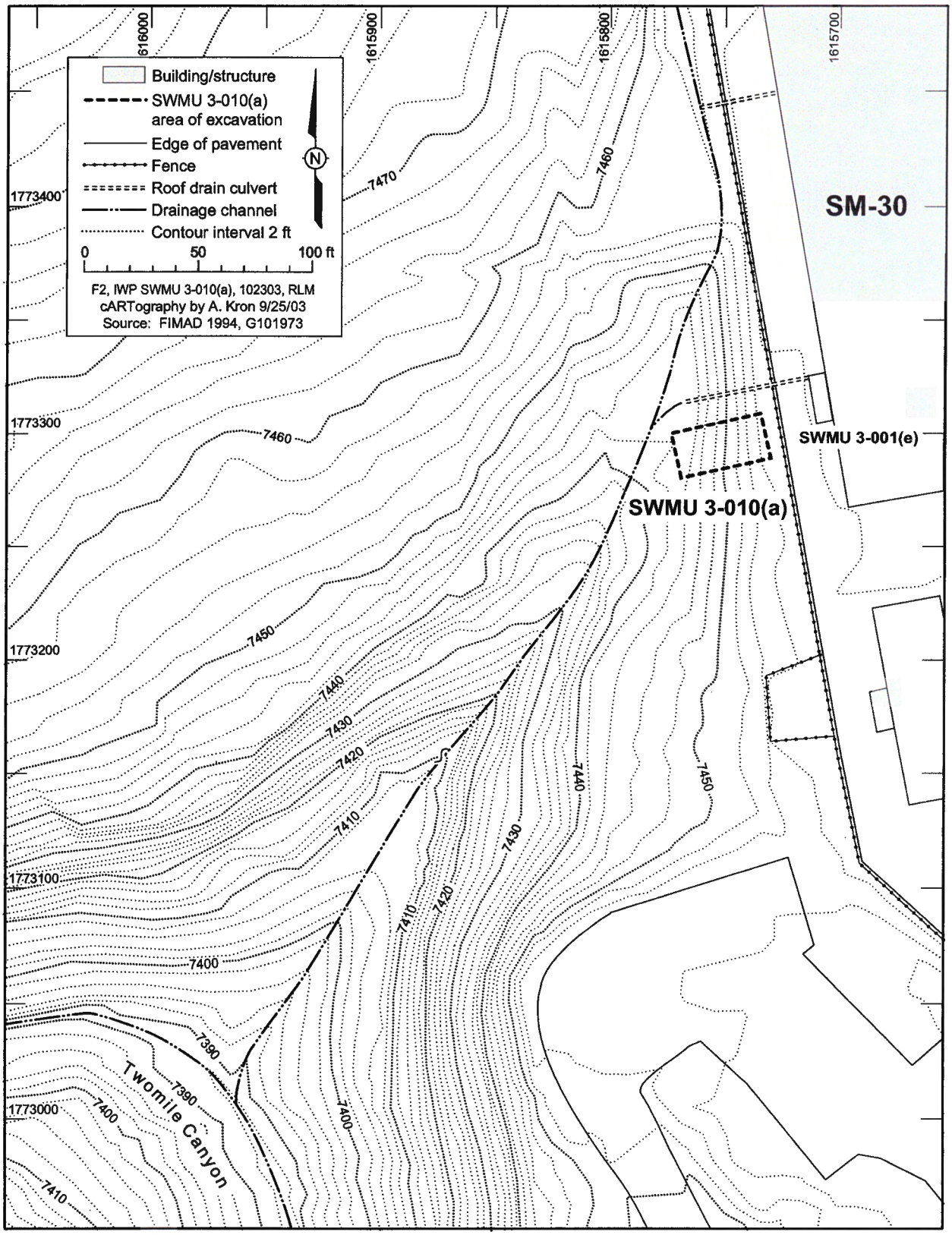


Figure 2. SWMU 3-010(a) drainage to Twomile Canyon

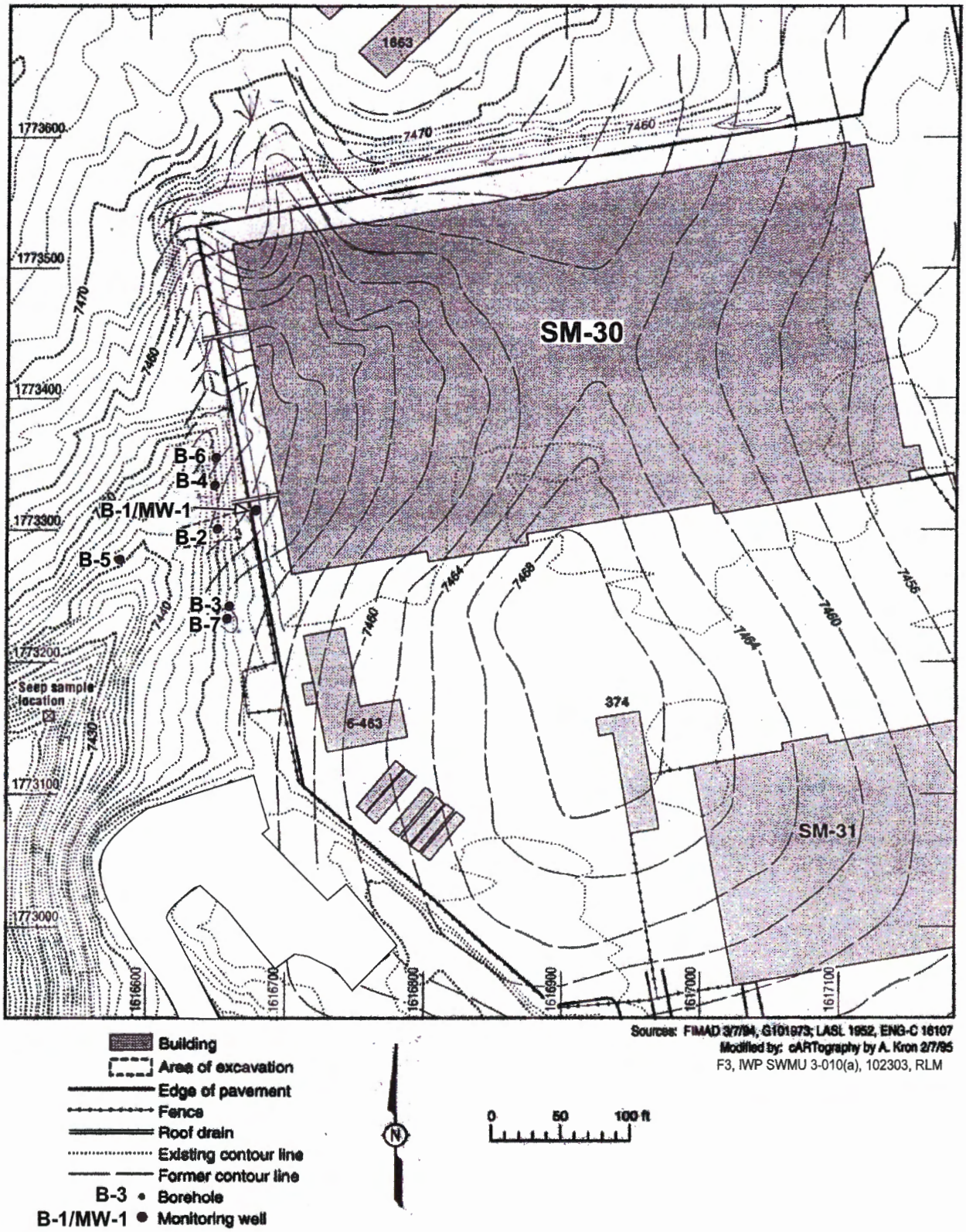


Figure 3. **Former and current topography of the Building SM-30 area**

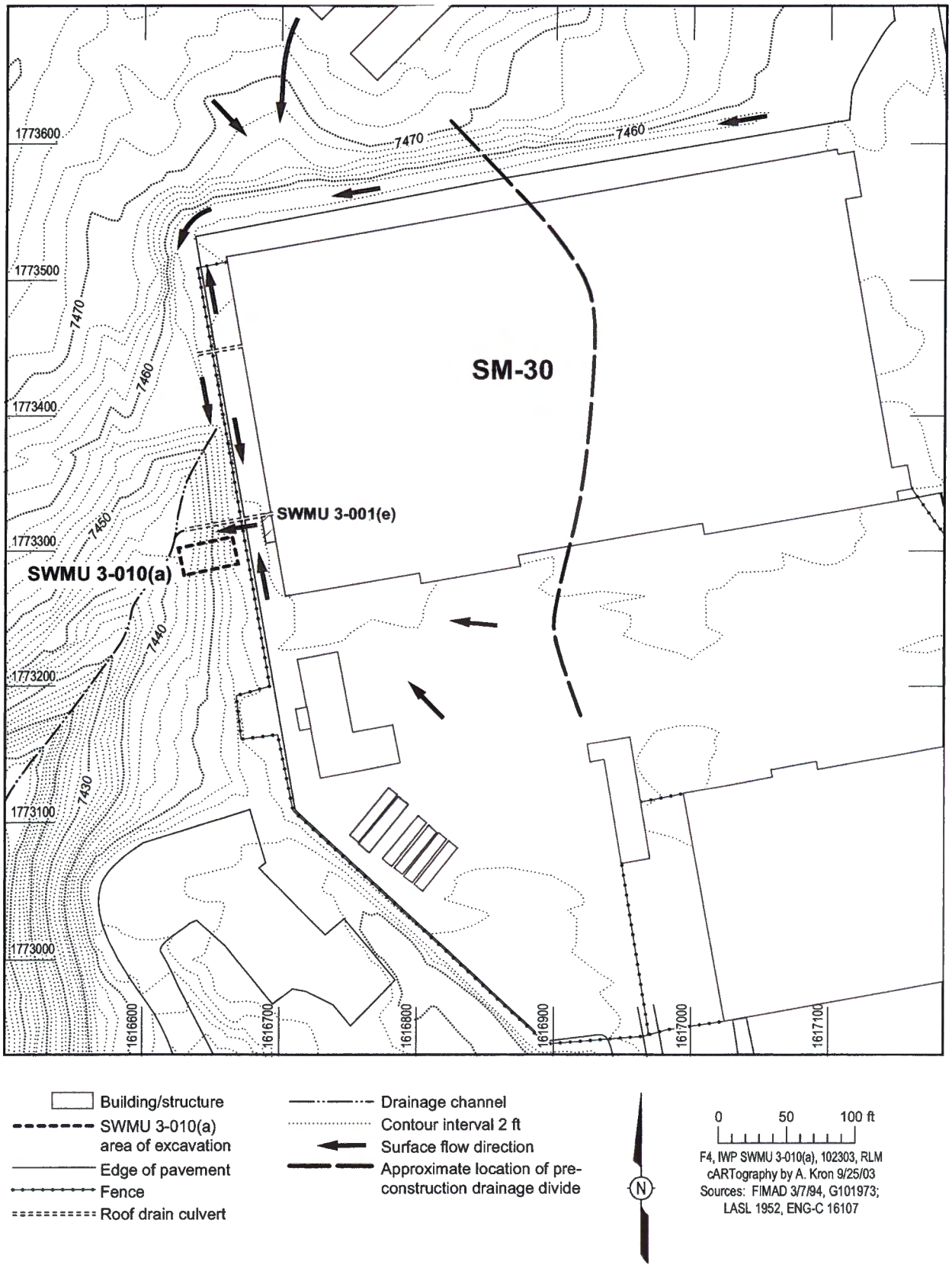
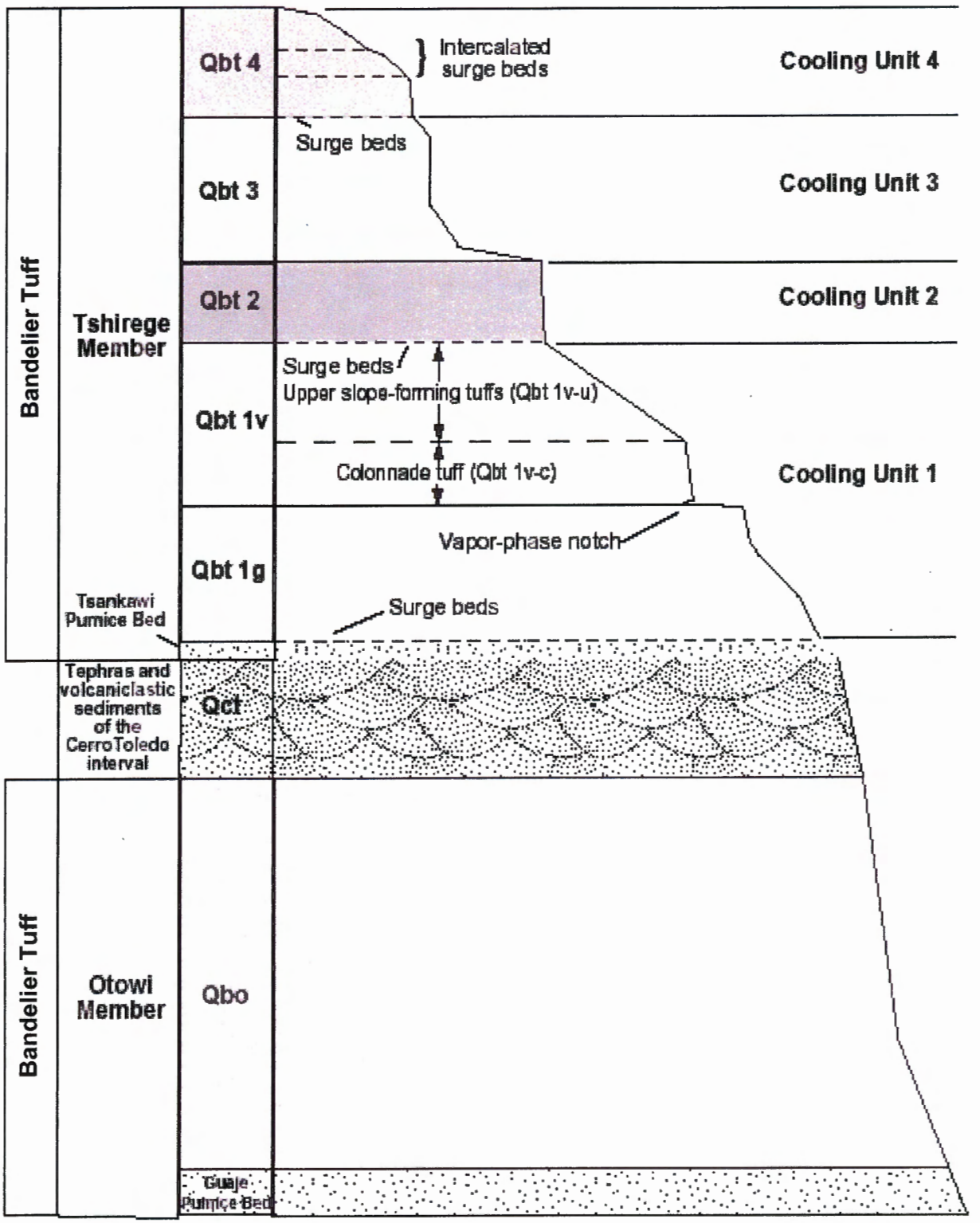


Figure 4. Building SM-30 and surrounding area



F5, IWP SWMU 3-010(a), 102303, RLM

Figure 5. Conceptual model of stratigraphy beneath Pajarito Plateau

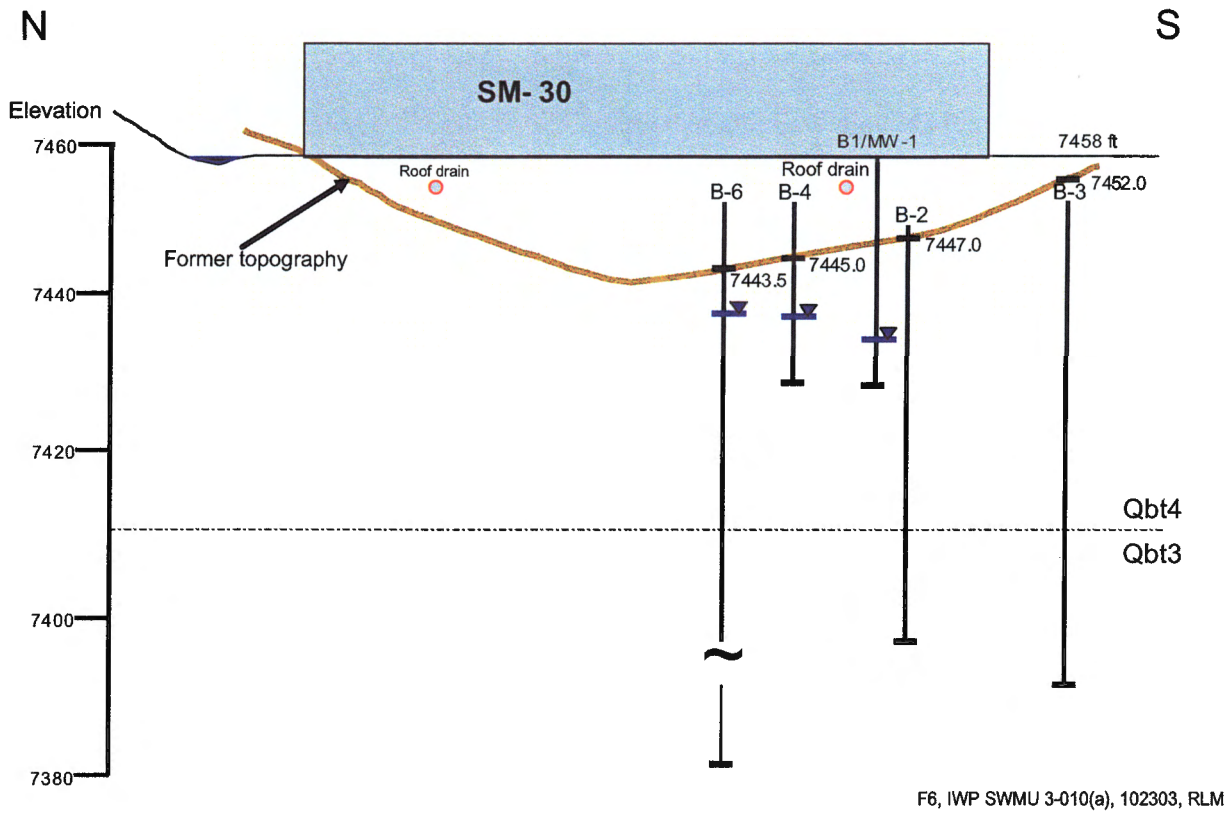


Figure 6. **Cross section of previous borings and topography along west side of Building SM-30**

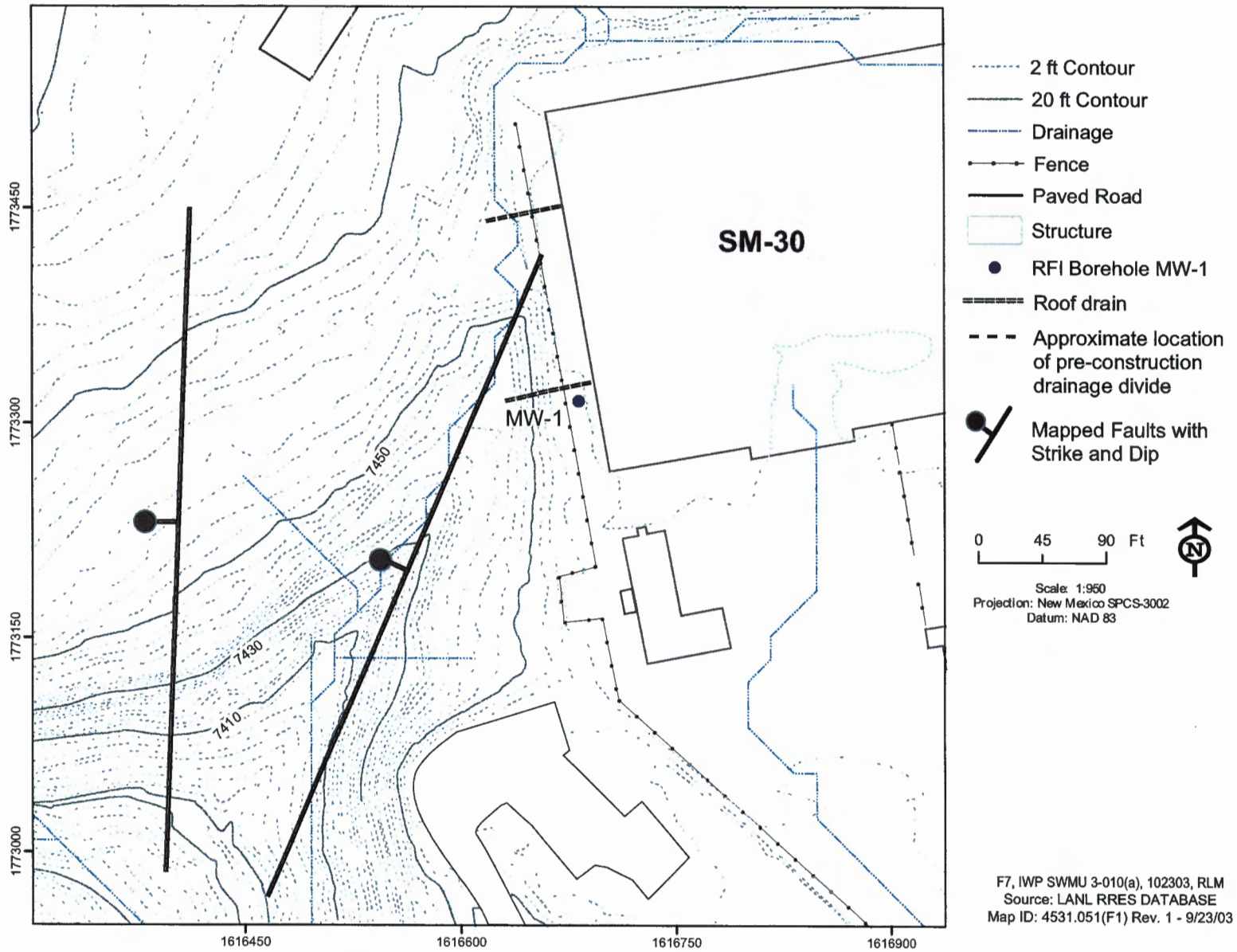


Figure 7. Faults in the vicinity of SWMU 3-010(a)

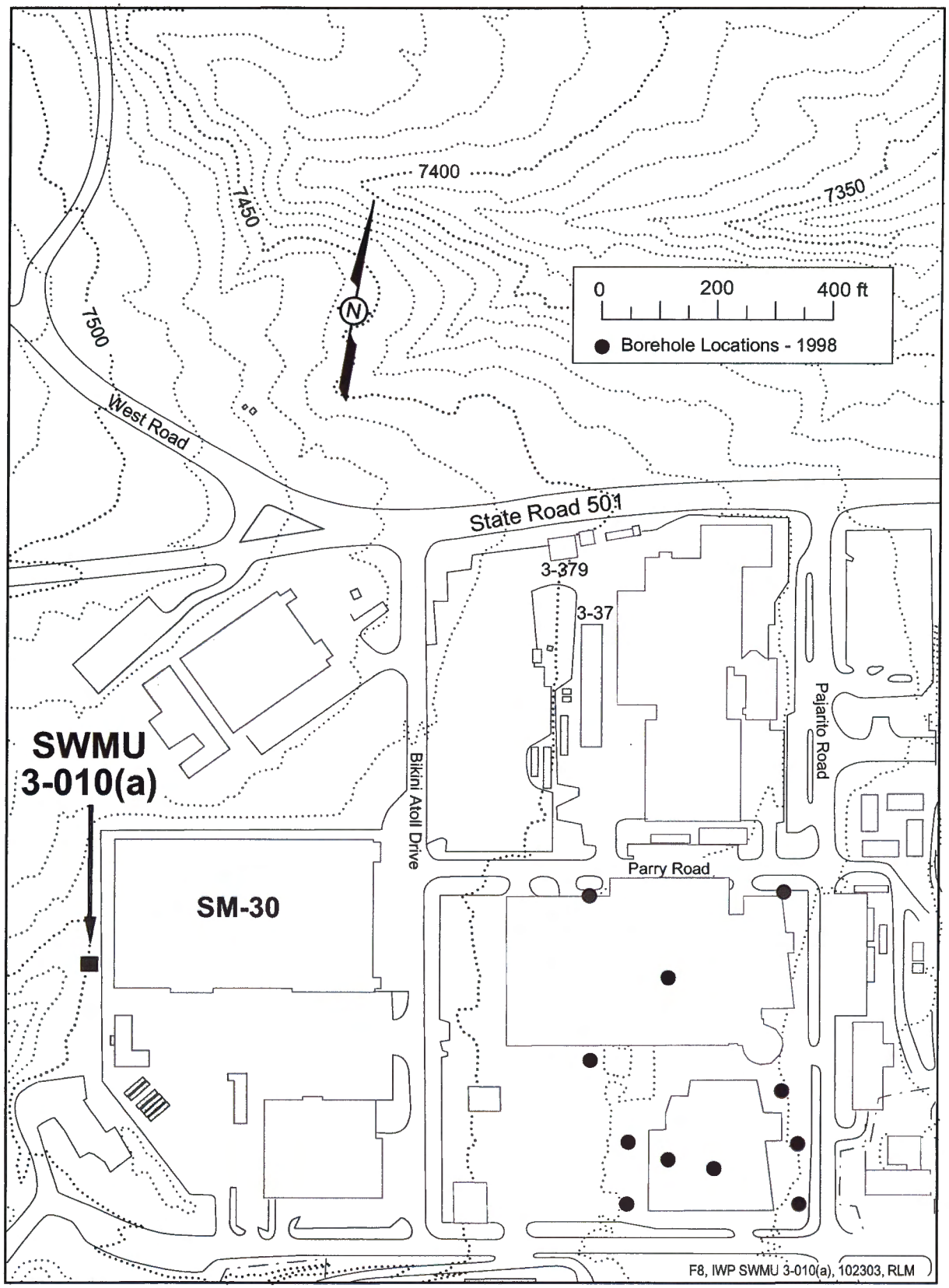
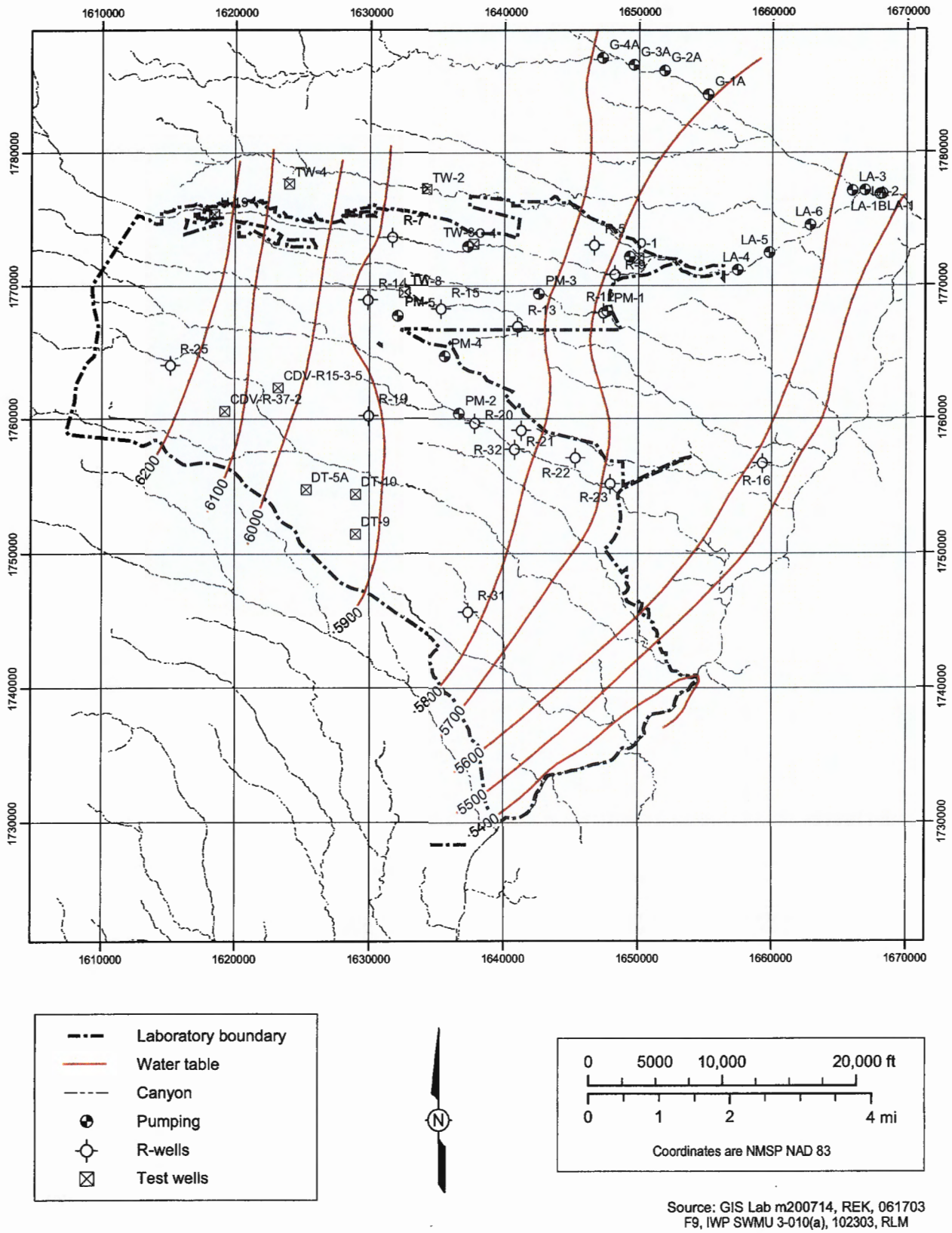


Figure 8. Location of 11 boreholes drilled east of SWMU 3-010(a) and Building SM-30



Source: GIS Lab m200714, REK, 061703
F9, IWP SWMU 3-010(a), 102303, RLM

Figure 9. Water table elevations across the Pajarito Plateau

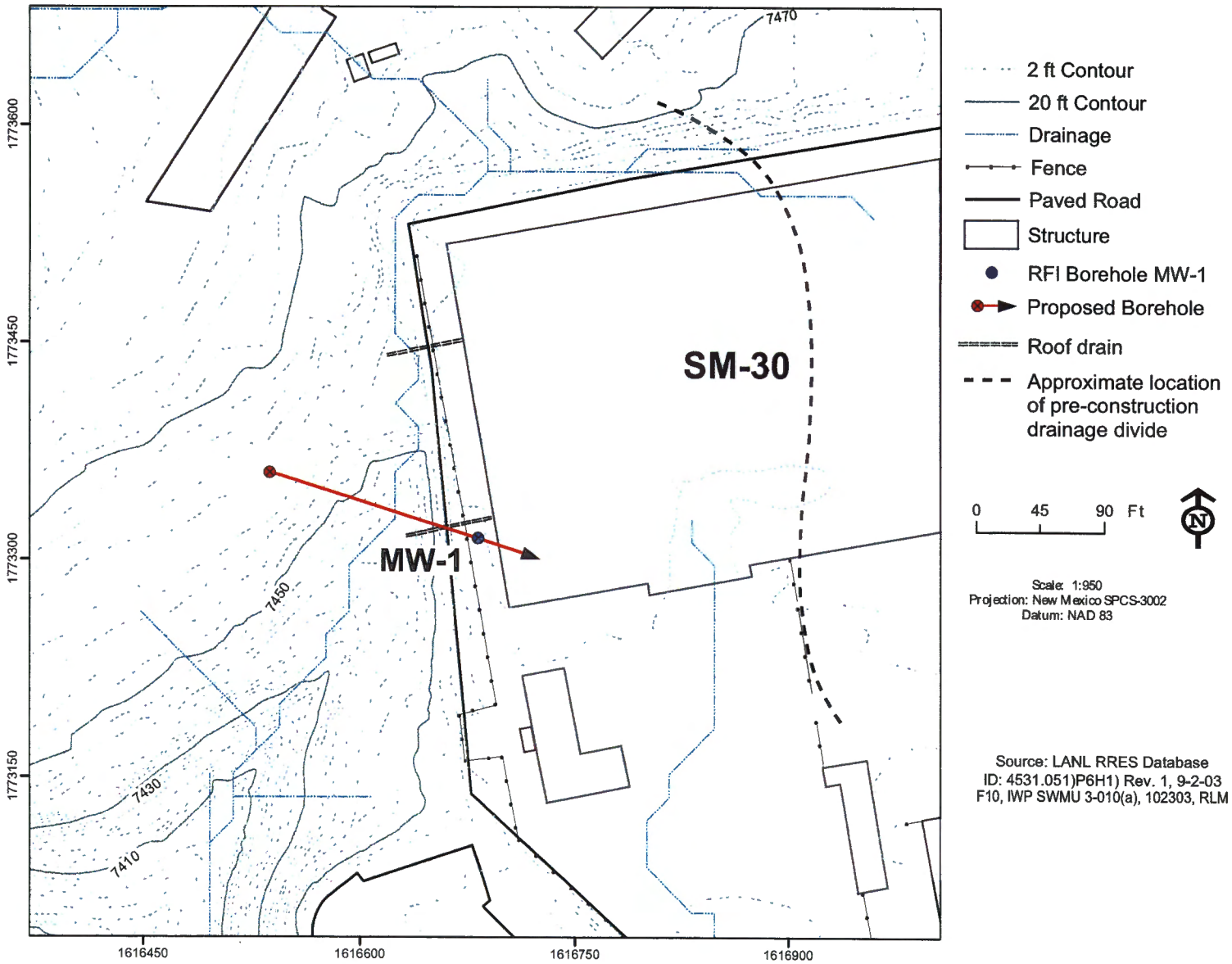


Figure 10. Proposed location of angled borehole under Building SM-30

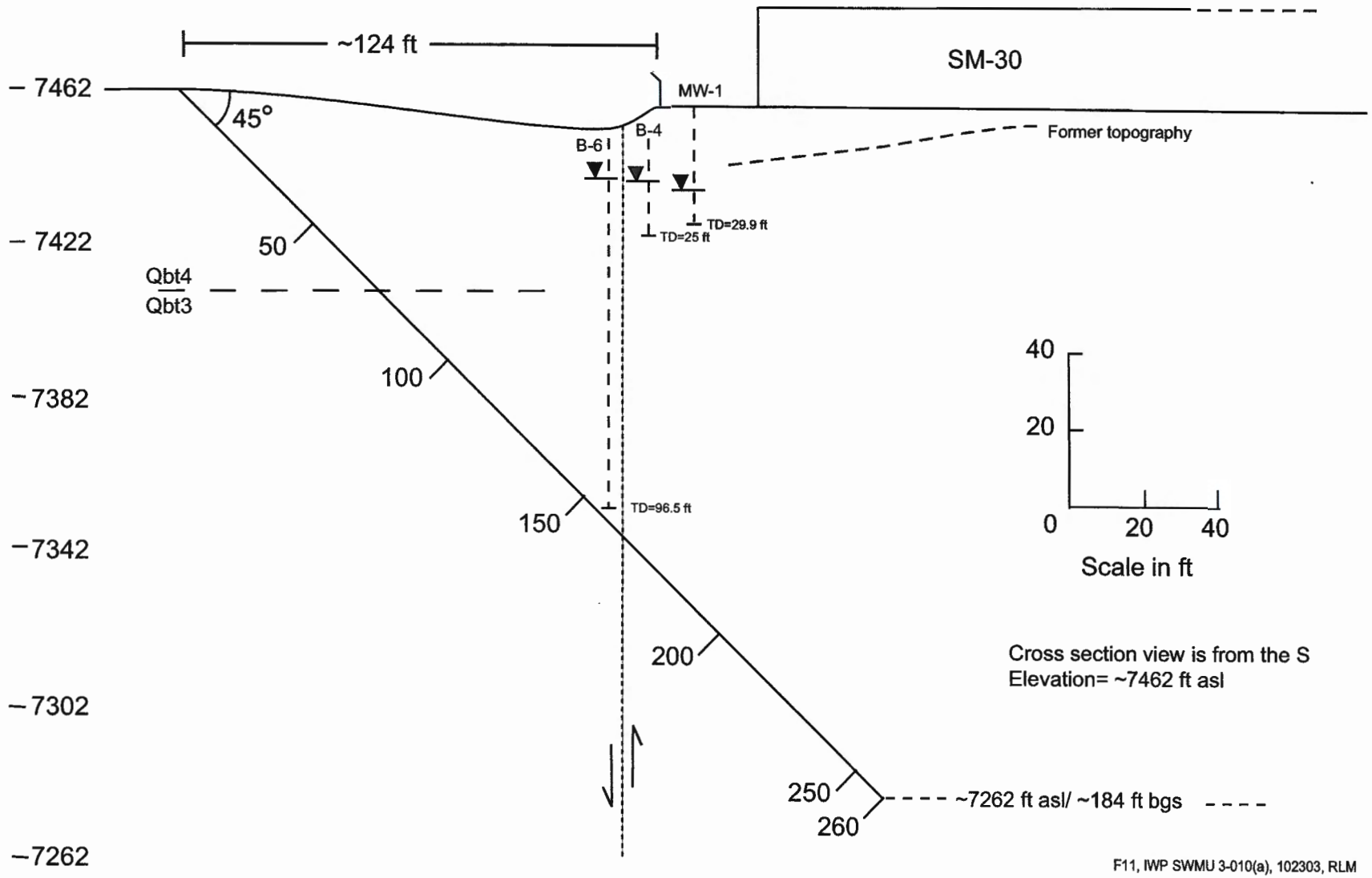


Figure 11. Profile of SWMU 3-010(a) planned boreholes with planned sample locations

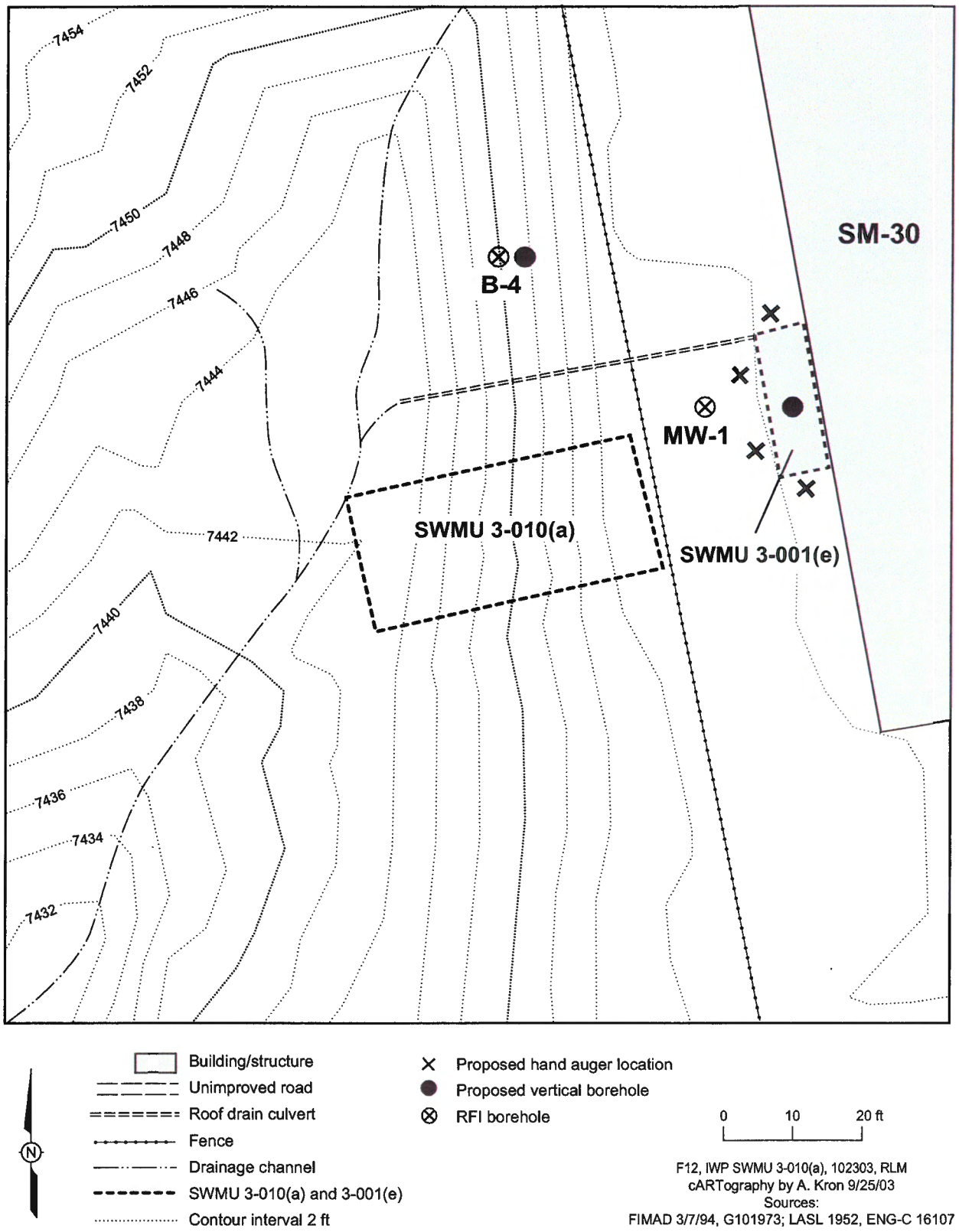


Figure 12. Proposed vertical borehole and hand auger locations

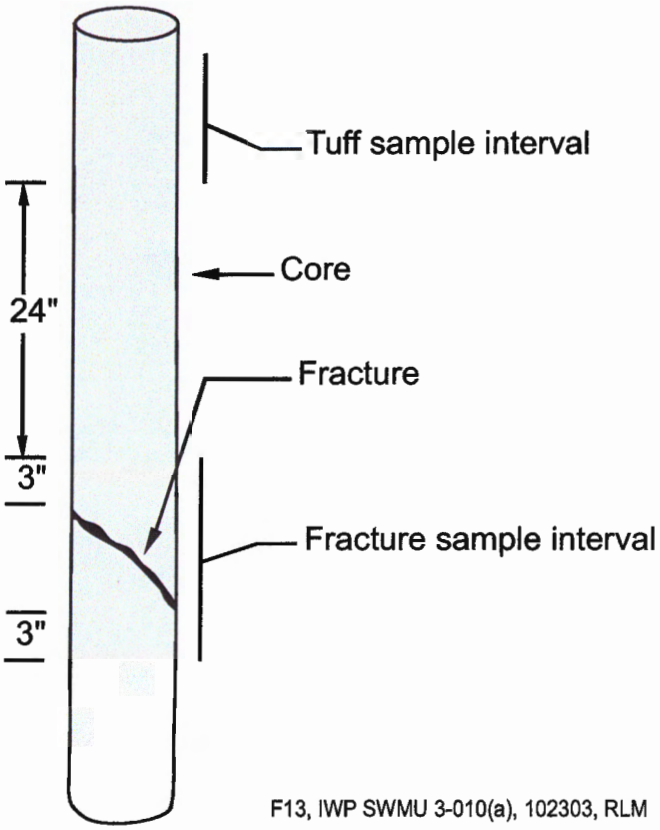
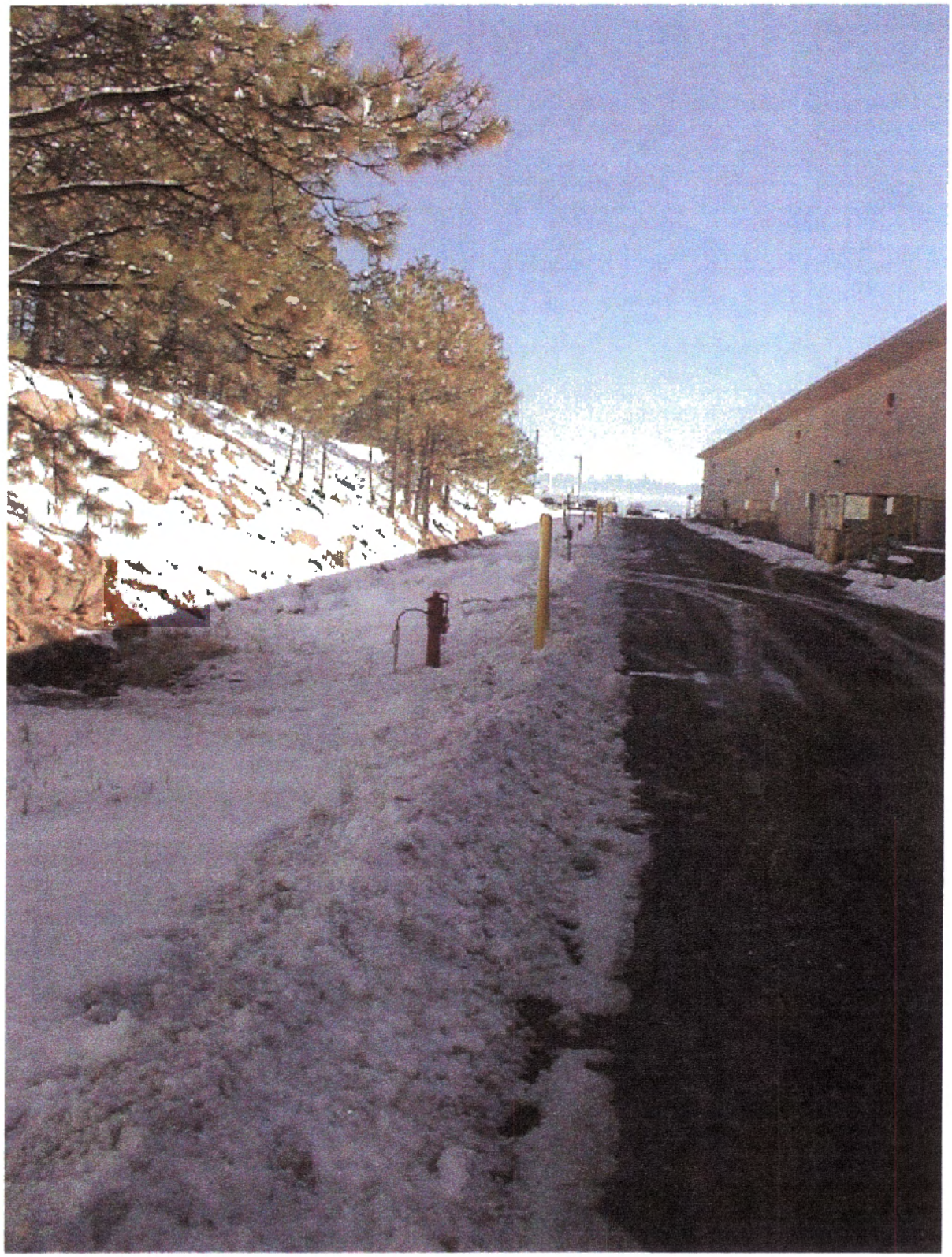


Figure 13. Paired fracture sampling diagram

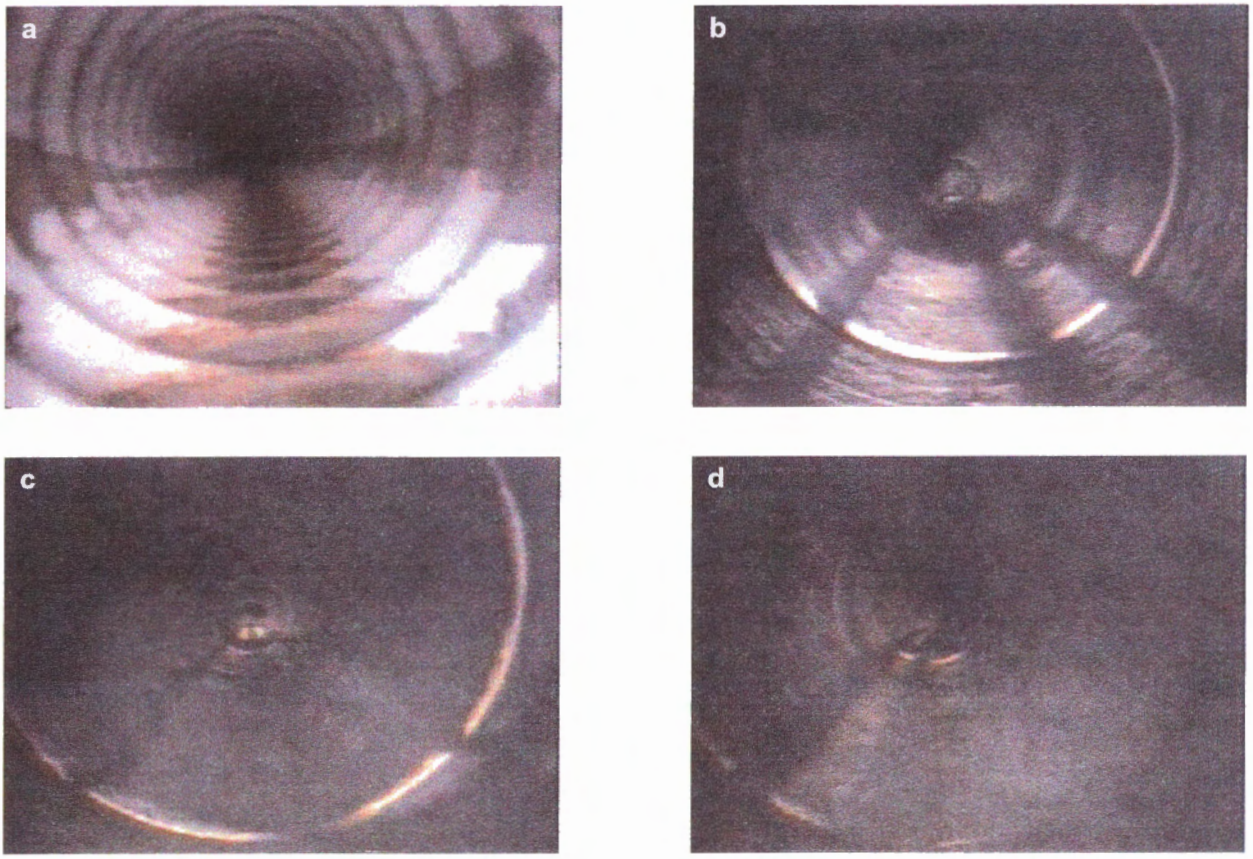
Photograph 1. MW-1 wellhead west of Building SM-30 (photo taken 12/05/02)



Photograph 2. Accumulation of plowed snow along north side of Building SM-30 (photo taken 12/05/02)

Photograph 3. South culvert roof drain west side of Building SM-30 (photo taken 12/05/02)

Photograph 4. North culvert roof drain west side of Building SM-30 (photo taken 12/05/02)



Photograph 5. Video capture photos from the camera survey within the northern culvert of the Building SM-30 roof drain system. Photos are from the following distances from the discharge point: (a) 0 ft (b) 33 ft (c) 44.5 ft (d) 78 ft.

Table 1
1999 Volatile Organic Compounds and Tritium Concentrations Range

VOC	Concentrations in MW-1	EPA Region VI Tap Water Screening Levels[a]	EPA MCLs[b]	NMWQCC Groundwater Human Health Standards[c]	Units
Chloroform	1.9 (J)[d]–3.3 (J)	0.16	0.08	0.1	µg/L[e]
DCA	15 (J)–16 (J)	810	None	0.025	µg/L
EDC	8.8–9.4 (J)	0.12	0.005	0.01	µg/L
DCE	30–43 (J)	340	0.007	0.005	µg/L
TCTF	1.6 (J)–4.5 (J)	59,000	None	None	µg/L
TCA	1100 (J)–1400	790	0.2	0.06	µg/L
TCE	7.5 (J)–13	0.028	0.005	0.1	µg/L
Tritium	1780	None	20,000	None	pCi/L[f]

[a] EPA Region 6 Corrective Action Strategy Appendix D, November 2000.
[b] EPA 816-F-02-013, July 2002; MCL = maximum contaminant level.
[c] 20.6.2 NMAC, September 15, 2002.
[d] J = Estimated value.
[e] µg/L = Micrograms/Liter.
[f] pCi/L = Picocuries/L.

Table 2
TA-3 Building SM-30 Summary of Borehole Sample Analyte Results

Sample ID	Location ID	Depth (ft bgs)	% Moisture	Tritium (pCi/L)	MDA[a] (pCi/L)	Acetone[b] (mg/kg)
RE03-03-51220	03-22098	4.5–6.0	10.78	31.1	193	n/a[c]
RE03-03-51221	03-22098	14.5–16.0	10.52	197	191	n/a
RE03-03-51222	03-22098	24.5–26.0	11.29	241	191	6.8
RE03-03-51223	03-22098	34.5–36.0	9.95	164	193	5.3 J
RE03-03-51224	03-22098	38.0–40.0	9.9	239	188	n/a

Note: CO^2 was found in all samples.
[a] Minimum detectable activity.
[b] Acetone was the only hit for VOCs.
[c] n/a=Not applicable.

Table 3
Summary of Transducer Data at Well MW-1

Date	Time	Temperature (°C)	Water Level (ft)
January 29–April 21, 2003			
1/29/2003	14:46:40	13.7	24.368
1/30/2003	0:16:40	13.52	24.535
1/30/2003	6:16:40	13.52	24.599
2/10/2003	11:46:40	13.53	26.1
2/10/2003	23:46:40	13.53	26.128
2/13/2003	13:46:40	13.53	23.212
2/13/2003	23:46:40	13.53	21.739
2/26/2003	20:46:40	13.52	19.956
2/27/2003	8:46:40	13.52	19.835
3/12/2003	14:16:40	13.42	22.125
3/13/2003	1:46:40	13.42	22.021
3/20/2003	2:46:40	13.4	19.801
3/21/2003	0:46:40	13.4	20.157
4/01/2003	10:46:40	13.32	21.04
4/01/2003	23:46:40	13.32	21.278
4/15/2003	6:46:40	13.26	22.888
4/15/2003	22:46:40	13.26	21.322
4/21/2003	0:46:40	13.24	21.147
4/21/2003	14:46:40	13.24	21.452
July 29–August 7, 2003			
7/29/2003	12:30:16	23.57	22.157
7/29/2003	20:30:16	13.22	22.045
7/30/2003	4:30:16	13.21	22.095
7/30/2003	12:30:16	13.21	22.142
7/30/2003	20:30:16	13.21	22.195
7/31/2003	4:30:16	13.22	22.244
7/31/2003	12:30:16	13.22	22.295
7/31/2003	20:30:16	13.22	22.341
8/1/2003	4:30:16	13.22	22.388
8/1/2003	12:30:16	13.22	22.437
8/1/2003	20:30:16	13.22	22.477
8/2/2003	4:30:16	13.22	22.521
8/2/2003	12:30:16	13.22	22.562
8/2/2003	20:30:16	13.21	22.597
8/3/2003	4:30:16	13.22	22.229

Table 3 (continued)

Date	Time	Temperature (°C)	Water Level (ft)
July 29–August 7, 2003 (continued)			
8/3/2003	12:30:16	13.22	22.246
8/3/2003	20:30:16	13.22	21.811
8/4/2003	4:30:16	13.22	21.157
8/4/2003	12:30:16	13.22	21.171
8/4/2003	20:30:16	13.22	21.409
8/5/2003	4:30:16	13.22	21.585
8/5/2003	12:30:16	13.22	21.714
8/5/2003	20:30:16	13.22	21.638
8/6/2003	4:30:16	13.22	21.231
8/6/2003	12:30:16	13.22	21.288
8/6/2003	20:30:16	13.22	21.481
8/7/2003	4:30:16	13.22	21.631

[a] Total depth of well is 27.05 ft.

[b] Data collected every 8 hr.

Appendix A

Acronyms, Glossary, and Metric Conversion Tables

APPENDIX A ACRONYMS, GLOSSARY, AND METRIC CONVERSION TABLES

A-1.0 ACRONYMS

asl	above sea level
bgs	below ground surface
BMP	best management practice
DCA	1,1-dichloroethane
DCE	1,1,-dichloroethylene
DOE	Department of Energy (US)
DOT	Department of Transportation (US)
EDC	1,2-dichloroethane
EM	electromagnetics
EPA	Environmental Protection Agency (US)
gpm	gallons per minute
HRR	high resolution resistivity
IDW	investigation-derived waste
LANL	Los Alamos National Laboratory
LIR	Laboratory Implementation Requirement
MCL	maximum contaminant level
MDA	minimum detectable activity
ml	milliliters
NFA	no further action
NMED	New Mexico Environment Department (New Mexico Environmental Improvement Division before 1991)
NMHWA	New Mexico Hazardous Waste Act
NOD	notice of deficiency
PID	photoionization detector
PPE	personal protective equipment
ppm	parts per million
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RPM	residual potential mapping

RRES-RS	Risk Reduction and Environmental Stewardship–Remediation Services
RSI	Request for Supplemental Information
SOP	standard operating procedure
SOW	statement of work
SWMU	solid waste management unit
TA	Technical Area
TAL	target analyte list (EPA)
TCA	1,1,1-trichloroethane
TCE	trichloroethene
TCTF	1,2,2-trichloro-1, 1,2-trifluoroethane
TD	total depth
TPH	total petroleum hydrocarbons
VCA	voluntary corrective action
WCSF	Waste Characterization Strategy Form
VOC	volatile organic compound

A-2.0 GLOSSARY

Alluvium. Clay, silt, sand, and gravel transported by water and deposited on streambeds, flood plains, and alluvial fans.

Chemical of potential concern (COPC). Chemical, detected at a site, that has the potential to adversely affect human and/or ecological receptors due to its concentration, distribution, and mechanism of toxicity. A COPC remains a concern until exposure pathways and receptors are evaluated in a site-specific risk assessment.

Department of Energy (DOE). Federal agency that sponsors energy research and regulates nuclear materials for weapons production.

Environmental Protection Agency (EPA). Federal agency responsible for enforcing environmental laws. While state regulatory agencies may be authorized to administer some of this responsibility, the EPA retains oversight authority to ensure protection of human health and the environment.

Estimated quantitation limit. The lowest concentration that can be reliably achieved within specified limits of precision and accuracy during routine analytical-laboratory operating conditions. Sample estimated quantitation limits are highly matrix-dependent, and the specified estimated quantitation limits might not always be achievable.

Evapotranspiration. The combined discharge of water from the earth's surface to the atmosphere by evaporation from lakes, streams, and soil surfaces, and by transpiration from plants.

Exposure pathway. Mode by which a receptor may be exposed to contaminants in environmental media (e.g., drinking water, ingesting food, or inhaling dust).

Fault. A fracture, or zone of fractures, in rock along which there has been vertical or horizontal movement; adjacent rock surfaces are displaced.

Field blank (also known as field reagent blank). A blank sample either prepared in the field or carried to the sampling site, exposed to sampling conditions (e.g., bottle caps removed, preservatives added), and returned to a laboratory for analysis in the same manner in which environmental samples are analyzed. Used to identify the presence of contamination potentially added during the sampling and analysis process.

Field duplicate. A second sample collected as near as possible to the original sample.

Gamma radiation. A form of electromagnetic, high-energy radiation emitted from a nucleus. Gamma rays are essentially the same as x-rays and require heavy shielding, such as concrete or steel, to be blocked.

Groundwater. Water in a subsurface saturated zone; water beneath the regional water table.

Hazardous and Solid Waste Amendments (HSWA). The Hazardous and Solid Waste Amendments of 1984 (Public Law No. 98-616, 98 Stat. 3221), which amended the Resource Conservation and Recovery Act of 1976, 42 U.S.C. § 6901 et seq.

HSWA module. Module VIII of the Laboratory's Hazardous Waste Facility Permit. This permit allows the Laboratory to operate as a treatment, storage, and disposal facility.

Hydraulic conductivity. The rate at which water moves through a medium in a unit of time under a unit hydraulic gradient through a unit area measured perpendicular to the direction of flow.

Method blank. An analyte-free matrix to which all reagents are added in the same volumes or proportions as those used in the environmental sample processing and which is prepared and analyzed in the same manner as the corresponding environmental samples. The method blank is used to assess the potential for contamination to the sample during preparation and analysis.

Method detection limit (MDL). The minimum concentration of a substance that can be measured and reported with a known statistical confidence that the analyte concentration is greater than zero. The MDL is determined from analysis of samples of a given matrix type that contain the analyte after subjecting the sample to the usual preparation and analyses. The MDL is used to establish detection status.

Minimum detectable activity. For the *analysis* of *radionuclides*, the minimum detectable activity is the lowest detectable radioactivity for a given analytical technique. The following equation shall be used to calculate the MDA unless otherwise noted or approved by the Laboratory:

$$\text{MDA} = \frac{4.65(\text{BKG})^{0.5} + 2.71}{2.22 \times \text{EFF} \times \text{V} \times \text{T}_\text{S} \times \text{Y}}$$

where BKG = the total background counts,
EFF = the fraction detector efficiency,
V = the volume or unit weight,
T_s = the *sample* count duration, and
Y = the fractional *chemical* recovery obtained from the *tracer* recovery.

Depending on the type of *analysis*, other terms may also be required in the denominator (e.g., gamma abundance).

No further action (NFA). A recommendation that not further investigation or remediation is warranted based on specific criteria.

Nondetect. Sample result that is less than the MDL. The laboratory reports nondetects as undetected at the EQL.

Operable unit (OU). At the Laboratory, one of 24 areas originally established for administering the ER Project. Set up as groups of potential release sites, the OUs were aggregated based on geographic proximity for the purpose of planning and conducting RCRA facility assessments and RCRA facility investigations. As the project matured, it became apparent that 24 were too many to allow efficient communication and to ensure consistency in approach. Therefore, in 1994, the 24 OUs were reduced to six administrative "field units."

Perched groundwater. Groundwater that lies above the regional water table and is separated from it by an unsaturated zone.

Quality assurance (QA). All those planned and systematic actions necessary to provide adequate confidence that a facility, structure, system, or component will perform satisfactorily in service.

Quality control (QC). (1) All those actions necessary to control and verify the features and characteristics of a material, process, product, or service to specified requirements. QC is the process through which actual quality performance is measured and compared with standards. (2) All methods and procedures used to obtain accurate and reliable results from environmental sampling and analysis. Includes rules for when, where, and how samples are taken; sample storage, preservation and transport; and the use of blanks, duplicates, and split samples during the analysis.

Radionuclide. A nuclide (species of atom) that exhibits radioactivity.

RCRA facility investigation (RFI). The investigation that determines if a release has occurred and the nature and extent of the contamination at a hazardous waste facility. The RFI is generally equivalent to the remedial investigation portion of the Comprehensive Environment Response, Compensation, and Liability Act (CERCLA) process.

Receptor. A person, plant, animal, or geographical location that is exposed to a chemical or physical agent released to the environment by human activities.

Recharge. The process by which water is added to the zone of saturation, either directly from the overlying unsaturated zone or indirectly by way of another material in the saturated zone.

Regional aquifer. Geologic material(s) or unit(s) of regional extent whose saturated portion yields significant quantities of water to wells, contains the regional zone of saturation, and is characterized by the regional water table or potentiometric surface.

Release. Any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous waste or hazardous constituents into the environment (including the abandonment or discarding of barrels, containers, and other closed receptacles that contain any hazardous wastes or hazardous constituents).

Reporting limit. The numerical value that an analytical laboratory (in conjunction with its client) selects to determine if a target analyte is detected. Results below the RL are considered not detected, while results greater than the RL are considered detected. The RLs are not necessarily based on instrument sensitivity. RLs can be established at the instrument detection limit, method detection limit, estimated quantitation limit, and contract-required detection limit.

Resource Conservation and Recovery Act (RCRA). The Solid Waste Disposal Act as amended by the Resource Conservation and Recovery Act of 1976. (40 CFR 270.2)

Runoff. The portion of the precipitation on a drainage area that is discharged from the area either by sheet flow or adjacent stream channels.

Run-on. Surface water flowing onto an area as a result of runoff occurring higher up the slope.

Sample. A portion of a material (e.g., rock, soil, water, air), which, alone or in combination with other samples, is expected to be representative of the material or area from which it is taken. Samples are typically sent to a laboratory for analysis or inspection or are analyzed in the field. When referring to samples of environmental media, the term field sample may be used.

Sediment. (1) A mass of fragmented material that comes from the weathering of rock and is carried or dropped by air, water, gravity, or ice; or a mass that is accumulated by any other natural agent and that forms in layers on the earth's surface such as sand, gravel, silt, mud, fill, or loess. (2) A solid material that is not in solution and either is distributed through the liquid or has settled out of the liquid.

Site characterization. Defining the pathways and methods of migration of the hazardous waste or constituents, including the media affected, the extent, direction and speed of the contaminants, complicating factors influencing movement, concentration profiles, etc. (US Environmental Protection Agency, May 1994. "RCRA Corrective Action Plan, Final," Publication EPA-520/R-94/004, Office of Solid Waste and Emergency Response, Washington, DC)

Solid waste management unit (SWMU). Any discernible unit at which solid wastes have been placed at any time, irrespective of whether the unit was intended for the management of solid or hazardous waste. Such units include any area at a facility at which solid wastes have been routinely and systematically released. This definition includes regulated units (i.e., landfills, surface impoundments, waste piles, and land treatment units) but does not include passive leakage or one-time spills from production areas and units in which wastes have not been managed (e.g., product storage areas).

Standard operating procedure (SOP). A document that details the method for an operation, analysis, or action with thoroughly prescribed techniques and steps, and is officially approved as the method for performing certain routine or repetitive tasks.

Stratigraphy. The science dealing with the succession, age, composition, and history of strata.

Target analyte. An element, chemical, or parameter, the concentration, mass, or magnitude of which is designed to be quantified by use of a particular test method.

Technical area (TA). The Laboratory established technical areas as administrative units for all its operations. There are currently 49 active TAs spread over 43 square miles.

Topography. The physical configuration of the land surface in an area.

Tracer. A substance, usually a radioactive isotope, added to a sample to determine the efficiency (chemical or physical losses) of the chemical extraction, reaction, or analysis. The tracer is assumed to behave in the same manner as that of the target radionuclides. Recovery guidelines for tracer results are 30% to 110% under the current contract laboratory statement of work and will be 40% to 105% under the new statement of work. Correction of the analytical results for the tracer recovery is performed for each sample. The concentration of the tracer added needs to be sufficient to result in a maximum of 10% uncertainty at the 95% confidence level in the measured recovery.

Tuff. A compacted deposit of volcanic ash and dust that contains rock and mineral fragments accumulated during an eruption.

Vadose zone. The unsaturated zone. Portion of the subsurface above the regional water table in which pores are not fully saturated.

A-3.0 METRIC CONVERSION TABLES

Metric to English Conversions

Multiply SI (Metric) Unit	by	To Obtain US Customary Unit
kilometers (km)	0.62137	miles (mi)
kilometers (km)	3281	feet (ft)
meters (m)	3.2808	feet (ft)
meters (m)	39.3701	inches (in.)
centimeters (cm)	0.03281	feet (ft)
centimeters (cm)	0.3937	inches (in.)
millimeters (mm)	0.0394	inches (in.)
micrometers or microns (µm)	0.00004	inches (in.)
square kilometers (km^2)	0.3861	square miles (mi^2)
hectares (ha)	2.4710	acres
square meters (m^2)	10.7639	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)	0.26471	gallons (gal.)
milligrams per liter (mg/l)	1	parts per million (ppm)
degrees Celsius (°C)	9/5 + 32	degrees Fahrenheit (°F)

Metric Prefixes

Term	Power of 10	Symbol
mega-	10^6	M
kilo-	10^3	k
deci-	10^{-1}	d
centi-	10^{-2}	c
milli-	10^{-3}	m
micro-	10^{-6}	µ
nano-	10^{-9}	n
pico-	10^{-12}	p

Appendix B

2002 Geophysical Investigation Report

EXECUTIVE SUMMARY

A geophysical investigation was conducted by hydroGeophysics, Inc., in 2002 at Solid Waste Management Unit (SWMU) 3-010(a) at Technical Area (TA-) 3 adjacent to Building SM-30. The investigation was undertaken to determine if geophysical methods could define the extent of a localized perched aquifer beneath and west of Building SM-30 in TA-3, and, if so, map the extent of the shallow groundwater.

The geophysical methods selected for the investigation were high resolution resistivity (HRR), residual potential mapping (RPM), and conventional electromagnetics (EM). In addition to the above geophysical methods, some utility tracing and land surveying were done to locate survey stations and underground utilities.

Five lines of HRR, six lines of RPM, and twelve lines of EM were completed and concluded the following:

- the fill material beneath Building SM-30 is "wet," and results indicate that local saturation may occur;
- the increase of moisture content in the fill appears to be vertically limited;
- no seepage or elevated moisture content is evident in the alluvial-fill slope west of Building SM-30; and
- the appearance of a deep conductive zone is probably an artifact of the lightning rod grounding system (the boreholes showed of saturation in that zone).

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B-1.0 INTRODUCTION

Solid Waste Management Unit (SWMU) 3-010(a) was created by a former vacuum pump repair shop that operated from 1950 to 1957 that disposed of used vacuum pump oil and other by-products (e.g., cleaning solvents) on site. The site was approximately 40 ft long by 15 ft wide and is located on a moderately steep hillside on the western margin of Technical Area 3 (TA-3). The oil contained radionuclides and mercury. In May of 1994, the contaminated soil was excavated from the disposal site and a monitoring well (MW-1) was installed on the west side of Building SM-30.

After six years of observation, water levels in the 29.5 ft MW-1 varied slightly throughout the year. The constant saturation monitored in MW-1 and the lack of constant flow in the tributary of Twomile Canyon indicate the presence of a shallow groundwater zone.

In 2002, hydroGeophysics was contracted to determine if geophysical methods could define the extent of a localized perched aquifer beneath Building SM-30. The geophysical methods selected for the investigation were high resolution resistivity (HRR), residual potential mapping (RPM), and conventional electromagnetics (EM). In addition to the above geophysical methods, some utility tracing and land surveying were done to locate survey stations and underground utilities. If the extent of the localized perched aquifer was defined through these methods, the shallow groundwater would be mapped.

B-2.0 SITE, SURVEY, AND SET-UP LOCATIONS

The site investigation area is adjacent and to the west, north, and south of Building SM-30 within TA-3 of the Los Alamos National Laboratory (hereafter, the Laboratory). The area surveyed was on the pavement (asphalt) making up the north and west alley driveways, the south parking lot, and the slope west of the west alley road fence (Figure B-1).

For resistivity and potential mapping surveys, the remote reference electrode was located north of West Jemez Road approximately 2500 ft to the northwest of the site. For safety reasons, the remote transmitting electrode was located in the bottom of Twomile Canyon approximately 1500 ft to the south of SWMU 3-010(a).

B-3.0 FIELD INVESTIGATION METHODS

B-3.1 High Resolution Resistivity (HRR)

Five lines of HRR were performed near the west end of Building SM-30. Station spacing ranged from 5 to 200 ft on each line.

HRR Line 1 was considered a test line and was run 5 ft west of, and parallel to, the chain-link fence along the west side of Building SM-30. It was "anchored" in outcropping Bandelier Tuff at the north end of the line and Bandelier sub-crop at the southern end.

HRR Line 2 was located parallel to, and 10 ft west of, Line 1. Because an outcropping of the Bandelier Tuff was present at the north end of the line, Line 2 was 80 ft shorter than Line 1.

HRR Line 3 was not performed, but Line 3 exists in the RPM data series.

HRR line 4, along the north side of Building SM-30, was performed and encountered a buried hydrant line parallel to the north drive. HRR Line 4 was a 100-ft-long test line to determine the impact on the data from the hydrant line. Strong hydrant line response negated any further use of this line.

HRR Line 5 was the target line and was centered on the SWMU. It ran parallel to the chain-link fence and approximately 10 ft to the east. HRR Line 5 was located in the middle of the paved driveway and required the installation of 12-in. spikes.

HRR Line 6 was located in the parking lot to the south of Building SM-30 for the purpose of determining whether the conductive zone seen on Lines 1 and 5 extended to the south. HRR Line 6 was located on asphalt and required the installation of 12-in. spikes.

B-3.2 Residual Potential Mapping (RPM)

All HRR lines were repeated for the RPM survey with the addition of Line 3. Line 3 was located parallel to and 10 ft west of HRR Line 2. All RPM data were acquired using MW-1 as the transmitting source. Generally, RPM data are acquired in a grid, preferably with multiple well casings or buried electrodes. RPM surveying was included because the data were easily acquired once the HRR lines had been laid out.

MW-1 is located in the driveway west of Building SM-30 and is constructed with 29.5 ft of stainless steel casing. An electrical connection was made with the outside of the casing to avoid opening the well.

B-3.3 Electromagnetics (EM)

The EM survey lines included all of the HRR and RPM lines. Again, a test area was selected to determine whether or not the GEM-2 Multi-Frequency EM system could acquire useful data in a culturally disturbed area. The areas were surveyed with the EM system at two intervals, 3 ft and 3 in., above the ground on a polyvinyl-chloride (PVC) cart. The cart-level data were acquired primarily to help identify specific cultural features and not to support the objectives of the survey.

The west side of Building SM-30 was surveyed both on the driveway and outside the fence. Eight lines of data were acquired, including HRR and RPM Lines 1, 2, 3, and 5. Three additional lines were acquired in the driveway to fill in the spacing so that the driveway line spacing was 5 ft. These series of lines constitute the west grid.

The north grid was performed along the north driveway and was run for the length of the building (approximately 500 ft). Six lines, each separated by 5-ft intervals, were acquired.

The south grid was performed in the asphalt parking lot to the south of Building SM-30. Eight lines, each separated by 5-ft intervals, were acquired. The EM coverage essentially straddled the HRR/RPM line.

B-3.4 Utilities Tracing

Various utilities were traced to ensure survey team safety and provide guidance in line layout. Utilities tracing was performed with a Ditch Witch® Subsite Model 950TR instrument and the GEM-2 (see www.ditchwitch.com for instrument specifications). To indicate they were only design lines, critical utilities were marked with white paint. Laboratory-accepted utilities tracing was performed prior to any intrusive activities such as placing the 12-in. spikes that would impact critical utilities.

B-3.5 Land Surveying

All lines were surveyed using a total station on loan from the Laboratory. The instrument used was a Total Station, Leica Tachymat, Wild TC 1000 with Electron Distance Measurement, Serial Number 364033. Survey control was provided by Johnson Controls. All lines were tied to a local control point.

B-4.0 EQUIPMENT

B-4.1 HRR

All HRR data were acquired using an Advanced Geosciences Inc. Sting R1 resistivity instrument Serial Number 38010020 (see www.aguisa.com for instrument specifications). The transmitting and receiving electrodes were stainless steel rods in soil-accessible areas and 12 in. steel spikes installed through the asphalt in the driveway and parking lot. The remote potential electrode consisted of two nonpolarizing (copper/copper sulfate) electrodes.

B-4.2 RPM

All RPM data were acquired using an Advanced Geosciences, Inc., Sting R1 resistivity instrument Serial Number 38010020 (see www.aguisa.com for instrument specifications). The transmitting electrode was well MW-1.

B-4.3 EM

All EM data were acquired using a Geophex. Ltd. GEM-2 electromagnetic instrument Serial Number 299005. The GEM-2 is a hand-held, digital, multifrequency sensor for mapping shallow geology and conductivity. It operates in a frequency range of 330 Hz to 24 kHz and can transmit an arbitrary waveform containing multiple frequencies. The depth of exploration for a given earth medium is determined by the operating frequency. Therefore, measuring the earth response at multiple frequencies is equivalent to measuring the earth response from multiple depths. Hence, such data can be used to image a three-dimensional distribution of subsurface objects. Its built-in operating software allows a surveyor to cover about one ac per hour at line spacings of five ft. Results from several environmental sites indicate that the multifrequency data from GEM-2 more efficient in characterizing buried metallic and non-metallic targets than data from conventional single-frequency sensors. (For detailed specifications see www.geophex.com).

B-5.0 METHODOLOGY

B-5.1 HRR

B-5.1.1 Data Acquisition

Data were acquired using a pole-pole electrode array. The locations of the remote electrodes were described in Section B-3.0 of this appendix.

B-5.1.2 Data Processing

Once downloaded from the Sting R1, the data were processed with proprietary software package belonging to hydroGeophysics, Inc. The processing consists of basic conversion to half-space apparent resistivities, topographic compensation, topographic correction, and direct inversion using a geometrically-constrained algorithm.

B-5.1.3 Data Presentation

The inverted resistivity data are presented as geo-electric sections relative to surface topography (Figure B-2). The red (hot) gradients represent relatively high resistivities and the blue (cold) colors

represent relatively low resistivities. The range of resistivities determines the mode of contouring, which in this case, is linear with a two ohm-meter interval. Each geo-electric section represents a vertical section of earth beneath the line, but it also includes effects from features adjacent to the line on either side of the line.

B-5.2 RPM

B-5.2.1 Data Acquisition

RPM data were acquired during a separate pass on the HRR lines and using the MW-1 as the transmitting source. RPM data are best acquired using multiple wells and a grid of stations, but the availability of MW-1 gave the opportunity to test in addition to the HRR.

B-5.2.2 Data Processing

After downloading, the data were processed using hydroGeophysics' proprietary reduction software to produce a residual potential map.

B-5.2.3 Data Presentation

The RPM data are presented as a color-contoured map showing the processed residual potential field (Figure B-3).

B-5.3 GEM-2 Electromagnetics

B-5.3.1 Data Acquisition

GEM-2 data were acquired in the in-line mode with vertical-axis loop orientation. The unit was held at waist height for all data presented. Data were also acquired on a cart carrying the GEM-2 at a 3-in. height to enhance utility detection.

B-5.3.2 Data Processing

Data processing consists of downloading the data into Geophex software and reducing the EM data to apparent conductivities. No additional processing was performed.

B-5.3.3 Data Presentation

The EM data are presented as color-contoured plan maps for the three grids combined into a single plot (Figure B-4).

B-5.4 Utilities Tracing

Tracing of underground power-lines consisted of using the passive 60 Hz. detection mode. Other conductive pipelines and communication lines were traced using the active inductive mode with a separate transmitter and receiver. No data processing or presentation was required.

B-5.5 Land Surveying

Survey data were acquired using manual recording and a single prism rod. Acquired data were converted to New Mexico State Plane coordinates in feet. The only form of presentation for the land surveying data is the base map and the line locations for the various geophysical surveys.

B-6.0 INTERPRETATION

B-6.1 HRR

All HRR data are combined and presented in two figures, Figure B-2 and Figure B-5. Figure B-2 shows Lines 1, 2, and 5, all of which were parallel and close-spaced. Figure B-5 shows Lines 4 and 6; which were parallel on opposite sides of Building SM-30.

B-6.1.1 Lines 1, 2, and 5

Figure B-2 shows the three HRR lines on the west side of Building SM-30 in contoured geo-electric format. North is to the left and south to the right. The view angle is nearly due east. The three scales, line length, section depth, and line spacing, are exaggerated to enable clear viewing of the sections.

The color scale shows the logarithm of apparent resistivity resulting from to the wide range of observed apparent resistivities. Cooler colors (bluish) represent lower apparent resistivities, and hotter colors (reddish) represent higher apparent resistivities.

Three resistivity "zones" are evident in the sections: (1) a surficial low resistivity zone; (2) a more resistive layer beneath the surficial feature; and () a deeper low resistivity zone. The surficial feature is absent in Line 2.

According to the hydroGeophysics, Inc., report, the surficial low resistivity zone represents moist alluvial fill, based on the backfilling of a drainage ravine in this area prior to construction of the building. This zone is may contain the groundwater of concern.

Lines 1 and 5, although 15 ft apart, are similar, indicating good continuity of the features between the lines. The northern ends of the lines show higher resistivities in the vicinity of outcropping Bandelier Tuff, as was expected. The southern ends of the lines also show higher resistivities in the vicinity of sub-cropping Bandelier Tuff, as expected.

The area on the lines between these two occurrences of tuff is bowl-shaped and conforms to the paleo-topography, And further supports the interpretation that the low resistivity zone represents moist fill material.

It should be noted that Line 1 was located at the same elevation as Line 5 although it is five ft west of the chain-link fence bounding the site. Line 1 was located at the crest of the fill and had very little topographic relief. Line 2, on the other hand, was located downhill from Line 1 and, based on field observations, appeared to be in outcropping Bandelier Tuff or within a very thin veneer of soil above subcropping Bandelier Tuff. The absence of the surficial zone in Line 2 may indicate the absence of alluvial fill.

One salient feature present on all three lines is the low resistivity feature at depth. The presence of this feature on all three lines suggests in may be geologic. The lines were run parallel to considerable culture, which for the most part, did not seem to make any discernible difference in the data. However, this

conductive zone could be a manifestation of the fence or other culture, such as the lightning rod grounding system that also parallels the west side of the building.

The core from the borehole 03-02680 was viewed for any indication of a change in character of the Bandelier Tuff at a depth comparable to that of the low resistivity zone on the geo-electric sections. A 20-ft thick zone, observed at the appropriate depth, was less indurated and consisted solely of unconsolidated, fragmented core. No additional moisture was found in the bags in which the samples were saved, although the manner in which the core and bagged samples were handled may not have been conducive to preserving moisture information. Therefore, the source of the deep conductive zone remains unexplained.

B-6.1.2 Lines 4 and 6

As with Lines 1, 2, and 5, Lines 4 and 6 are shown in perspective and are not to scale (Figure B-5). West is to the left, and east is to the right. The view angle is roughly north. The two lines are on opposite sides of Building SM-30. Line 4 was a short test line. The west end of Line 4 was in outcropping Bandelier Tuff and is resistive, as seen on the north end of Lines 1 and 5. The beginning point for Line 4 is the same as the beginning point for Line 1. In other words, the first electrode is in common.

The same color scale and contour interval are used for Lines 4 and 6 as are used on Lines 1, 2, and 5. Line 4 shows a rapid decrease in resistivities going to the east towards the known hydrant line. The hydrant line comes in from the east and terminates around station 50 (the stations are shown in Figure B-5). The results suggest that these low resistivities are caused by the metallic hydrant line which is parallel to and just a few feet south of Line 4.

Line 6, on the other hand, shows a trend more like that seen on Lines 1, 2, and 5. The eastern end of Line 6 should be in sub-cropping Bandelier Tuff, but the entire area is covered by asphalt. The old maps indicate that this area was cut into the Bandelier Tuff for construction. The data indicate that the Bandelier Tuff is immediately beneath the asphalt from around station 75 on to the east. West of station 75, it appears that the fill, it appears that a thin layer of fill may be present, indicating that the southern extent of the fill terminates close to this line.

The same deep low resistivity zone is also seen on Line 6. Again, because the line is parallel to the building, the source of the low resistivity zone may be related to the building or other infrastructure.

B-6.2 RPM

The limited amount of data acquired from RPM limits the reliability of the data because of the statistical requirements. However, the data were processed and the results presented in Figure B-3.

The RPM results indicate very localized data variations that may be related to fracture flow conditions. The presence of higher residual potentials to the west of MW-1 indicates limited moisture increase in that direction and corresponds to the HRR data.

B-6.3 EM

The EM surveying was performed as a test to see if sufficient useable information might be extracted from what was expected to be highly contaminated (from metallic clutter) data. EM methods are very sensitive to any metallic objects above and below ground surface, whereas HRR is sensitive only to grounded metallic objects. EM responses could be associated with the metallic culture observed with the building

and the site. However, there were a few "windows" through the contaminated data that allowed some indication of "background" or geologic response (Figure B-4).

The driveway west of the building produced very noisy data but there appeared to be a slight increase in background conductivity that was associated with the fill. On their own, these data would not be conclusive, but combined with the HRR data, the correspondence between the low resistivity (HRR) zone and the elevated conductivities in the EM data indicate that compared to HRR the EM may be an effective and inexpensive tool to acquire more detailed data over larger grids compared. However, the data are much more difficult to interpret in complex area such as this site.

The north grid produced a predictable trend from slightly conductive in the west to less conductive in the east. Again, this finding confirms the pre-construction topography and verifies that the alluvial fill is limited in the northern section of the site. Additionally, it indicates that no localized anomalously conductive area within the fill might be associated with groundwater.

B-7.0 CONCLUSIONS

The combined results of the three geophysical methods indicate that

1. there is no substantial increase in low resistivities associated with the fill;
2. the lack of such an increase lessens but does not eliminate a thin zone of saturation;
3. the low resistivities associated with the fill are constrained to the north, south, and west;
4. such constraints limit the possible areal extent of any zone of increased moisture content associated with the fill; and
5. the presence of a zone of higher resistivity beneath the fill indicates a reasonable degree of vertical confinement.

B-8.0 RECOMMENDATIONS FROM hydroGeophysics, Inc.

If drilling is required to further characterize the shallow groundwater, a single borehole should be placed through the thickest zone of fill indicated by the HRR results (HRR Line 5, station 130, Figure B-2). This borehole should be cored and sampled for moisture analysis. The borehole should be deep enough to allow evaluation of a possible deeper conductive zone indicated by the HRR data. Long focus induction logging, natural gamma, and neutron logging should also be performed.

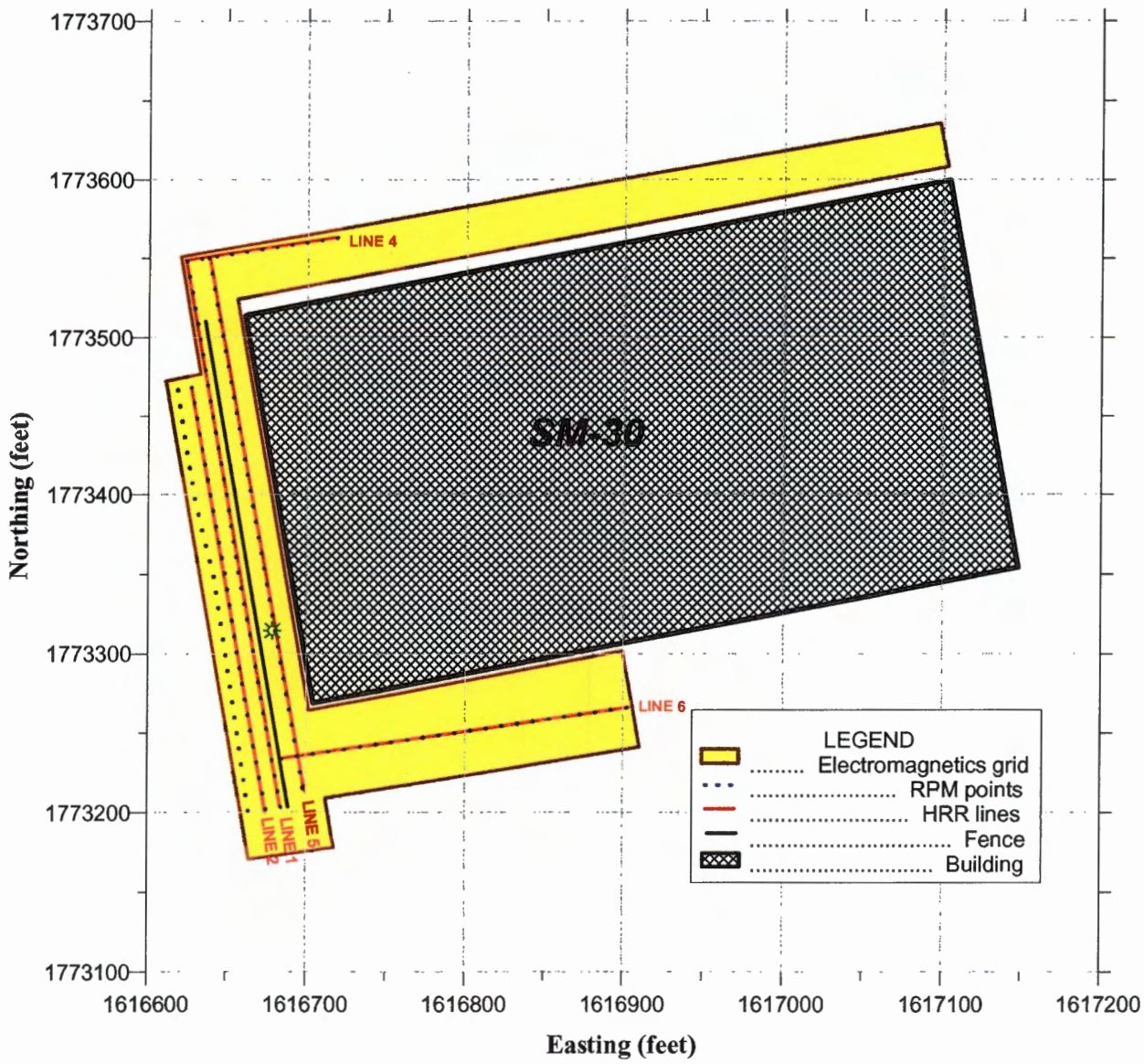

Figure B-1. Base map showing location of geophysical surveys

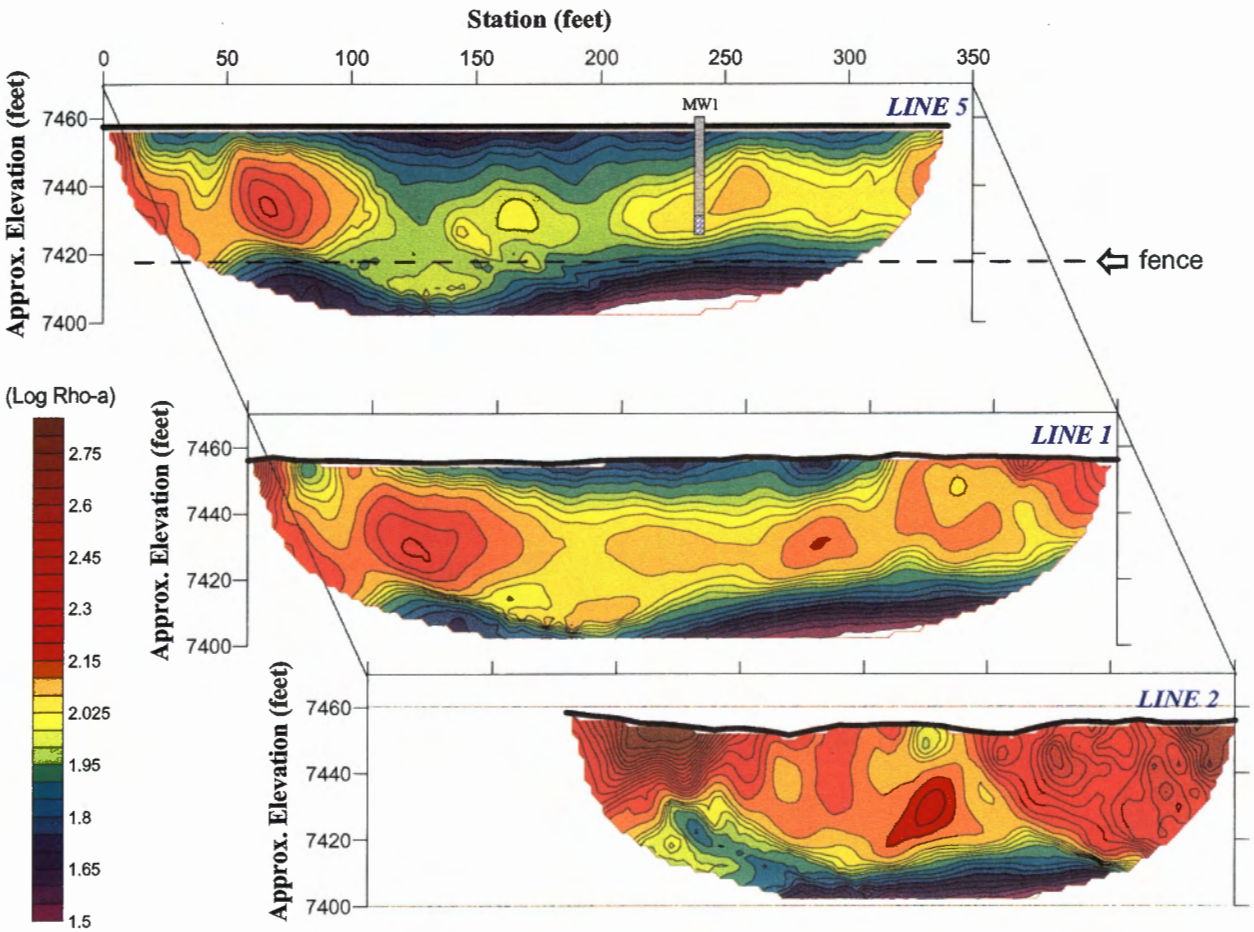

Figure B-2. HRR Lines 1, 2, and 5 looking easterly

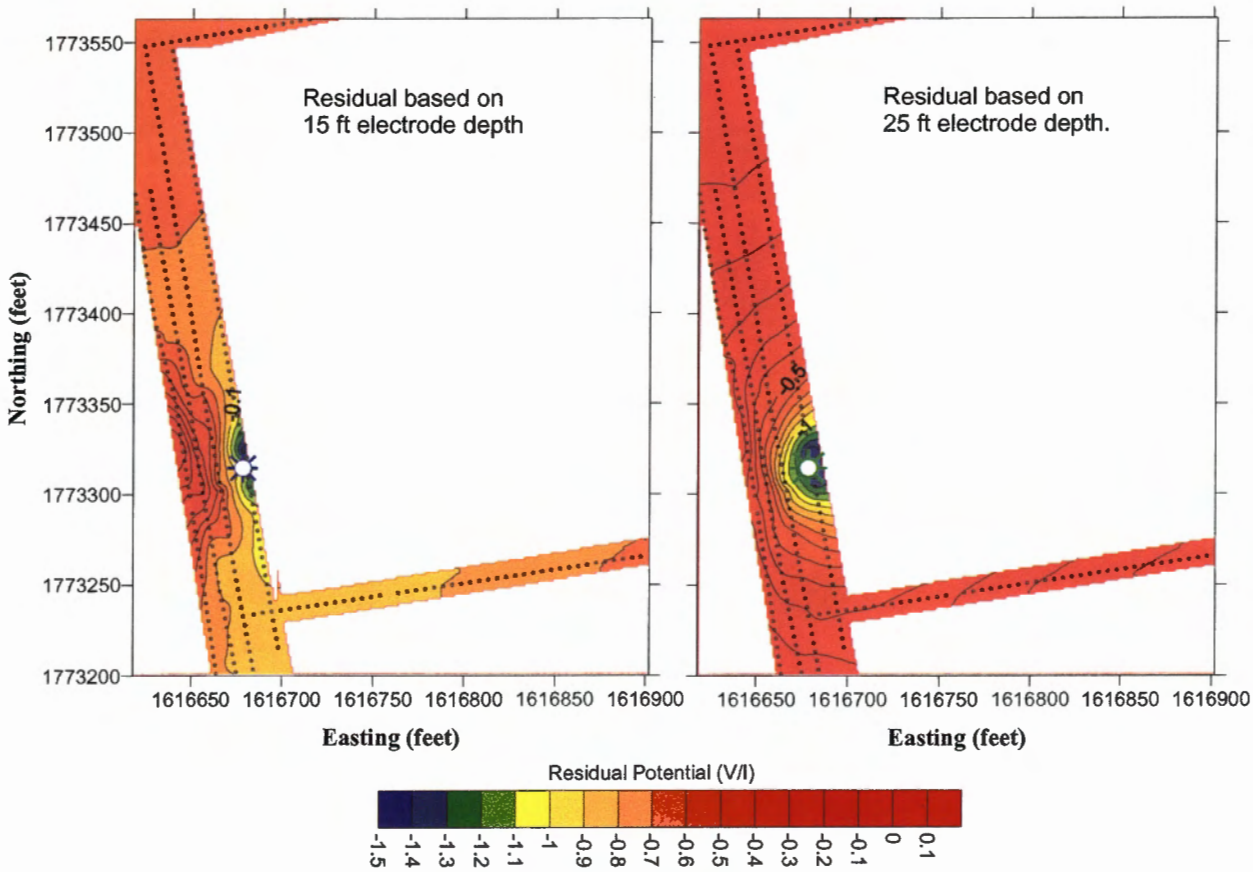

Figure B-3. RPM data using a point source depth of 15 ft in MW-1

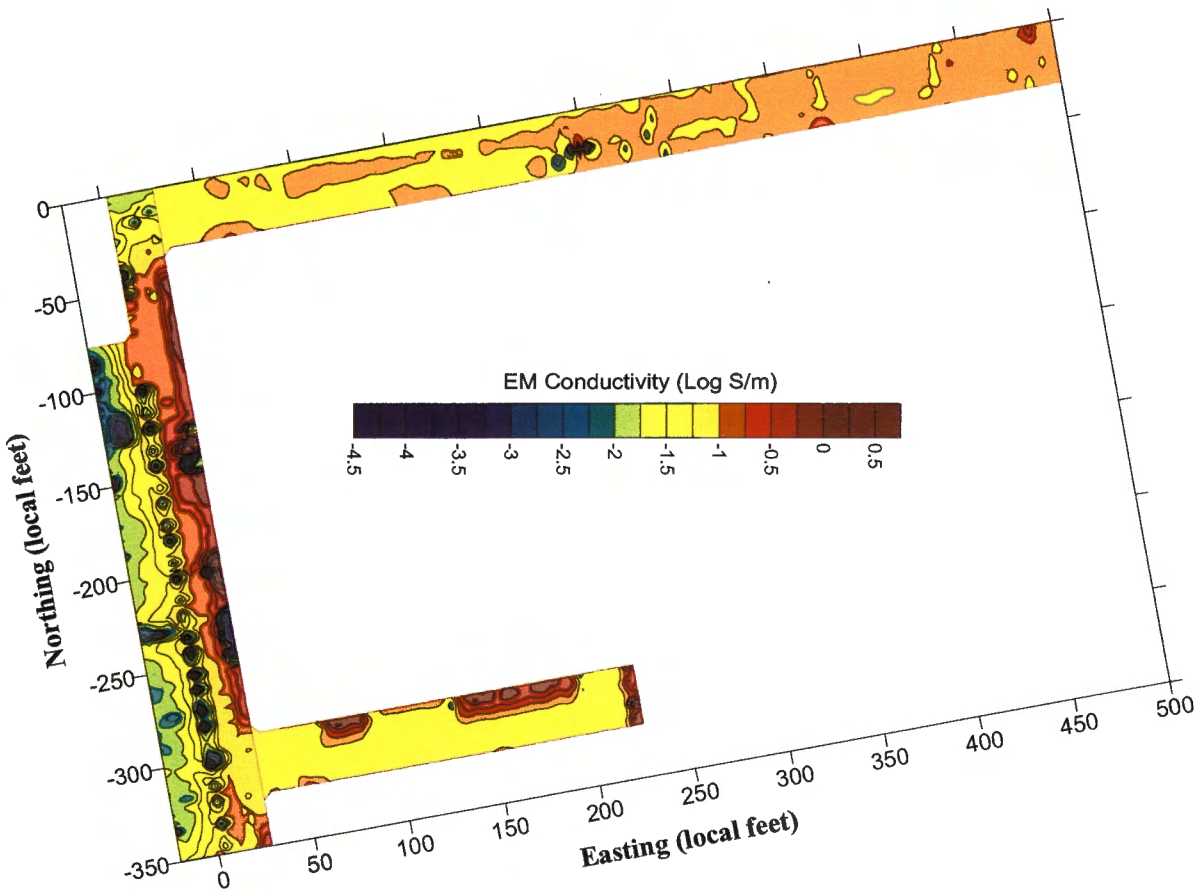

Figure B-4. Electromagnetic conductivity contour plot

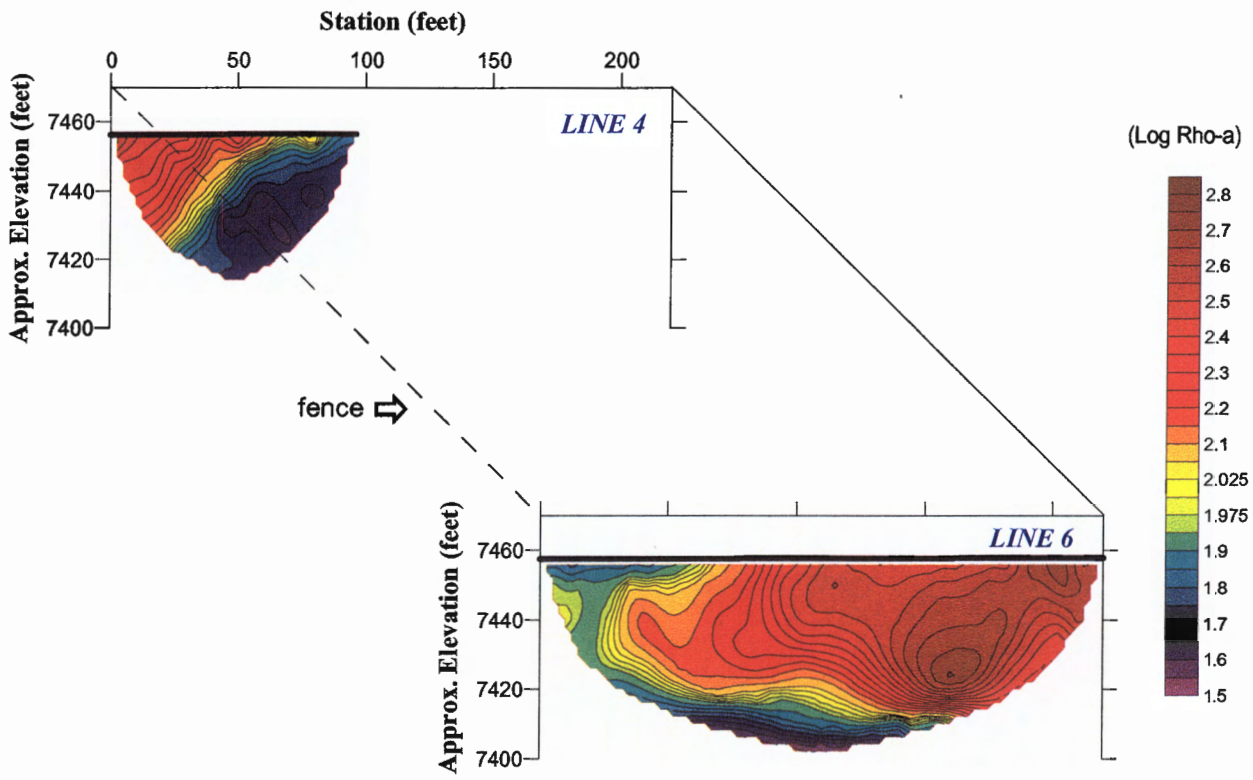

Figure B-5. HRR Lines 4 and 6 looking north

Appendix C

Investigation-Derived Waste Management

APPENDIX C INVESTIGATION-DERIVED WASTE MANAGEMENT

This section of the work plan describes how investigation-derived waste (IDW) generated during the investigation of Solid Waste Management Unit (SWMU) 3-010(a) at Technical Area 3 of Los Alamos National Laboratory (the Laboratory) will be managed. IDW is solid waste generated as a result of field investigation activities and may include, but is not limited to, drill cuttings; purge water; contaminated personal protective equipment (PPE), sampling supplies, and plastic; fluids from the decontamination of PPE and sampling equipment; and all other wastes potentially contacting contaminants. Certain field investigation activities may also displace environmental media, which is defined as naturally occurring material indigenous to the environment, including groundwater, surface water, surface and subsurface soils, rocks, bedrock, and gravel. Consistent with the US Environmental Protection Agency (EPA) "area of contamination" policy, environmental media is not considered to be a waste (and, hence, not IDW) if it is returned to its point of origin. IDW generated during the investigation of SWMU 3-010(a) will be managed in a way that protects human health and the environment, complies with applicable regulatory requirements, and is consistent with Los Alamos National Laboratory (the Laboratory) waste minimization goals.

All IDW generated during field investigation activities will be managed in accordance with applicable Risk Reduction and Environmental Stewardship–Remediation Services (RRES-RS) standard operating procedures (SOPs). These SOPs incorporate the requirements of all applicable EPA and New Mexico Environment Department (NMED) regulations, Department of Energy (DOE) orders, and Laboratory Implementation Requirements (LIRs). RRES-RS SOPs applicable to the characterization and management of IDW are:

> ER-SOP-1.06, Management of Environmental Restoration Project Waste and
> ER-SOP-1.10, Waste Characterization.

These SOPs are among the SOPs applicable to the investigation at SWMU 3-010(a). They can be found at the following URL: http://erproject.lanl.gov/documents/procedures.html.

Investigation activities will be conducted in a manner that minimizes the generation of waste. Waste minimization is accomplished by implementing the requirements of the RRES-RS Waste Minimization Awareness Plan, which is updated annually as a requirement of Module VIII of the Laboratory's Hazardous Waste Facility Permit.

Prior to the start of field investigation activities, a Waste Characterization Strategy Form (WCSF) will be prepared and approved per requirements of ER-SOP 01.10. The WCSF will provide detailed information on IDW characterization, management, containerization, and potential volume generation. IDW characterization will be achieved through existing data and/or documentation, through direct sampling of the IDW, or sampling of the media being investigated (i.e., surface soil, subsurface soil, etc.). If sampling is necessary, it will be described in a sampling and analysis plan developed in conjunction with the WCSF.

The selection of waste containers will be based on the appropriate Department of Transportation (DOT) requirements and the type and amount of IDW planned for generation. Immediately following containerization, each waste container will be individually labeled by the waste classification, item identification number, radioactivity (if applicable), and date generated. Waste containers will be managed in clearly marked and appropriately constructed waste accumulation areas. Waste accumulation area postings, regulated storage duration, and inspection requirements will be based on the type of IDW and its classification. Container and storage requirements will be detailed in the WCSF and approved prior to waste generation.